Pennsylvanian Coal Ball Flora of Indiana

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Abstract

This study was undertaken to further the understanding of the flora of Indiana of the Pennsylvanian Period. While other workers have studied compression fossils of Indiana from the Pennsylvanian Period, the present study represents the first comprehensive work on coal ball plants. Coal balls are specialized calcium carbonate concretions which are sometimes found in coal seams. These concretions usually contain well-preserved petrified plant remains.

Utilizing the "peel technique," detailed analysis is made of selected coal balls which were collected in southwestern Indiana. The plants, or plant parts, are classified to genus, using the system proposed by Andrews. Five divisions are represented, including a total of 27 genera.

The Pennsylvanian plant assemblage of Indiana, based on the present study, is compared to the Pennsylvanian plant assemblage of Illinois. Only minor differences in the represented genera appear, which suggests that a relatively uniform flora may have existed over portions of Indiana and Illinois during that Period.

Methods and Materials

During 1966 and 1967, collecting trips were made to the coal mining regions of Indiana. Most of the collecting was done during the summer of 1967 after analysis and sampling had revealed the most profitable collecting areas.

Coal balls used in the present study were collected from eight sites

TABLE 1. *Coal Ball Collecting Sites.*

Site 1	T 5 S, R 8 W, Sec 10	Warrick County
Site 2	T 5 S, R 8 W, Sec 14	Warrick County
Site 3	T 1 N, R 8 W, Sec 13	Pike County
Site 4	T 1 N, R 7 W, Sec 7	Pike County
Site 5	T 5 S, R 5 W, Sec 12	Spencer County
Site 6	T 5 S, R 8 W, Sec 10	Warrick County
Site 7	T 14 N, R 8 W, Sec 27	Vermillion County
Site 8	T 5 S, R 8 W, Sec 32	Warrick County
Site 9	T 5 S, R 8 W, Sec 9	Warrick County

in southern Indiana and the best specimens were then selected for intensive study. Table 1 shows the location of each collecting site.

The coal balls were prepared for study by first cutting them into uniform slabs about ¾ inch in thickness. The cutting was done on an 18-inch Highland Park mechanically-fed diamond saw. Following the cutting process, the slabs were washed in detergent to remove the coolant. After drying, the material was prepared for study by using the peel technique.

With this technique the slabs were first etched in a dilute (5-10%) solution of hydrochloric acid and allowed to air dry. The etched surface was then flooded with acetone, and a sheet of cellulose acetate film (.005″) was immediately placed on the wet surface. By rapidly rolling the acetate film onto the slab, nearly all air bubbles were eliminated. For routine operations the slabs were then allowed to air dry for twenty to twenty-five minutes. When dry, the film was peeled from each slab. The organic material of the preserved plants which adhered to the film provided the thin layer of plant material necessary for microscopic examination.

The materials were cataloged and the acetate peels were examined under a 20X binocular microscope. Desired portions were cut from the peels, cleared in xylene, and mounted in Kleermount on microscope slides. The microscope slides prepared by this procedure were carefully analyzed and served as the source of data for the present study. The coal balls, acetate peels, and microscope slides were then stored as a reference collection at Ball State University.

Discussion

The classification system used in the present study is the system established by Andrews (1). Five divisions of plants are represented in the present study.

Lycopodophyta

The lycopods of the past were a rich and varied group which exhibited far greater dominance than do the modern forms. Whereas the existing lycopods are mostly creeping or herbaceous forms, many extinct members of this group attained tree size and developed complex reproductive structures approaching the seed habit. The two dominant families are the Lepododendraceae and Sigilliariaceae. All lycopod material in the present collection is placed in the Lepidodendraceae, although other workers might place some of the specimens in the Sigillariaceae because of the great similarity which exists between the organs of the two families.

Probably the genus most frequently encountered by researchers is *Lepidodendron*. This genus includes many species. Even though all these organs have never been correlated for a single species, the genus *Lepidodendron* is very well understood.

The leaves of *Lepidodendron* are long and grass-like and vary a great deal in size from one plant to the next. As the leaves fell from the stem they left a characteristic scar which persisted even on very old trunks. The cones are basically similar to those of living lycopods, but larger.

The anatomy of the stem of *Lepidodendron* is rather complex. Nothing comparable to secondary phloem was produced in the steles. Surrounding the stele is an extensive cortex that was the site of abundant periderm formation as the tree matured. This periderm, unlike the cork of modern trees, remained alive and meristematic. As it became thicker, splits developed in the surface and eventually the outer portions of periderm were sloughed off. Since the stele of the stem never attained great size, the large diameter of some trunks was due mainly to the large periderm region.

