Educational Series 13 [redacted]

GUIDE TO PENNSYLVANIAN FOSSIL PLANTS OF ILLINOIS

James R. Jennings

Illinois State Geological Survey 1990

Cover Venation of a small fragment of foliage from a tree fern that grew during the Pennsylvanian Period. *Pecopteris mazoniana,* X 6.3 - Francis Creek Shale, Grundy County (see section on Ferns, page 21)

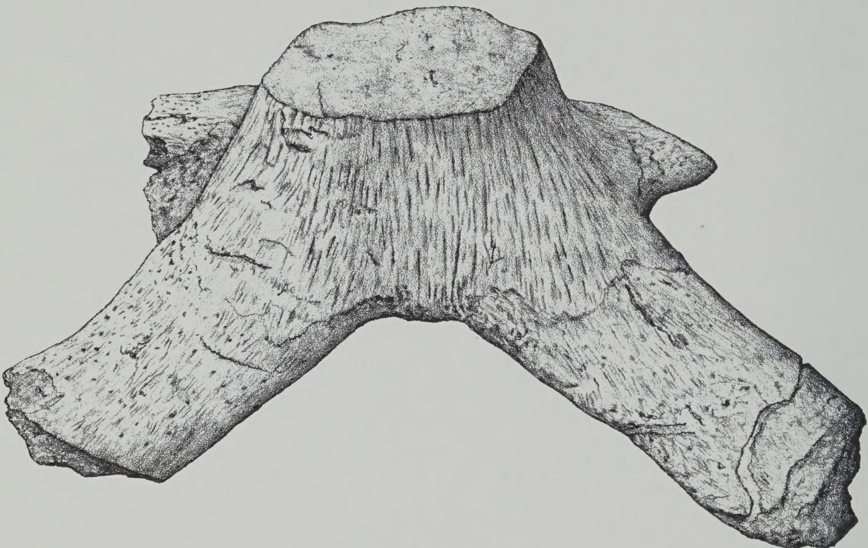
GUIDE TO PENNSYLVANIAN FOSSIL PLANTS OF ILLINOIS

James R. Jennings

EDUCATIONAL SERIES 13

ILLINOIS STATE GEOLOGICAL SURVEY
Morris W. Leighton, Chief

Natural Resources Building
615 East Peabody Drive
Champaign, IL 61820



Stump of a scale tree, measuring 1 ft in diameter at the trunk and 3 ft at the base, from a southern Illinois coal mine. After the plant died, its hollow center filled with sediment and formed the cast illustrated. The surface of this fossil represents the thick bark (periderm) that was characteristic of scale trees of the Pennsylvanian Period. Lycopod, X 0.125 - Energy Shale (?), Franklin County

GEOLOGY LIBRARY

CONTENTS

FIGURES

PLATES

FOREWORD

Although Educational Series 13 is a direct descendant of Illinois State Geological Survey Educational Series 6 (Collinson and Skartvedt, 1960), it is significantly different from the guide it replaces. It is larger, more comprehensive, and designed to serve a broader range of users. The present work was prepared by Dr. James R. Jennings, a research paleobotanist with training and experience in the collection and study of plant fossils of the Pennsylvanian Period found in Illinois. Although it will be useful to the inexperienced collector, it will best serve the advanced amateur, the earth science student, and the professional geologist who will find it a welcome guide to identification, classification, and general information on plant fossils.

Educational Series 13 owes it existence to fortuitous circumstance. The author, hired for a mineral resources study, indicated his willingness to devote spare time to revise the out-of-print Educational Series 6. I enthusiastically welcomed the proposal and offered the original Educational Series 6 materials and support for any other needs. Shortly thereafter, in the summer of 1987, a period of intense evening and weekend effort followed. Dr. Jennings scouted new collecting localities and revisited old ones, contacted plant fossil collectors for specimens and information, and developed or revised drawings and text. A fine product emerged that I hope will represent a revival of the series and serve the decade of the 90s.

Charles Collinson

PREFACE

In the nearly 30 years that have elapsed since the publication of Illinois State Geological Survey Educational Series 6 (Collinson and Skartvedt, 1960), many important advances have been made in the study of fossil plants. These advances are reflected throughout the book, particularly in the reconstructions of fossil plants and the time chart. The field book has been greatly expanded and now includes 27 pages of illustrated specimens for comparative purposes.

All of the illustrated fossils were collected in Illinois, but they are essentially similar to fossil plants of the Pennsylvanian Period throughout North America. Although fossil plant specimens from the middle part of the Pennsylvanian System predominate, examples from the lower and upper parts are also illustrated. Many of the collecting localities mentioned in Collinson and Skartvedt (1960) have been re-examined, although it was not practical to visit all of them. Nevertheless, all localities listed in this work that are not listed in Collinson and Skartvedt (1960), have been examined. Fossils from some of them are figured. Information has been drawn from many sources, and an updated list of publications is provided for those who wish to pursue the subject further.

Diagrams and reconstructions are provided for the purpose of relating fragmentary specimens to the complete plants from which they came. Wherever there is some evidence of biological relationship, fossils are grouped accordingly, if possible, in both the text and the plates. Therefore, some members of artificial form genera (see page 3) are separated from others. For example, some fossils belonging to the form genus *Sphenopteris* must be placed with the ferns (plate 16, fig. 4), while other members are grouped with the seed ferns (plate 23, plate 24, figs. 1-4).

A deliberate effort has been made to minimize changes in nomenclature, although unavoidable problems have been encountered. Regarding some sterile fern foliage, Darrah (1969) pointed out that few, if any, specimens from the Mazon Creek area can be correctly assigned to *Pecopteris miltonii*. In this field guide the most common type of fern foliage in the Mazon Creek area is placed in *Pecopteris mazoniana* Lesquereux. This is a new combination of names introduced because foliage of this type was incorrectly placed in the genus *Alethopteris* (Lesquereux, 1870). It was later placed incorrectly in *Mariopteris* (Janssen, 1940). *Pecopteris mazoniana* has priority over both *P. lamuriana* and *P. vestita* to which foliage of the same type has also been assigned.

Neuropteris capitata Lesquereux (1870) is regarded as the type specimen of a valid species distinct from *N. ovata* and *N. heterophylla*, although Lesquereux included specimens that belong to other species in his description. *Neuropteris capitata* has priority over *N. caudata*. Large terminal pinnules are a particularly noteworthy feature of this species.

Although some recent authors have given generic rank to subdivisions of older form genera, this publication does not follow that practice. Specimens assigned to *Flemingites* by some authors are included in *Lepidostrobus*, those assigned to *Eusphenopteris* are included in *Sphenopteris*, and those assigned to *Karinopteris* are placed in *Mariopteris*. Specimens assigned to *Reticulopteris* are included in *Linopteris*, those assigned to *Lonchopteridium* are included in *Lonchopteris*, and those assigned to *Neuralethopteris* or *Paripteris* are placed in *Neuropteris*. Problems exist regarding use of these names for genera. The question of whether some of them may constitute useful subgenera is beyond the scope of this guide.

I am especially indebted to Charles Collinson for his continuing support and encouragement. He graciously made available material from ISGS Educational Series 6, which has been used freely for this guide, and supplied the drawing for plate 19, figure 4. Acknowledgment is extended to Marie Litterer, who illustrated ISGS Educational Series 6. Many of these illustrations are included in this field book with little or no modification.

I am also grateful to George Fraunfelter, who provided the specimen illustrated in plate 5, figure 4, and made helpful comments on the manuscript; T. L. Phillips, who made available specimens from the Carr and Daniels collections; and R. L. Leary, who made available specimens in the Illinois State Museum collections.

I thank H. H. Damberger, T. Delevoryas, R. D. Norby, R. A. Peppers, W. N. Stewart, W. D. Tidwell, and R. H. Wagner for reviewing the manuscript. I am also grateful to D. L. Reinertsen and J. A. Devera for suggesting collecting localities and providing comments, and to the many land owners who allowed fossils to be collected from their property. Mention of a fossil plant collecting locality in this field guide does not, however, obligate land owners to permit future access. Collectors should obtain permission each time they enter private property.

Many persons at the ISGS assisted in the production of this guide. B. J. Stiff assisted in drafting the map of the Mazon Creek area, the venation diagrams, figures 15-17, and illustrations for the time chart; P. K. Foster drafted the geologic column and maps of localities; and R. C. Vaiden assisted in drawing the specimen illustrated in plate 4, figure 4. All illustrations not specifically acknowledged were done by the author. I also thank K. L. Cooley, M. D. Eastin, J. E. Klitzing, D. S. Sands, and D. M. Spence for typing the manuscript.

James R. Jennings

Figure 1 Reconstruction of a Pennsylvanian coal swamp

PRIMEVAL ILLINOIS

Plants that flourished more than 280 million years ago have made Illinois one of the best known fossil collecting regions in the world. Although fossil plants are found in Illinois rocks formed during the geologic periods (see appendix, page 72) termed Devonian, Mississippian, Cretaceous, Tertiary, and Quaternary, it is the remarkable fossil flora of the Pennsylvanian Period that has drawn collectors from across the world to Illinois. Indeed, prized specimens from Pennsylvanian rocks of Illinois have been sent to museums worldwide.

The major coal beds of Illinois were formed during Pennsylvanian time as a result of special geologic conditions that occurred repeatedly throughout the period. At the time, Illinois was part of a vast lowland area that extended hundreds of miles, interrupted only by a few areas of low hills. Although true highland areas lay far to the northeast, they supplied the sand, silt, and clay that were continually carried into the lowland area by primordial river systems. At times, much of Illinois subsided and was covered by a shallow ocean teeming with marine animals (Collinson, 1956, ISGS Educational Series 4). At other times, the sand, silt, and clay brought from the northeast nearly filled the sea, leaving only a few bays or inlets open to the ocean. Widespread swamp forests quickly developed on the accumulated sediment. These were populated by a luxuriant growth of herbs and vines as well as enormous trees unlike any known before or since (fig. 1).

As plants died and fell into the swamp water, their remains accumulated to considerable thickness. Generally, remains of dead plants do not accumulate. When they are exposed to air, bacterial and chemical action cause rapid decay and the remains ultimately disintegrate into water, nitrogen, and carbon dioxide. In stagnant swamp water, however, oxygen becomes depleted and limited circulation of the water prevents the oxygen from being replenished. Under such conditions, slightly altered plant debris may be preserved almost indefinitely. This allows it to accumulate, as it does in modern peat bogs and swamps.

During each episode of swamp development, Illinois must have looked much like the modern wetlands adjacent to the Mississippi River in the delta region south of New Orleans, like the Okefenokee Swamp, the Florida Everglades, or various tropical deltas. Each of the Pennsylvanian swamp forests was eventually killed when it subsided and sea water spread over the area. The area below water then filled with enough sediment to allow yet another swamp forest to develop. This cycle of growth and burial of swamp forests was repeated numerous times. After burial, the peat (formed from accumulated plant material) was compressed and heated beneath the overlying deposits, thereby gradually losing most of its liquids and gases. The result was the conversion of a layer of peat into one of the numerous coal beds found in Illinois. As each swamp forest was buried, some portion of the plant material, rather than being included in peat, was buried instead in the sediment (mostly sand, silt, or clay) that covered it, and preserved there.

TYPES OF PRESERVATION

Depending on conditions at the burial site, plant material may be preserved in various ways. When original organic matter is lost, leaving behind a cavity in the rock that preserves the original three-dimensional form of the plant, the resulting fossil is called a **mold**. If the mold later is filled with sediment (typically, sand or silt) or mineral, it forms a replica of the original plant and is termed a **cast**. Casts and molds faithfully reproduce the outside form of a plant, but lack any indication of its original internal structure (anatomy). Casts and molds are particularly common among fossil plants that are preserved in sandstone. In some cases a plant fragment may be greatly flattened by pressure from the overlying sediment, and a virtually two-dimensional fossil is the result. If the fossil has little or none of the original organic matter, it is called an **impression**. If original organic material is present (ordinarily a black film covering the specimen), the fossil is considered a **compression**. Although compressions generally do not show internal plant structure, they commonly retain the waxy covering (cuticle) of leaves and small stems. This cuticle may exhibit delicate microscopic patterns from the outermost cell layer (epidermis). Fossil plants preserved as impressions and compressions are especially abundant in some shales, and are easily collected where they occur in hard (mineral-cemented) nodules that weather free from the enclosing shale.

Plant remains become **petrified** when they are buried and mineral matter is introduced, thereby preserving the internal (anatomical) structure of the plant. Details of the plant tissues (histology) can be retained, sometimes including minute features of an individual cell. When the mineral is incorporated into plant tissues while some of the original organic material remains, it forms the type of petrifaction known as **permineralization**. If the mineral substitutes for the original organic material, the result is the type of a petrifaction called **replacement**. Common petrifying minerals include iron sulphides (pyrite and marcasite), carbonates (primarily calcite), and silica (agate and opal). Petrified plants occur in sandstone, siltstone, and shale, but the most significant petrified plants in Pennsylvanian rocks of Illinois are found in coal balls. Coal balls are limestone rocks that occur directly within coal beds and preserve delicate cellular structures of the original peat plants with amazing fidelity. An introduction to the fascinating subject of coal balls can be found in ISGS Educational Series 11 (Phillips et al., 1976).

NAMING FOSSIL FRAGMENTS

Unfortunately, unlike many types of animals, plants are never preserved whole. The leaves, stems, roots, and reproductive structures of the same plant (if preserved at all) are almost always found at different places in the rock. It is difficult to reassemble the separated plant fragments and thereby understand the makeup of complete plants. Different plant parts, therefore, have frequently been assigned separate names even though some of them had a common origin. The names for individual plant parts are based on similarity of appearance and are called form names (form taxa). Initially, many form names were given in the belief that specimens of different forms always represented distinct types of plants. Since that time, some fossils have been found with two or more forms in a single specimen. In some cases, a single plant species produced fossils that have been given several form names. In other cases, a single form name has been applied to a structure that was produced by dozens of distinct biological species. Form names persist because of the uncertainties that remain about the origin of many fossil plant parts.

Even though the exact affinities of different plant parts are not always clear, isolated parts still have great usefulness for dating the enclosing rock or for identifying an ancient environment. Each individual part may be studied even though it is not connected to the rest of the plant. For example, the study of fossil pollen and spores (palynology) is usually approached as a distinct field of investigation. Palynology is a particularly powerful tool for unraveling the sequence of coal beds (see Peppers, 1964 and Winslow, 1959).

In addition, a plant known from fossils of one preservational mode may be difficult to recognize when found preserved in some other fashion. Thus, in many cases there is one set of names applied to petrified material and another set applied to compression and impression remains. Occasionally, however, specimens are discovered that combine two or more types of preservation. Such specimens offer the opportunity to correlate specimens of one preservational type with those of another.

The problem created by the abundance of form names is further compounded by the fact that many plant remains are simply unidentifiable. Impressions of wood and bark are generally in this category because they lack the cellular structure and surface patterns that might provide clues about their origin. Despite the many problems, fossil plants preserved in Pennsylvanian rocks of Illinois provide an exciting glimpse of a strange, long-vanished world. Serious collecting is sure to uncover new bits of information about it.

FLORA OF THE PENNSYLVANIAN PERIOD

The Pennsylvanian Swamp Forest

The far-reaching Pennsylvanian swamplands of Illinois were populated by abundant, huge trees of types that have been extinct for many millions of years. During Pennsylvanian time, flowering plants did not exist anywhere. Indeed, flowering deciduous trees, which dominate modern forests, did not arrive for another 100 million years (see appendix, page 72). The tangled forests of the swampy lowlands (fig. 1) were dominated by giant ancestors of the modern club mosses, scouring rushes, ferns, cycads, and conifers. In addition, there was rich undergrowth consisting mainly of small ferns, club mosses, and relatives of the horsetails. Petrifactions of these plants give no indication (such as growth rings) of seasons, and plant life in the swamp forests apparently grew rampantly except during a few short episodes of dryness. During these periods of drought, fires evidently raged across the exposed peat.

A few primitive animals, ancient even when compared with dinosaurs, inhabited the swamp forests. Sluggish, salamander-like amphibians and small reptiles occupied the land, while insects flourished in the air above. Many of the insects were 4 inches long, and some even attained a length of more than 1 foot with a comparable wing spread. A few ancestors of modern spiders, centipedes, and scorpions coexisted with them.

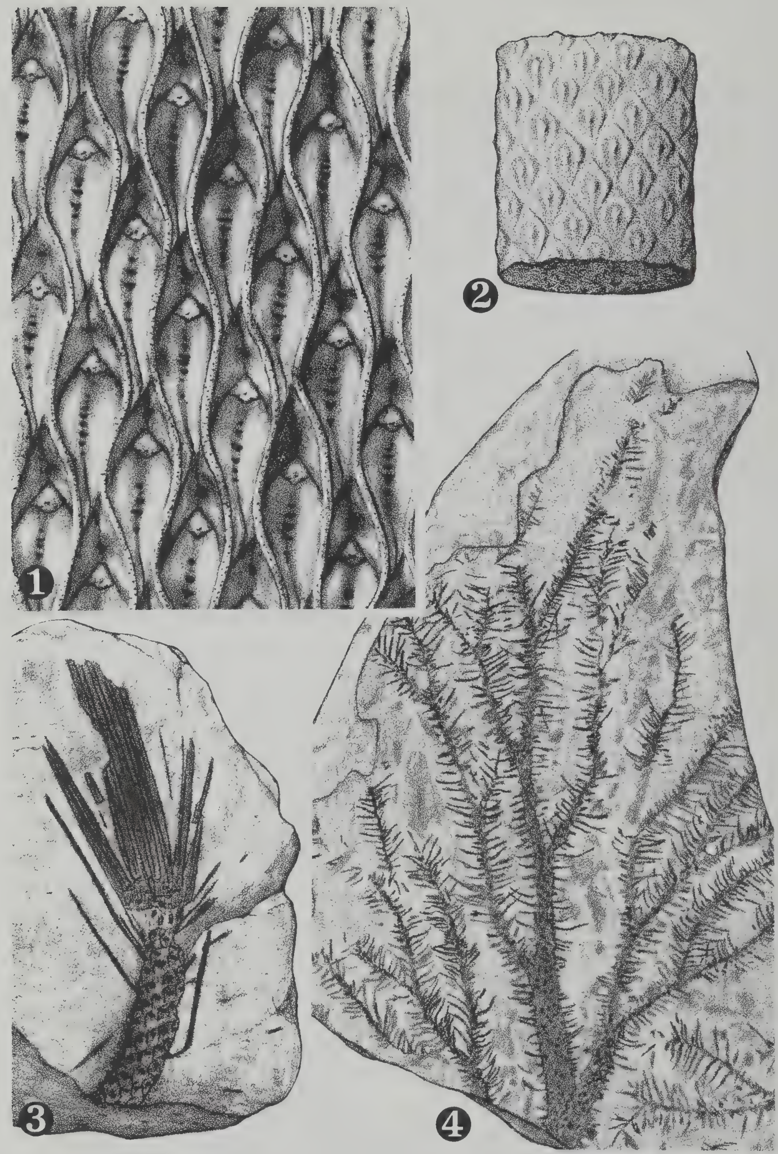
The plants of the Pennsylvanian belonged to several major groups: the scale and seal trees (lycopods), ancient relatives of the jointed horsetails and scouring rushes (sphenophytes or arthrophytes), ferns (pteridophytes), seed ferns (pteridosperms), and primitive conifer-like plants (cordaiteans).

Scale and Seal Trees (Lycopods)--Plates 1-4

Scale and seal trees (figs. 2 and 3) were dominant plants during the Pennsylvanian Period, and their remains make up a large part of most Illinois coal beds. Although they reproduced in the manner of modern ferns and are distantly related to the diminutive club mosses and ground pines (*Lycopodium*) of the present, they grew to great heights, sometimes well over 100 feet (fig. 2).

