HEAVY MINERALS IN THE UNDERCLAY OF THE ILLINOIS NO. 2 COAL

WALTER E. PARHAM
Illinois State Geological Survey, Urbana

Introduction

This study was made to determine what heavy minerals were present in the underclay of the Illinois No. 2 Coal. This underclay is of Pennsylvanian age and in Illinois is found in the Liverpool Cyclothem of the Carbondale Group. Illinois No. 2 Coal has been correlated with Indiana IIIa Coal, Kentucky 8a Coal, and Missouri Croweburg Coal.

The subjacent sediment of this underclay varies in lithology throughout the Eastern Interior Basin, but the underclay and its coal are persistent units. At some locations the underclay apparently is transitional into the subjacent sediment, while in others the break between the two sediments is sharp. The thickness of the underclay ranges from 5 inches to 7 feet or more; the average thickness for the 68 localities is approximately 3 feet.

The underclay is typically light gray with a thin, darker, plastic zone a few inches thick at the top. *Stigmaria* are commonly present. Small slickensides can be found throughout, some as much as an inch or two in length. Limonite staining is common along small cracks at many of the clay outcrops.

Review of the Literature

Allen (1932: 565-570) in his study of the mineralogy of the Pennsylvanian underclays of Illinois briefly mentioned four heavy minerals he had identified — muscovite, biotite, epidote, and hornblende. He noted that both the epidote and hornblende were altering to clay minerals from the outside inward and that the percentage of biotite and heavy minerals was more closely related to texture than to the depth below the coal. He believed that this percentage-texture relationship was controlled by conditions of deposition rather than of weathering.

Grim and Allen (1938: 1496, 1502) in their work on the petrology of the Pennsylvanian underclays of Illinois found that heavy minerals constitute a very small part of the underclays. They recognized muscovite, biotite, pyrite, zircon, tourmaline, rutile, garnet, apatite, barite, glauconite (?), epidote, hornblende, and chloritic mica, the last probably derived from the decomposition of biotite. They found that some grains of epidote and hornblende had been altered along their edges and along cracks, but that others showed no alteration.

Spencer (1955) made a petrographic study of the underclay of Illinois No. 6 coal. The principal heavy minerals found were zircon, tourmaline, leucoxene, and rutile; muscovite, chlorite, pyrite, hornblende, and garnet also were found in smaller amounts. This stable heavy-mineral assemblage suggested to Spencer that the materials composing the underclay were derived from pre-existing sediments. Both well-rounded and euhedral tourmaline crystals were found in the underclay, and Spencer suggested that the euhedral variety had formed authigenically. Zoned zircons were present, as were well-rounded and euhedral varieties. Rutile varied from well-formed elbow twins to well-rounded grains. The twinned variety showed no signs of wear and was thought to be authigenic. Pyrite was more prevalent in the upper than in the lower portions of the underclay sections.

Wahl (1957), who made a petrographic study of the underclay of Illinois No. 5 Coal, found that pyrite, tourmaline, and zircon were the most common heavy minerals present but that the suite included garnet, leucoxene, hypersthene, chlorite, and muscovite. All the tourmaline crystals he observed were elongate and euhedral, and he too believed that the tourmaline had formed authigenically. The zircon occurred both as elongate, doubly terminated crystals and as well-rounded grains. The garnet showed little rounding.

Sampling Procedure

In the course of my study, 87 samples of the underclay of Illinois No. 2 Coal were collected from outcrops and diamond-drill cores in Illinois, Indiana, Kentucky, and Missouri. The samples represent 68 locations throughout the Eastern Interior Basin (Fig. 1). The sampled area has a maximum north-south distance of 360 miles and a maximum east-west distance of 240 miles.

Each underclay outcrop or core was examined to determine whether there were any apparent lithological changes in the section. If changes were noted, the various lithologies were sampled separately. Throughout the remainder of the study, these samples were treated separately in all analytical procedures. Channel samples were obtained from all outcrops, and chips were taken at about one-inch intervals from the diamond-drill cores.

