

Preliminary Report on a Coal Ball Flora from Indiana

WILLIAM S. BENNINGHOFF, Harvard University

Occurrence

Calcareous, dolomitic, or pyritic nodules occasionally found just below the roof shales of coal seams are commonly called "coal balls"; and frequently they contain portions of fossil plants in good states of preservation with little distortion from compression. Coal balls of the calcareous type were collected by the author in June, 1938, at the Rosebud Mine, two miles north of Petersburg, in Pike County, Indiana.¹ The coal seam bearing these nodules has been assigned to upper Coal No. 5 of the Indiana series.² Coal No. 5 is equivalent to the upper Allegheny group of the Appalachian Carboniferous. It is noteworthy that this coal is composed almost exclusively of vitrain and durain. In the Rosebud slope-shaft mine the seam averages approximately 5 feet in thickness, and the coal balls were found in the upper 6 inches next to a hard, gray-brown roof shale. The coal balls range in size from one inch to 8 inches in diameter, the smaller specimens being roughly spherical and the larger ones more or less discoidal. Calcium carbonate is the principal constituent of the coal balls containing fossil plants, although a few showed low concentrations of pyrite in the form of minute crystals. Several larger nodules of pure pyrite were collected, but proved to be practically sterile of recognizable plant remains. Large "ironstone" concretions devoid of fossils occur frequently in the roof shales of this locality, but coal balls bearing plant remains suitable for study were found only in one area of approximately 200 square feet. One hundred sixty specimens were collected, and many of these contain several coal balls solidly imbedded in coal. The sawed pieces have been inserted in the Paleobotanical Collections of the Harvard Botanical Museum and bear numbers from 39001 to 39158, and from 39198 to 39329.

Preparation of the material

For this reconnaissance survey of this coal ball flora, the nodules were first sectioned at random by means of a carborundum disc saw. Then the sawed surfaces were ground flat on a lapidary, and nitrocellulose peels were made from these surfaces according to the method of Darrah.³

¹The occurrence of coal balls at this locality was brought to the author's attention by Dr. C. E. Read of the National Museum.

²Dr. Ralph Esary, personal communication, October 19, 1940. The nomenclature for the Indiana coal series was established by G. H. Ashley in the *Twenty-third Annual Report of the Indiana Department of Geology and Natural Resources*, 1899, pp. 1-1741.

³Darrah, W. C. 1936: The peel method in paleobotany. *Bot. Mus. Leaflets. Harvard Univ.* 4(5):69-83. Also, *idem.* 1939: Textbook of Paleobotany. D. Appleton-Century, New York. Pp. 13-16.

In many of the specimens the limestone had become somewhat "rotten", probably because of the constant passage of ground water through the roof of the mine gallery. On all of the specimens only a very low concentration (3-5%) of hydrochloric acid could be used for etching the ground surfaces.

The nitrocellulose peels were first examined under a 10-power binocular dissecting microscope. The sections worthy of study were cut out and mounted on microscope slides in damar, in order to facilitate observations under higher powers.

The detailed study of this coal ball flora will involve investigations of the significant plant remains by serial sections (i. e. the preparation of consecutive peels at evenly spaced intervals through the specimen). In many cases differently oriented saw cuts should confirm the identifications of plant remains disclosed by this preliminary survey.

Description of the flora

The following list enumerates the plants and plant parts identified during the reconnaissance survey of this flora:

LYCOPSIDA

Lepidodendrales

Lepidodendron group *selaginoides* Sternberg (= *L. vasculare* Binney)

Lepidostrobus sp.

Lepidocarpon glabrum Darrah

Lepidodendron leaves

Lepidodendrid megaspores

" microspores

Stigmarian rootlets

SPHENOPSIDA

Sphenophyllales

Sphenophyllum cf. *plurifoliatum* Williamson and Scott

Equisetales

Calamites sp.

PTEROPSIDA

Filicinae

Botryopteris sp.