In material from the present collection, the stem of *Lepidodendron* is represented by one nearly entire stem specimen and several stele fragments. The nearly entire stem (Figure 1) illustrates the exarch protostelic nature of the genus, but exhibits very little of the periderm region. In another specimen some traces of the periderm region are found in association with what is believed to be a leaf base.

The underground portions of *Lepidodendron* are placed in the genus *Stigmaria.* Two closely spaced dichotomies occurred at the base of the trunk resulting in the formation of four main rhizomes. The small roots which arise from the ultimate branches of the rhizopore are protostelic. The small vascular trace of the root is composed of 8-10 tracheids, and is surrounded by three distinct regions of cortex. In the distal portion of the root, the middle cortex is not found, having presumably undergone natural disintegration. The vascular trace and small inner cortex are then found somewhat eccentrically suspended by small remnants of cortical tissue called trabeculae.

The present collection contains many specimens of *Stigmaria* roots. Several specimens have been isolated which exhibit the three distinctive cortex regions and are thus believed to be sections from near the rhizophore. Another section (Figure 2) shows the characteristic arrangement of tissues which results when the middle cortex disintegrates and the vascular tissue is displaced.

Although the size of the leaves varies from species to species, and even on the same plant, they remain similar in structure. The leaves are long and linear, with a prominent midrib projecting on the abaxial surface. The single, centrally-located vascular bundle is composed of a group of tracheids surrounded by thin-walled cells which probably represent phloem tissue. The blade of the leaf contains rather extensive thick-walled hypodermal cells under both the upper and lower epidermis, between which is found a loosely arranged photosynthetic tissue.

The previously indicated widespread occurrence of *Lepidodendron* in Indiana is further substantiated by the great number of Lepidophylloides

Figure 1

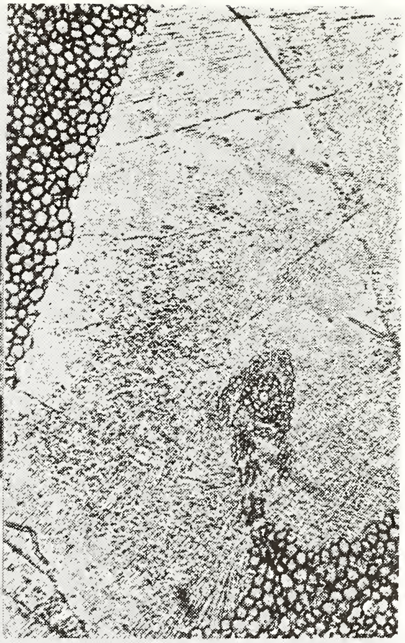

Figure 2

Figure 3

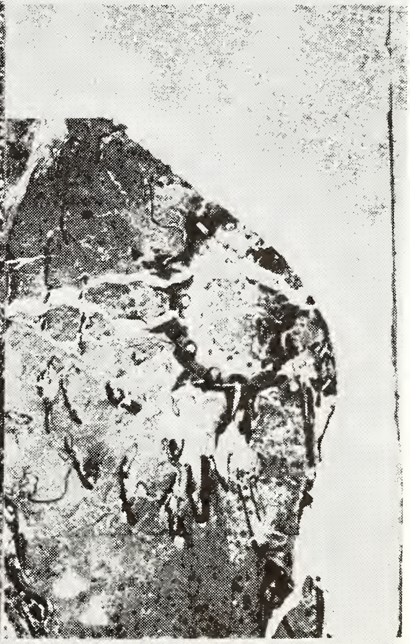

Figure 4

found in the present collection. Some specimens show the vascular bundle and sheath quite well (Figure 3), but no leaves were found with sufficient internal preservation to illustrate phloem tissue. This specimen also shows the hypodermal regions and portions of the spongy mesophyll. All specimens found illustrate the prominent midrib on the abaxial surface of the leaf.

Many species of cones have been described which are borne on *Lepidodendron;* most of these have been assigned to the genus *Lepidostrobus.* These cones vary in size over a considerable range, with specimens averaging 13 mm. in diameter and 15 cm. in length commonly found. Some exceedingly large specimens 8 cm. in diameter and over 30 cm. long are occasionally encountered. The cones are borne terminally, with the sporophylls spirally arranged about a central axis. Nearly all the cones found have been heterosporous, with both unisexual and disexual cones found. The sporangia, borne on the adaxial surface of the sporophyll, are elongate and nearly circulate in cross section. The distal portion of the sporophyll, called the lamins, is upturned and overlaps the sporophylls above, forming a protective outer covering.

Portions of the cone axis and sporophylls are found only occasionally in the present material, which would perhaps indicate that the cones were not so widely distributed as the other organs of this plant. The cross section of one cone shows the sporophylls grouped about the axis in an orderly arrangement. In another specimen (Figure 4) the vascular tissue of the axis is shown and some of the sporangia may be observed to be filled with microspores.