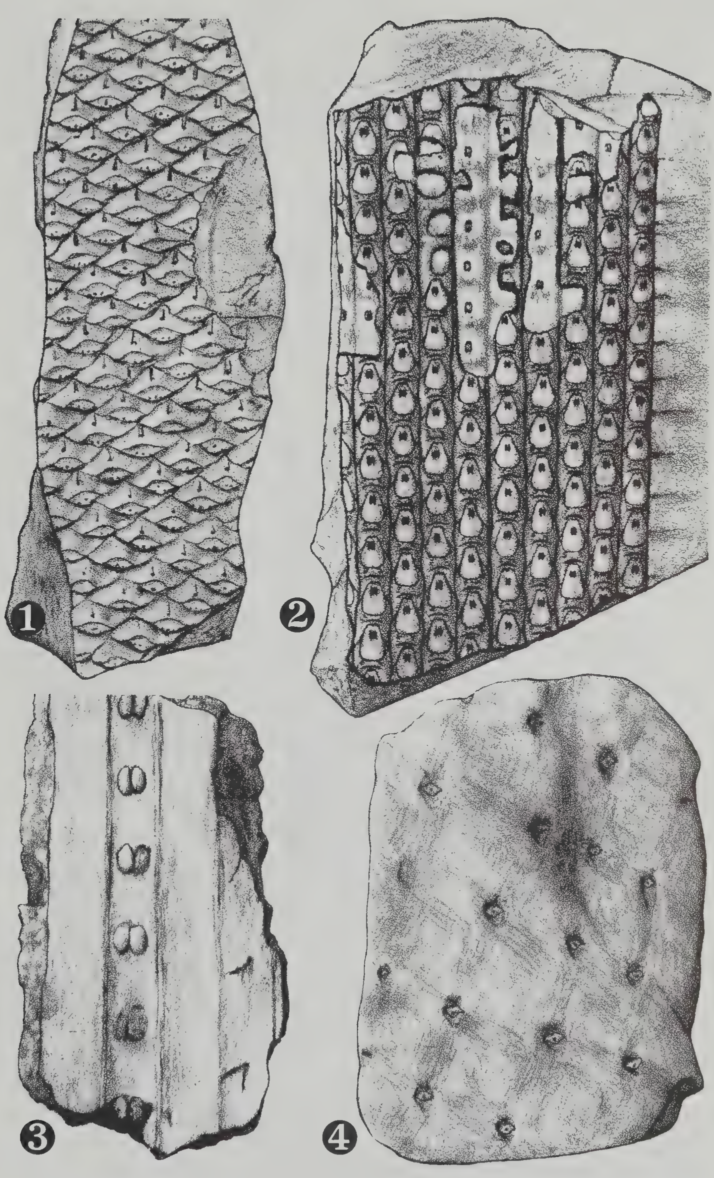
Figure 2 Reconstruction of *Lepidodendron* (a scale tree)

Figure 3 Reconstruction of *Sigillaria* (a seal tree)



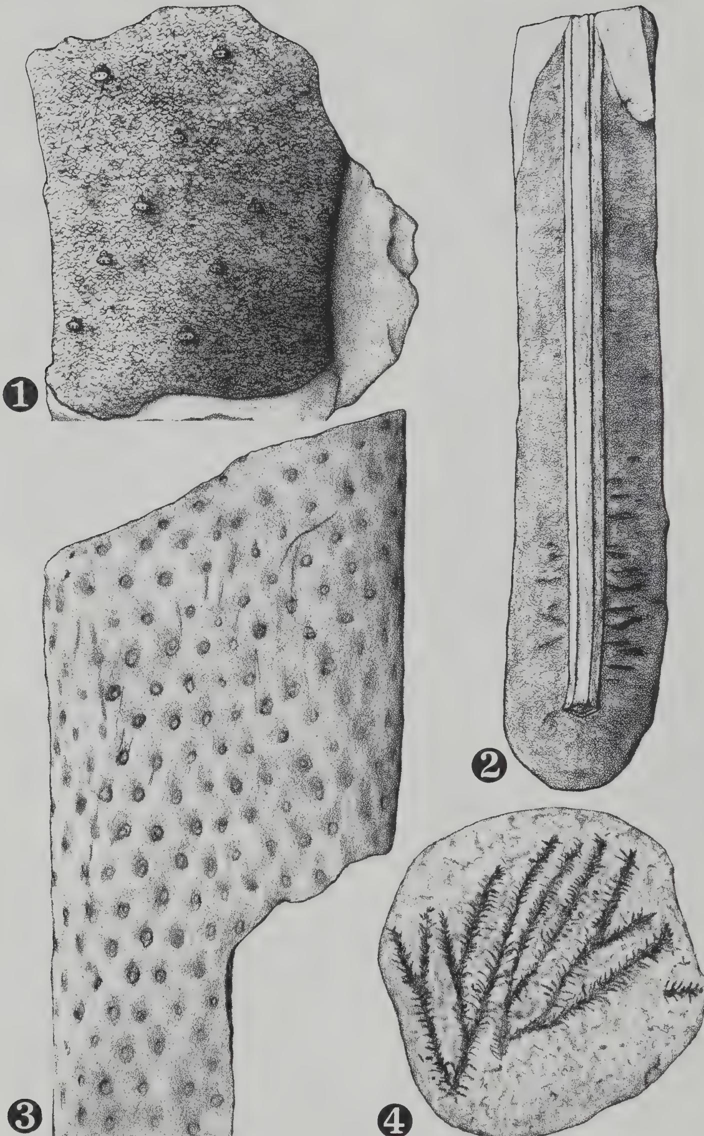
1. *Lepidodendron aculeatum,* X 0.8 - Caseyville Fm., Union Co.
2. *Lepidodendron* sp. (outer part of the cortex lost), X 0.4, Francis Creek Shale, Will or Grundy Co. (after Collinson and Skartvedt, 1960)
3. *Lepidodendron* cf. *L. rigens* with relatively large leaves, X 0.63 - Francis Creek Shale, Grundy Co.
4. *Lepidodendron* sp. with relatively small leaves, X 0.32 - Energy Shale, Franklin Co.

Plate 1 Lycopods: stems and leaves



1. *Lepidophloios laricinus*, X 0.63 - Energy Shale, Franklin Co.
2. *Sigillaria mammilaris*, X 0.5 - Energy Shale, Franklin Co.
3. *Syringodendron* sp., X 0.5 - Spoon Formation, Mercer Co.
4. *Asolanus camptotaenia*, X 0.5 - Energy Shale, Williamson Co.

Plate 2 Lycopods: stems



1. *Bothrodendron minutifolium,* X 1.25 - Caseyville Fm., Jackson Co.
2. lycopod leaf, X 0.63 - Francis Creek Shale, Will Co.
3. *Stigmaria ficoides,* X 0.4 - Carbondale Fm., Franklin (?) Co.
4. *Lycopodites meeki,* X 0.8 - Francis Creek Shale, Will Co.

Plate 3 Lycopods: stems, leaves, and rooting structures

Branching of the scale trees involved the division of a stem into two, nearly equal parts (dichotomous branching). The scaly appearance of fossil stems from these plants results from the numerous protruding pads (leaf cushions) they produced, each of which formed at the base of a leaf. Diamond-shaped areas (leaf scars) occur on each leaf cushion at the point where a leaf was once attached. On each leaf scar are three small scars (one vascular tissue scar and two parichnos tissue scars). Just above the leaf scar another small scar (ligule pit scar) developed (fig. 4). *Lepidodendron* (plate 1, figs. 1-4) and *Lepidophloios* (plate 2, fig. 1) are widespread genera of this type. They both had long, straight trunks with much-branched crowns. The long dimension of the leaf cushions of *Lepidodendron* (plate 1, fig. 1) is typically vertical, whereas in *Lepidophloios* (plate 2, fig. 1), leaf cushions are normally broader than they are long. This character is not altogether consistent, however, because leaf cushions on one part of a plant often were a different size and shape from those on another part.

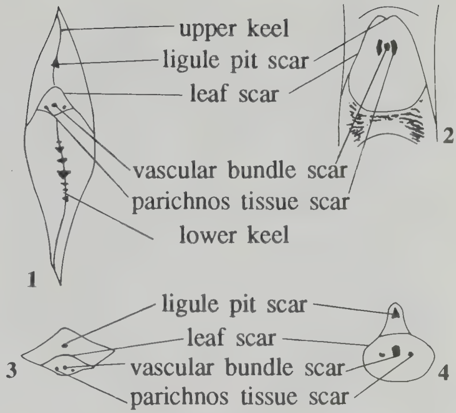
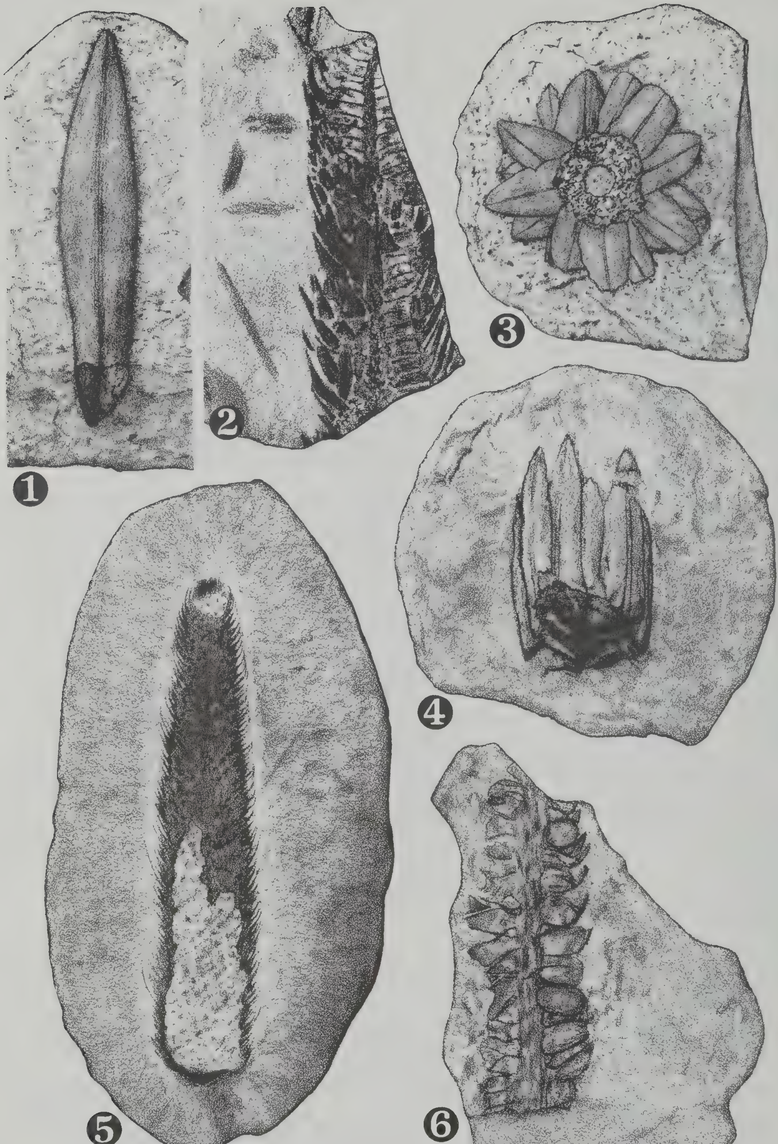


Figure 4 Diagrams showing some of the features of leaf cushions of various lycopods: (1) *Lepidodendron aculeatum*, X 2.0; (2) *Sigillaria mammillaris*, X 2.0; (3) *Lepidophloios laricinus*, X 2.0; (4) *Bothrodendron minutifolium*, X 2.0.

The name of the seal tree, *Sigillaria* (fig. 3), is derived from the signet-like appearance of its leaf scars and leaf cushions. The plant grew large, up to 6 feet in diameter near the base, although it was less branched than *Lepidodendron* and *Lepidophloios*. Fossils of sigillarian stems have more or less hexagonal leaf scars, arranged in vertical rows along the stem. These two characters allow stems of *Sigillaria* (plate 2, fig. 2) to be distinguished from stems of other lycopods. A surface with pairs of elliptical scars (parichnos tissue scars) was frequently preserved after the outer part of a sigillarian stem was stripped away. Such fossils are called *Syringodendron* (plate 2, fig. 3). Sigillarian cones are called *Sigillariostrobus* (plate 4, fig. 6). *Asolanus* (plate 2, fig. 4) was a plant that was related to *Sigillaria*, but was smaller, perhaps the size of a small bush.



1. *Lepidostrobophyllum lanceolatum*, X 0.63 - Francis Creek Shale, Will or Grundy Co.
2. *Lepidostrobus ovatifolius*, X 0.5 - Francis Creek Shale, Will Co.
3. *Lepidostrobus ovatifolius*, X 1.0 - Francis Creek Shale, Grundy Co.
4. *Lepidostrobus ovatifolius*, X 0.63 - Francis Creek Shale, Grundy Co.
5. *Lepidostrobus* sp., X 0.63 - Energy Shale, Williamson Co.
6. *Sigillariostrobus quadrangularis*, X 1.25 - Caseyville Fm., Union Co.

Plate 4 Lycopods: cones and cone scales

Another lycopod, *Bothrodendron* (plate 3, fig. 1), was similar in many respects to *Lepidodendron, Lepidophloios,* and *Sigillaria,* but it had minute, rounded leaf scars. The surface of the stem was nearly smooth, but it was covered by tiny ridges and furrows. The height of *Bothrodendron* was almost certainly not as great as the height of various other lycopods, although some were probably small trees. Some species of *Bothrodendron* bore well-defined cones, but other species may simply have had fertile areas scattered along the stem.

Leaves of the scale trees were very long and narrow and had just a single vein located at the center. The names, *Lepidophyllum, Cyperites, Poacites,* and *Lepidophylloides,* have been applied to leaves of the scale trees (plate 3, fig. 2), although none of the names is very satisfactory. The large, grass-like leaves of *Sigillaria* commonly cannot be distinguished from leaves of other lycopods, but their impressions have been termed *Sigillariophyllum* and their petrifactions have been called *Sigillariopsis.*

The underground part of the scale and seal trees is called *Stigmaria* (plate 3, fig. 3), one of the most widespread types of fossils in the Pennsylvanian. The stigmarian system functioned as a root, although it resembled a branching system in its internal structure. Stigmarian casts bear circular scars, arranged in an irregular helix. Each circular scar marks the point of attachment for a root (or rootlet). Stigmarian roots are characteristically abundant in the strata immediately underlying Pennsylvanian coal beds. This stigmarian layer is regarded as the soil in which the swamp forest began to grow.

Toward the base of the large lycopods, a thick zone of bark-like tissue (periderm) developed, causing the leaf cushions to shed. Impressions of this periderm look much like impressions of bark of some modern forest trees, but do not show any characters that allow their identification. When the outer surface of the plant was removed after the death of the plant, subsurface patterns were sometimes preserved. Such names as *Aspidiaria, Bergeria, Knorria,* and *Aspidiopsis* have been applied to these.

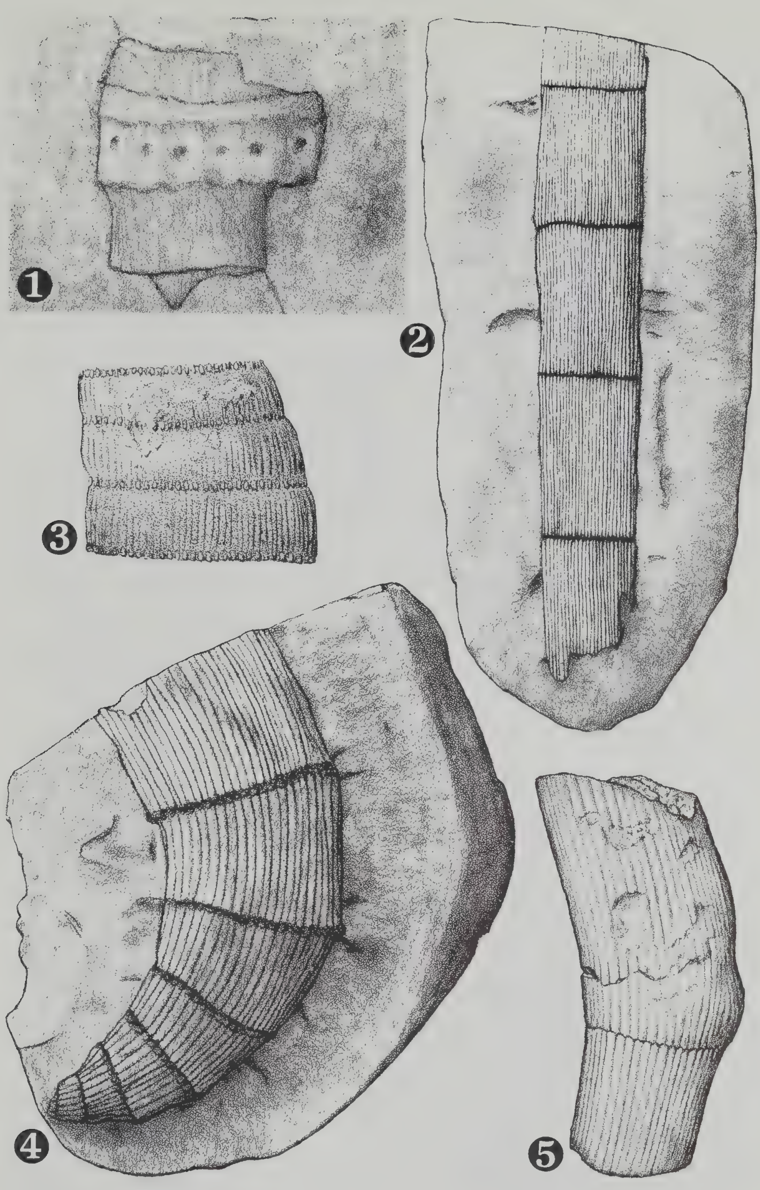
Not all Pennsylvanian lycopods were large trees or even bushes. A number of small forms are known, some of which were quite similar to the large ones in their internal structure. *Lycopodites* (plate 3, fig. 4) was one of the more important herbaceous inhabitants in the undergrowth of the swamp forest.

Neither the scale trees nor their smaller relatives had seeds. Instead, individual cells served for reproduction (as in modern ferns, club mosses, and scouring rushes). Reproductive cells in groups of four (tetrads) are produced by a type of cell division called meiosis. Each reproductive cell may then develop a resistant, protective coat to become a spore. The spores of scale and seal trees developed insides small sacs (sporangia) located on the upper (adaxial) surface of specialized leaves (sporophylls). These structures were typically grouped at the ends of branches to form cones. Cones of the scale trees are usually called *Lepidostrobus* (plate 4, figs. 2-5); whereas those of seal trees are known as *Sigillariostrobus* (plate 4, fig. 6). When an individual fertile leaf is found separate from the rest of the cone, it is included in *Lepidostrobophyllum* (plate 4, fig. 1). Scale trees produced both male spores (microspores), which were exceedingly small, and female spores (mega-spores), which were somewhat larger. Fossil megaspores can occasionally be seen by the unaided eye. In the most extreme cases, megaspores were so large that just one filled an entire sporangium. Fossils of these sporangia superficially resemble seeds and are called *Lepidocarpon.* Because scale trees produced immense numbers of spores, made durable by their protective coat, the microscopic remains of these spores are scattered abundantly through many Pennsylvanian rocks.


Figure 5 Reconstruction of *Calamites*

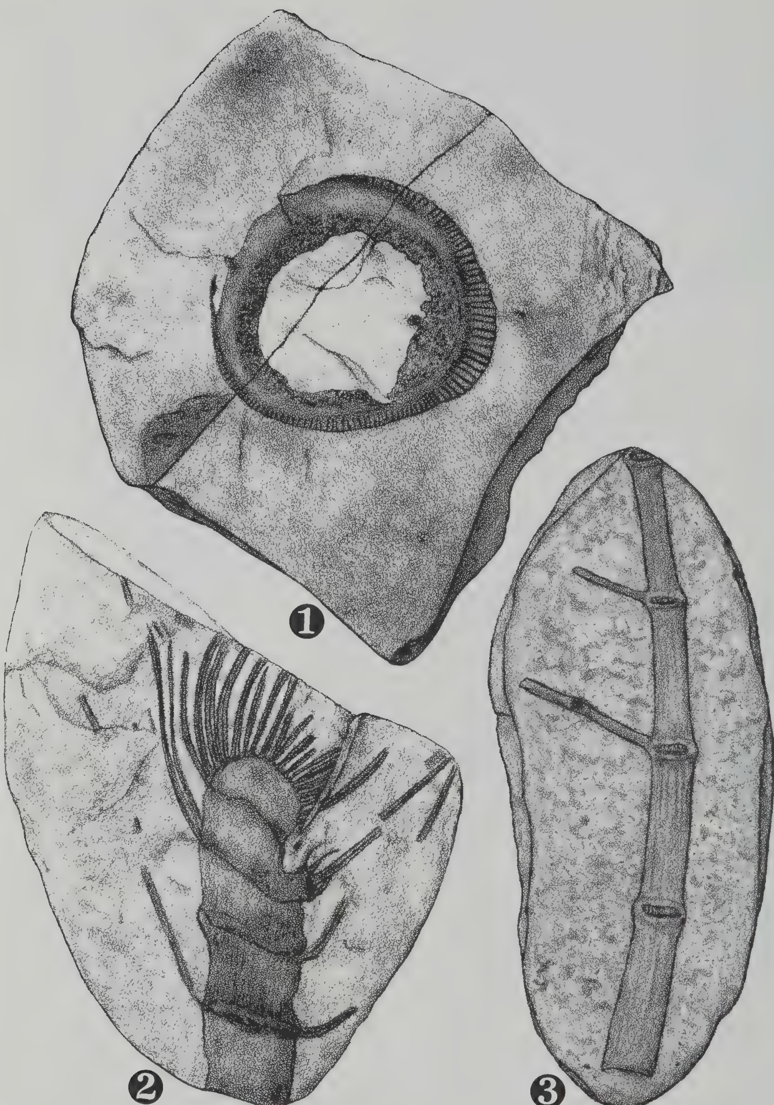
Jointed Plants (Sphenophytes or Arthrophytes)--Plates 5-11

Except for size, sphenophytes from the Pennsylvanian (e.g., *Calamites*), were very similar to modern types (i.e., species of the scouring rush, *Equisetum*). Although none are known to have attained the dimensions of the largest tree-sized lycopods, some sphenophytes reached heights of 50 feet or more and had trunks greater than 2 feet in diameter (fig. 5). Conspicuously jointed



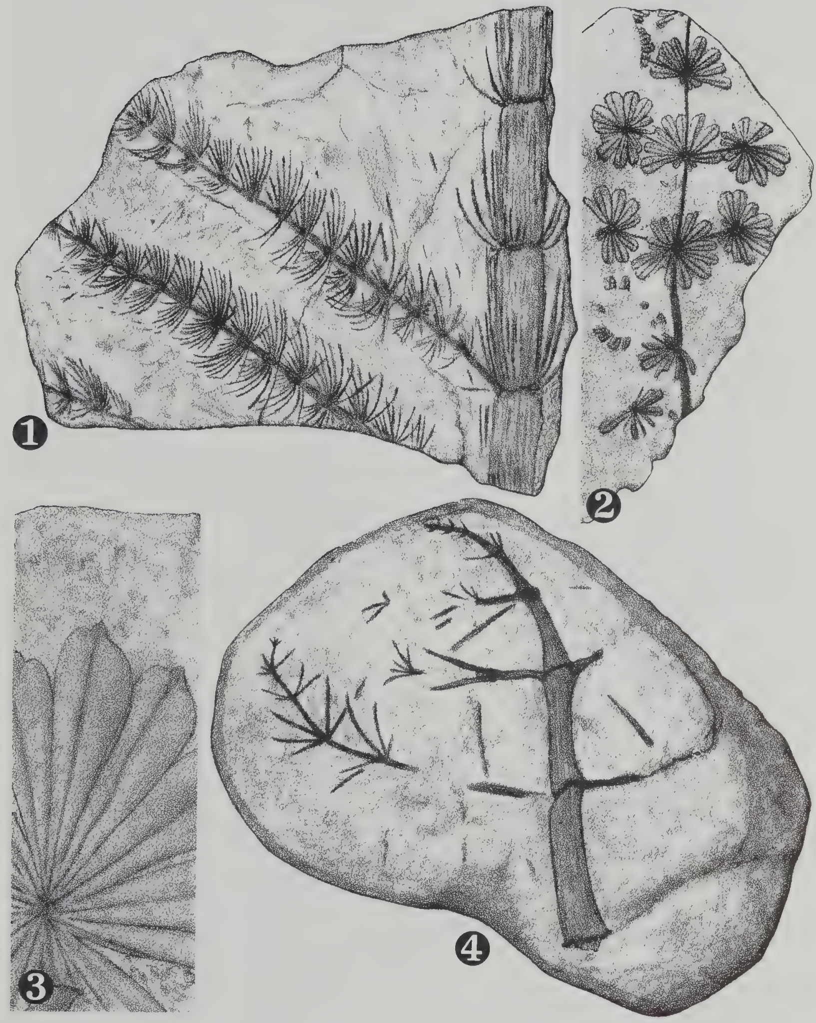
1. *Calamites* cf. *C. sachsei*, surface impression with branch scars, X 0.8 - Caseyville Fm., Pope Co.
2. *Calamites cistii*, pith impression, X 0.4 - Energy Shale, Williamson Co.
3. *Calamites suckowii*, pith cast, X 0.1 - Francis Creek Shale, Will or Grundy Co. (after Collinson and Skartvedt, 1960)
4. *Calamites suckowii*, base of pith, X 0.5 - Energy Shale, Williamson Co.
5. *Calamites* sp., pith cast, X 0.5 - Francis Creek Shale, Will or Grundy Co. (after Collinson and Skartvedt, 1960)

Plate 5 Sphenophytes: calamitean stems



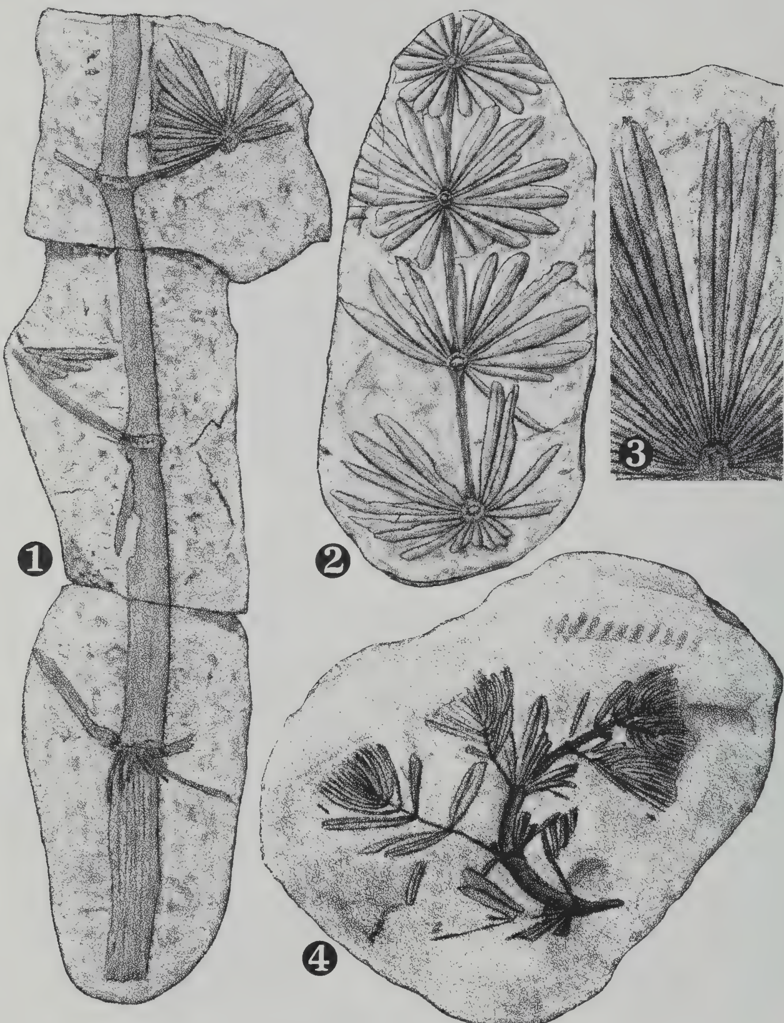
1. *Calamites* sp., compression of a nodal cross section, X 0.4 - Francis Greek Shale, Grundy Co.
2. *Calamites* sp., stem with leaves, X 1.0 - Francis Creek Shale, Will Co.
3. *Calamites* sp., branching stem, X 0.4 - Francis Creek Shale, Will Co.

