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Author(s): Homer G. Turner and H. R. Randall

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A PRELIMINARY REPORT ON THE MICROSCOPY OF ANTHRACITE COAL

HOMER G. TURNER AND H. R. RANDALL
Lehigh University

INTRODUCTION

In connection with petrographic studies during the winter of 1921-22, the authors became interested in the microscopic characteristics of anthracite coal. A review of the literature, however, revealed the fact that very little had been accomplished in this field. The reason appeared to be the inability to prepare specimens that would show their microscopic structures. An investigation was therefore begun which had as its purpose the treatment of anthracite so that its microscopic features could be easily discerned. The results of the method finally adopted are revealed in the accompanying photographs which show some of the most conspicuous structures observed. While no attempt is made at this time to classify definitely the organic forms, some tentative conclusions nevertheless seem warranted from the observations thus far made.

The coal used in connection with this investigation came from the Northern, Western Middle, and Southern Fields of the Pennsylvania anthracite region. Specimens from the Buck Mountain, Primrose, and Mammoth beds from each field were studied.

METHODS ADOPTED

After considerable experimentation with thin sections and various chemical reagents, with unsatisfactory results, the method herein described was developed. It consists briefly of obtaining a polished surface on the coal and etching with heat. Although pieces of various sizes and shapes are used, blocks of coal about two centimeters square take the most uniform polish and are large enough to be handled with ease. Larger pieces can be used provided that one has the equipment for polishing them, and such may be

desirable when one wishes to study some particular form which extends for some distance through the coal. The microscopic examination of a large surface, however, is very fatiguing. Furthermore, one may easily miss important forms or spend hours re-locating minute structures.

Small blocks are therefore cut from the coal by means of an ordinary hacksaw. Two surfaces, one parallel to the bedding and one at right angles to it, are ground to planes. All sharp edges are beveled slightly to prevent pieces from breaking off and scratching during the subsequent smoothing. These plane surfaces are then polished to remove saw marks and scratches.

Different ways of obtaining a polish were tried. The method which gave the quickest and most satisfactory results, however, consisted of first grinding on a revolving iron lap with medium-sized carborundum powder and water; next smoothing by hand on plate glass, using one-minute tripoli powder and water; and finally polishing by rubbing in one direction on a novaculite honestone with a paste of rouge and water. This paste should be fairly thick, for the best polish is obtained when the specimen is rubbed until the paste is almost dry and the coal sticks to the hone. A few brisk rubs on dry chamois with rouge, or on broadcloth with diamantine, remove all water stains and leave a very high gloss. Chromic oxide may be substituted for rouge with equally good results. On account of its green color it possesses the added advantage of not being confused with the reddish oxide of iron resulting from the oxidation of iron compounds in the etched coal.

The polished surface obtained in the above way, although not entirely free from scratches, suffices for good results. When the few remaining scratches interfere, they are removed by rubbing on a dry hone without rouge and finally polishing further with diamantine on a flat block covered with broadcloth. The hone, when used dry, has a tendency to become covered with a dark gumlike substance due to the adherence of fine particles of coal. This is overcome by rubbing down from time to time with a second hone, using a lather of soap and water. Not only is the gumlike coating removed but the surface of the hone is also kept flat by this treatment.

The polished specimen is finally placed in a drying oven over a Bunsen burner and heated from room temperature to about 220 degrees Centigrade, to remove moisture, and to obviate splitting of the surface due to sudden heating during the etching process. After this temperature has been maintained for about an hour, the specimen is removed with the forceps and the polished surface immediately brought to a red heat by means of the oxidizing blow-pipe flame. A differential oxidation is thus produced which reveals the structure in relief without destroying the polish to any great extent. The surface should appear only slightly foggy owing to an almost imperceptible film of ash.

