# REVIEW OF AMERICAN COAL BALL STUDIES

BY

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In Autumn, 1922, I wrote a letter to Dr. David White informing him that coal balls had recently been found in Illinois, and at a conference during the Christmas vacation of the same year, I showed a sectioned coal ball to him. This was the first coal ball observed in Illinois. It had been collected by Dr. Gilbert A. Cady in the O'Gara mine number 9 near Harrisburg. When the concretion, which looked like an ordinary impurity of the coal, had been left by Dr. Cady with the Illinois Geological Survey and was shown to me by Dr. Harold E. Culver, I recognized it as a coal ball, took it into my laboratory, and cut it with a diamond saw. This was the first known coal ball found in North America and recognized as such.

In December 1929, Dr. David White showed me some concretions taken out of a coal seam in 1910 which undoubtedly can be called coal balls, but which were not recognized as such at the time. Also the fossiliferous structure from the Waverly shales of Kentucky, which E. C. Jeffry described in collaboration with D. H. Scott, are not coal balls, nor are the Lepidostrobus cones which were described by J. M. Coulter and W. J. G. Land in the Botanical Gazette, Vol. 51, 1911.

A great deal of additional coal ball material was collected at the O'Gara mine number 9. Numerous other deposits of coal balls were found in succeeding years in the strip mines of southern Illinois and western Indiana and in various shaft mines, especially in the mine of the Hegeler Zinc Company at Danville, Illinois.

This material is being studied by the author and various of his former students and several of his friends. Also quite a number of coal balls had been sent in the form of exchanges to various scientists in this country and abroad and the author's hope that an ever-increasing number of people would study the coal balls of America is gradually being gratified.

The general policy of the growing group of paleobotanists who work on America coal balls is to concentrate work on individual genera, with the result that the main genera are well-represented in a series

of papers which have appeared primarily in the Botanical Gazette, the Journal of Geology, the Transactions of the Illinois State Academy of Science, and the Mid-west Naturalist. A comprehensive study of the subject with numerous contributions by the author and by his collaborators in this field will appear in the near future as Monograph No. 2 of the Illinois State Geological Survey. It is an attempt to give the result of all previous investigations on coal balls from Illinois, Western Indiana, and Western Kentucky, and to add a number of new discoveries and studies. New material is constantly investigated and new facts are brought to light. Although there are convenient stopping points where a portion of the material may be brought to a conclusion, if we consider the enormous wealth of the available material, we can easily see that it will take a long number of years before we obtain full knowledge of the coal ball flora of Illinois, west Kentucky, and Indiana.

The size of the coal balls found in this field varies between that of a pea and that of a pumpkin. They are usually covered by a brittle and lustrous layer of coal and consist of a dark brown mass of calcium carbonate mixed with mangan and iron. Enclosed plant remains appear distinctly when the coal balls are examined in thin sections or with the help of the cellulous film method. They can be made visible to the naked eye with the help of chloric acid.

The distribution of the coal balls in a seam is sporadical. Sometimes they appear in large banded zones, sometimes irregularly in nests and are usually surrounded on all sides by coal.

The coal balls of Illinois, Indiana, and Kentucky seem to be restricted to a few horizons. These are coals 5, 6, and 7 in Illinois, coals 2, 5, and 6 in Indiana, and coals 9, 11, and 12 in Kentucky.

Even delicate plant organs are excellently preserved, as shown in the thin sections. For this reason, the coal balls must have been formed at the time when these organs were not yet decomposed and had not been compressed by overlying sediments. As the coal balls are found only in coal beds immediately overlain by marine sediments, the presence of marine water must have been necessary for their formation, and indeed the excellent preservation of delicate plant organs can be explained by the preserving quality of sea water. We must assume that the coal balls represent peat masses which petrified gradually, not suddenly, the plant organs being preserved in the concretions while the unprotected portions of peat were coalified.

Microscopic investigations of the coal ball has resulted in the identification of a number of Pennsylvanian plant species. These are:

Lycopodials:
- Lepidodendron selaginoides
- L. harcourti
- L. hickii
- Lepidocarpon lomaxi
- Lepidostrobus sp.
- Lepidodendron (spores)
- Sigillario (stem)
- Stigmaria ficoides

Articulatales:
- Arthropitys communis
- Calamosstachys oldhamia
- Sphenophyllum plurifoliatum

Filicales:
- Botryopteris forensis
- B. tridentata
- Botryopteris (petioles)
- Ankyriopteris (petioles)
- Etapteris lacattei
- Scolecopteris (sporangia)
- Sturiella (sporangia)
- Ptychocarpus
- Pteridotheca
- Psaronius (stem)

Pteridosperms:
- Medullosa (roots)
- Myeloxylon
- Lagenostoma lomaxi
- Trigonocarpus

Cordaitales:
- Cordaites sp.
- Cardiocarpon

The structures of the plant organs contained in coal balls allow us to draw conclusions upon the climatic conditions of Illinois during the Pennsylvanian period. The tree flora, consisting of Cordaites, Sigillaria, and Lepidodendron, had a more or less xerophytic appearance adapted to a dryer climate, whereas the ground flora, consisting of ferns, tree ferns, and pteridosperms, distinguished itself by hydrophilic characters or adaptation to a moist and hot climate. We find this combination of two opposed types in the modern tropical rain forests.

If we turn to the anatomy of the stems of Pennsylvanian plants we are struck by the almost complete absence of annual rings. This indicates a uniform climate without seasonal changes of temperature and moisture. The conclusion which we may draw from the structure of these plants upon the climate of that period in Illinois are, (1) it must have been warm but not necessarily tropical, (2) it must have been very moist, and (3) it must have been very uniform during the entire year.

The outstanding morphological results of American coal ball investigation are the addition of a few new species, especially ferns, and a better knowledge of the anatomic structure of paleozoic seeds. The largest seeds whose structure is preserved have been found in the Illinois and Indiana coal balls and some uncut material still promises to give us more information on seed structure. It is to be hoped that we may find in one of these beautifully preserved seeds an embryo. No paleozoic embryo has yet been found and it would be a monu-

mental discovery if we could produce the first paleozoic embryo. Another very interesting discovery was the correlation of some external leaf type with the inner structure and the sporangium structure of such leaves.

We are still at the beginning of our knowledge of anatomic structure in American paleozoic plants and it will be many years before knowledge of the subject will be fairly complete.