Plate 6 Sphenophytes: calamitean stems and leaves



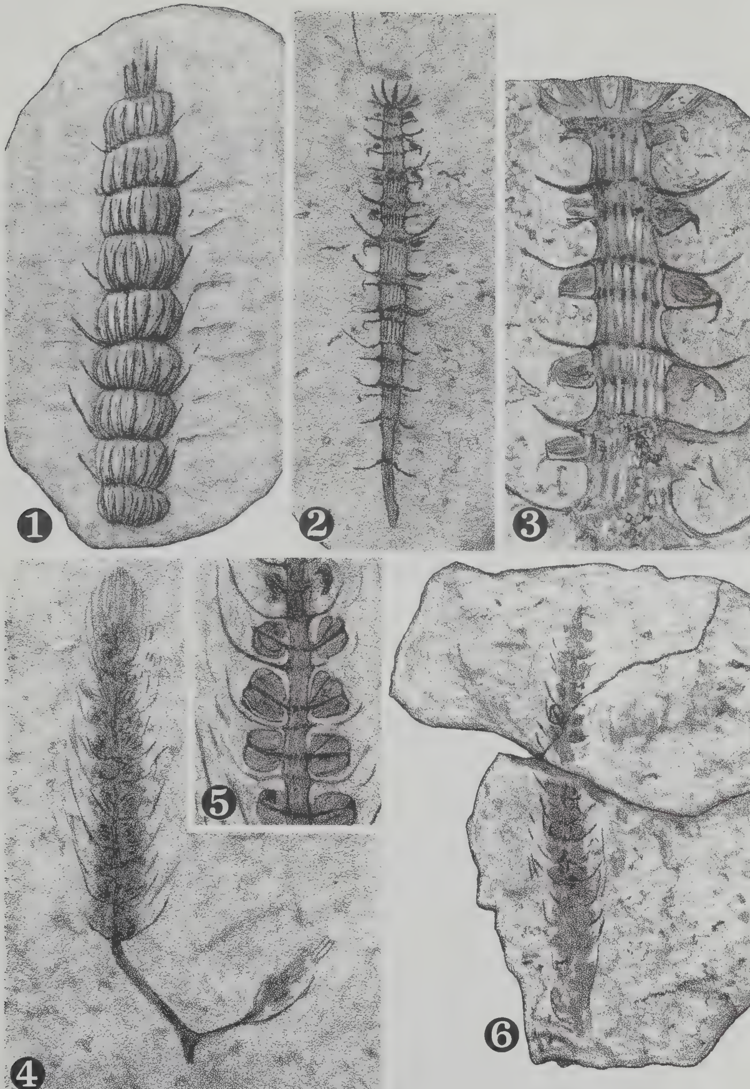
1. *Asterophyllites equisetiformis*, X 0.63 - Francis Creek Shale, Grundy Co.
2. *Annularia sphenophylloides*, X 1.25 - Francis Creek Shale, Will Co.
3. *Annularia sphenophylloides*, X 5.0 - Francis Creek Shale, Will Co.
4. *Annularia radiata*, X 1.0 - Francis Creek Shale, Will Co.

Plate 7 Sphenophytes: calamitean foliage



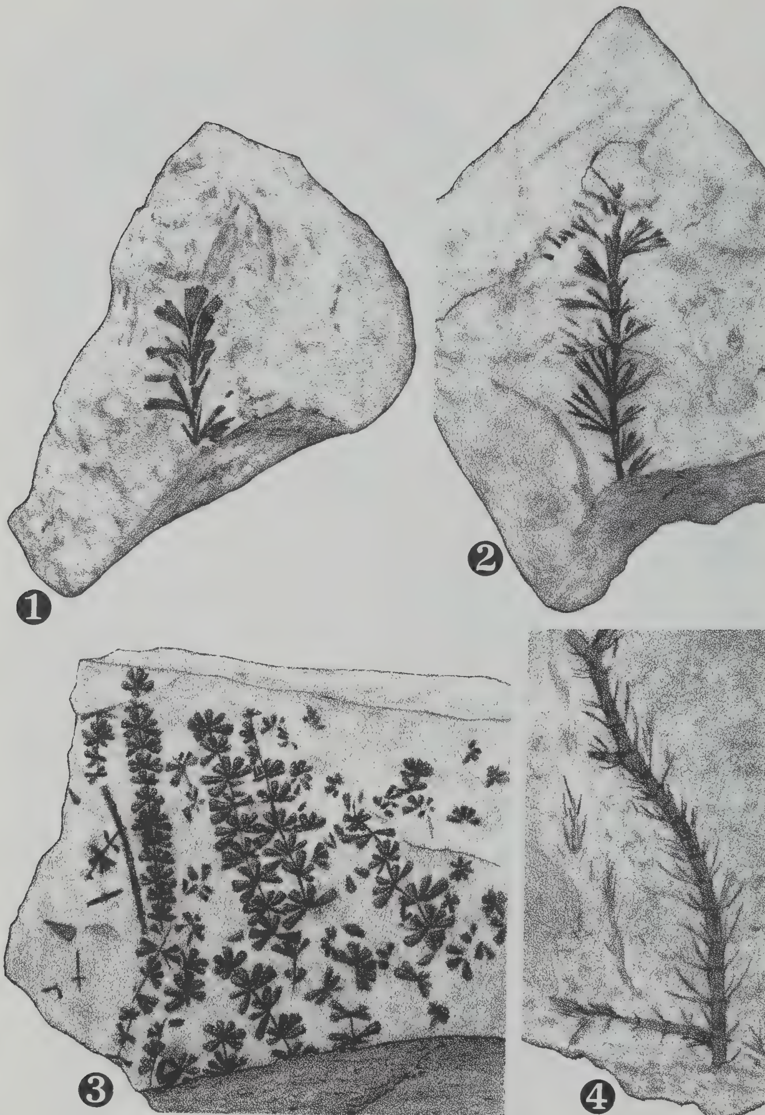
1. *Annularia stellata,* X 0.5 - Energy Shale, Williamson Co.
2. *Annularia stellata,* X 0.63 - Francis Creek Shale, Grundy Co.
3. *Annularia stellata,* X 1.25 - Francis Creek Shale, Grundy Co.
4. *Annularia stellata,* X 0.63 - Francis Creek Shale, Grundy Co.

Plate 8 Sphenophytes: calamitean foliage



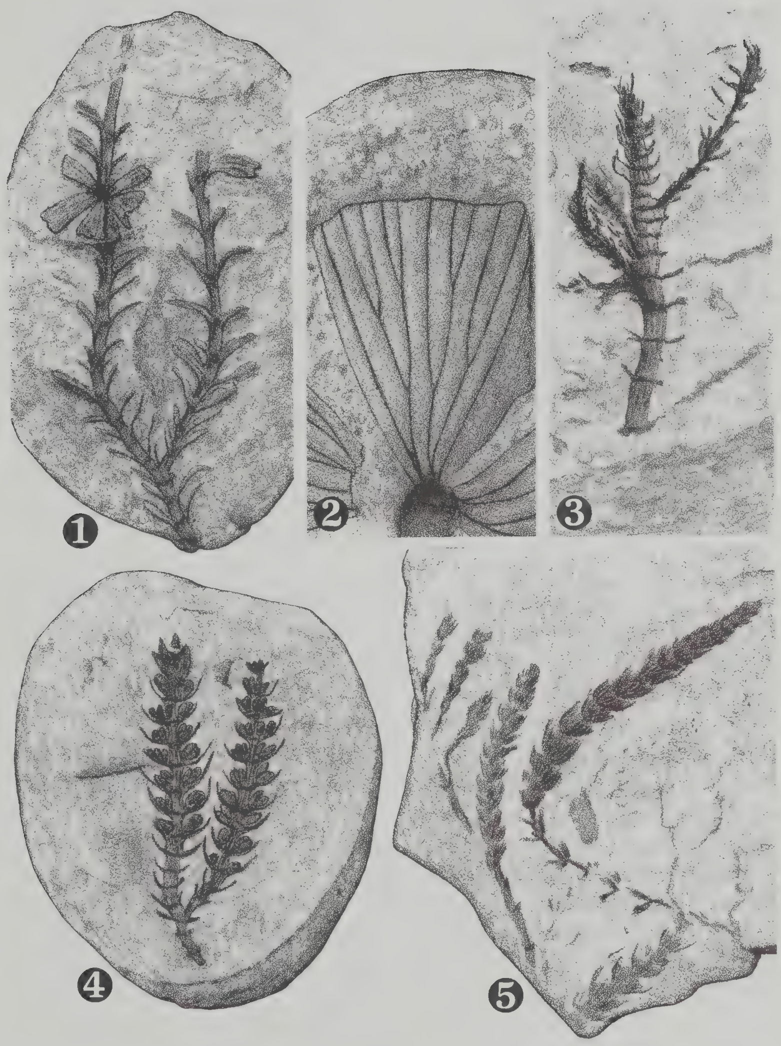
1. *Calamostachys germanica*, X 1.25 - Francis Creek Shale, Will Co.
2. *Calamostachys germanica*, X 0.8 - Francis Creek Shale, Will Co.
3. *Calamostachys germanica*, X 2.0 - Francis Creek Shale, Grundy or Will Co.
4. *Calamostachys (Paracalamostachys) cartervilli*, X 1.6 - Energy Shale, Williamson Co.
5. *Calamostachys (Paracalamostachys) cartervilli*, detail of fig. 4, X 3.2 - Energy Shale, Williamson Co.
6. *Palaeostachya* sp., X 1.0 - Caseyville Fm., Union Co.

Plate 9 Sphenophytes: calamitean cones



1. *Sphenophyllum cuneifolium*, dissected form, X 0.63 - Caseyville Fm., Pope Co.
2. *Sphenophyllum cuneifolium*, X 0.63 - Caseyville Fm., Pope Co.
3. *Sphenophyllum emarginatum*, X 0.4 - Energy Shale, Franklin Co.
4. *Sphenophyllum emarginatum*, dissected form, X 1.25 - Francis Creek Shale, Grundy Co.

Plate 10 Sphenophytes: sphenophyllalean stems and leaves



1. *Sphenophyllum emarginatum*, X 1.25 - Francis Creek Shale, Will Co.
2. *Sphenophyllum emarginatum*, X 4.0 - Francis Creek Shale, Will Co.
3. *Sphenophyllum* cf. *S. emarginatum*, X 1.25 apex - Francis Creek Shale, Grundy Co.
4. *Bowmanites* sp., X 1.25 - Francis Creek Shale, Will Co.
5. *Bowmanites* sp. with sterile foliage attached, X 0.63 - Francis Creek Shale, Grundy Co.

Plate 11 Sphenophytes: sphenophyllalean stems, leaves, and cones stems are characteristic of all members of this plant group. In the modern scouring rush this feature makes it easy to pull the plant apart into sections. Both branches and leaves are borne in whorls at joints (nodes), each of which is generally preserved as a groove extending across the stem.

Calamitean scouring rushes of the Pennsylvanian had a stem with a nearly smooth outer surface between nodes (internode), although there were very fine ridges and grooves oriented lengthwise (plate 5, fig. 1; plate 6, figs. 2-3). A large, cylindrical cavity, formed by the breakdown of pith, extended down the center of the stem (plate 6, fig. 1). In calamitean scouring rushes, the surface of this central pith cavity typically had much more pronounced lengthwise ridges and grooves (plate 5, figs. 2-5) than did the outer surface of the stem. At the base of the stem and branches, the pith cavity tapered rapidly and was often strongly curved (plate 5, fig. 4). After a plant died, the central pith cavity of a stem fragment commonly filled with sediment. If it filled with sand, which later hardened into sandstone, a cast was the most common result. If the pith cavity filled with clay, which later hardened into shale, a flattened impression was more commonly formed.

Leaves of *Calamites* are placed in several different genera. One common Pennsylvanian form, which has narrow, needle-like leaves that arc toward the tip of the branch, is called *Asterophyllites* (plate 7, fig. 1). *Annularia* (plate 7, figs. 2-4; plate 8) is another common form. It has leaf whorls that are typically spread out on a bedding plane. It also has broader individual leaves than has *Asterophyllites*. Spores of calamiteans were borne in aggregates (cones). Sporangia developed on small stalks (sporangiophores) that grew from the main stem of the cone. The position of these stalks is the primary character that allows recognition of different genera. *Calamostachys* (plate 9, figs. 1-5) and *Palaeostachya* (plate 9, fig. 6) are two of the most common types of calamitean cones, although others (e.g., *Mazostachys* and *Macrostachya*) also exist. If the position of the stalk (sporangiophore) is not clear, the cone may be referred to *Paracalamostachys*.

Sphenophyllum (plates 10-11), a small plant, was related to the scouring rushes, as its jointed stem and whorls of leaves illustrate. It is common in Pennsylvanian floras, and evidently formed a significant portion of the undergrowth in the swamp forests. On its slender stems, *Sphenophyllum* typically bore delicate, wedge-shaped leaves (plate 10, figs. 1, 3; plate 11, figs. 1-2), but some of its leaves were so deeply divided that they simply consisted of many narrow filaments (plate 10, figs. 2, 4). The diminutive cones of the plant are mostly called *Bowmanites* (plate 11, figs. 4-5). Unlike the calamiteans, *Sphenophyllum* became extinct during the Triassic Period and did not leave any closely related descendants.

Figure 6 Reconstruction of *Psaronius*

Ferns (Pteridophytes)--
Plates 12-16

True ferns, unmistakably resembling diminutive forms that inhabit modern woodlands, were common in Pennnsylvanian swamp forests. Some were large tree ferns that attained heights of 30 or 40 feet (fig. 6). Their fronds (compound leaves) were large and commonly reached a length of 5 to 6 feet. Each frond was typically divided into hundreds of individual, leaf-like segments called leaflets or pinnules.

Although true ferns, large and small, reproduce by means of spores, their sporangia are not borne in cones as are sporangia of lycopods and sphenophytes. Instead, their sporangia develop on the lower (abaxial) surface of the frond, often in clusters (sori). Because fossil fern fronds with attached sporangia are uncommon, the shape of individual leaflets (pinnules), their manner of attachment, and the pattern of their veins (fig. 7) are generally used to establish convenient groups (form genera and form species). If the fertile structures for a form species that is based on sterile foliage have not been found attached, it is impossible to determine whether various members of the group are actually related. This is true even when the sterile remains look essentially alike. In extreme cases, it may not even be clear whether an individual fossil represents a true fern or a seed plant. On the other hand, if fertile foliage is found, the affinities of the fossil can be determined more precisely. A separate name may sometimes be given for the fertile structure. Because of the value of

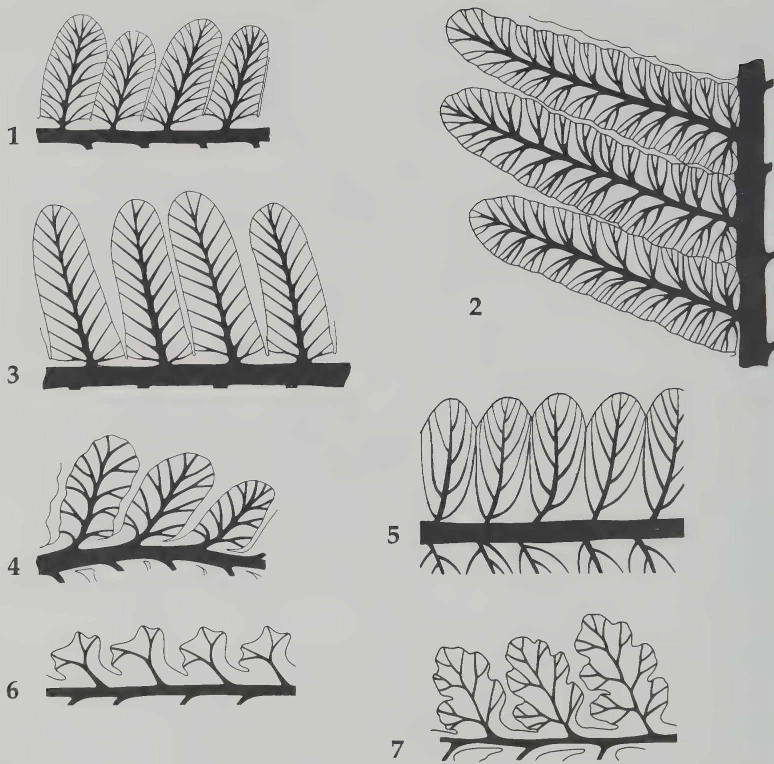


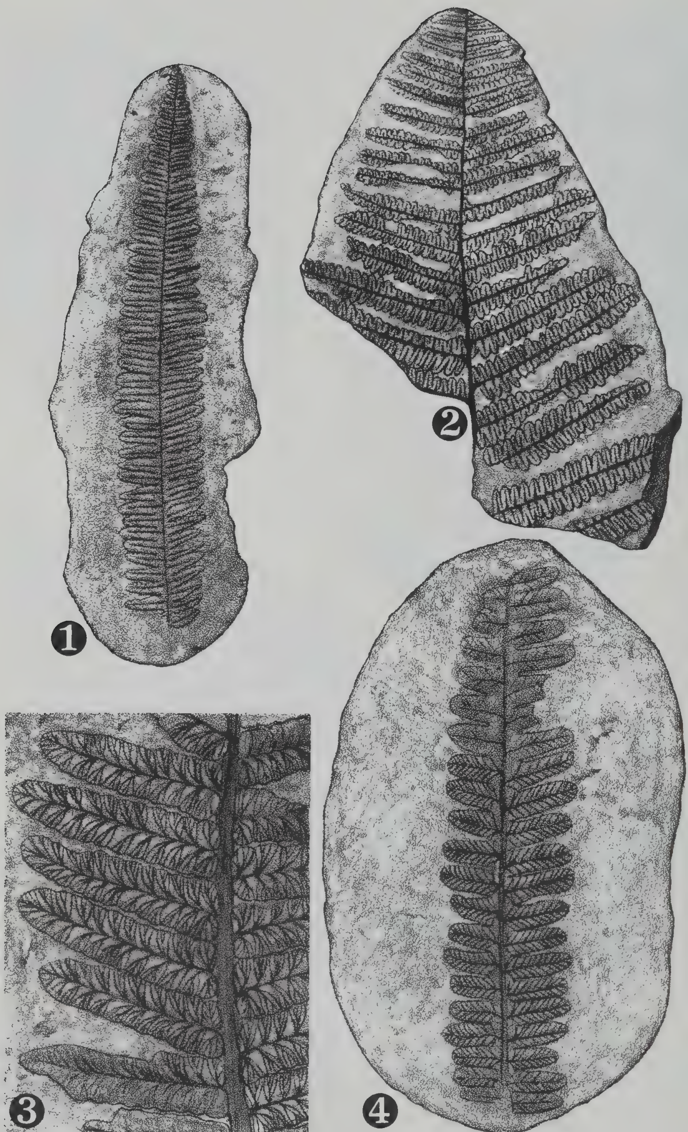
Figure 7 Venation of various forms of fern foliage: (1) *Pecopteris mazoniana*, X 2.5; (2) *Pecopteris mazoniana*, X 2.5; (3) *Pecopteris hemitelioides*, X 2.5; (4) *Pecopteris miltonii*, X 2.5; (5) *Pecopteris unita*, X 2.5; (6) *Alloiopteris angustissima*, X 4.0; (7) *Sphenopteris gracilis*, X 4.0

fertile foliage, collectors should make an extra effort to obtain this type of material.