The duller layers in the coal etch more rapidly than the bright ones, making it necessary at times to warm and etch repeatedly in order to bring out the greatest detail. Those varieties which show little lamination and are made up almost wholly of jetty bright coal must be etched in a little different way to overcome splitting of the surface. Instead of the oven a sand bath is used. The coal is immersed in clean dry sand with only the polished surface exposed. The bath is placed over a battery of four Bunsen burners and brought to a temperature of 300 degrees Centigrade. This temperature is maintained for about half an hour when the polished surface is heated in place to a bright red heat with a blast lamp, using a rather large blue flame which is played slowly back and forth over the surface. A little experience will demonstrate the advisability of re-etching to further define partially hidden structure.

Various attempts were also made to utilize oxygen in etching. A stream of cold oxygen was directed on the surface of a specimen heated to about 400° Centigrade, but only served to keep the surface cool and prevent etching. Warm oxygen used in the same way gave no better results. Oxygen at very high temperatures was not used in this way. Etching is produced, however, by heating polished specimens in an atmosphere of hot oxygen under slight pressure. In the latter case the coal is placed in a piece of glass combustion tubing about two feet long. Oxygen is passed through water in a wash bottle and into the combustion tube through a rubber stopper

in the upper end. In the lower end is placed a two-hole rubber stopper through which a thermometer is inserted. The temperature is raised to 250° Centigrade by heating the tube with a Bunsen burner just beyond the coal, between it and the intake. The action is continued until the polish begins to grow dim. Great care must be exercised to prevent the surface of the coal from coking. The forms revealed by this method of treatment are not as sharply defined as those produced by direct heating and since it requires more time, care, and apparatus, it is not recommended where direct heating can be used. The only advantage is that the surface remains flat and therefore shows some structures in coal which might otherwise be largely reduced to fragments by direct heating.

The etched coal is finally studied with the metallographic microscope, using vertical illumination from a carbon arc. A good working objective is one of medium power giving a magnification of about 250 diameters. A clean-cut image can be obtained up to a magnification of 1,000 diameters. In all cases the eye can discern finer details than are shown in the photographs.

The method as outlined, except for a modification of the etching process, has been successfully applied to bituminous coal and cannel coal. The polished cannel coal was held for a few moments in the oxidizing Bunsen flame without being previously heated in the oven. Good results can probably be obtained with carbonaceous shale and other materials of similar nature.

GENERAL RESULTS

A preliminary examination of the specimens of anthracite from the different fields shows that all varieties are composed of laminae of different luster, texture, and thickness. Brilliant jet black layers alternate with glossy black or gray bands in which are imbedded thin sheets of dull material resembling charcoal. The brilliant black layers vary in thickness from a few microns to many centimeters. The glossy gray bands are thicker than the jet black ones although, on close inspection, they are shown to contain many thin sheets of the brilliant black coal and thin sheets of dull material. The brilliant layers are more compact than the duller ones and



FIG. 1.—($\times 170$) crosswise to the bedding, from Pennsylvania anthracite. Shows spore exines. The markings on the spores are probably lines of dehiscence. This group of spore exines was found in the duller layers.



FIG. 2.—Section ($\times 170$) crosswise to the bedding, from Pennsylvania anthracite. Shows large, wrinkled spore exines found in the duller layers.

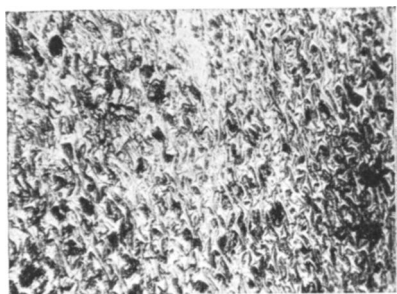


FIG. 3.—Section ($\times 125$) crosswise to the bedding, from Pennsylvania anthracite, showing crushed and warped cells, observed in a zone surrounding a knot of almost structureless charcoal.

possess a more perfect conchoidal fracture. Where they are thick, the broken surface often shows rounded or oval fracture forms. Although the above distinctions hold true for most of the anthracite, some varieties appear at first glance to be composed wholly of the brilliant coal, revealing their various laminae only on careful examination.