Asterotheca sp.

Myriotheca sp.

Ptychocarpus sp.

Psaronius

Stipitopteris sp.

Pecopteris villosa Brongn.

Gymnospermae

Pteridospermae

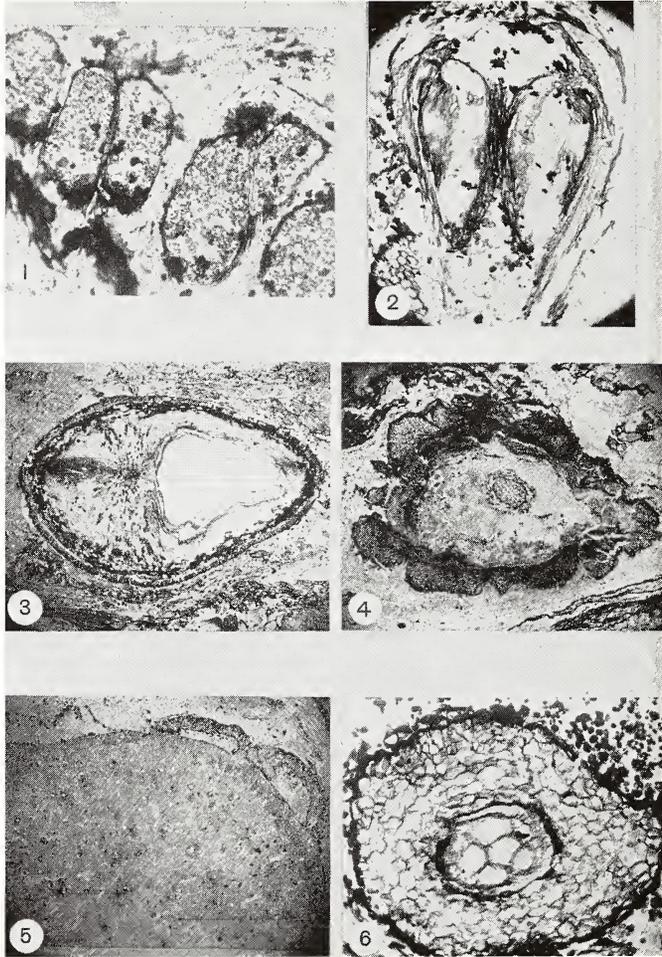
Myeloxylon

Neuropteris cf. group *rarinervis* Bunb'y

Cordaitales

Cordaicarpus ? sp.

The *Lepidodendron* fragments, especially stems and leaf bases, are conspicuous by their numbers in this material. The stems have been assigned to *L. selaginoides* Sternberg (= *L. vasculare* Binney) since the primary wood extends to the center of the stèle where short tracheids



EXPLANATION OF PLATE I

Fig. 1. Pecopterid sporangia of a type which is very common in this flora. X 36.

Fig. 2. *Ptychocarpus* sp. Longitudinal section. X 28.

Fig. 3. *Lepidocarpon glabrum* Darrah. Longitudinal section. X 7.

Fig. 4. *Lepidodendron* group *selaginoides* Sternberg (= *L. vasculare* Binney). Transverse section of stem. X 5.

Fig. 5. Portion of *Myeloxylon* petiole with pinnule in attachment. Transverse section. X 6.

Fig. 6. An ultimate petiole of *Botryopteris* sp. Transverse section. X 37.

having characteristic reticulate thickenings are mixed with parenchymatous cells. To the extent that they are displayed in these specimens, the other definitive characters conform to the *sluginoides* group (Plate I, Fig. 4). All of the specimens are small branches 8 to 25 mm in diameter including the leaf bases. A few show the beginnings of secondary wood development.