Large tree ferns called *Psaronius* were abundant in the middle and upper parts of the Pennsylvanian. Pieces of their large fronds are among the most common fossils in beds of this age and are assigned to the form genus *Pecopteris* (plate 12, figs. 3-4; plate 13; plate 14; plate 15; plate 16, figs. 1-2) unless fertile structures are present. The leaflets (pinnules) of this form are broadly attached at the base, the side margins of the pinnules are essentially parallel, and the tips are bluntly rounded. There is a midvein at the center of each pinnule, and the veins that branch from it

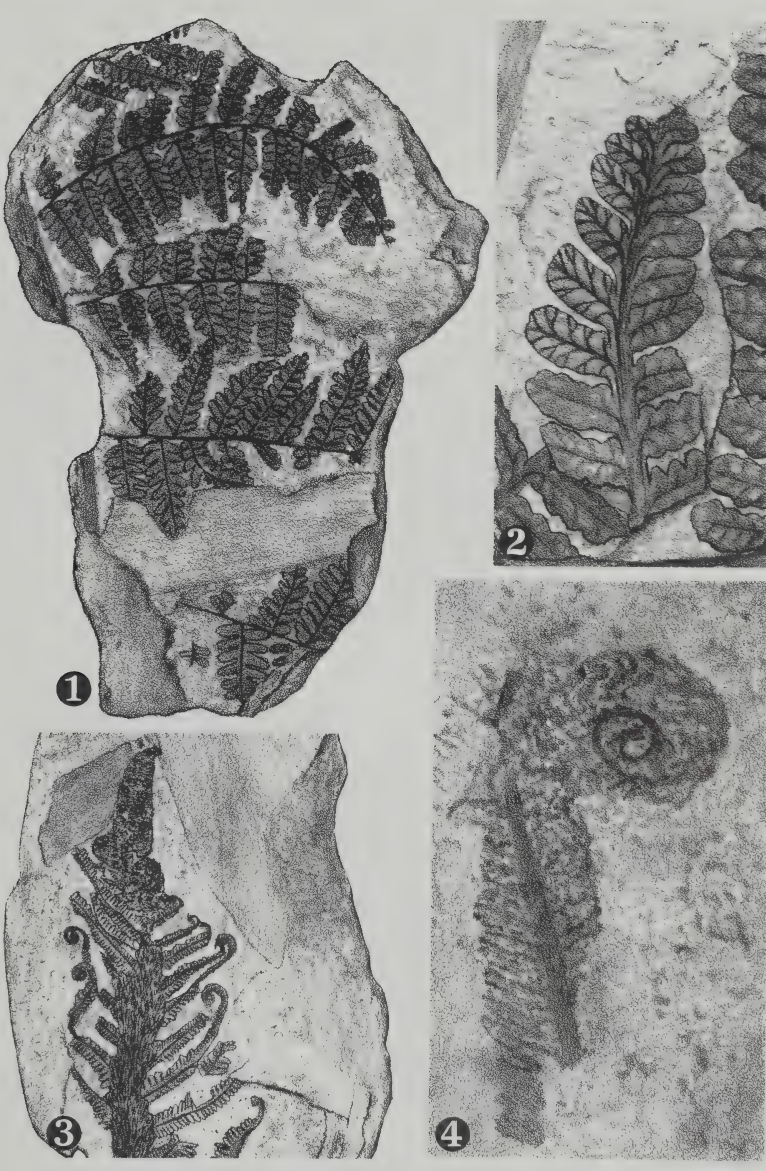
1. *Caulopteris anglica*, X 0.63 - Energy Shale, Franklin Co.
2. *Artisophyton insignis*, X 0.63 - Energy Shale, Franklin Co.
3. *Pecopteris mazoniana*, X 0.32 - Francis Creek Shale, Grundy Co.
4. *Pecopteris mazoniana*, detail of fig. 3, X 2.5 - Francis Creek Shale, Grundy Co.

Plate 12 Ferns: tree fern stems and foliage



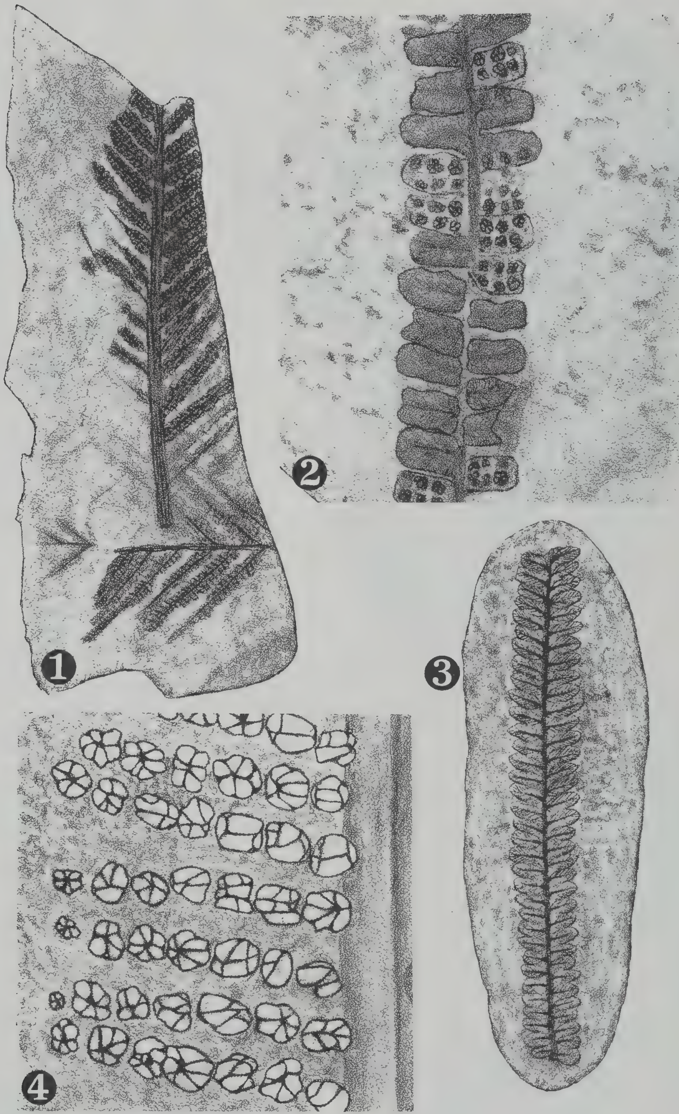
1. *Pecopteris mazoniana*, X 0.4 - Francis Creek Shale, Grundy Co.
2. *Pecopteris mazoniana*, X 0.4 - Energy Shale, Williamson Co.
3. *Pecopteris mazoniana*, X 1.6 - Francis Creek Shale, Grundy Co.
4. *Pecopteris hemitelioides*, X 1.0 - Francis Creek Shale, Will or Grundy Co.

Plate 13 Ferns: tree fern foliage



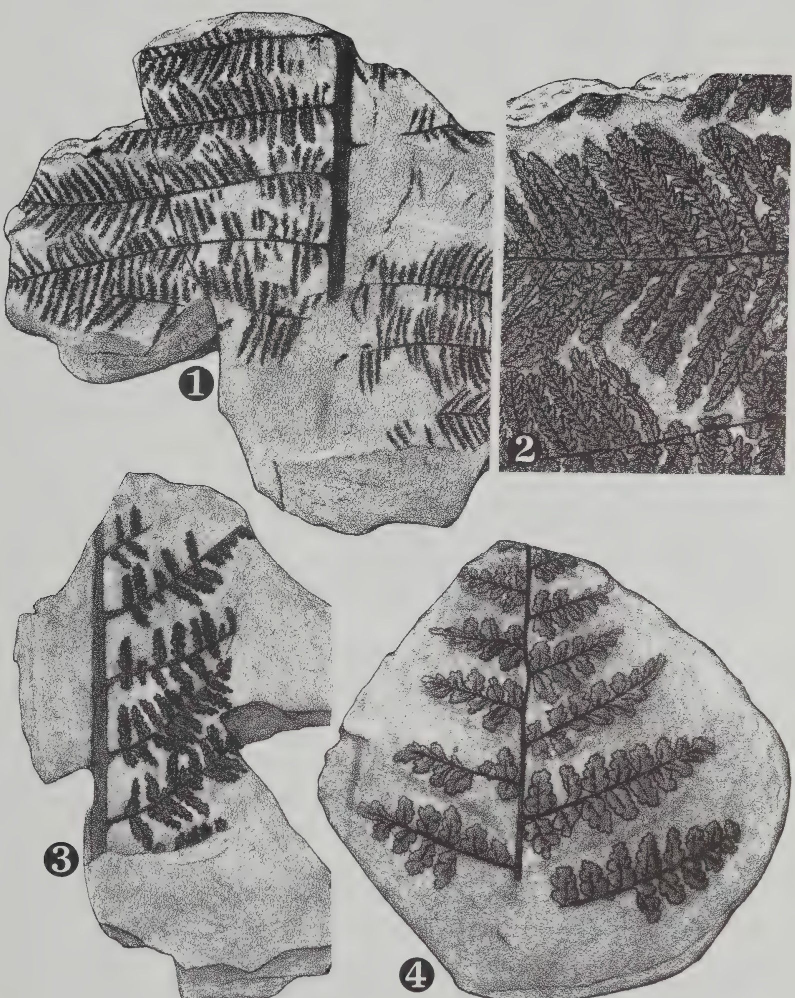
1. *Pecopteris miltonii,* X 0.5 - Abbott Fm., Schuyler Co.
2. *Pecopteris miltonii,* X 2.0 - Abbott Fm., Schuyler Co.
3. *Pecopteris squamosa,* X 0.5 - Francis Creek Shale, Grundy Co.
4. *Pecopteris squamosa,* detail of fig. 3, X 4.0 - Francis Creek Shale, Grundy Co.

Plate 14 Ferns: tree fern foliage



1. *Pecopteris arborescens,* X 0.5 - Mattoon Fm., Fayette Co.
2. *Pecopteris arborescens,* fertile, X 3.2 - Mattoon Fm., Fayette Co.
3. *Pecopteris unita,* sterile, X 0.5 - Energy Shale, Williamson Co.
4. *Pecopteris unita,* fertile, X 6.3 - Francis Creek Shale, Will Co.

Plate 15 Ferns: tree fern foliage, sterile and fertile



1. *Pecopteris plumosa*, X 0.16 - Energy Shale, Franklin Co.
2. *Pecopteris plumosa*, detail of fig. 1, X 0.5 - Energy Shale, Franklin Co.
3. *Alloiopteris angustissima*, X 0.63 - Caseyville Fm., Union Co.
4. *Sphenopteris gracilis*, X 0.8 - Energy Shale, Williamson Co.

Plate 16 Ferns: foliage of small ferns

are straight or gently curved. The young frond, like young fronds of modern ferns, was enrolled (plate 14, figs. 3-4). It uncurled as development proceeded. Fossils of immature, enrolled foliage are called *Spiropteris*, if they are not otherwise identifiable.

Fertile structures of the Pennsylvania tree ferns (plate 15, figs. 2 and 4) are placed in the genera *Asterotheca* (some authors use *Cyathocarpus*) and *Stellatheca*. If sufficient cellular structure is preserved, they are placed in *Scolecopteris, Acaulangium, Cyathotrachis, or Eoangiopteris*. Some fertile material from Illinois was formerly called *Ptychocarpus*, but now is known not to belong to this genus and is placed in *Scolecopteris*. The sporangia in all of these genera are not merely clustered (as in a sorus of modern ferns), but actually have tissue joining them to their neighboring sporangia. The complete structure is called a synangium.

Stems of *Psaronius* were small compared with the size of the plant, and much smaller near the base than higher up; therefore, the stem could not function as the sole support for the plant. The stem was surrounded by a large mantle of roots produced high above the ground. These roots grew almost vertically down into the soil, anchoring the plant and absorbing nutrients. The combination of stem and root mantle functioned like a true stem and was often more than one foot in diameter.

Small ferns thrived in the shadow of the giants of the Pennsylvanian swamp forests. Their fronds are frequently encountered as fossils, and are surprisingly diversified. Among the different kinds of foliage that they produced are forms assigned to *Pecopteris, Sphenopteris*, and *Alloiopteris* (plate 16). Sterile, pecopteroid foliage of small ferns is difficult to distinguish from sterile foliage of tree ferns. Many of their fertile remains (of the kind known as *Senftenbergia*), however, are readily distinguishable because their sporangia are borne singly rather than in groups. *Sphenopteris* includes a wide variety of sterile foliage. The base of the pinnules in the form genus is constricted, and the pinnules are variously lobed or toothed. *Discopteris* is one type of fertile structure found attached to sphenopteroid fronds. Pinnules of *Alloiopteris* are inserted at a steep angle along the frond axis and are joined at the base. The margin of the pinnules has prominent pointed lobes or teeth. *Corynepteris* is one type of fertile structure borne on *Alloiopteris*-type fronds.

Seed Ferns (Pteridosperms)--Plates 17-25

In the Pennsylvanian swamp forests the seed ferns (fig. 8) were a diverse group of plants. They produced fronds that were superficially very similar to fern fronds, but they reproduced by means of seeds. Unfortunately, attached seeds are extremely rare as fossils. Thus, the assignment of many fossils to the group is based on other evidence, such as comparison of cellular structure and consistent association with particular fertile structures. In spite of the use of these types of evidence, there still remains a great deal of foliage with questionable affinities.

Figure 8 Reconstruction of *Medullosa* (redrawn from Stewart and Delevoryas, 1956; see Stewart, 1983)

Although the seed ferns have been extinct at least since the Jurassic Period, they overshadowed the true ferns in both numbers and diversity during the lower part of the Pennsylvanian. Both large and small seed ferns grew in the swamp forests. There were even vine-like seed ferns. *Medullosa* is probably the best known of the tree-sized seed ferns, although it was relatively small compared to some of the other inhabitants of the swamp forests. Other seed ferns, such as *Heterangium* or *Callistophyton*, were quite small. Impressions of stems and of frond-bearing stalks (petioles) from seed ferns are common, but tend not to show distinguishing characteristics. Many unidentifiable fossils may represent seed fern petioles.

The fronds of the seed ferns are abundant and have diverse identifying character. Many can be assigned to the following form genera: *Alethopteris, Eremopteris, Linopteris, Lonchopteris, Mariopteris, Neuropteris, Odontopteris, and Sphenopteris* (figs. 9-12; plates 17-24). Some seed ferns had

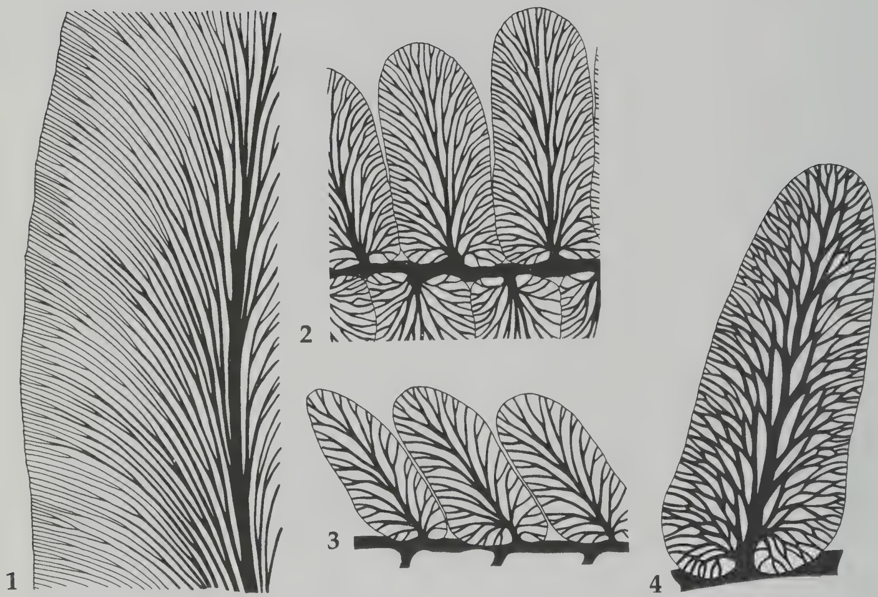


Figure 9 Venation of various forms of seed ferns foliage, neuropteroid group: (1) *Neuropteris scheuchzeri,* X 2.0; (2) *Neuropteris ovata,* X 2.0; (3) *Neuropteris rarinervis,* X 3.2; (4) *Linopteris muensteri,* X 2.5

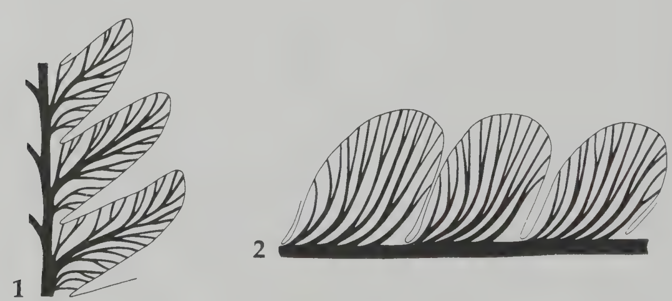


Figure 11 Venation of various forms of seed ferns foliage: (1) *Mariopteris nervosa,* X 2.0; (2) *Odontopteris aequalis,* X 2.0

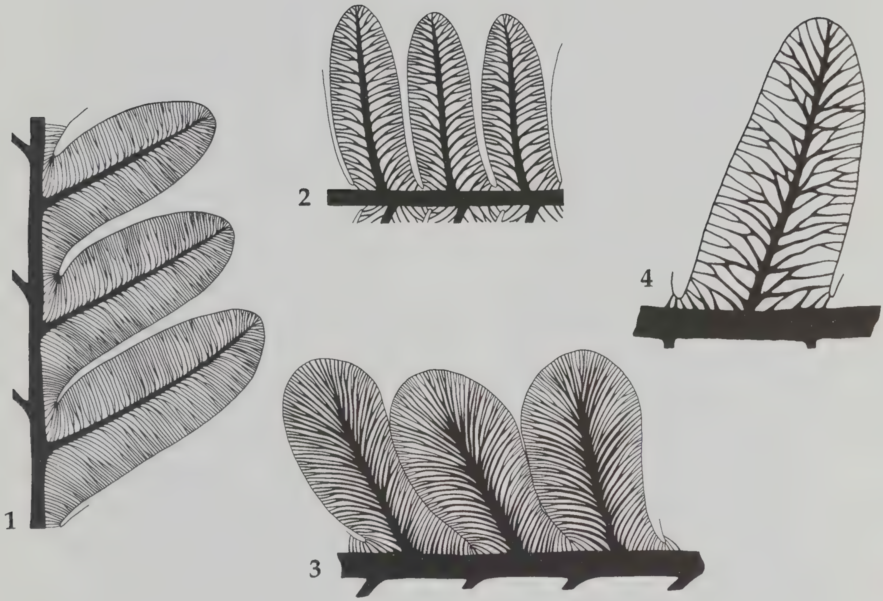
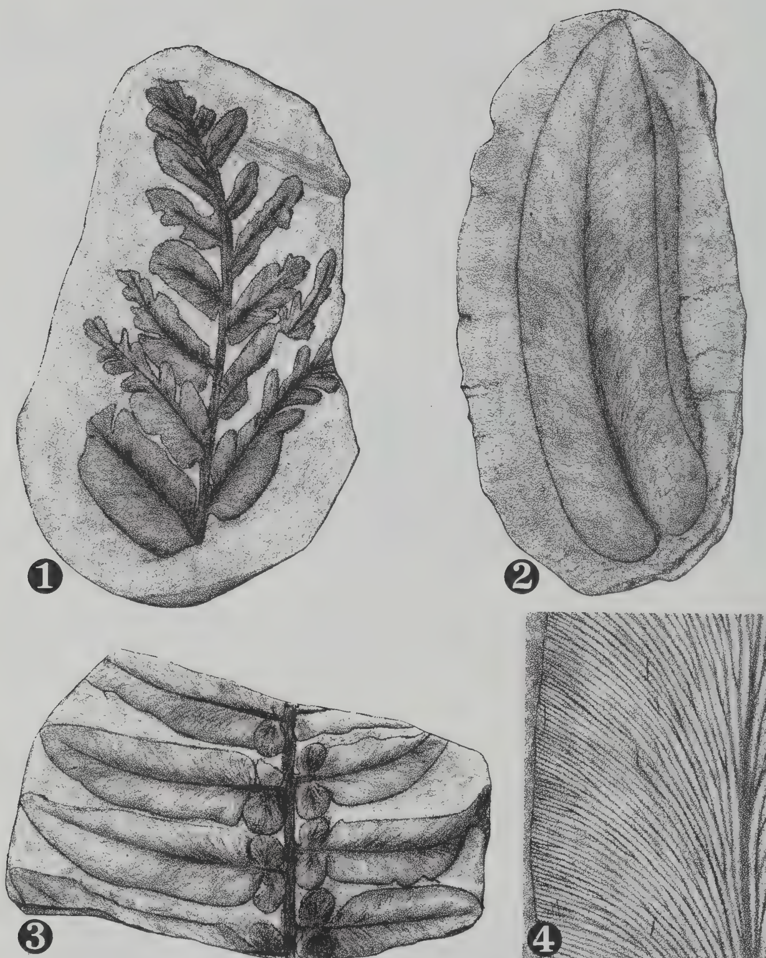


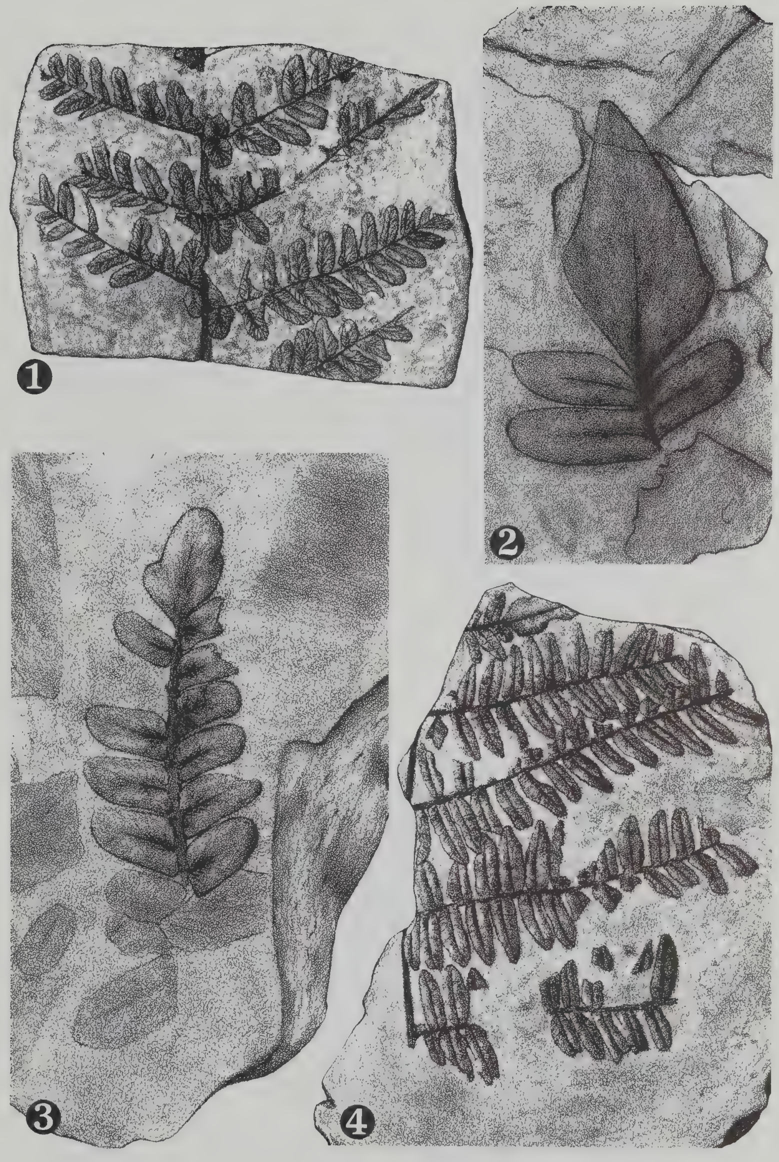
Figure 10 Venation of various forms of seed ferns foliage, alethopteroid group: (1) *Alethopteris serlii*, X 2.0; (2) *Alethopteris ambigua*, X 2.0; (3) *Alethopteris sullivantii*, X 2.0; (4) *Lonchopteris eschweileriana*, X 3.2

Figure 12 Venation of various forms of seed fern foliage, sphenopteroid group: (1) *Sphenoteris rotundiloba*, X 4.0; (2) *Sphenopteris bronnii*, X 4.0.