While many cones of *Lepidodendron* contain a large number of spores in each sporangium, others contain as few as four. The genus *Lepidocarpon,* established by D. H. Scott in 1901, has only one functional megaspore in each megasporangium, although three aborted megaspores are associated with the functional one. When mature, two lateral alations of the sporophyll grow upward to almost completely envelop the sporangium, leaving only a slit-like opening at the top. The resulting structure is a seed in the sense that it is an integumented megasporangium with a slit-like opening in the top, analogous to the micropyle of a modern seed.

Lepidocarpon "seeds" are very abundant in the present material. Although clusters of the "seeds" are found, they are not found in organic contact with each other or with any other organ. Many of the present specimens show the enveloping alations and slit-like opening at the top (Figure 5). In some longitudinal sections of the "seeds" the sporangial walls can be seen distinctly separate from the sporophyll alations.

Coniferophyta

The division Coniferophyta contains two orders, the Cordaitales and Coniferales. The former was a dominant group of Pennsylvanian seed plants from which the Coniferales are believed to have evolved. Rapid

Figure 5

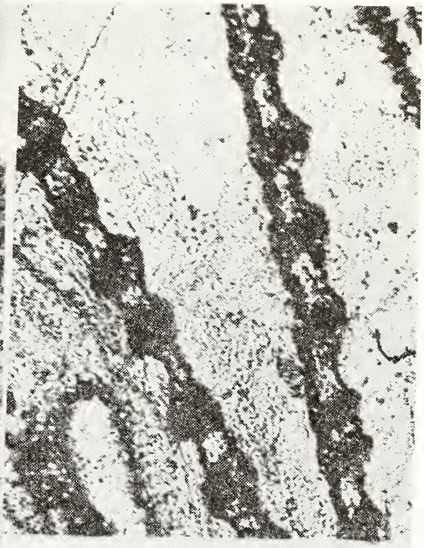

Figure 6

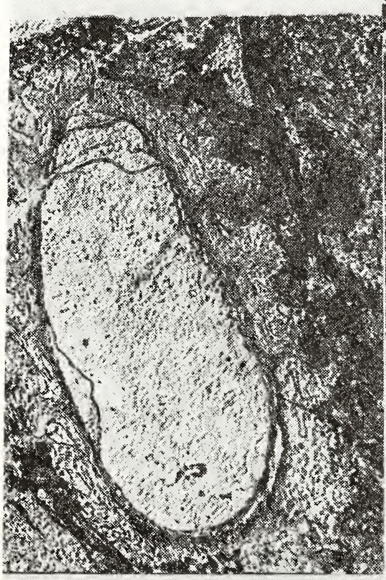

Figure 7

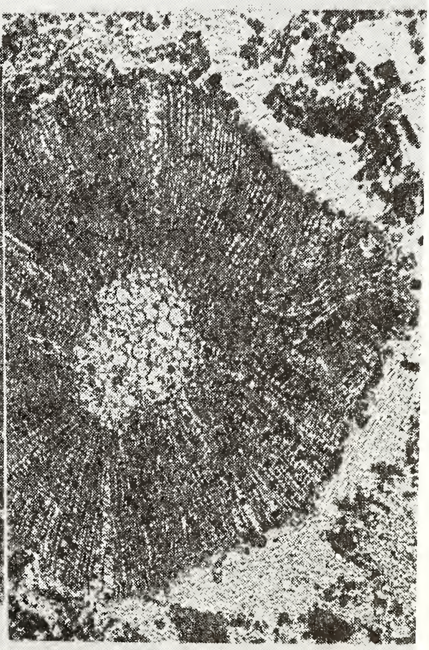

Figure 8

evolution and diversification of the Coniferales apparently occurred during the Permian Period. Some of the modern coniferous trees have changed little from their Permian ancestors.

Members of the Corditales were large trees, often seventy-five to one hundred feet in height, with a crown of large, strap-shaped leaves. Although *Cordaites* is the name proposed first for the leaves of the tree, researchers include more of the plant organs within the genus *Cordaites* as the affinities of the organs become known.

The stem of *Cordaites* contains a chambered or septate pith which is made up of closely spaced plates of parenchymatous pith separated by air spaces. This distinctive and characteristic pith is very similar to that found in the modern genus *Juglans.* Outside the xylem the stem produced a narrow band of cortical tissue, encircled by a zone of periderm.

