Technical Papers

Floral-Faunal Associations in American Coal Balls[1]

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Coal balls are accumulations of fossil plant material that has been impregnated with calcium or magnesium carbonate, iron sulfides, and minor amounts of other mineral constituents. These nodules differ considerably in size and shape, ranging from the size of an acorn to masses hundreds of pounds in weight and from spherical to elliptical, or lens shaped. Besides these, however, huge irregular masses of coal ball material several tons in weight have been found. Coal ball material occurs only within bituminous coal seams that are capped by marine limestone. Geographically, it is widely distributed, and occurrences have been reported in the United States, England, western Europe, Spain, and the Donetz Basin of Russia. So far as is known, coal balls are confined to strata of Late Carboniferous or Pennsylvanian age (*1*).

Coal balls have been known for a century in England and for about three decades in the United States. Their organic content is commonly preserved in the most minute detail and is conveniently investigated by means of the Parlodion peel technique (*2*). Such investigations have contributed much to our knowledge of Pennsylvanian plants, as, for example, the discovery of the Paleozoic pteridosperms, a bizarre group of fernlike plants that bore seeds.

In any discussion of coal balls, questions concerning their origin and nature arise, and it is hoped that continuing investigations of the material discussed in this preliminary report will eventually shed some light on these questions. The purpose of the present paper is to describe the features with which any hypothesis of origin must be consistent rather than to venture possibly premature conclusions.

During the field season of 1952, Mamay collected coal balls from a stream-bed exposure near Berryville in southern Illinois and from strip pits of the Pittsburgh and Midway Coal Company near West Mineral in southeastern Kansas. The bulk of these collections, totaling somewhat more than a ton in weight, contains the usual assemblage of plant stems, roots, leaves, and fructifications, but a few of these coal balls are remarkable because they carry an association of marine invertebrate and terrestrial plant fossils such as has not, to our knowledge, previously been recorded. It is this new material on which the following discussion is primarily based.

The Kansas collection consists of approximately 150 coal balls. Five of these were found to contain a diverse assemblage of marine invertebrate remains, homogeneously scattered among the plant fragments. Since many of the invertebrates are preserved as molds or replacements by silica or pyrite, both of which are insoluble in dilute hydrochloric acid, chunks of the coal balls were dissolved in this reagent. The reaction was allowed to continue until all the carbonates were dissolved; the remaining sludge was dried, sieved through coarse screens, and examined for organic remains. The following invertebrates, which comprise a typical Pennsylvanian fauna, have tentatively been identified by the authors with the assistance of various colleagues:

Foraminifera: *Tolypammina* sp.
?Porifera: New genus.
Pelecypoda: *Schizodus* sp.; *Parallelodon* sp.; *Pleurophorus* sp.; *Astartella* sp.; *?Pterina* sp.; fragments of several other genera.
Gastropoda: *Glabrocingulum* sp.; *?Anomphalous* sp.; *Donaldina* sp.
Brachiopoda: *Chonetes* sp.; *Marginifera* sp.; *Derbyia* sp.
Ostracoda: *Hollinella* sp.

These coal balls also contain numerous roughly spherical pellets, consistently about 1 cm in diameter. They are dark brown and stand out in marked contrast with the generally lighter colored matrix. These pellets are composed of small bits of finely macerated plant tissues and are interpreted as the fecal pellets of an herbivorous animal.

Large plant fragments have not been recovered by the acid treatment. However, smaller bits are abundant in the organic residues and have been recovered in a fully distended, uncompressed condition.

Megaspores are the most abundant of the plant structures found in the residues. Most of these are large, spherical trilete forms; one type averages about 3 mm in diameter and bears a wide equatorial frill with delicate spongy texture. Preservation of the larger spores is so good that the thin endosporal membranes may be dissected out. The proximal portions of most of these membranes contain a number of small, evenly distributed, dark round spots. Their size, distribution, and restriction to the proximal parts of the spores suggest that these spots may represent the remains of archegonia.