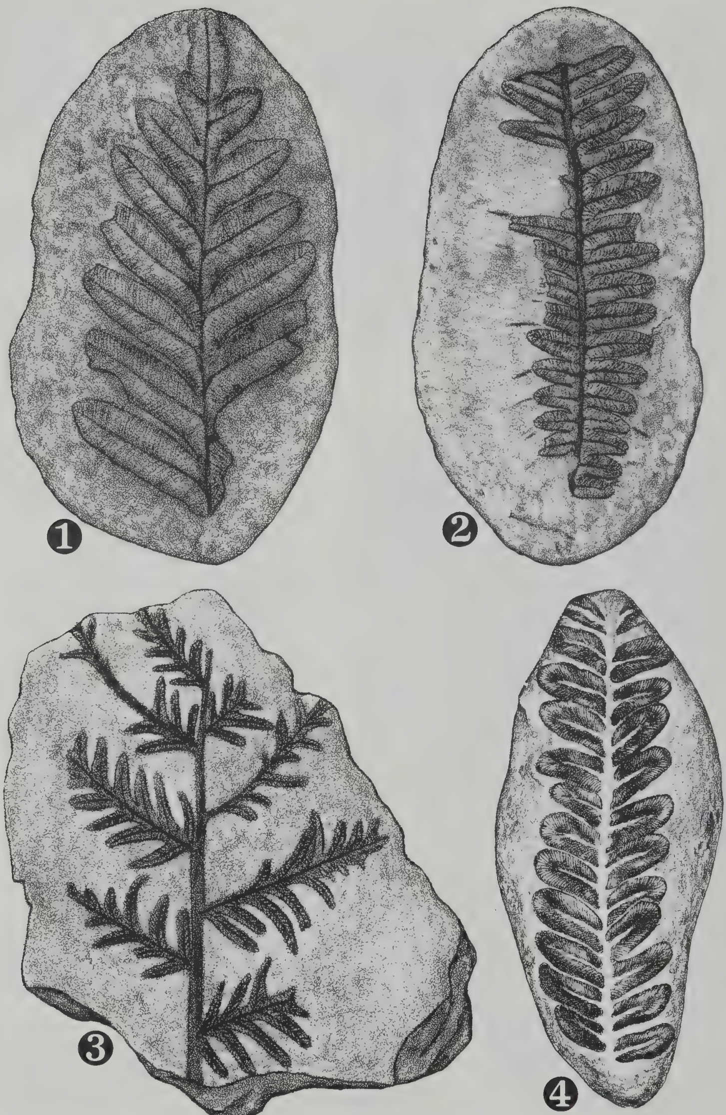
1. *Neuropteris scheuchzeri,* X 0.5 - Francis Creek Shale, Grundy Co.
2. *Neuropteris scheuchzeri,* X 0.63 - Francis Creek Shale, Grundy Co.
3. *Neuropteris scheuchzeri,* X 0.63 - Energy Shale, Williamson Co.
4. *Neuropteris scheuchzeri,* detail of fig. 2, X 2.0 - Francis Creek Shale, Grundy Co.

Plate 17 Seed ferns: foliage



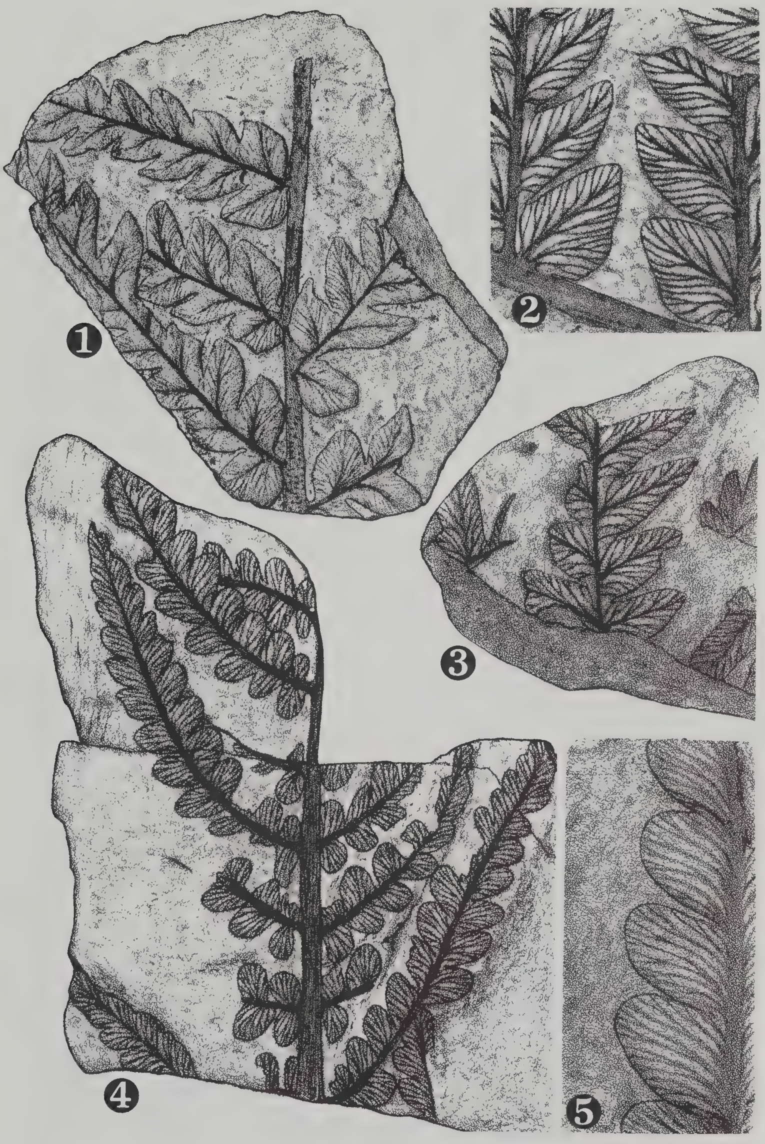
1. *Neuropteris rarinervis*, X 0.5 - Francis Creek Shale, Will Co.
2. *Neuropteris capitata*, X 0.8 - Spoon Fm., Jackson Co.
3. *Neuropteris ovata*, X 1.0 - Mattoon Fm., Richland Co.
4. *Neuropteris schlehani*, X 0.63 - Caseyville Fm., Gallatin Co.

Plate 18 Seed ferns: foliage



1. *Alethopteris serlii,* X 0.63 - Francis Creek Shale, Will Co.
2. *Alethopteris ambigua,* X 0.63 - Francis Creek Shale, Will Co.
3. *Alethopteris decurrens,* X 1.0 - Caseyville Fm., Union Co.
4. *Alethopteris sullivantii,* 0.5 - Francis Creek Shale, Grundy Co.

Plate 19 Seed ferns: foliage

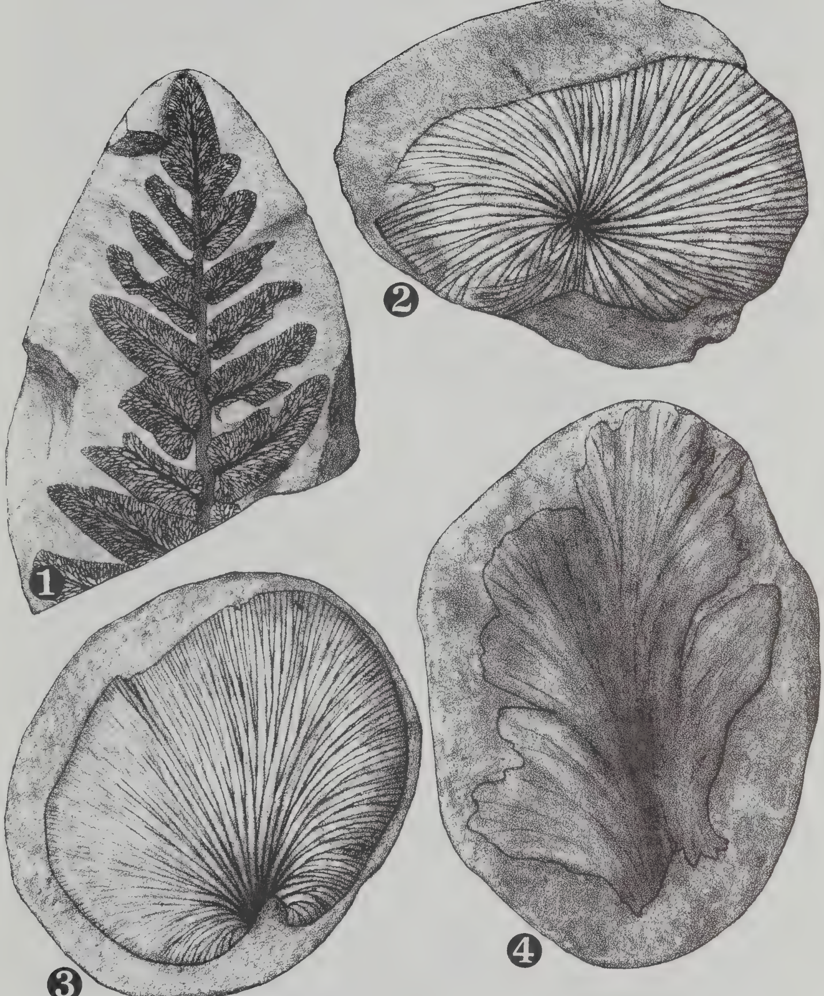


1. *Mariopteris nervosa*, X 0.8 - Francis Creek Shale, Grundy Co.
2. *Mariopteris nervosa*, X 1.6 - Energy Shale, Grundy Co.
3. *Mariopteris nervosa*, X 1.0 - Energy Shale, Vermilion Co.
4. *Odontopteris aequalis*, X 0.63 - Energy Shale, Williamson Co.
5. *Odontopteris aequalis*, detail of fig. 3, X 1.6 - Energy Shale Williamson Co.

Plate 20 Seed ferns: foliage

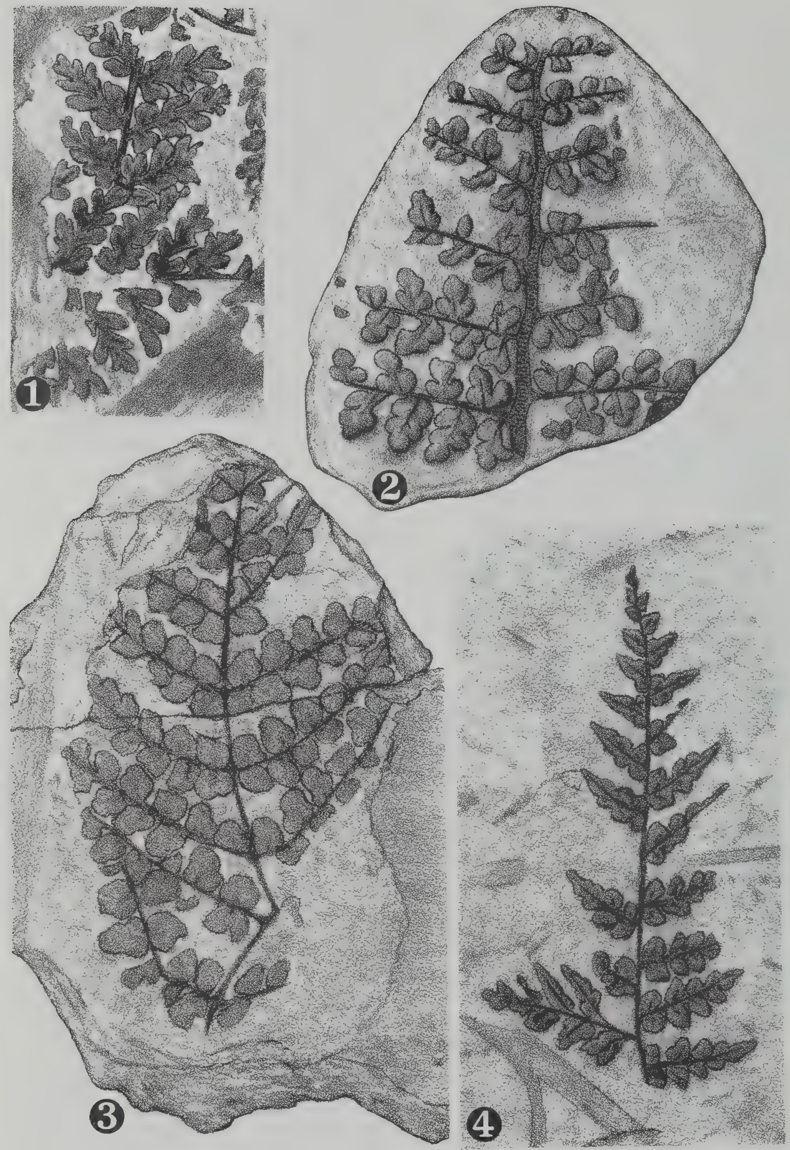
1. *Lonchopteris eschweileriana*, X 0.63 - Caseyville Fm., Johnson Co.
2. *Lonchopteris eschweileriana*, detail of fig. 1, X 1.6 - Caseyville Fm., Johnson Co.
3. *Lonchopteris eschweileriana*, close-up of pinnule of specimen shown in fig. 1, X 8.0 - Caseyville Fm., Johnson Co.

Plate 21 Seed ferns: foliage



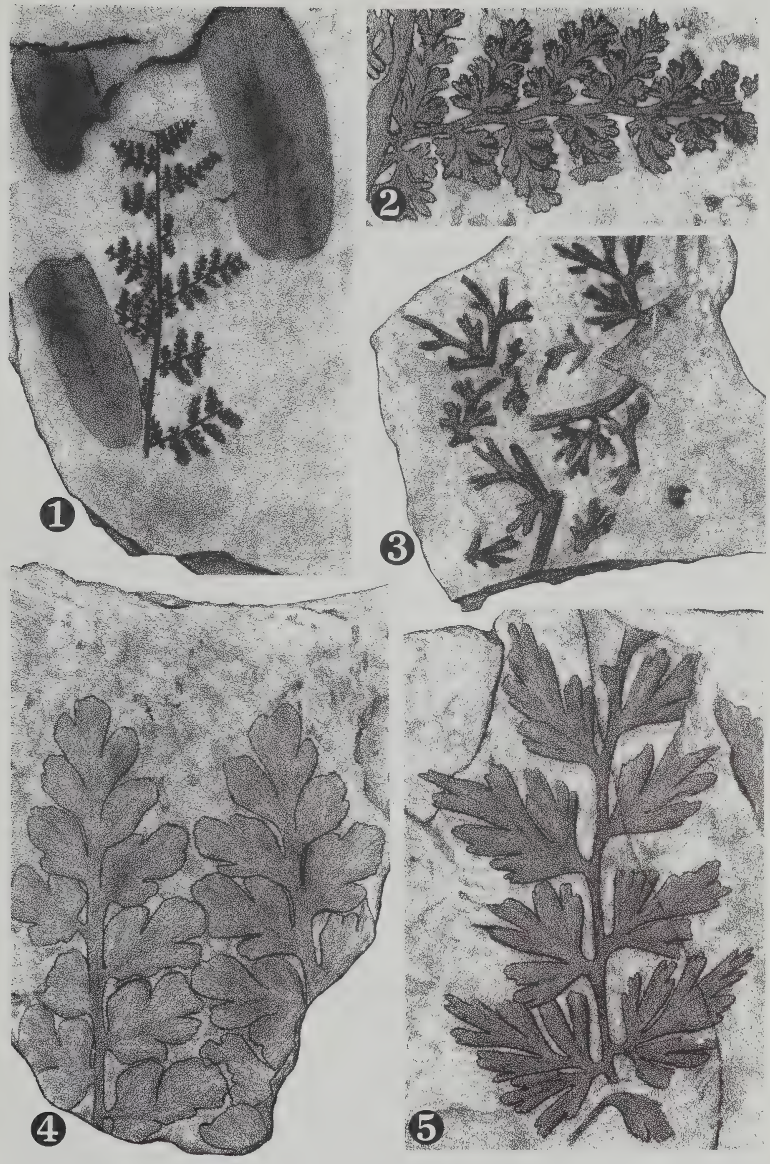
1. *Linopteris muensteri,* X 0.8 - Francis Creek Shale, Grundy or Will Co.
2. *Cyclopteris* cf. *C. dilatata,* X 1.0 - Energy Shale, Williamson Co.
3. *Cyclopteris trichomanoides,* X 1.25 - Francis Creek Shale, Grundy or Will Co.
4. *Aphlebia* cf. *A. clarkii,* X 1.25 - Francis Creek Shale, Will Co.

Plate 22 Seed ferns: foliage



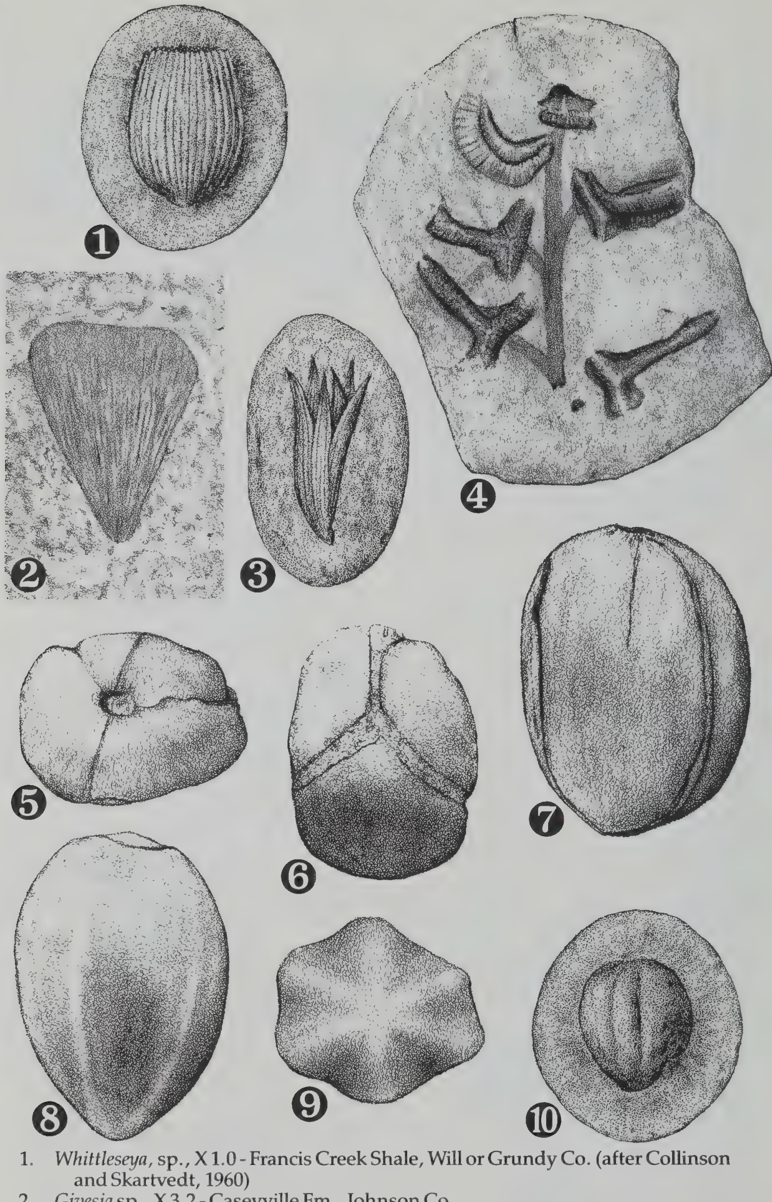
1. *Sphenopteris sauveurii*, X 1.25 - Spoon Fm., Jackson Co.
2. *Sphenopteris rotundiloba*, X 0.8 - Energy Shale, Williamson Co.
3. *Sphenopteris neuropteroides*, X 0.8 - Abbott Fm., Schuyler Co.
4. *Sphenopteris pygmaea*, X 1.25 - Caseyville Fm., Johnson Co.

Plate 23 Seed ferns: foliage



1. *Sphenopteris bronnii*, X 0.8 - Mattoon Fm., Richland Co.
2. *Sphenopteris bronnii*, detail of fig. 1, X 3.2 - Mattoon Fm., Richland Co.
3. *Sphenopteris* cf. *S. furcata*, X 0.8 - Francis Creek Shale, Grundy Co.
4. *Sphenopteris cheathamii*, X 2.5 - Caseyville Fm., Pope Co.
5. *Eremopteris gracilis*, X 1.0 - Caseyville Fm., Johnson Co.

Plate 24 Seed ferns: foliage



1. *Whittleseya*, sp., X 1.0 - Francis Creek Shale, Will or Grundy Co. (after Collinson and Skartvedt, 1960)
2. *Givesia* sp., X 3.2 - Caseyville Fm., Johnson Co.
3. *Codonotheca caduca*, X 1.0 - Francis Creek Shale, Will or Grundy Co. (after Collinson and Skartvedt, 1960)
4. *Crossotheca sagittata*, X 1.6 - Francis Creek Shale

5,6,7. *Trigonocarpus parkinsonii*, X 1.25 - Caseyville Fm., Jackson Co.