The *Cordaites* leaf is superficially very similar to a modern Iris leaf except in size. Specimens of the leaves have been found which attained a length of one meter and a width of nearly 15 cm. The veins of the leaf are dichotomously branched, but the veins ascend so steeply that the venation pattern appears to be parallel. The structure of the individual bundles is identical to that of the vascular bundles in modern cycads. In some specimens of *Cordaites* leaves the mesophyll is undifferentiated, while in others the mesophyll is arranged into a palisade-like upper region and a more loosely arranged lower region. The overall structure suggests a tough and stress resistant leaf.

Cordaites leaves are quite abundant in the present collection, suggesting that *Cordaites* must have been one of the prominent plants of the Pennsylvanian swamps in Indiana. Most of the leaf specimens in the present material display relatively poor internal preservation. Figure 6 shows a typical *Cordaites* leaf in cross section. The vascular bundles with their hypodermal "ribs" are well illustrated in this specimen. The evenly spaced vascular bundles indicate the nearly parallel venation pattern.

The reproductive structures of *Cordaites* are assigned to the genus *Cordaianthus.* The phrase "dwarf shoot" is accurately applied to these reproductive structures to distinguish them from the cones of modern conifers. Each shoot is 4-6 mm. long and is made up of twenty to thirty closely inserted scales which are spirally arranged around the central axis. The most distal scales of the microsporangia dwarf shoot are fertile, each bearing about six sporangia. In the megasporangiate shoot only one fertile scale is found, bearing a single ovule, which is generally hidden by the overlapping sterile scales. It is readily apparent that *Cordaianthus* bears little resemblance to the cones of modern conifers.

Cordaianthus is represented sparingly in the present collection. A single specimen illustrates a tangential section of *Cordaianthus* which shows the sterile scales, but no fertile ones.

Most of the isolated seeds attributed to *Cordaites* are assigned to the genus *Cardiocarpus.* Nearly all the seeds of the Pennsylvanian age which exhibit bilateral symmetry in cross section are arbitrarily placed within this genus.

Several good specimens of *Cardiocarpus* are represented in the present collection. Figure 7 shows a longitudinal section of *Cardiocarpus spinatus,* illustrating the projections of the sclerotesta and traces of the nucellus.

Arthrophyta

A burst of evolution in the Arthrophyta division during the Pennsylvanian Period produced some of the most unique plants that have ever lived. The great columnar trunks of Calamites with their whorles of branches, perhaps resembling a giant-size *Equisetum,* surely must have been a striking feature of the Pennsylvanian landscape. While Arthrophyta is a very diverse division, certain characteristics tend to bind its members together as a unit. The chief characteristics of the arthrophytes are their ribbed and jointed stems, and the whorled arrangement of the leaves and sporangia-bearing organs. A rapid decline in the number and variety of arthrophytes apparently began during the Permian Period, and only a single genus, *Equisetum,* survives today.

The two major orders of Arthrophyta are Sphenophyllales and Equisetales. The latter is made up of two families, the Equisetaceae containing the fossil representative.

The family Calamitaceae contains the arborescent arthrophytes. The largest members of this family were trees well over fifty feet in height. While the isolated organs of the members of this family are assigned generic and specific names, the organs are believed to belong, for the most part, to a single, well defined plant named *Calamites.*

The stem structure of *Calamites* is generally similar to that of modern *Equisetum.* The larger stems have a pith cavity and strongly developed secondary wood. *Arthropitys,* the most frequently encountered stem genus, exhibits secondary wood which is divided into sectors by rays only one or two cells wide. In *Calamodendron,* the rays are bordered by vertically aligned fiber cells. In the third genus, *Arthroxylon,* fibers are densely interspersed within the rays.

One fairly complete stem specimen of Calamites is represented in the present collection which illustrates the pith and secondary wood in somewhat crushed condition. Many isolated wood fragments are characteristically found in coal ball petrifactions, and analysis of some fragments in the present collection have shown them to represent *Arthropitys.* Other fragmentary wood specimens from the present collection indicate the possibility of the presence of additional wood genera.

The anatomy of *Calamites* roots, assigned to the genus *Asteromyelon,* is different from that of the stem. The roots lack the jointed feature of the stem, and a well preserved pith is usually present. The cortex is rarely preserved in the roots, but when present, large cavities similar to the canals found in the cortex of *Equisetum* are observed.

Several sections from the present collection illustrate internal anatomy which is characteristic of *Asteromyelon.* The cortex is not present in any of the present sections, making positive identification difficult. The large well preserved pith and typical wood development are evident in several specimens. On the basis of the pith and wood features, the present specimens are assigned to *Asteromyelon.* In some of the sections (Figure 8) a branch root can be seen emerging from the main root. The relative scarcity of specimens from this genus seems to indicate that the roots are not widely distributed in Indiana.