Two specimens of *Lepidostrobus* have been found. One is a very small immature strobilus in which the fertile portions of the sporophylls were just beginning to develop. The other is a fragment of the mature strobilus of which several microsporophylls and their spores are well preserved. In this piece the microspores average 93μ in diameter; each possesses an equatorial "wing" the margin of which is crenulate, and the surface of each spore bears a coarse reticulum which is more delicate near the pronounced triradiate scar. Neither of these specimens of *Lepidostrobus* are sufficiently well preserved to be assigned to species.

One specimen of *Lepidocarpon glabrum* Darrah was found (Plate I, Fig. 3). This seed is 7.8 mm in length and 4.2 mm in width, thus slightly less elongate than Darrah's type.⁴ Fortunately the seed happened to be cut in a median plane approximately 1 mm to the side of the central vascular strand. The preservation is unusually good, and particularly well shown is the vascularization. At three-quarters of the way from the proximal end of the seed to the megagametophyte the central vascular strand sends out two branches at right angles to the plane of the section shown in figure 3; just distal to this point two more vascular branches are given off in the plane of the section. These latter two strands will be seen to follow closely the proximal margin of the megagametophyte, and it is likely that the other two strands at right angles to these are just as intimately associated with the megagametophyte. Miss Reed⁵ described the structure of several seeds from coal balls collected in Coal No. 5 in southern Indiana and Illinois, but the *Lepidocarpon glabrum* form was not encountered in that material.

Numerous transverse sections of leaves of arborescent Lycopods were found. All contain only one leaf trace, and are therefore to be referred to *Lepidodendron* rather than *Sigillaria*, the leaf of which has two traces. The microspores and megaspores of Lepidodendrid types are abundant in many of the coal balls. Four of the broad-winged type of Lepidodendrid microspores drifted into the specimen of *Ptychocarpus* shown in figure 2. As in nearly all Lepidodendrid floras, Stigmarian rootlets are common, although poorly preserved, in these coal balls.

Stems of *Sphenophyllum* are frequent in this material. All but one may be referred to *S. plurifoliatum* Williamson and Scott. This one exception possesses a very small triarch stele with no secondary wood. The inner cortex has disappeared, but the outer cortex is composed of cells with very strong walls; and the stem has six conspicuous ridges. This specimen is probably a *Sphenophyllum* rootlet. The decorticated stems of *Calamites* are present in approximately the same abundance as

⁴ Darrah, W. C. 1941. The fossil flora of Iowa coal balls. IV. *Lepidocarpon*. *Bot. Mus. Leaflets, Harvard Univ.* 9(5):85-100.

⁵ Reed, Fredda D. 1939: Structure of some Carboniferous seeds from American coal fields. *Bot. Gaz.* 100:769-787.

Sphenophyllum. The *Calamites* wood in these coal balls consistently has a large quantity of included pyrite crystals, and the preservation of cell wall details is poor.

The representatives of the true ferns in this flora belong to two groups, the Coenopterid genus *Botryopteris* and the presumably Marattiaceous *Pecopteris* complex. *Botryopteris* is represented by a few very small "petioles" (i. e. axes of various parts of pinnae). These petioles average 2 mm in diameter, and each has a small circular protostele made up of tracheids with annular and scalariform thickenings (Plate I, Fig. 6). The cortex resembles very closely the type of cortex possessed by *B. americana* Graham, but this latter form is characterized by a trident-shaped stele and averages 4.8 mm in diameter.⁶ It is probable that the *Botryopteris* petioles in the Indiana coal balls are ultimate axes of pinnae and are borne upon "primary" petioles such as *B. americana*. It is hoped that serial sections of these petioles will reveal the nature of their attachment. No Botryopterid sporangia have been found so far in these coal balls.