8,9. *Hexagonocarpus crassus*, X 2.5 - Caseyville Fm., Jackson Co.

10. *Carpolithes* sp., X 0.63 - Francis Creek Shale, Will or Grundy Co. (after Collinson and Skartvedt, 1960)

Plate 25 Seed ferns: seeds and pollen organs specialized leaflets (pinnules) at the base of the stalk (petiole) that bore the leaf (frond) or at smiliar sites within the frond. If these pinnules have circular outline, they are called *Cyclopteris* (plate 22, figs. 2-3). If the pinnules have an irregular outline, they are instead termed *Aphlebia* (plate 22, fig. 4). Inasmuch as the seed ferns bore fronds that unrolled in much the same manner as fronds of the true ferns, some *Spiropteris*-type specimens also were produced by seed ferns.

Isolated pollen organs and seeds (or ovules) are not as common as foliar remains at most collecting sites, but are widely distributed in Pennsylvanian rocks (plate 25). Compressions of pollen organs include *Codonotheca,* a cup-shaped structure with long lobes; *Crossotheca,* a small structure with sporangia arranged in a ring or arrow on a modified leaflet; *Givesia,* a structure preserved to look like a very small fan; and *Whittleseya,* a larger pollen organ that also appears fan-like. Seeds and ovules of the seed ferns show radial symmetry, which means that they can be rotated around a central line (axis of symmetry) to several points that look identical. Among such seeds and ovules, *Trigonocarpus* is probably the most common. Casts of the inside of its seed coat have a prominent three-parted symmetry. *Hexagonocarpus* is similar, but has six prominent ridges instead of three. *Holcospermum* is probably also attributable to the seed ferns, and has many ridges and grooves oriented lengthwise. *Carpolithes* is a catch-all form genus for seed-like bodies that do not fit easily into other categories. Some of these were surely produced by the seed ferns.


Figure 13 Reconstruction of *Cordaites*

Conifer-like Plants (Cordaiteans)--Plates 26-27

Cordaitean trees of the Pennsylvanian (fig. 13)

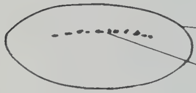
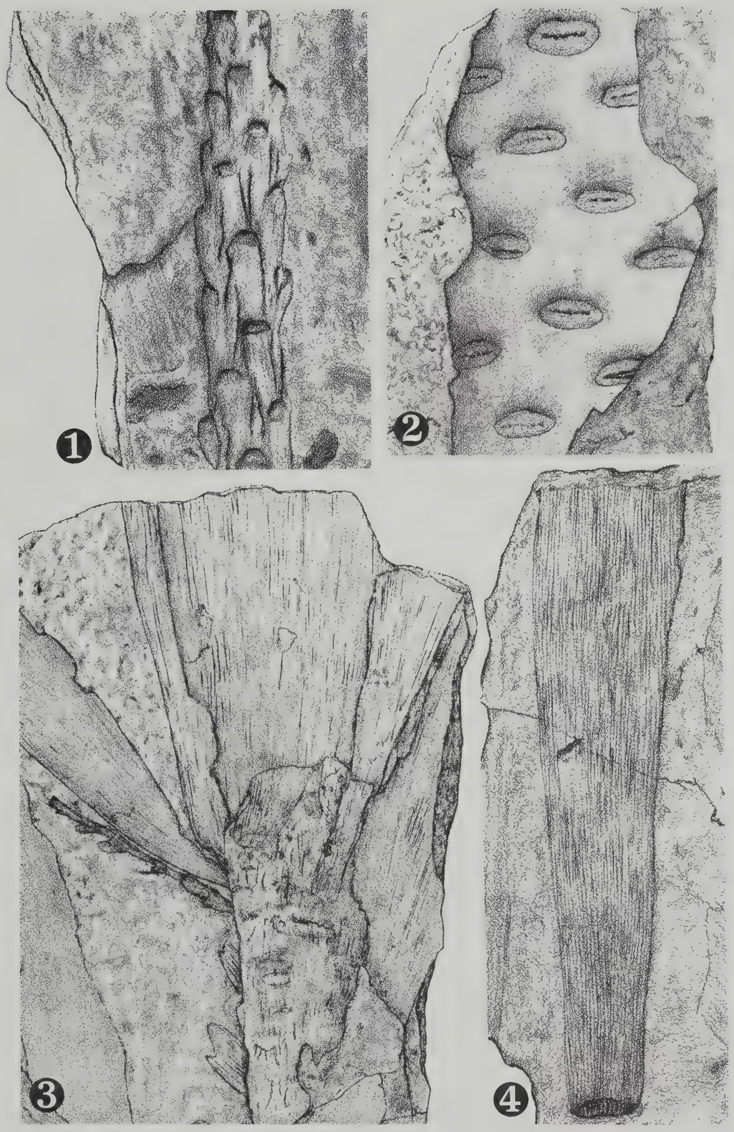


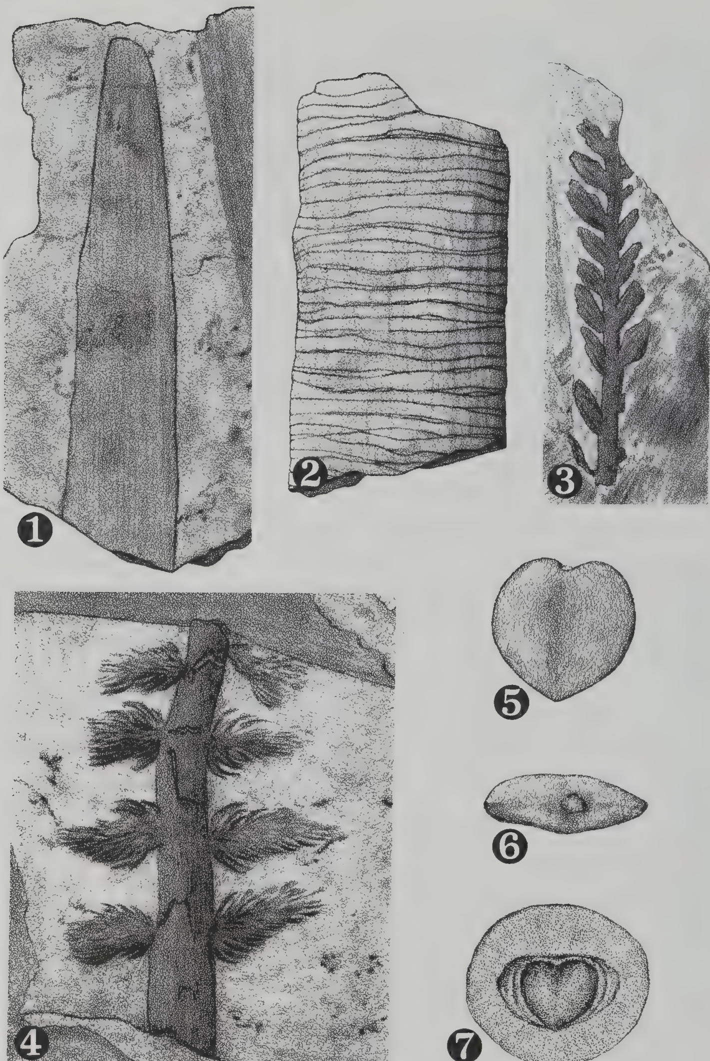
Figure 14 Diagram of a cordaitean leaf scar

were forerunners of modern conifers, such as the familiar pine and spruce trees. Whereas most of the trunk of the lycopods was bark (periderm) and most of the trunk of the tree ferns consisted of roots, the trunk of the *Cordaites* was mainly wood (secondary xylem), very much like modern conifer wood. Members of the genus were abundant in some coal swamps and grew to a very large size, up to 120 feet tall in some cases. The leaves were large (up to 3 feet long) and strap-shaped. Their veins were numerous and lie nearly parallel to each other (plate 26, figs. 3-4; plate 27, fig. 1). The leaves were borne in a helix on the stem (plate 26, figs. 1-2), which is known as *Cordaicladus*, in a manner similar to leaves of the tree-sized lycopods. Indeed, cordaitean stems can be mistaken for lycopods. Cordaitean leaf scars, however, have an outline that is an ellipse with its long axis horizontal. Each leaf scar typically has many small scars (vascular-tissue scars) in a horizontal row along the center (fig. 14). Casts of the pith are not uncommon. Because *Cordaites* grew horizontal plates of tissue in the pith region, casts of it have a distinctive pattern of ridges and furrows called *Artisia* (plate 27, fig. 2). Both pollen and seeds were aggregated to form cone-like structures generally called *Cordaianthus* (plate 27, figs. 3-4), though the seeds are rarely found attached. Dispersed seeds are generally heart-shaped (plate 27, figs. 5-7) and are called *Cordaicarpus (Cordaicarpon)*. If they are flattened in a way that makes them appear winged, they are called *Samaropsis*. Cordaitean seeds are abundant at some localities, especially in the lower part of the Pennsylvanian.



1. *Cordaicladus* sp., X 0.32 - McLeansboro Group, White Co.
2. *Cordaicladus* sp., X 1.0 - Energy Shale, Williamson Co.
3. Cordaitean stem with attached leaves, X 1.0 - Spoon Fm., Jackson Co.
4. *Cordaites principalis*, X 0.63 - Spoon Fm., Jackson Co.

Plate 26 Cordaiteans: stems and leaves



1. *Cordaites principalis,* X 0.8 - Spoon Fm., Jackson Co.
2. *Artisia transversa,* X 0.63 - Purington Shale, Knox Co.
3. *Cordaianthus gracilis,* X 1.8 - Spoon Fm., Jackson Co.
4. *Cordaianthus gracilis,* X 1.25 - Mattoon Fm., Fayette Co.
5. *Cordaicarpon (Cordaicarpus) major,* X 2 - Caseyville Fm., Jackson Co.
6. *Cordaicarpon (Cordaicarpus) major,* X 2 - Caseyville Fm., Jackson Co.
7. *Samaropsis* sp., X 0.5 - Francis Creek Shale, Will or Grundy Co. (after Collinson and Skartvedt, 1960)

Plate 27 Cordaiteans: leaves, pollens organs, and seeds

SUGGESTIONS FOR COLLECTING PENNSYLVANIAN PLANT FOSSILS

Rocks Where Fossil Plants Occur

Plant fossils occur in all types of sedimentary rock, but they are much more abundant in certain settings than in others. Coal is rock composed almost entirely of fossil plant material, and bits of wood or bark commonly can be found along some of its layers. The fossil plants in coal are, however, only rarely well preserved. Coal balls, masses of petrified peat preserved by infiltration of lime-rich water (see ISGS Educational Series 11), and paper coal provide occasional exceptions. Paper coal is a deposit consisting almost entirely of the waxy material that covers small stems and leaves (cuticle), and beautiful specimens can sometimes be obtained from it.

The layer directly underneath most coal beds, which is regarded as the soil of the developing coal swamp forest, generally has abundant root fossils. The absence of other types of fossils is partly the result of the destructive action of root penetration on whatever fossils may once have been present. The most conspicuous fossils beneath most Pennsylvanian coal beds are stigmarian axes and their roots (sometimes called rootlets). Often little else occurs there. Various well-preserved fossil plants may sometimes occur in shale and siltstone below the base of root penetration. This horizon, however, is not so frequently exposed during mining as are the overlying strata. Therefore, it is not very commonly accessible to the collector.

Where gray shale directly overlies coal, plant material is commonly found dispersed through the shale, especially near the base. Such fossils are abundant in places and may occur either in ironstone (siderite) nodules or along bedding planes of the shale. Both should be examined. Shale above coal beds is removed during strip mining and during shaft mining by the longwall method. Consequently, dumps from these operations are good places to look for fossil plants. Nevertheless, shales are not fossiliferous everywhere, and on many spoil heaps fossils are absent.

When the rock immediately overlying a coal bed consists of black, slaty shale or limestone containing marine fossils, plant remains are only rarely abundant or well-preserved. Plant fossils may be common in some sandstones, but are generally poorly preserved, except in a few silty or shaly lenses.

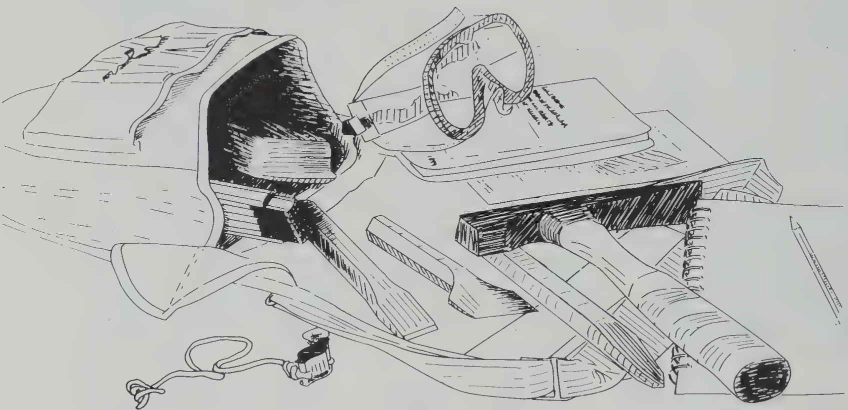


Figure 15 Collecting equipment

Collecting Equipment

A collector of plant fossils should have the following tools and equipment (fig. 15):

- Hammer. A bricklayer's hammer works particularly well.
- Cold chisels, preferably large and small.
- Hand lens for looking at small structures.
- Knapsack, cardboard box, or basket in which to carry specimens.
- Newspaper and a roll of tissue paper for protecting fragile specimens.
- Pencil and paper for labeling specimens and making notes about the collecting locality from which the fossils came. A fine-tipped marker pen with permanent ink is also handy. Much of the value of a particular fossil lies in knowing precisely where it was found and the layer of rock from which it came. Ideally, the locality should be recorded with a land description like that on a deed, including township, range, and section. These can be found on quadrangle maps of the area (obtainable from the Illinois State Geological Survey or U. S. Geological Survey) and other maps (e.g., county highway maps, county plat books).

- Safety glasses. A collector should always use glasses or other eye protection when hammering or chiseling rock.

Rules of Courtesy
As a collector you should carefully observe several rules:

- For your own protection get permission to enter and collect on any private property. Such action also will help to assure your welcome if you wish to return.
- Leave the gates exactly as you find them, open or closed. Do not climb fences that may break or sag under your weight. Crawl under or go around.
- Don't litter, even far from any house or other buildings. Do not disturb the owner's equipment, stock, or planted areas.

Handling Specimens
When the shale around a fossil plant is well cemented (usually by iron carbonate) a hard nodule results. It must be split to reveal the enclosed fossil. The most successful way to split an ironstone nodule is to set it on edge, long axis horizontal, on a large rock and strike the edge of the nodule with a hammer (fig. 16). The nodule will split along its weakest plane. That plane of weakness is usually the fossil, if the nodule contains one. Sometimes one side of the nodule will break off in the middle, in which case the

Figure 16 Splitting a nodule

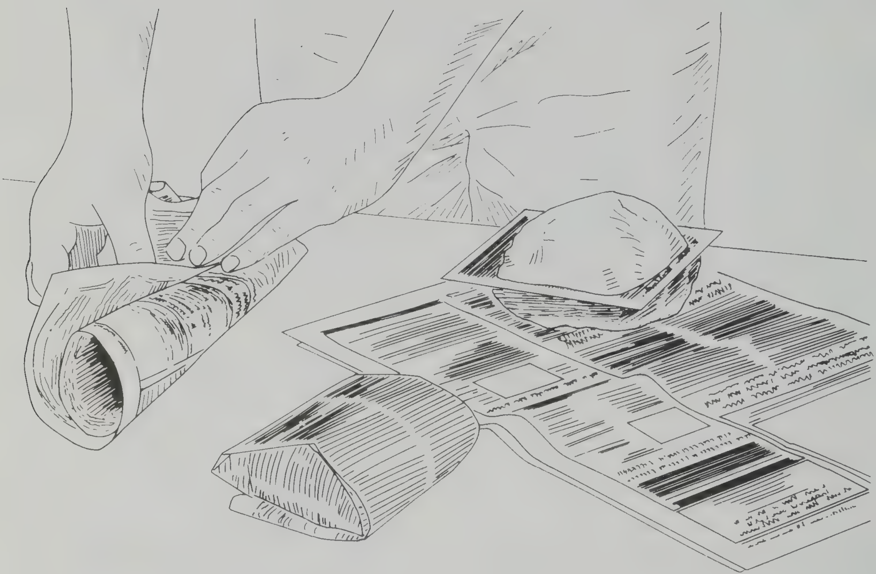


Figure 17 Wrapping a nodule

remainder can be tapped firmly but gently on the upper edge until the fossil is completely uncovered. Pieces of the broken half should be glued together neatly so that the entire specimen can be retained. Nodules split best when they have been somewhat weathered. Unweathered nodules can be left outdoors for one or two winters or, alternatively, can be frozen and thawed in a shallow pan of water a few times in a refrigerator.

The usual method of wrapping plant-bearing nodules is to place the end of a sheet of newspaper between the two halves of the nodule, fold the paper over the nodule, and roll it up in the sheet (fig. 17). For more fragile specimens tissue paper or even cotton balls can be used between the two halves.

Fossils embedded in shale may be recovered by first excavating pieces of the rock. Each piece can then be struck on its long axis with a hammer so that it splits along the layering. The flat blade of a mason's hammer is particularly useful for this purpose. Alternatively, a chisel inserted along the layering may be struck repeatedly with a hammer. When a fossil is exposed, the matrix can be chiseled away by slow, painstaking effort. It is advisable to wrap fossils preserved in shale as soon as they are collected and to leave them wrapped until they are fully dry (typically several weeks). Slow drying tends to minimize cracking of the shale as it dries. It also usually reduces the undesirable tendency for carbonaceous material of a compression fossil to curl up and come loose from the matrix.

Some fossils are so fragile or porous that they need to be covered with a hard protective coat. Crude gum arabic solution (refined gum arabic will not serve) may be applied with a fine brush in successive layers. Sturdier fossils may be dipped in it.

When a fossil is so delicate that the surface tension of the gum arabic solution causes the fossil to "spread," celluloid (or other plastics) dissolved in acetone may be substituted. Before this solution is used, the specimen must be completely dry or the coating will become cloudy or opaque. If the specimen is pyritized, it can be sprayed with lacquer or shellac to retard disintegration.

If these protective sprays are used, they must be applied to dry specimens during dry weather or the coating will remain sticky. As an extra precaution, specimens preserved in iron sulphides (pyrite and marcasite) should be stored in glass containers in a dry place, because pyrite and marcasite produce acid as they disintegrate and may damage paper or wood.

When several localities are visited in one collecting trip, the fossils from each one should be kept separate. Cloth bags or small cardboard trays are convenient for this purpose. At the time the fossils are collected, notes about each locality should be put in the same bag or tray as the fossils from that locality. This practice minimizes the possibility of confusion.

COLLECTING AREAS FOR PENNSYLVANIAN PLANT FOSSILS

Northern and Western Illinois

Plant fossils can be found in almost any area where Pennsylvanian rocks are exposed (figs. 18-19) but in some places they are much better preserved and more numerous than in others. Most of the well-known collecting areas and a few of the lesser-known ones are discussed below. Even though some of the specific localities were recorded many years ago and may no longer be productive, they can indicate general areas that are still favorable for collecting.

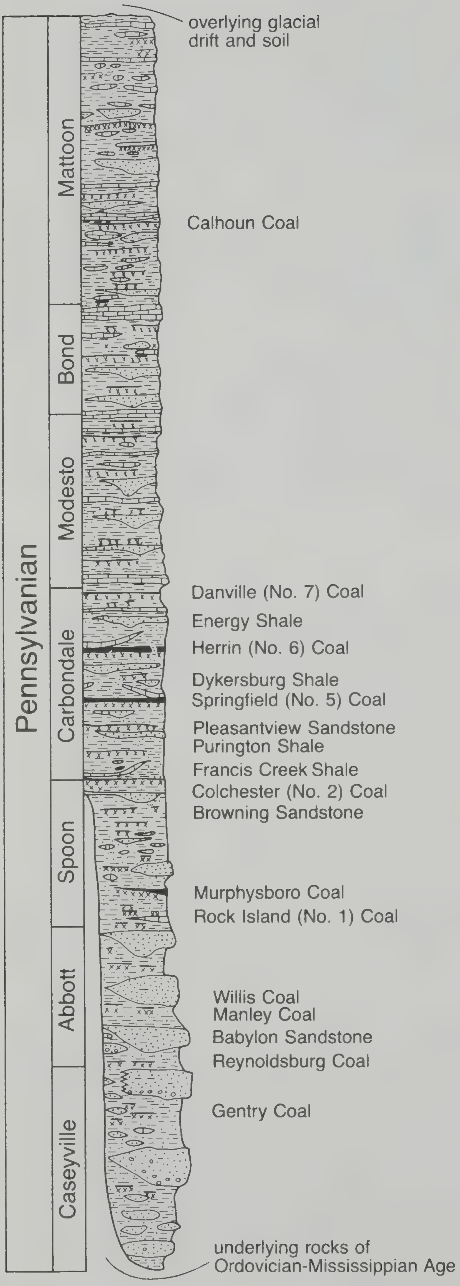


Figure 18 Generalized geologic column of Pennsylvanian rock in Illinois. The many coal beds are especially noteworthy. (Much of the information is from Willman et al., 1975.)

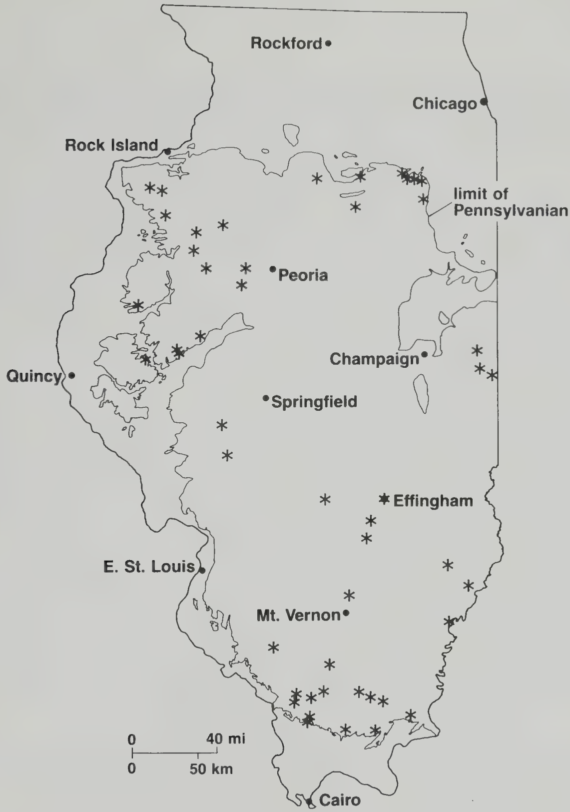


Figure 19 Map of Illinois showing the area underlain by Pennsylvanian strata and collecting localities (indicated by *)

Areas near Mazon Creek

Of all the fossils that have been found in Illinois, the most famous are the plant remains from the Mazon Creek area in the northeastern part of the state (fig. 20). In this region, located in Grundy, Will, and Kankakee Counties, plant fossils are present in ironstone concretions that occur in the lower part of the Francis Creek Shale directly overlying the Colchester (No. 2) Coal.