Cones which are believed to have calamitean affinities vary a great deal; however, all have the characteristic whorled arrangement of sporangiophytes. *Calamostachys,* the most common petrified genus, has suggestive whorles of sporangiophores alternating with whorles of sterile bracts. The sporangiophores are pelate (as in modern *Equisetum*) with the sporangia oriented toward the cone axis.

In the present collection, specimens of *Calamites* cones are found in small numbers and are poorly preserved. The author found one specimen believed to be a sporangiophore with fragments of the pelate sporangiophore. Based on this evidence, the specimen is assigned to *Calamostachys.* The lack of additional material suggests a rather sparse distribution of the cones of *Calamites* in Indiana.

The order Sphenophyllales contains only one genus, *Sphenophyllum,* although several other generic names are applied to the cones of this plant. The growth habit has been variously interpreted as aquatic, creeping or climbing; and erect, terrestrial and self-supporting. The leaves of *Sphenophyllum* were borne in whorles at the nodes of a slender, ribbed, and jointed stem. Each leaf was somewhat wedge-shaped and attached to the stem at the narrow end. The broad end of the leaf was variously cleft or notched. The leaves were nacrophyllous, with from three to many vascular bundles in each leaf. While nearly all knowledge about the leaves of *Sphenophyllum* has been derived from the study of coal balls.

The stem of *Sphenophyllum* is protostelic, and the wood is unlike that found in any other plant. The center of the stem contains a triangular group of primary tracheids with small protoxylem cells located at the apices of the primary wood. In older stems a considerable amount of secondary wood is found. The tracheids of the secondary xylem which are located outside the apices of primary wood, are smaller than the remaining tracheids of the secondary wood. Some specimens have been found with a cortex of thin-walled cells, but the cortical tissue is not generally preserved.

A fairly widespread distribution of *Sphenophyllum* during the Pennsylvanian times is suggested by the many good preservations of the stele region of the stems in the present collection. Figure 9 illustrates the triarch protostele which characterizes the stem of *Sphenophyllum.* The structure of the secondary wood may easily be seen, and the smaller

Figure 9

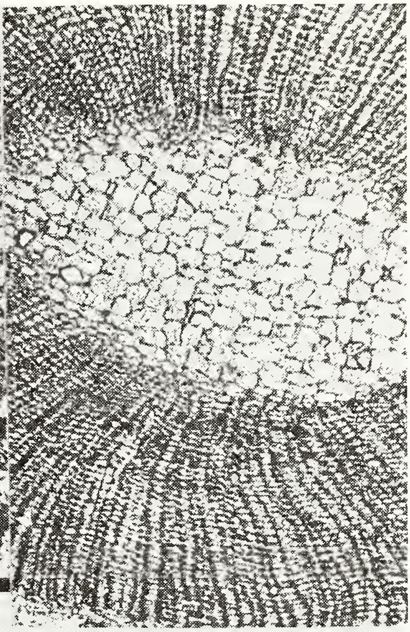

Figure 10

Figure 11

Figure 12

tracheids outside the protoxylem are clearly evident. This section also illustrates the small ray cells among the tracheids of the secondary wood.

The roots of *Sphenophyllum* lack the ribbed and jointed features of the stem. The internal anatomy of the root is similar to that of the stem, except that the protostele is diarch instead of triarch.

Several specimens of *Sphenophyllum* roots are represented in the present collection, although they are not encountered so frequently as specimens of the stem. The diarch protostele of the root is clearly evident in one specimen and the secondary wood appears similar to that of the stem. The cortex region is also shown in the specimen.

Pteridospermophyta

The plants in this division exhibit a combination of two characteristics which are unique and quite interesting. The plants possess fern foliage and bear small nut-like seeds. The combination of these two characteristics gives rise to the name Pteridospermophyta or seed ferns. While joined by these two unifying characters, the seed ferns were in other ways quite diverse and were widespread in the swampy regions during the Pennsylvanian Period.

Two classes of pteridosperms are recognized, the *Lynginopteridaceae* and the *Medullosaceae.* One member of the Lynginopteridaceae is *Callistophyton.* The stem of this plant contains a large pith region of very thin-walled cells. Remnants of the primary xylem tissue can often be observed at the periphery of the pith, followed by a broad zone of secondary wood. A considerable amount of secondary phloem was produced outside the xylem, but this tissue is seldom preserved. Periderm was probably produced on the outside of the stem, but little positive evidence has been advanced to support this idea.

The stem of *Callistophyton* is represented by a single specimen in the present collection. The large pith region is obvious (Figure 10), and traces of primary xylem may be observed at some points around the periphery of the pith. The well developed zone of secondary wood with its narrow rays can also be seen in this specimen.