Mineral charcoal was quite abundant in almost all the coal examined. Cleaving coal parallel to the bedding exposed charcoal-covered surfaces in every specimen which showed distinct lamination. On the other hand the varieties which were poorly laminated and almost uniform in luster contained very little charcoal.

In addition to the thin sheets of charcoal so commonly found in the bedding planes, one finds occasional large fragments which cross several of the horizontal layers. These large pieces of charcoal are of particular interest because of the fact that they show in most cases perfect cells almost entirely devoid of filling. The cell walls are thicker than those of the original wood and appear to be lined with a bright jet black layer which permits good photographs by reflected light. All

the large lumps of charcoal examined have the structure of conifer wood. Rings of growth, medullary rays, and bordered pits are distinctly shown.

Ordinary commercial charcoal differs from the mineral charcoal in no essential detail when examined with the microscope. This condition seems to argue against regarding the charcoal as the product of forest fires, for it seems probable that the cells would either have been filled with the putrefaction product solutions during subsequent immersion in the bog, or crushed under the pressure of overlying material.

The brilliant layers of the coals examined show, under the microscope, either no structure or a preponderance of wood fiber and wood cells. In the glossy duller layers are found spore exines, former resinous materials, apparent vascular bundles, cuticles, wood fiber, cell laminae, and other forms not yet identified. The thin dull black layers usually show wood fiber and wood cells either well preserved or crushed to an almost structureless mass. Further microscopic details can be most advantageously described in the legends of the microphotography.

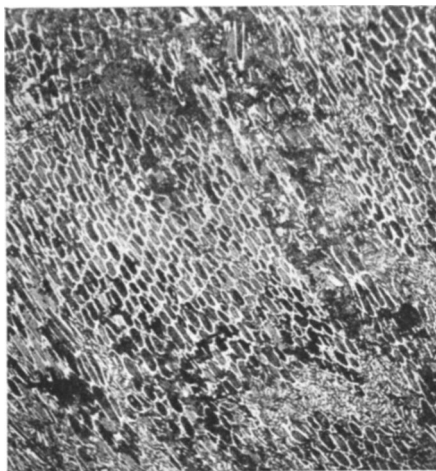


FIG. 4.—Section ($\times 50$) parallel to the bedding of the Forge split of the Mammoth bed from Nanticoke, Pennsylvania. A section of wood showing original cell laminae. The remarkable preservation of these cells may be due in part to the silicious filling shown by the gray areas within the cell walls, although some of the cells are filled with black, lusterless carbonaceous material.

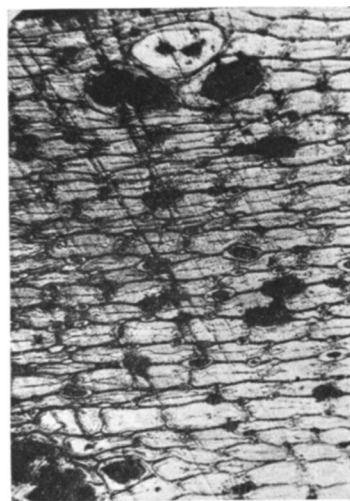


FIG. 5.—Section ($\times 126$) crosswise to the bedding and oblique to an apparent stem in anthracite from Pennsylvania. This section is of particular interest because it is in the brilliant jetty coal and not in the duller layers where such forms are usually found.

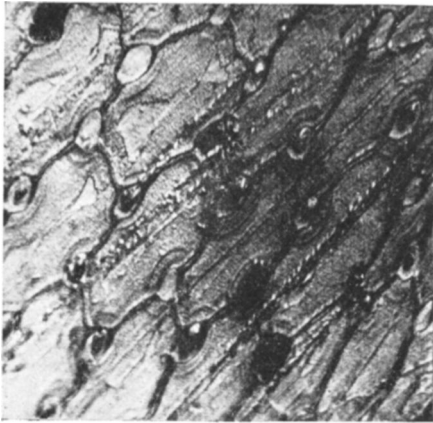


FIG. 6.—A part of Fig. 5 ($\times 500$) showing the great detail revealed by the method of treatment described in this paper. Note the delicate dumbbell-shaped membrane with the cells and the elliptical markings surrounding the small knots along the cells walls.