Fossils were discovered well over a century ago in natural outcrops along Mazon Creek southeast of the town of Morris. Collecting conditions vary considerably from season to season, however, and may vary daily as the weather changes. The area is entirely under private ownership and access is difficult to obtain. Thus, fossils are not as easily obtained from Mazon Creek as from the strip-mine spoil heaps. Most of the fossils at Mazon Creek are plant remains (especially ferns), although fossils of insects, crustaceans, worms, and salamanders have also been found.

Collections also have been made from scores of conical spoil heaps of underground mines in the area. The mine dumps of the Wilmington Star No. 7 mine, 2 1/4 miles west of Coal City, and the Skinner No. 2 mine, 2 miles northeast of Braidwood are especially notable. Similarly, in the vicinity of Morris on the northwest edge of the Mazon Creek area, fossil ferns have been found along the north side of the Illinois River.

When large-scale coal stripping began in Will and Grundy Counties during the 1920s, great numbers of specimens were exposed. In strip mining operations, the shale beds just above the coal are typically the last to be placed on a spoil heap. These beds usually have the greatest abundance of fossil plants and fossiliferous nodules. Weathering softens the shale, which is then eroded, leaving a concentration of nodules at the surface. Each season, a new crop of nodules is exposed. The nodules generally have a flattened oval to elongate shape and range from less than an inch to a foot or more in maximum dimension. Typically, about one nodule in ten contains plant remains worth collecting.

The productivity of the area was demonstrated in the late 1930s by George Langford, Sr., a well-known midwestern fossil collector. He and his son split an estimated 225,000 concretions during a 150-day period and obtained more than 20,000 plant specimens. Today, most of the strip-mined area is closed to the public, and large areas are overgrown with vegetation. If access can be obtained, however, there are places where fine specimens can still be collected in a few hours.

Fossiliferous concretions exist at many strip mines in the region, although historically the most productive areas were probably in the old Northern Illinois Coal Corporation mines between the towns of Braidwood and Wilmington. Some of the strip mines near Morris contain fossil-bearing concretions in shale and irregular sandstone layers, although much of the best collecting area has been leveled. Fossil plants are also present in Peabody Pit 11, a mine that straddles the Will-Kankakee County line northwest of Essex and is famous for soft-bodied fossil invertebrate animals. Nevertheless, plant fossils are not nearly as common there as they are in spoil heaps of mines farther north.

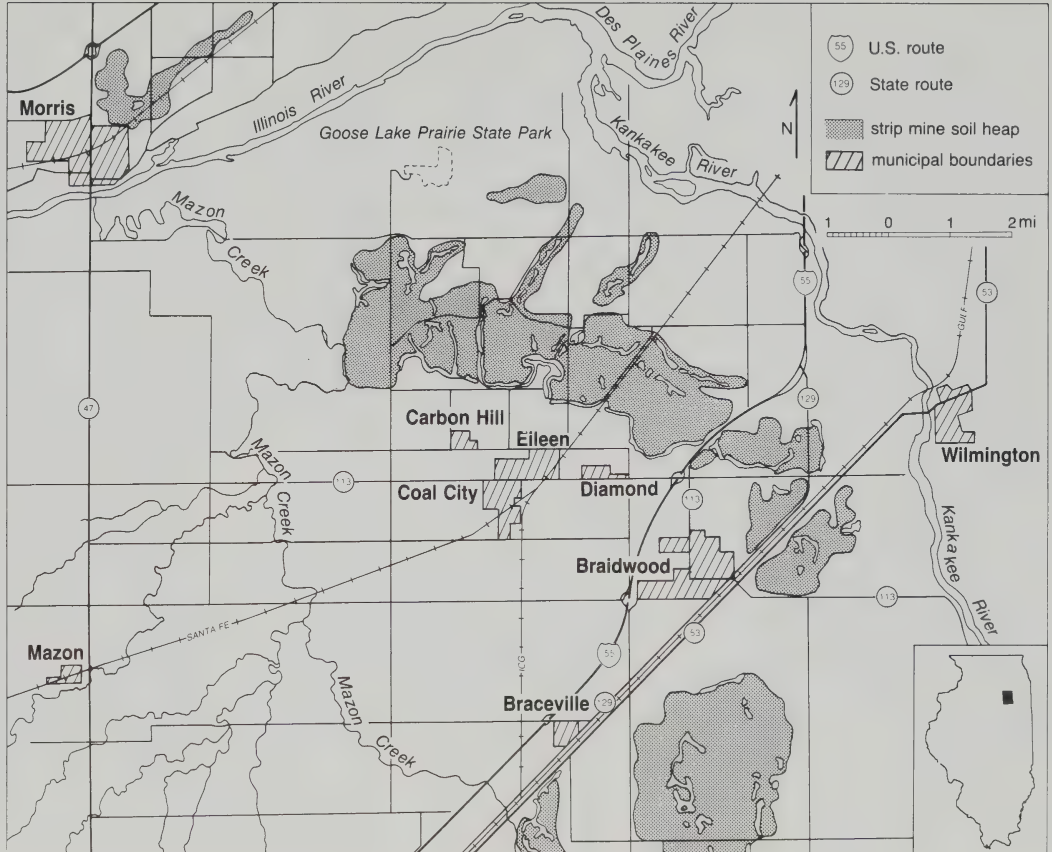


Figure 20 Map of the Mazon Creek area

Brown County
Fossil plants have been found in rock at the very base of the Pennsylvanian System in northeast Brown County in the bluffs of the La Moine River (formerly Crooked Creek) about 5 miles northwest of Ripley. They occur in a ravine just southeast of Scotts Mill.

Fulton and Peoria Counties
Although no exceptionally good collecting localities have been discovered, there are numerous occurrences of plant fossils in the extensive strip mines and outcrops of Fulton and Peoria Counties.

A fairly productive locality is located in southern Fulton County in the stream bluff of Kerton Creek about 3 1/4 miles north and 1/4 mile west of Bluff City. At this site the plants are present in strata about 18 feet below a coal bed. Numerous fern impressions have been found in shale beds above the Herrin (No. 6) Coal along the Middle Branch of Copperas Creek, 6 miles west of Glasford. A few plant impressions have been found associated with the Springfield (No. 5) and Herrin (No. 6) Coals in mines near Middle Grove west of Farmington. The plant-bearing beds crop out at many places in the area. Other sites also may contain plant material.

The Exline Limestone contains fossil plants in the area just north of Hanna City in Peoria County. Cordaitean leaves are the most abundant fossil but lycopods, calamiteans, and neuropteroid seed ferns are also known to be present.

Knox County
A notable number and variety of well-preserved plant fossils have been collected from localities in and near East Galesburg along Court Creek. The fossils occur in the Purington Shale and the overlying Pleasantview Sandstone. These units are exposed in road and railroad cuts, in streams or gullies, and in abandoned clay pits.

Fossil plants also have been found in shales above the Colchester (No. 2) Coal in the vicinity of De Long and associated with the Herrin (No. 6) Coal in mines southeast of Victoria.

La Salle and Bureau Counties
The Francis Creek Shale, the unit in which the famous fossils of Mazon Creek in Grundy County are preserved, extends westward into La Salle and Bureau Counties. It lies near the surface in a broad belt adjacent to

the Illinois River. Any one of the many coal mine dumps, claypits, or natural outcrops in the region is a potential source of fossil plants, although none of the known localities is nearly as productive as the strip mines farther east. Coal mines at Spring Valley yielded fine specimens when they were active, and spoil piles in the area may contain similar material. Abandoned clay pits north of the Illinois River and just east of Ottawa contain many nodules, a few of which enclose well-preserved fossil plants. Petrified logs occur there, also.

Fossil plants occur at several localities in the Streator area. One site is in a creek bed in the northern part of town where scattered plant fossils occur together with abundant invertebrate animal remains (of branchiopods) in beds below the Herrin (No. 6) Coal.

McDonough County

Near Colchester, the Francis Creek Shale, overlying the Colchester (No. 2) Coal, contains fossiliferous ironstone nodules, as it does in northeastern Illinois. More than 50 species of plant fossils have been reported from the area, although they were collected many years ago from spoil heaps of abandoned underground mines. The Francis Creek Shale, currently exposed in clay pits just north of Colchester, is very fossiliferous at its base. Plant fossils are also present near the base of the Pennsylvanian strata in quarries north of the East Fork, La Moine River. These quarries are about 1 1/2 miles north of Tennessee and about 2 miles west of Colchester.

Mercer and Warren Counties

In northern Warren and southern Mercer Counties the sandstone underlying the Rock Island (No. 1) Coal is termed the "stigmarian" sandstone because of numerous casts of the genus found in the bed. Many of the fossils have been collected from an old mine dump and from ravines along the Edwards River northeast of Aledo.

A number of representatives of *Sphenophyllum, Neuropteris, and Annularia* have been collected from ironstone concretions occurring in shale about 3 miles southwest of Alexis. They occur in a gully about 1/3 mile southeast of the site of Center School.

In the same general area, fossil plants still may be found in the abandoned clay pit of the Hydraulic-Press Brick Company at Shale City. *Sigillaria, Stigmaria, and Pecopteris* are especially common.

Schuyler County

Fern and cordaitean leaves have been collected along Mill Creek about a mile northeast of Pleasantview. The fossils occur near the base of the Pennsylvanian in shale associated with the Manley Coal. Nearby, impressions and casts of *Stigmaria, Lepidodendron, and Cordaites* have been found in the Babylon Sandstone.

A productive site exists about 3 miles north of Pleasantview. It is located 1/3 mile northwest of the site of Union School in a cut along Scab Hollow Road. Various fossil plant stems and leaves have been collected at this locality from silty beds in the upper part of the Browning Sandstone.

Other Northern and Western Illinois Localities

In addition to the counties listed, others have produced plant fossils. For example, plant fossils have been reported from several places in the southern and western parts of Rock Island County. Local exploration is certain to turn up numerous other collecting places presently unknown.

Central and Southern Illinois

Fayette and Effingham Counties

The bedrock that outcrops in Fayette and Effingham Counties belongs to the upper part of the Pennsylvanian System. Although exposures are not plentiful, a few sites contain plant fossils. In the southeastern corner of Fayette County, about 3 miles east of Farina, fossil plants are preserved in rock exposed along Crooked Creek. Many of the fossils at this locality are preserved in shale, but some of the most interesting specimens are preserved in a thin limestone bed. *Cordaites* and *Pecopteris* are particularly abundant. In the northwestern part of the county along Ramsey Creek, about 4 miles southeast of the town of Ramsey, plant fragments are preserved in shale that is interbedded with thin layers of coal. Small neuropteroid pinnules are the most abundant kind of fossil, but *Sphenophyllum* and *Annularia* are also known to be present.

At a site about 3 1/2 miles north of Edgewood, in southern Effingham County, the Calhoun Coal is exposed along Limestone Creek. The shale just above it contains abundant plant fossils, especially *Neuropteris*. *Neuropteris* is also common in an exposure of sandy shale located at Effingham in a creek bank just east of Interstate 57/70 and just north of the southernmost Effingham interchange. *Cordaites* and *Calamites* are present there, also.

Lawrence County

The Calhoun Coal is exposed in places near the Lawrence-Richland County line, not far from the towns of Berryville and Calhoun. Within this coal bed are many of the limestone masses called coal balls. Within these coal balls, the cellular structures of many kinds of stems, roots, and leaves are beautifully preserved. A large number of compression fossils, especially *Neuropteris*, are present in shale that underlies the Calhoun coal.

Perry and Jackson Counties

In the vicinity of DuQuoin and Murphysboro, a variety of well-preserved plant fossils have been collected from shales overlying the Herrin (No. 6) Coal and the Murphysboro Coal. Many have come from shaft mines that are not easily accessible to the collector. Some strip mines in the Pinckneyville area have yielded coal balls from the Herrin (No. 6) Coal.

Just southeast of Murphysboro is currently a productive outcrop area for collecting plant compressions from shale associated with the Murphysboro Coal. Abandoned mines southeast of Carbondale expose similar strata and also have fossil plants.

Pope, Johnson, and Saline Counties

Saline County contains more recorded plant fossil localities than any other southern Illinois county. Fossil plant collecting localities are numerous, though isolated, in the area southwest of Harrisburg. In particular, many coal balls have been collected from the Herrin (No. 6) Coal in this region. In addition, compression fossils are abundant in the Dykersburg Shale above the Springfield (No. 5) Coal in mine dumps near Ledford. Mine dumps, such as in the area 5 or 6 miles northwest of Eddyville, and natural outcrops are numerous throughout the region. Plant fossils associated with the Murphysboro, Delwood, Willis, Reynoldsburg, and Gentry Coals can probably be found in this region.

Cuts along Interstates 57 and 24 expose lower Pennsylvanian strata and contain fossil plants in places. Natural outcrops in creek banks of some nearby areas have plant fossils as well.

Vermilion County

In outcrops about 3 miles below Georgetown on the Little Vermilion River, several fossil plant species and one insect species have been collected from shales overlying the Herrin (No. 6) Coal, locally called the

"Grape Creek Coal." Most of the fossils occur in concretions that resemble those at Mazon Creek.

The spoil at the site of an abandoned shaft mine 3 miles south of Catlin has also proved productive. The fossils are enclosed in shale that has been fired to a red, brick-like material by heat from spontaneous combustion in the dump. Other shaft-mine dumps dot the area and may have fossils.

An occasional stem replacement or impression is found in the concretionary shale above the Danville (No. 7) Coal in the strip mine area west of Hillary. Isolated fragmentary plant specimens are fairly common throughout the Danville mining area.

White County
Fossil plants from the bluffs of the Wabash River at Grayville have been known since the middle of the nineteenth century. They occur in shale, siltstone, and sandstone below a thin coal bed. The shale contains nodules that are somewhat similar to nodules at Mazon Creek. Plant fossils occur in these nodules and in the enclosing shale. Specimens of *Neuropteris* are the most abundant type of fossil at this locality, but other kinds are present, especially in the sandstone.

Williamson County
Large quantities of coal have been mined in Williamson County, and fossil plants are present in some mine dumps. Good material has been obtained from the Energy Shale in mine dumps near Carterville. Although most of these dumps have been leveled or are overgrown with vegetation, some plant fossils may still be available. Mines east of Crab Orchard have yielded fossil plants from siltstone and fine-grained sandstone beds.

Other Central and Southern Illinois Localities
Collecting localities have been recorded west of McLeansboro in Hamilton County, northwest of Mt. Vernon in Jefferson County, in a creek adjacent to the railroad at Neeleyville in Morgan County, from underground mines in Franklin County, near Palmyra in Macoupin County, and in the Friendsville area of Wabash County. Careful search will undoubtedly turn up many more.

Indeed, throughout the large coal-producing areas of southern Illinois plant fossils can be found in many spoil heaps from mining activity or in outcrops along streams, roads, and railroads. Thick Pennsylvanian sandstones crop out widely in a belt extending through Gallatin, Saline, Williamson, and Jackson Counties, and contain compressions or casts of trunks and in some places, other woody plant parts.

GLOSSARY

abaxial - the part of an appendage that lies away from the main axis (in stems and leaves it is the lower part).

adaxial - the part of an appendage that lies toward the main axis (in stems and leaves it is the upper part).

adventitious root - a root produced above the ground by a stem or any plant part other than another root.

agate - dense, transparent to translucent, microcrystalline quartz, often banded or colored, sometimes mixed with opaline silica.

angiosperm - a flowering plant. These produce seeds inside an enclosure (ovary).

apex - see shoot apex.

axis - in plants, an elongate, cylindrical structure such as stems, roots, or petioles.

axis of symmetry - a line around which an object can be rotated and arrive at another, identical point.

bark=secondary cortex - cortex produced as a result of cambial activity (see cork cambium and cortex).

bilateral symmetry - a symmetry in which one half of an object is the mirror image of the other half.

branch scar - a mark on a stem left when a branch falls. Some tree-sized lycopods normally shed their branches.

calcite - a mineral composed of calcium carbonate ($CaCO_3$). It is the primary constituent of limestone.

carbonate - mineral or rock that consists in part of carbonate ions (CO_3). Such minerals include calcite ($CaCO_3$), dolomite ($[Ca,Mg]CO_3$) and siderite ($FeCO_3$). Carbonate rocks include limestone and dolomite.

cast - a fossil in which the external form of the original plant is reproduced by rock or mineral matter, but does not retain cellular structure.

cell - the smallest division of a living thing that is capable of carrying on all life functions. It consists of a membrane surrounding fluid contents and a nucleus.

cell division - see mitosis and meiosis.

cell wall - the relatively inflexible layer of reinforcing material next to the cell membrane in plant tissues.

club moss - a common name for some modern lycopods of the genus *Lycopodium.*

coal - a black combustible rock consisting primarily of the highly altered remains of plant material. It is formed by the alteration of peat-like material.

coal balls - carbonate rocks (usually limestone) that preserve the cellular structure of their enclosed plants and occur within a coal bed.

compound leaf - a leaf that consists of many individual segments. Each of the segments is a flat structure resembling an entire leaf. They are, however, borne in a flattened array rather than three dimensionally, as are leaves on a stem. When a compound leaf dies it is shed as a single unit.

compression - a flattened fossil that retains a significant amount of original organic material.

cone - a dense aggregation of reproductive structures borne around a central axis (e.g., a pine cone or lycopod cones).

conglomerate - a sedimentary rock consisting predominantly of comparatively large particles (more than 2 mm in diameter).

coniferophyte - a plant belonging to the conifers or showing similarities with them. The coniferophytes have abundant wood and reproduce by means of seeds borne in cones, but they lack flowers. True conifers also have needle-like leaves.

cordaitean - a member of the extinct coniferophyte group Cordaitales. These plants had dense coniferophytic wood and large, strap-shaped leaves arranged in a helix. They bore seeds that were most commonly heart-shaped.

cork cambium - a layer of actively dividing cells that produce parenchymatous (see parenchyma) cells rather than conductive (vascular) tissue.

cortex - a tissue region that lies between the epidermis and the conductive (vascular) tissue and consists predominantly of parenchyma.

cuticle - the resistant waxy covering of plant leaves and small stems.

cycad - a plant with a massive pith, stems armored by persistent leaf bases, large compound leaves reminiscent of palms, and vascular supply to the leaves that winds around the stem (girdling leaf traces).

cycadeoid - an extinct group of plants abundant during the Mesozoic that resemble cycads in their growth habit. They differ from cycads in cuticular structure, in the lack of a girdling vascular supply to leaves, and in the structure of their cones.

deciduous - exhibiting the characteristic of dropping appendages. Modern temperate angiosperm trees are deciduous, since they drop their leaves in the fall.

dichotomous branching - branching that results in two equal parts. This branching is different from a main stem with laterals (monopodial branching).

dinosaur - a term used loosely for any of the large reptiles that existed during the Mesozic Era. More strictly used it applies to moderate or very large land reptiles belonging to the two orders, Saurischia or Ornithishia.

dolomite - a rock or mineral consisting of calcium magnesium carbonate ($[Ca,Mg]CO_3$). The mineral forms crystals in the geometric shape called rhombohedron, and exhibits slightly curved crystal faces.

epidermis - the outermost cell layer of leaves and small stems.

era - a very large span of geologic time consisting of two or more periods. The terms, Paleozoic, Mesozoic, and Cenozoic Eras, are in general use, while disagreement persists with regard to the Precambrian.

fern - see pteridophyte.

foliar - of or pertaining to a leaf or leaves.

form genus - a genus that is based on form without regard to biological relationships.

form species - a species that is based on form without regard to biological relationships.

formation - a mappable named body of stratified rock, distinguishable on the basis of rock characteristics alone (e.g., color, grain size, type of bedding) and not by other characteristics (e.g., age, types of fossils).

frond - the compound leaf of ferns and seed ferns.

genus - a group of related plants or animals that consists of one or more species.

geologic time scale - the sequence of named divisions of geologic time. The geologic time scale indicates relative age which can only be related to absolute age (in years) by using dates obtained from radioactive substances (e.g., Carbon 14/Carbon 12, Potassium 40/Argon 40, Uranium 238/Lead 206, Uranium 235/Lead 207, Thorium 232/Lead 208).

ginkgophyte - a member of the seed-bearing, but non-flowering plant group Ginkgoales. These are additionally characterized by fan-shaped to regularly divided leaves, dichotomous venation, and seeds borne on the end of shoots.

group - a named unit of rock strata consisting of two or more formations.

helix - a three-dimensional curve formed by tracing around a cylinder or cone at a constant angle. Coiled springs have this form.

hematite - a mineral consisting of iron oxide (Fe_2O_3), which may form metallic-looking steel-gray or iron-black rhombohedral crystals, but commonly occurs as granular or earthy dark red masses. It is the principal ore of iron.

histology - the study of tissues in a plant or animal. Plant tissues include xylem, phloem, parenchyma, and epidermis among others.

horsetail - a common name for some much-branched members of the modern sphenophyte genus *Equisetum*.

impression - a type of fossil in which the original plant fragment has been greatly flattened, and which is nearly devoid of original organic material.

internode - the part of a stem that lies between the positions where appendages are or were attached.

leaf - a thin, flattened structure that contains some vascular tissue and is adapted for efficient absorption of sunlight. Leaves are ordinarily green and most of the sugars are produced there.

leaf cushion - on the stem of many lycopods, a protuding pad of tissue that helped provide support for a leaf.

leaf scar - the mark on a stem left behind by a fallen leaf.

leaflet - an individual flattened segment within a compound leaf.

ligule - a small flap of tissue present on the upper (adaxial) surface of some lycopod leaves.

ligule pit scar - a scar on a leaf near its base or on the adjacent stem which represents a depression that contained a small flap of tissue (ligule).

limestone - a sedimentary rock composed predominantly of calcite.

limonite - a field term for a mixture of various iron oxide and hydrated iron oxide minerals (e.g., goethite-FeO(OH) and hematite - Fe_2O_3).