The class Lygihopteridaceae contains a variety of seeds. *Physostoma* is a small seed, about 6 mm. long and 2.5 mm. in diameter. The cup-shaped pollen chamber is very distinctive, and may contain a large number of pollen grains. The integument of the seed is fused with the nucellus except at the apex. At the apical end the integument is extended beyond the body of the seed into ten to twelve projections. The outer region of the integument is composed of brick-shaped cells arranged radially, while the inner region is composed of longitudinally arranged cells. Large unicellular hairs are sometimes found attached to the outside of the integument. *Conostoma* is the genus of a similar, but slightly smaller seed than *Physostoma.* The structure of the integument is fused with the nucellus except at the apex. No projections of the integument are present in *Conostoma.*

Many seeds are represented in the present collection which are probably assignable to the Lyginopteridaceae. Considerable difficulty was encountered in attempts to identify these seeds. The general literature does not provide adequate information to permit separation of genera of seeds, particularly if the entire specimen is not present. For this reason, the classification of the two genera below is tentative.

Both *Physostoma* and *Conostoma* are represented in the present collection. Figure 11 shows a longitudinal section of *Physostoma* which illustrates the arrangement of cells in the integument. The distinctive pollen chamber and the projections of the integument are not shown because a suitable section could not be made. *Conostoma* seen in cross section illustrates the typical ovoid shape. Remains of the nucellus may be observed in this specimen.

The family Medullosaceae is identified chiefly by the presence of a polystelic vascular system in the stem. Nearly all members of this family are assigned to *Medullosa* which is evidently a genus of very broad limits. The foliage borne on the stem was of the *Alethopteris* or *Neuropteris* type and, when seen in cross section, the large petioles of the fronds bear a considerable resemblance to the stem of modern *Zea*. The seeds associated with *Medullosa* are larger than those of the Lyginopteridaceae.

The stem of *Medullosa* contains from 3-27 small oval protosteles surrounded by a broad region of cortical tissue. The stem itself represented only a small part of the total size of the Medullosa trunk. The enveloping petiole bases account for most of the diameter of the large trunk.

Isolated petiole bases are frequently represented in coal balls, and are assigned to the genus *Myeloxylon*. The petioles are quite large, commonly 4 cm. or more in diameter where they grow free from the stem. *Myeloxylon* contains many vascular bundles scattered through a zone of thin-walled pith cells. The bundles, derived from repeated divisions of the main leaf traces consist of several xylem elements surrounded by a bundle sheath. Phloem tissue is not usually preserved in the bundles. The outer region of the petiole consists of a hypodermal zone of thick-walled fibrous strands, among which secretory canals may occasionally be observed to occur.

Myeloxylon is represented frequently in the present collection. The hypodermal zone and scattered arrangement of the vascular bundles can be seen in several specimens. The overall resemblance of *Myeloxylon* to the stem of *Zea* is evident.

The foliage of *Medullosa* is of the *Alethopteris* or *Neuropteris* type. The differences between these genera, established mainly on the basis of compression fossils, are mainly differences in the venation pattern and the mode of attachment of the leaflets to the rachis. In cross section, the two genera are quite similar except that the midrib of *Alethopteris* is more prominent than that of *Neuropteris*.

As seen in cross section, *Alethopteris* leaves are revolute or curled at the margins. The parenchymatous mesophyll is palisade-like in the upper region and more loosely arranged in the lower portion of the leaf. The midrib is very prominent on the abaxial surface, and the main vascular bundle it contains shows the same structure as the bundles in the *Myeloxylon* petiole. The secondary vascular bundles exhibit the same tissue arrangement as the main bundle, but have some fibers associated with the xylem cells.

Two genera of seeds are normally found in association with *Alethopteris* and *Medullosa*. *Pachytesta* seeds are quite large, some reaching a length of 6 cm. or more. The seed is more or less circular in median cross section and becomes somewhat triangular toward the micropylar end. In overall general appearance, *Pachytesta* resembles a pecan seed.

Two specimens of *Pachytesta* are represented in the present collection. One specimen, representing a small variety of seed, clearly illustrates the structure of the integument. The nucellus of this specimen is free from the integument, and the conspicuous ribs of the integument are also evident. The second specimen, representing a much larger variety, was found partially exposed at the surface of a weathered coal ball. The seed was nearly complete, including the integument, and was 5 cm. long and about 2.5 cm. in diameter. Although the external preservation of the seed was good, examination revealed little internal preservation.

Stephanospermum is another well-known seed believed to be borne on *Medullosa*. Seeds of this genus are comparatively small, usually about 10 mm. long and 5 mm. in diameter. The most striking feature of *Stephanospermum* is the presence of a well-developed collar of the sclerotesta around the micropylar region. The apex of the pollen chamber extends well beyond the body of the seed.