The preservation of the fossils presents an interesting problem in replacement. As a general rule, the brachiopod shells remain calcareous and must be mechanically removed from the matrix for study. Ostracods and pelecypods, as well as a few brachiopods, are pyritized; gastropods are calcareous, pyritized, or silicified. Furthermore, many of the spores contain internal molds, either pyritic, calcareous, or siliceous. The surfaces of many of the molds show the triradiate

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marks that appear on the proximal surfaces of the spores.

Several coal balls also containing invertebrates were found in the collection from the Berryville locality in Illinois. These differ from the Kansas material in several aspects and serve to enhance the general interest of this problem.

Although invertebrates are homogeneously scattered through the matrix of the Kansas coal balls, the animal content of the Berryville material is restricted to a clearly defined mass of marine limestone located at or near the center of the coal ball. The limestone is in the form of elongate, more or less rounded, rod-shaped masses and is lithically and faunally similar to the marine limestone immediately overlying that part of the coal seam where the coal balls occur. The contact between the included limestone mass and the remainder of the coal ball is generally sharp, but an occasional plant axis may extend about 1 cm into the limestone. Scattered bits of plant debris are present within the limestone masses, but the organic content is predominantly of invertebrate origin.

With the exception of some pyritized bryozoans, the invertebrate remains in the Berryville material are calcareous and hence not adapted to the hydrochloric acid treatment. They have been studied by mechanical preparation. Unlike the Kansas specimens, they are not readily determinable to the generic level.

The faunal assemblage in the Berryville coal balls is somewhat different from that of the Kansas balls. The following invertebrate remains have been tentatively identified:

Foraminifera: calcitarnellid forms.
Coelenterata: lophophyllid coral.
Echinodermata: crinoid stems, seemingly all of one type.
Bryozoa: rhomboporoid forms.
Gastropoda: Three shell types observed in various sectional planes.
Pelecypoda (or Brachiopoda): Small biconvex sections and scattered shell fragments.

Pellets similar in size, shape, and content to those found in the Kansas material are present in the Berryville coal balls. Some of the Berryville specimens, however, are unusual in that they contain an abundance of small spores, all apparently of the same kind. It is difficult to explain such concentrations of spores outside the sporangium itself, unless one considers them as having been concentrated in the intestines of herbivorous animals and preserved as coprolites. Occasionally the diets of these herbivores included fertile foliage; this would explain the presence of many spores in some of the pellets and their complete absence in others.

Although the primary purpose of this communication is to report this unique plant-animal association in American coal balls, we wish briefly to mention the outstanding problems posed by this material.

The occurrence of invertebrate-containing coal balls among normal plant-bearing coal balls and the inclusion of marine limestone masses within otherwise normal individual coal balls is difficult to explain. That some transportation of material was involved is suggested by the swirled or rolled structure of the invertebrate-containing coal balls as contrasted with the bedded structure of normal coal balls, as well as by the fact that occasional spores, cuticles, and other terrestrial plant structures bear adherent tests of marine Foraminifera. It is hoped that distances and modes of transportation involved may be determined by further field observations, formulated to test alternative hypotheses suggested by laboratory studies.

The chemical processes involved in the preservation of the fossils is perplexing. One might assume that differences in mineral replacement of these fossils by and large reflect differences in the original composition and structure of the organisms. This alone, however, does not explain the occurrence, in the same coal ball, of both silicified and pyritized specimens of gastropods that obviously belong to the same species, or the fact that internal molds of the same species of spores may be calcareous, pyritic, or siliceous.

The origin of the carbonates that form the matrix of the coal balls needs explanation. This calls for studies of the associated sediments and considerations of chemical relationships between marine and coal swamp waters.

An investigation of this problem is now being carried out, with a view to publication in a forthcoming paper. In addition to discussions of the questions mentioned, it is intended that this paper will include a systematic analysis of the fauna and flora associated in these coal balls.

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Bilateral Interaction in the Lateral Geniculate Body[1]

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In the higher vertebrates the lateral geniculate body is the only synaptic center on the direct path between retina and cerebral cortex. With the partial decussation that occurs in the optic chiasma, it might be expected that the preliminary mechanisms concerned in binocular fusion would be located in the lateral geniculate body. It is widely believed (*1, 2*), however, that the pathways from each eye retain their separateness both anatomically and physiologically through the synapses in the lateral geniculate up to the visual

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