The members of the *Pecopteris* complex found in this flora are *Asterotheca* sp., *Myriotheca* sp., *Ptychocarpus* sp., *Psaronius*, *Stipitopteris* sp., and *Pecopteris villosa* Brongn. Sporangia are very abundant in this flora; and although nearly all lack attachment with other plant parts, most of them have been determined as Pecopterid (Plate I, Fig. 1) on the basis of the form and disposition of the sporangia and the characteristic spores.⁷ Specimens of *Asterotheca* are numerous, but sporangia referable to *Myriotheca* are the most abundant of these fructifications. The determinations of the specimens of *Asterotheca* were made on the basis of the distinctive radiate disposition of the 4 to 7 sporangia in the synangial clusters and the shapes of the individual sporangia. All of these sporangia were devoid of spores. The reference of specimens to *Myriotheca* was made on the basis of the large numbers of sporangia regularly disposed within the groups and the profusion of spores of the type described by Sellards⁸ for *Myriotheca*.

Two synangia resembling *Ptychocarpus* were revealed in the coal balls. The better specimen (Plate I, Fig. 2) conforms very closely to *Ptychocarpus unita* Brongn. in size, gross structure, and the disposition of the central column of dense tissue, as described by Graham.⁹ This synangium is 1.7 mm long from the lamina to the distal end and 0.7 mm in diameter. However, close examination reveals that the sporangia are suspended by short peduncles from the lamina and that the synangium is sheathed in an extra integument which follows the contours of the

⁶ Graham, R. 1935: Pennsylvanian flora of Illinois as revealed in coal balls. II. *Bot. Gaz.* **97**:156-168. Darrah, W. C. 1941: The Coenopterid ferns in American coal balls. *Amer. Midl. Nat.* **25**:233-269.

⁷ The author has recently isolated the spores from various accurately determined fructifications of Carboniferous plants in order to assist in determinations such as these.

⁸ Sellards, E. H. 1902: On the fertile fronds of *Crossotheca* and *Myriotheca*, and on the spores of other carboniferous ferns, from Mazon Creek, Illinois. *Amer. Jour. Sci.* 4th ser. **14**:195-202.

⁹ Graham, R. 1934: Pennsylvanian flora of Illinois as revealed in coal balls. I. *Bot. Gaz.* **95**:453-476.

syngangium and has distally a sort of stoma guarded by reflexed hairs. Unfortunately with this specimen there are associated five different types of spores, none of which are the typical spores of *Ptychocarpus*. This specimen is provisionally referred to *Ptychocarpus* until more detailed study may definitely determine its characters and identity.

Psaronius, a Marattiaceous type of stem which usually bore Pecopterid foliage, is represented in these coal balls by numerous fragments of the cortex. Four petioles of the genus *Stipitopteris* were discovered. The *Stipitopteris* petiole possesses a vascular bundle which has the shape of an "elongated horseshoe" in transverse section, and a leaf trace diverging from the bundle appears as an "isolated W-shaped segment within the outer band."¹⁰ Lenz has shown that the bundle of this petiole conforms exactly with the shape of the bundle scars on the decorticated *Psaronius* stems known by the form-genus name *Caulopteris*. The specimens of *Stipitopteris* in the Indiana coal balls are oval in outline with the long axis extending through the leaf trace gap, and average 1.9 mm by 3.2 mm. The vascular bundles average 1.3 mm in greatest diameter. None of the petioles in this material show an isolated leaf trace. Protoxylem points are found on the two edges of the horseshoe-shaped stele, and two or three more occur on the inner side of the stele opposite the gap. The study of these petioles by serial sections will be necessary before they can be assigned to species.

In this material many pinnules occur. By far the greatest number of them have a "ram's horn" shape in transverse section, average 2.5 mm in breadth, and contain a leaf trace of the *Stipitopteris* type with the gap toward the upper surface of the lamina. Characteristic of most of these pinnules are the numerous hairs on the under surface of the lamina and on the prominent midrib. These pinnules have been assigned to *Pecopteris villosa* Brongn. and were probably originally attached to *Stipitopteris* petioles which were in turn attached to *Psaronius* stems.