Several specimens of *Stephanospermum* are represented in the present collection. None of the specimens could be cut in such a way as to reveal the distinctive collar of the sclerotesta. In cross section, some of the integument structure can be observed, although the outer fleshy layer is not preserved in these specimens. The remains of the nucellus may be seen as a thin band around the inside of the seed.

The microsporangiate organs of *Medullosa* are assigned to *Dolerotheca*. This is a complex organ, consisting of many tubular microsporangia imbedded in a cellular matrix. In overall appearance, *Dolerotheca* probably resembled a small wasp's nest, about 4 cm. in diameter and 20 mm. thick. When mature, this organ produced huge ovoid microspores, approximately .4 mm. long. Several fragments, believed to be the isolated microsporangia of *Dolerotheca*, are represented in the present collection. No specimen of the entire organ was found.

Pterophyta

The members of this division include both the true ferns and an interesting group of plants called preferns. The preferns began to evolve during mid-Devonian time into plants which are considered transitional between the earlier psilophytes and the later true ferns. Knowledge of preferns is based on a variety of fossil evidence from both compressions and petrifactions.

Two orders of preferns exist, the Protopteridales and the Coenopteridales. It is unfortunate that the distinction between the two is highly artificial, the former known only from compression fossils and the latter from petrifactions. Considerable overlapping of the plants included in the two orders probably exists; but based on the present knowledge, this classification is the most expedient way to identify these plants.

Several families of the order Coenopteridales are represented in the present collection. The family Botryopteridaceae is represented by the genus *Botryopteris.* The stem of this genus is protostelic, about 12 mm. in diameter, and possessed a zone of cortex around the stele. Several petioles branched from the stem, each bearing a bundle with three xylem arms arranged in a characteristic W-shape. The primary petiole branches continued to divide and apparently terminated in slender, cylindrical branchlets.

Isolated petioles of *Botryopteris* are represented frequently in the present collection. In Figure 12 the typical W-shape xylem arrangement of the vascular tissue, as well as the surrounding cortex region are clearly evident.

The family Anachoropteridaceae is represented by the genus *Tubicaulis.* The simple protostelic stem of this plant gave rise to many spirally arranged petioles. The unusual feature of this plant is that the petiole, as seen in cross section, contains a C-shape vascular trace with the open side of the bundle pointing toward the abaxial surface. Very little is known about the remaining organs of this interesting plant.

Many isolated petioles of *Tubicaulis* are represented in the present collection. The C-shaped vascular tissue with its abaxial orientation are shown in several specimens. The cortex surrounding the vascular tissue is also quite apparent.

The family Zygopteridaceae is represented by the petiole genus *Etapteris.* The distinguishing feature of this genus is the H-shaped arrangement of the vascular tissue. In recent years, *Etapteris* petioles have been definitely correlated with a more completely understood plant called *Zygopteris.*

Only a few specimens of *Etapteris* are represented in the present collection. Figure 13 illustrates the petiole with its H-shaped xylem tissue. The cortex which surrounds the vascular tissue in this genus is similar to the cortex of the *Botryopteris* petiole.

Figure 13

Figure 14

Figure 15

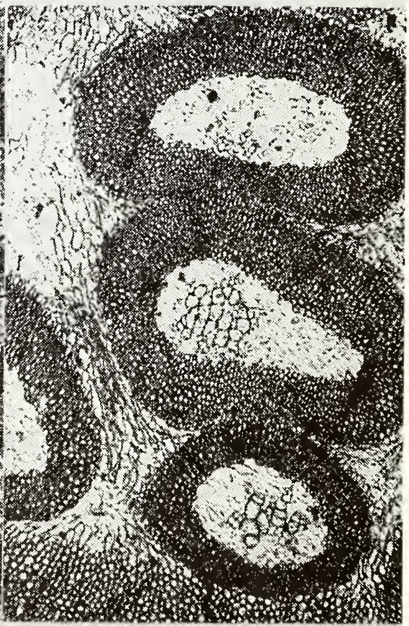

Figure 16

Only one family of the true ferns is represented, the Marratiaceae. Petrified material of this family which existed during the Mississippian, Pennsylvanian, and Permian Periods is usually assigned to the genus *Psaronius.* This genus greatly resembled the modern tree ferns and was one of the dominant elements of the Pennsylvanian and Permian Periods. The trunk of this plant was an unbranched, gradually tapering column, and was covered by a dense mantle of adventitious roots. The mantle of roots was especially thick in the lower trunk region, resulting in the formation of a heavily buttressed base. The crown of the plant was composed of leaves which were few in number, but of great size, some as long as three meters.