FIG. 7.—Cross section ($\times 83$) of a charcoal stem of coniferous wood found in anthracite from coal measures around Minersville, Pennsylvania. Note the well-defined medullary rays and annual rings. The rather thick cell walls are composed almost entirely of bright, jetty material making possible this photograph by reflected light. The black spots within the cell walls are holes.

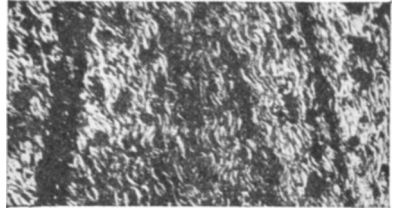


FIG. 8.—Section ($\times 118$) crosswise to the bedding of coal from the Primrose bed, William Penn colliery. This section through the duller layers shows wood fiber much contorted.

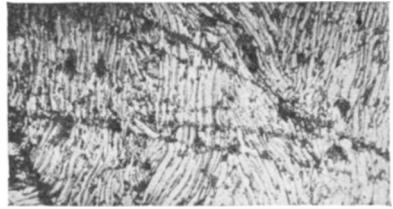


FIG. 9.—Section ($\times 118$) crosswise to the bedding of the Primrose bed showing less flattened wood fiber.

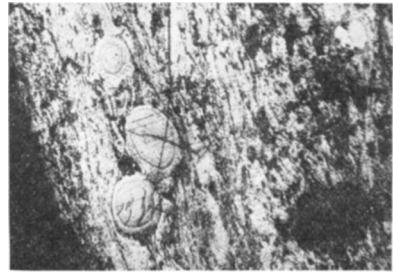


FIG. 10.—Section ($\times 124$) crosswise to the bedding, from Pennsylvania Anthracite. This section through the duller layers shows a somewhat macerated wood fragment containing round bodies which are probably vessels formerly filled with resin or gum.

Almost all the specimens studied show remarkably smooth and regular vertical joints at right angles to the bedding planes. Some of the less distinctly laminated varieties possess, in addition to the regular vertical joints, bright slickensided surfaces at low angles to the bedding. Those varieties which show distinct lamination can be cleaved easily parallel to the bedding while the more massive types possess almost no cleavage.

Aside from the more splendid luster, anthracite is shown, from the above description, to possess all the essential megascopic characteristics of bituminous coal; in addition it shows the same types of organisms under the microscope; and further, these organisms are apparently no more distorted than those of the bituminous coal.

The authors expect to make a detailed study of some of the best-known anthracite seams of Pennsylvania. It is hoped that this study will lead to a better knowledge of the factors involved in the origin of anthracite. From the observations thus far made, it seems highly probable, also, that the various beds can be correlated through the identification of dominant plant types and through other microscopic characteristics, although this will obviously involve a great deal of study and observation both in the laboratory and in the field.

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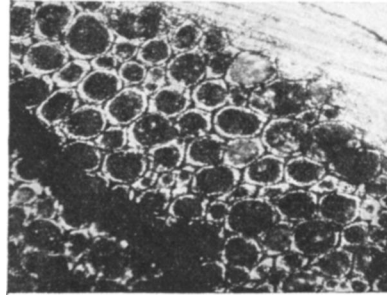


FIG. 11.—Section ($\times 125$) crosswise to the bedding of coal representing the Forge split of the Mammoth from Nanticoke, Pennsylvania. Shows cells of xylem or phloem of a vascular bundle. This is a section through a dull knot. Some of the cells are partly filled with small grains of pyrite which do not show in the photograph. The black centers are dull carbonaceous material.