lower keel - the part of a leaf cushion of various tree-sized lycopods that lies below the leaf scar.

lycopod - a member of the lycophyta, a group of plants that originated in the Late Silurian or Early Devonian Period. They have helically arranged leaves, reproduce by means of spores, and have narrow leaves with a single vein.

marcasite - a mineral with the composition, iron sulphide (FeS_2). Although its chemical composition is like pyrite, it has a different crystal form, lower specific gravity, less chemical stability, and usually a paler color.

megaspore - the larger spore in plants that produce spores in two sizes. It is regarded as female.

meiosis - the cell division that produces sex cells. It begins with a single body cell that has two sets of hereditary information (chromosomes) . After division the result is four cells, each with one set of chromosomes (contrasts with mitosis).

member - a named rock unit that represents only part of a formation.

microspore - the smaller spore in plants that produce spores in two sizes. It is regarded as male.

mitosis - the cell division characteristic of body cells. The amount of hereditary material is the same in the parental cell and its two daughter cells (contrasts with meiosis).

mold - a three-dimensional void space in a sedimentary rock that retains the form of a once-living animal or plant.

monopodial branching - branching that results in a main axis with laterals (contrasts with dichotomous).

node - the position on a stem where one or more appendages are attached.

nodule - a hard lump of mineral or mineral-cemented material within a rock mass, usually without internal structure.

opal - a mineral or mineral gel consisting of hydrated silica ($SiO_2 \cdot nH_2O$). It exhibits an iridescent play of colors.

ovule - an unfertilized seed.

palynology - the study of pollen and spores. It is widely applied to the study of isolated fossil pollen and spores in the rock record.

paper coal - a coal that consists largely of plant cuticle. Because of this composition it commonly splits into layers revealing well-preserved leaves and other plant parts.

parenchyma - a plant cell that is essentially the same diameter in all directions, with relatively thin cell walls, and unspecialized borders around the thin areas in their walls (pits).

parichnos tissue - a tissue in some lycopods that consists of parenchyma and considerable air space and lies near the vascular supply of the leaves.

parichnos tissue scar - a small scar that lies on either side of the vascular tissue scar on some lycopod leaf scars.

peat - an unconsolidated material that forms in a water-saturated environment and consists primarily of slightly altered plant debris.

periderm - secondary cortex produced by a cork cambium. Roughly equivalent to bark.

period - a major episode of geologic time during which rocks of the corresponding system were deposited. It is a subdivision of an era.

permineralization - a type of petrifaction in which mineral is deposited in the empty spaces of plant remains without replacing the original organic material.

petiole - the stalk at the base of a leaf.

petrifaction - a type of fossil in which the introduction of mineral matter has caused the preservation of internal cellular structure.

petrification - see petrifaction.

phloem - conductive tissue specialized for the transmission of food products in a plant. It consists predominantly of sieve cells and sieve tube elements.

pinnule - a single piece of flattened tissue in a compound leaf (frond) of ferns or seed ferns (equivalent to a leaflet).

pith - a region near the center of the stem that consists of parenchyma cells.

plane of symmetry - a flat surface that divides an object into mirror-image halves.

pollen - the minute male reproductive structures of seed plants. Pollen is covered by a resistant coat similar to that of microspores.

primary cortex - cortex produced by a shoot apex.

primary xylem - xylem that forms from cells produced at the end of a shoot and not produced by a cambium (contrasts with secondary xylem).

progymnosperm - a plant with conifer or seed fern-like wood that reproduced by means of spores.

pteridophyte - a member of the ferns. Ferns reproduce by means of spores and typically have large compound leaves (fronds).

pteridosperm - a member of the seed ferns. Seed ferns have fern-like fronds but reproduce by means of seeds.

pyrite - a brassy yellow mineral consisting of iron and sulphur (FeS_2) that crystalizes most commonly as a cube.

radially symmetrical - exhibiting more than one identical point when rotated one full turn around a central line (axis).

radiometric age determination - determining an age (in years) of geologic material using the ratios of radioactive substances that remain. (e.g., Carbon 14/Carbon 12, Potassium 40/Argon 40, Uranium 238/Lead 206, Uranium 235/Lead 207, Thorium 232/Lead 208).

replacement - a type of petrifaction in which mineral has replaced the original material of the plant or animal.

rhyniophyte - a primitive vascular plant characterized by dichotomous branching, sporangia borne at branch ends, and an absence of leaves.

root - a structure, usually underground, that anchors a plant and absorbs water and nutrients from the soil.

rootlet - a root borne on a stigmarian axis; sometimes any small root.

sandstone - a sedimentary rock consisting predominantly of small particles visible to the naked eye (1/16 to 2 mm in diameter).

scouring rush - a common name for some plants of the genus *Equisetum* and applied to related plants (sphenophytes). The name is derived from the use of *Equisetum* for scouring pots and pans. Its value for scouring results from the secretion of silica in the cells of the plant.

secondary xylem - xylem produced by a cambium rather than by a shoot apex; sometimes called wood (contrasts with primary xylem).

sediment - a loose, unconsolidated deposit formed by material that settles out of suspension or precipitates out of solution. Such deposits are characteristically layered.

sedimentary rock - a rock formed by the hardening or consolidation of a sediment.

seed - a fertilized ovule. A seed contains a plant embryo within a resistant coat, and upon germination develops into a new plant like the one that produced it.

seed fern - see pteridosperm.

shale - a sedimentary rock with extremely minute grains (less than 1/256 mm) that tends to split readily along flat surfaces. It usually is soft and composed of clay minerals.

shoot apex - the tip of a stem where cell division, elongation, and differentiation into distinct cell types take place.

siderite - a mineral consisting of iron carbonate ($FeCO_3$) that crystalizes in a geometric form called a rhombohedron. It is usually yellowish brown, brownish red, or brownish black.

silica - a material consisting of silicon dioxide (SiO_2). Several varieties occur naturally. The most common is quartz.

siltstone - a sedimentary rock consisting mainly of dust sized particles (1/16 - 1/256 mm in diameter).

sorus (sori) - a cluster of sporangia on a fern frond.

species - a group of closely related plants or animals that may interbreed to produce fertile offspring. If breeding ability cannot be determined (as in paleontology), a species may be considered a group of related plants or animals that show closely similar structure. Related species may be grouped into genera.

sphenophyte - a member of the group sphenophyta (or arthrophyta) characterized by whorled appendages borne at intervals along the stem.

sporangiophore - a small stalk on which one or more sporangia are borne. These are characteristic of sphenophytes.

sporangium - a structure in which spores develop. Sporangia are shaped like minute bags (sacs) and are sometimes stalked.

spore - a single cell with a resistant coat that can germinate to produce a new plant.

strata - layers of a sediment or sedimentary rock.

stromatolite - a variously shaped mound built by lime-secreting algae.

symmetry - having a regular repetition of similar form on either side of a plane or around a central axis.

synangium - a group of sporangia that are joined by tissue that develops between them.

system - a major rock unit of worldwide extent deposited during a geologic period.

taxon - any scientific name for plant or animal groups.

taxonomy - the orderly, scientific naming of plants or animals.

tetrad - a group of four spores (or pollen grains) produced by meiosis.

trimerophytean - an early vascular plant with a stem that appeared to be monopodial, had lateral branches that divided dichotomously, and had clusters of paired sporangia.

upper keel - the part of a leaf cushion of various tree-sized lycopods that lies above the leaf scar.

vascular cambium - an actively dividing layer of cells that increases the girth of a plant by producing vascular tissue (xylem and phloem).

vascular plant - a plant having tissue specialized for conduction (xylem and usually phloem).

vascular tissue - conductive tissue in a plant. It transports water and nutrients from one place to another and includes xylem and phloem.

vascular tissue scar - a small mark on a leaf scar at the position of the vascular tissue.

whorl - an arrangement of three or more appendages (leaves or petals) radiating from a single point on a stem.

wood - xylem produced by a cambium rather than by a shoot apex (see secondary xylem).

xylem - a tissue specialized for conduction of water and nutrients and which may also function for strengthening and storage. The tracheid is a cell type universally present in xylem. This type of cell is elongate with tapered ends, has a moderately thick wall, and a wall with thin areas (pits) with overarching borders (see also primary xylem, secondary xylem, and wood).

zosterophyll - an early vascular plant with globe or kidney-shaped sporangia borne along the sides of stems, and solid, comparatively massive (cylindrical or flattened) strands of xylem.

BIBLIOGRAPHY AND REFERENCES

Arnold, C. A., 1947, An introduction to paleobotany: McGraw-Hill Book Co., New York, 433 p.

Bradley, F. H., 1870, Grundy and Will Counties, *in* Worthen et al., Geology and paleontology: Geological Survey of Illinois, vol. 4, p. 190-225.

Chamberlain, C. J., 1919, The living cycads: University of Chicago Press, Chicago, 172 p.

Collinson, C., 1956, Guide for beginning fossil hunters: Illinois State Geological Survey Educational Series 4, 36 p. (revised 1959, 40 p.).

Collinson, C., and R. Skartvedt, 1960, Field book. Pennsylvanian plant fossils of Illinois: Illinois State Geological Survey Educational Series 6, 35 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: William C. Darrah, Gettysburg, PA, 220 p.

Delevoryas, T., 1962, Morphology and evolution of fossil plants: Holt, Rinehart and Winston, New York, 189 p.

Dott, R., and R. L. Batten, 1981, Evolution of the Earth (3rd ed.), McGraw-Hill, New York, 571 p.

Dunbar, C. O., 1949, Historical geology: John Wiley & Sons, Inc., New York, 576 p.

Fuller, H. J., and O. Tippo, 1954, College botany: Henry Holt & Co., New York, 993 p.

Hanagan, B. J., I. E. Odom, S. J. Trueblood, G. M. Wilson, J. E. Lamar, and J. C. Bradbury, 1959, Guide to rocks and minerals of Illinois: Illinois State Geological Survey Educational Series 5, 40 p.

Hirmer, M., 1927, Handbuch der paläobotanik, Bd.1: *Thallophyta, Bryophyta, Pteridophyta:* R. Oldenbourg, Munich and Berlin, 708 p.

Janssen, R. E., 1940, Some fossil plant types of Illinois: Illinois State Museum Scientific Paper 1, 124 p.

Janssen, R. E., 1957, Leaves and stems of fossil forests: Illinois State Museum Popular Science Series, v. 1 (2nd ed.), 190 p.

Jennings, J. R., 1984, Distribution of fossil plant taxa in the Upper Mississippian and Lower Pennsylvanian of the Illinois Basin: Neuvième Congrès International de Stratigraphie et de Géologie du Carbonifère, Compte Rendu, Vol. 2: 301-312, Southern Illinois University Press, Carbondale, 630 p.

Knowlton, F. H., 1927, Plants of the past: Princeton University Press, Princeton, NJ, 275 p.

Langford, G., 1958, Wilmington coal flora from a Pennsylvanian deposit in Will County, Illinois: Esconi Associates, Downers Grove, IL, 360 p.

Leary, R. L., and H. W. Pfefferkorn, 1977, An early Pennsylvanian flora with *Megalopteris* and Noeggerathiales from west-central Illinois: Illinois State Geological Survey Circular 500, 77 p.

Lesquereux, L., 1870, Report on the fossil plants of Illinois, *in* Worthen et al., Geology and paleontology: Geological Survey of Illinois, vol. 4, Geology and Palaeontology, Section 2, p. 375-508.

Levin, H. L., 1978, The Earth through time: W. B. Saunders, Philadelphia, 530 p.

Moore, R. C., 1958, Introduction to historical geology: McGraw-Hill Book Co., Inc., New York, 656 p.

Nadokavukaren, M., and D. McCracken, 1985, Botany. An introduction to plant biology: West Publishing Co., St. Paul, MN, 591 p.

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

Peppers, R. A., 1964, Spores in strata of Late Pennsylvanian cyclothems in the Illinois Basin: Illinois State Geological Survey Bulletin 90, 173 p.

Peppers, R. A., 1970, Correlation and palynology of coals in the Carbondale and Spoon Formations (Pennsylvanian) of the northeastern part of the Illinois Basin: Illinois State Geological Survey Bulletin 93, 173 p.

Peppers, R. A., 1984, Comparison of miospore assemblages in the Pennsylvanian System of the Illinois Basin with those in the Upper Carboniferous of western Europe: Neuvième Congrès International de Stratigraphie et de Géologie du Carbonifère, Compte Rendu, Vol. 2: 483-502, Southern Illinois University Press, Carbondale, 630 p.

Pfefferkorn, H. W. 1976, Pennsylvanian tree fern compressions *Caulopteris, Megaphyton,* and *Artisophyton* gen. nov. in Illinois: Illinois State Geological Survey Circular 492, 31 p.

Pfefferkorn, H. W., R. A. Peppers, and T. L. Phillips, 1971, Some fern-like fructifications from the Mazon Creek compression flora of Illinois: Illinois State Geological Survey Circular 463, 55 p.

Phillips, T. L., M. J. Avcin, and D. Berggren, 1976, Fossil peat from the Illinois Basin. A guide to the study of coal balls of Pennsylvanian age: Illinois State Geological Survey Educational Series 11, 38 p.

Raven, P. H., R. F. Evert, and S. E. Eichhorn, 1986, The biology of plants (4th ed.): Worth Publishers, New York, 775 p.

Reinertsen, D. L., 1981, A guide to the geology of the Danville area: Illinois State Geological Survey Field Trip Guide Leaflet, 1981B, 24 p.

Reinertsen, D. L., 1976, Mt. Carmel area: Illinois State Geological Survey Guide Leaflet, Geological Science Field Trip, 1976D and 1977A, 29 p.

Stewart, W. N., 1950, Report on the Carr and Daniels Collections of fossil plants from Mazon Creek: Illinois Academy of Science Transactions, v. 43, p. 41-45.

Stewart, W. N., 1983, Paleobotany and the evolution of plants: Cambridge University Press, Cambridge, England, 405 p.

Taylor, T. N., 1981, Paleobotany. An introduction to fossil plant biology: McGraw-Hill Book Company, New York, 589 p.

Wagner, R. H., 1984, Megafloral zones of the Carboniferous: Neuvième Congrès International de Stratigraphie et de Géologie du Carbonifère, Compte Rendu, vol, 2:109-134, Southern Illinois University Press, Carbondale, 630 p.

Willman, H. B., E. Atherton, T. C. Buschbach, C. Collinson, J. C. Frye, M. E. Hopkins, J. A. Lineback, and J. A. Simon, 1975: Handbook of Illinois stratigraphy: Illinois State Geological Survey Bulletin 95, 261 p.

Winslow, M. R., 1959, Upper Mississippian and Pennsylvanian megaspores and other plant microfossils from Illinois: Illinois State Geological Survey Bulletin 86, 135p.

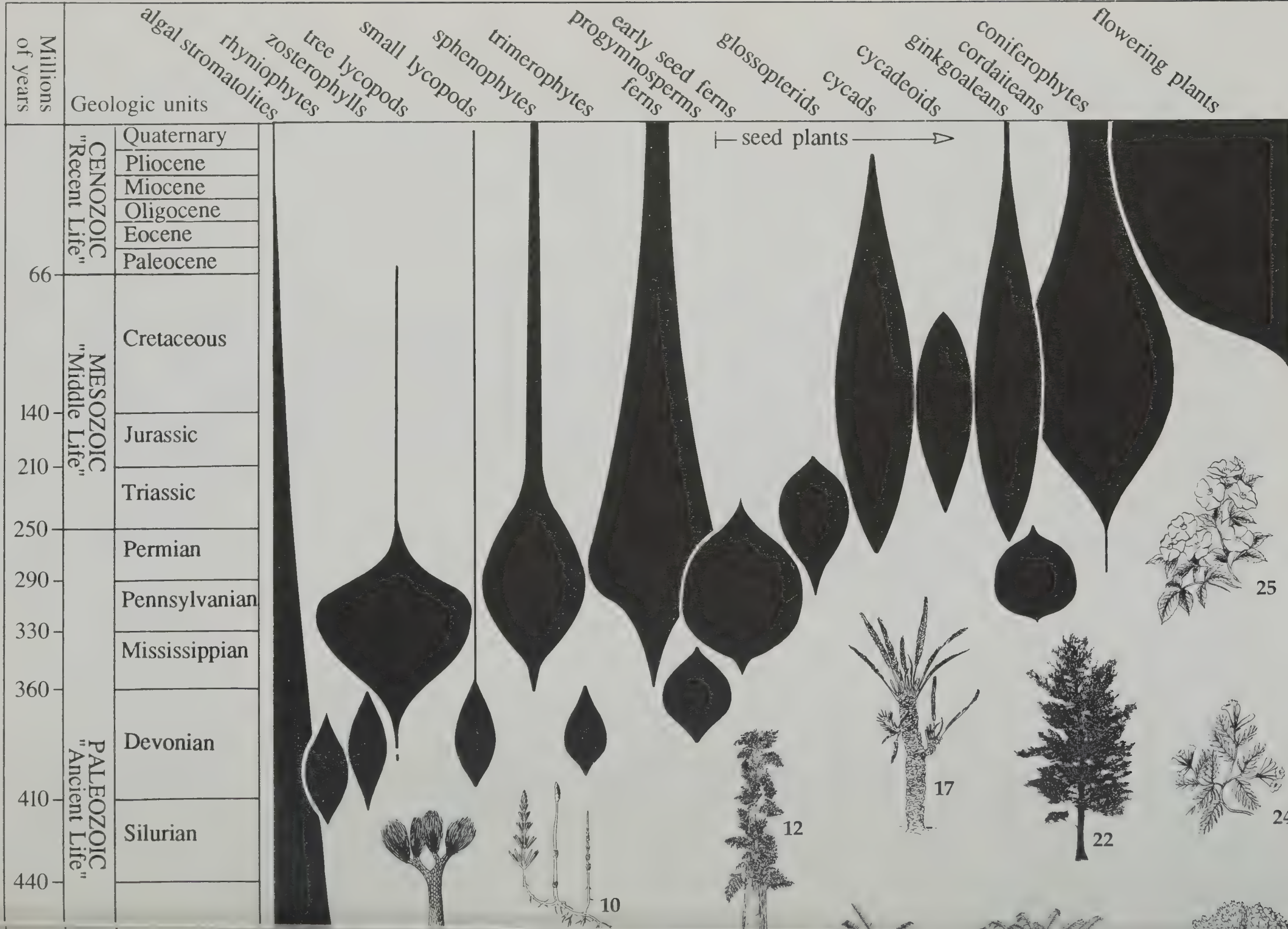

Millions of years
Geologic units
algal stromatolites
rhyniophytes
zosterophylls
tree lycopods
small lycopods
sphenophytes
trimerophytes
ferns
progymnosperms
early seed ferns
glossopterids
cycads
cycadeoids
ginkgoaleans
cordaiteans
coniferophytes
flowering plants
seed plants
CENOZOIC
"Recent Life"
Quaternary
Pliocene
Miocene
Oligocene
Eocene
Paleocene
66
MESOZOIC
"Middle Life"
Cretaceous
140
Jurassic
210
Triassic
250
PALEOZOIC
"Ancient Life"
Permian
290
Pennsylvanian
330
Mississippian
360
Devonian
410
Silurian
440
10
12
17
22
24
25

Figure A1 Geologic Time Scale showing the ranges of various plant groups. The width of line indicates approximate abundance. A key to the figures on the time scale begins on page 74.

Key to various plant groups in figure A1.

Algae (Precambrian-recent)

1. algal mounds (stromatolites) and algal layering (Precambrian-recent)

Vascular plants (plants with water conductive cells, i.e., xylem)

Spore-bearing plants

rhyniophytes--simple leafless plants with sporangia at the ends of branches (Silurian-Devonian)

2. *Rhynia* (Devonian; redrawn from Kidston and Lang; see Stewart, 1983)

zosterophylls (Silurian-Devonian)

3. *Zosterophyllum* (Silurian-Devonian; redrawn from Kräusel and Weyland; see Stewart, 1983)

small lycopods (Silurian?, Devonian-recent)

4. *Drepanophycus* (Devonian; redrawn from Kräusel and Weyland; see Stewart, 1983)

tree lycopods (Devonian-Cretaceous)

5. *Lepidodendron* (Mississippian-Permian)
6. *Sigillaria* (Pennsylvanian-Permian)

trimerophyteans (Devonian)

7. *Psilophyton* (redrawn from Doran; Stewart, 1983)

sphenophytes (Devonian-recent)

8. *Sphenophyllum* (Devonian-Permian; from Collinson and Skartvedt, 1960)
9. *Calamites* (Mississippian-Permian)
10. *Equisetum* (Pennsylvanian?, Permian-recent; from Collinson and Skartvedt, 1960)

ferns (Devonian?, Mississippian-recent)

11. *Psaronius* (Pennsylvanian-Permian; redrawn from Morgan; see Stewart, 1983)
12. *Tempskya* (Cretaceous; redrawn from Andrews, 1948; see Stewart, 1983)

progymnosperms (Devonian-Mississippian)

13. *Archaeopteris* (Devonian; redrawn from Beck; see Stewart, 1983)

Seed plants

early seed ferns (Devonian-Permian)

14. *Medullosa* (Pennsylvanian-Permian; redrawn from Stewart and Delevoryas, 1952

glossopterids (Pennsylvanian-Triassic, Jurassic?)

15. *Glossopteris* (Pennsylvanian-Triassic; redrawn from Stewart, 1983)

cycads (Permian-recent)

16. *Leptocycas* (Triassic; redrawn from Delevoryas and Hope; see Stewart, 1983)

cycadeoids (Triassic-Cretaceous)

17. *Williamsonia* (Triassic-Cretaceous; redrawn from Sahni, 1932; see Andrews, 1961)
18. *Cycadeoidea* (Jurassic-Cretaceous; redrawn from Delevoryas, 1971)

cordaiteans (Pennyslvanian-Permian)

19. *Cordaites* (Pennsylvanian-Permian; from Collinson and Skartvedt, 1960)

ginkgoaleans (Permian?, Triassic-recent)

20. *Ginkgo* (Jurassic-recent; from Collinson and Skartvedt, 1960)

coniferophytes (Pennsylvanian-recent)

21. *Araucaria* (Permian?, Triassic-recent)
22. *Pinus* (Cretaceous-recent; from Collinson and Skartvedt, 1960)

flowering plants (angiosperms; Triassic?, Cretaceous-recent)

23. *Acer*--common maple (Cretaceous?, Tertiary-recent)
24. *Campsis*--trumpet vine (Tertiary-recent; from Collinson and Skartvedt, 1960)
25. *Rosa*--e.g., prairie rose (Tertiary-recent; from Collinson and Skartvedt, 1960)