Two genera of sporangia exist which are attributed to *Psaronius,* with both genera apparently found on the same type of leaf. *Cyathotrachus* is a rather large synangium consisting of 7-9 sporangia, which are arranged around a central column for about half their length. Each sporangium is a distinct unit with a thin sporangial wall enclosing many spores. All of the sporangia are enclosed within a synangial cover, which apparently split at maturity to release the spores. *Scolecopteris* is the genus of a similar type of synangium which consists of six rather elongate sporangia joined only at their base. There is no synangial cover in *Scolecopteris.*

Scolecopteris synangia are represented in considerable numbers in the present collection, suggesting a rather widespread distribution. When the synangia are sectioned parallel to the leaf surface, the sporangia appear in cross section (Figure 14), and the structure of the thin sporangial walls may be observed. Figure 15 shows a longitudinal section of *Scolecopteris* and illustrates the elongate nature of the sporangia and their attachment to the leaf.

Another unusual feature of *Psaronius* is the thick mantle of roots which surround the stem. One specimen has been reported which had a stem two inches in diameter and a mantle of roots thirty inches thick. The broad mantle of roots in this genus is composed of two zones, an inner zone of small roots imbedded in a cellular matrix, and an outer zone of larger, free roots. Each root has a small, star-shaped protostele and a broad aerenchymatous cortex. The cortex is bounded by a region of thick-walled hypodermal cells which form the outer portion of the root. The presence of the aerenchymatous cortex suggests the possibility of a swampy habitat for the *Psaronius* trees.

One of the coal balls in the present collection was found to be composed entirely of *Psaronius* roots. The roots from this specimen illustrate the small protostele composed of xylem tracheids (Figure 16). The region of hypodermal cells is also clearly evident in this section. Several examples of isolated *Psaronius* roots were found in other coal balls which illustrate the aerenchymatous cortex.

Interpretation

Benninghoff (2) published a report of a coal ball flora from a mine near Petersburg, Indiana, in which he described thirteen genera of fossil plants. The genera described by Benninghoff, together with genera reported in selected Illinois studies, are compared to the genera in the present collection in Table 2. Benninghoff described three genera of synangia, *Asterotheca, Myriotheca,* and *Phytocarpus,* which are not represented in the present material nor in any of the Illinois studies. All other genera described by Benninghoff are included in the present study.

The degree of similarity existing between the assemblage of fossil plants of Indiana as represented in the present collection, and the assemblage of fossil plants of Illinois is summarized in Table 2.

Darrah (3) has said that the plant assemblages found in nearly all American coal ball floras are basically similar. The differences lie mainly in the change of dominant genera from flora to flora, or the occasional addition or deletion of a few genera. The present study tends to support Darrah's statement. Considerable similarity exists between the plant assemblage found in Illinois and the plant assemblage of Indiana. The present study provides the basis for a more detailed correlation.

TABLE 2. *Genera represented in Indiana and Illinois coal ball studies.*

Genus	Present	Benninghoff	Graham 1934	Graham 1935	Reed 1936	Reed 1938	Reed 1938	Hoskins 1926	Hoskins 1928	Krick 1932
Stigmaria	*	*							*	
Lepidodendron	*	*		*					*	
Lepidocarpon	*	*			*					*
Lepidophylloides	*									
Sigillaria				*						
Lepidostrobus	*	*		*						
Calamites	*	*				*				
Asteromyelon	*			*						
Calamostachys	*									
Paleostachys						*				
Asterophyllites						*				
Annularia									*	
Sphenophyllum Stem	*	*								
Sphenophyllum Root	*									
Callistophyton	*									
Physostoma	*									
Conostoma	*		*				*			*

TABLE 2. (*continued*)

Genus	Present	Benninghoff	Graham 1934	Graham 1935	Reed 1936	Reed 1938	Reed 1938	Hoskins 1926	Hoskins 1928	Krick 1932
Heterangium				*						
Medullosa Stem				*						
Myeloxylon	*	*		*						
Neuropteris		*								
Alethopteris	*									
Pachytesta	*						*			*
Stephanospermum	*									*
Telangium			*							
Cordaites Stem	*									
Cordaites Leaf	*									
Amyelon	*									
Cordaianthus	*									
Cardiocarpus	*	*		*						
Botryopteris	*	*		*						
Pecopteris	*	*						*		
Tubicaulis	*									
Etapteris	*									
Psaronius Root	*	*	*	*				*		
Psaronius Stem		*		*				*		
Scolecopteris	*		*					*		
Cyathotrachus			*							
Anachoropteris				*						
Notoschizaea			*							
Asterotheca		*								
Myriotheca		*								
Phytocarpus		*								

The striking similarities which appear between the Illinois studies and the present Indiana material suggest that a relatively uniform flora existed over portions of Illinois and Indiana during the Pennsylvanian Period.

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