Five petioles belonging to the form-genus *Myeloxylon* have been found in these coal balls, and a pinnule is in attachment with one of the petioles. In greatest diameter they range from 4.0 mm to 9.5 mm. The pinnule in attachment with one of the petioles (Plate I, Fig. 5) is the basal member of a pinna which was borne on this petiole and appears to conform with the pinnule type assigned to *Neuropteris*. In addition to the *Pecopteris* pinnules another type of pinnule occurs in considerable numbers. This latter type averages 4 mm in breadth, has a relatively thin lamina with no hairs on the under surface, and has a consistent layer of columnar heavy-walled cells immediately under the epidermis of the upper surface. Two of these pinnules chanced to be exposed in horizontal section so that the venation was revealed. The veins form a definite midrib through only the basal half of the pinnule; the lateral veins diverge from the mid-line at low angles, and they usually branch once, occasionally twice. These pinnules are ovate with the margins entire. Unfortunately the basal portions of neither of these pinnules were preserved, so the important characters of the mode of attachment to the petiole cannot be determined. One of this type pinnule was found

¹⁰ Lenz, L. W. 1942: Contributions to our knowledge of American Carboniferous floras. III. *Stipitopteris*. *Annals Missouri Bot. Garden* 29:59-68.

in attachment with a *Myeloxylon* petiole (Plate I, Fig. 5). It seems reasonable to assign this pinnule type to Neuropteris group *rarinervis* Bunb'y, and to assume that they probably were in attachment with *Myeloxylon* petioles as parts of Pteridospermous plants.

A seed-like structure which may possibly be an immature *Cordaicarpus* was found although no other Cordaitan material was discovered. This structure consists of an outer bag-like sclerenchyma coat and enclosing a heart-shaped cellular body which is half enclosed in a firm integument. Within the heart-shaped body is a body of similar form which appears to be non-cellular. The entire structure measures 1.15 mm in length, 0.90 mm wide at the broadest part, and 0.45 mm wide at the tip. The mode of attachment is not revealed. The fact that this seed structure is bilaterally symmetrical indicates that it belongs to the primitive gymnosperms known as Cordaitales and can best be referred to the form-genus *Cordaicarpus*.

Conclusion

Most abundant of the plant parts in these coal balls are fern pinnules, detached fern sporangia, and fragments of *Lepidodendron* stems and leaves. Stems of *Calamites* are just as frequent as the complete stems of *Lepidodendron*. Specimens of *Sphenophyllum* and *Myeloxylon* are less common, and the only evidence of members of the Cordaitales rests upon the single dubious specimen of *Cordaicarpus*. Therefore, on the basis of this preliminary survey, this assemblage of plants must be recognized as a *Lepidodendron*-*Calamites*-Fern flora in which specimens of *Sphenophyllum* and Pteridosperms are members of a minor element. It must be borne in mind, however, that these coal balls taken from a very small area may possibly not offer a flora that is strictly representative of the horizon.

In general, this coal ball flora from upper Coal No. 5 in Indiana is very similar in generic composition to the coal ball floras from Illinois. It may be compared also with the flora from Frontenac, Kansas, reported by Darrah.¹¹ In the Frontenac coal balls, on the other hand, the presence of Cordaitan material, although rare, gives the flora a somewhat different aspect, as if it were transitional (in time) between the *Lepidodendrid* floras of Illinois and Indiana and the Cordaitan floras of Iowa coal balls.¹¹ It remains to be shown in the Mid-continent Carboniferous whether such transitions between floras are to be recognized as phenomena of time or of space or both.

The author wishes to express his sincere appreciation and thanks to: Mr. Eli Hendricks, owner of the Rosebud Mine, for the privilege of collecting the coal balls and for valuable assistance in the field; to Mr. Frederick O. Thompson of Des Moines, Iowa, for funds for the preparation of the nitrocellulose peels; and to Mr. W. C. Darrah, Curator of Paleobotany at the Harvard Botanical Museum, for the use of reference materials and for indispensable personal guidance in this work.

¹¹ Darrah, W. C. 1941: Studies of American coal balls. *Amer. Jour., Sci.* 239:33-53.