Method of Analysis

Approximately 100 grams of each sample were allowed to disaggregate in water for at least 4 days. The sample was then mixed by an electric handmixer and allowed to settle for 20 minutes. At the end of this time, the material in suspension was decanted and the sample was remixed. This procedure was continued until the sample appeared to be free from suspended material at the end of a 20-minute period. The remainder of the sample was then washed into a 500-micron sieve and the minus 500-micron fraction was dried. About 7 grams of this fraction was placed in a 125-ml. separatory funnel with approximately 25 ml. of the heavy liquid bromoform (sp. grav. 2.85). The sample was stirred thoroughly in the funnel and allowed to settle for 24 hours. Occasionally during the 24-hour period the separatory funnels were agitated slightly to release any adhering particles from the sides of the funnel. After 24 hours the heavy minerals were removed, washed with acetone, and dried on filter paper.

The heavy minerals were mounted on slides that had been covered with a thin coating of balsam thinned with xylol. The coating was thin enough

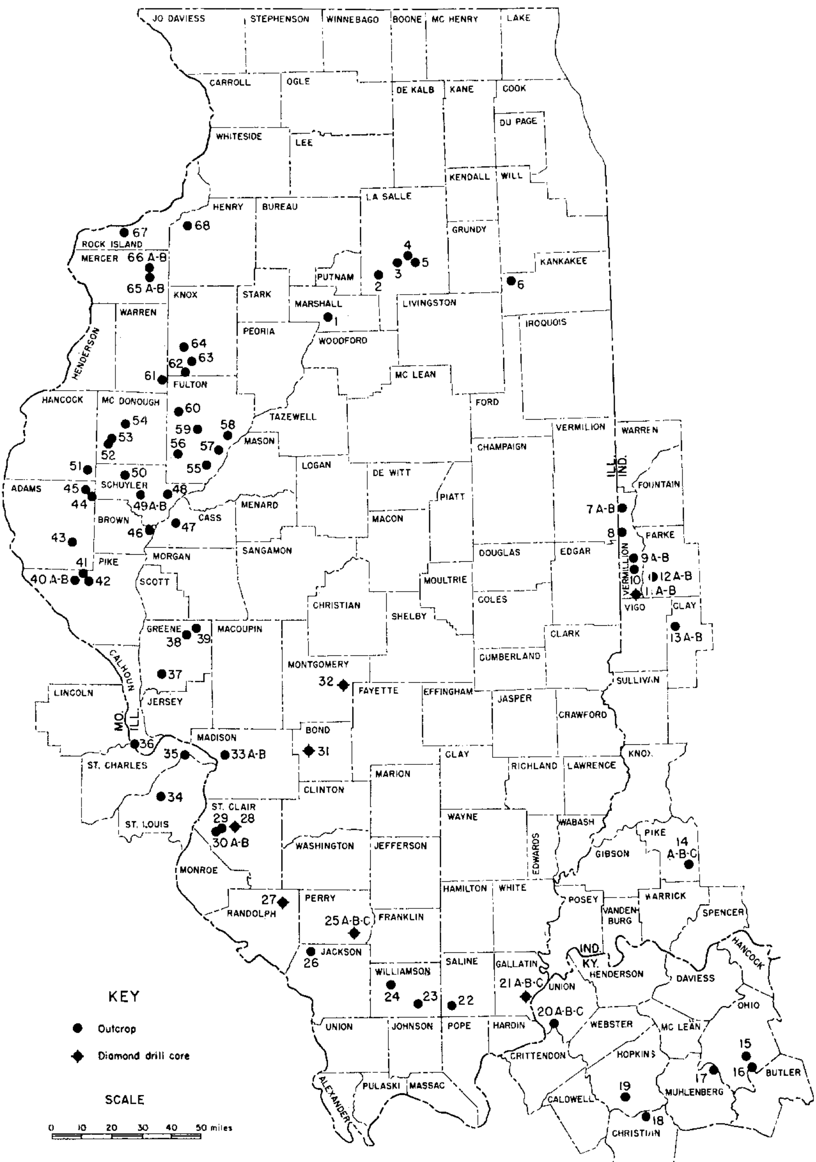

FIG. 1.—Locations of samples of the underclay of the Illinois No. 2 Coal.

so that when the heavy minerals were spread over the soft balsam their surfaces were not completely covered, thus making possible the use of oils in the determination of the mineral indices. The slides were then allowed to dry before further use.

Discussion

The minus 500-micron fraction of heavy minerals of each sample was mounted as described and studied with a petrographic microscope.

Muscovite is present in 92% of the samples. Its size and outline generally are irregular, although in a few instances a faint hexagonal outline can be distinguished. Some of the flakes appear to be very thick. All of the muscovite observed was colorless.

Pyrite is present in 73% of the samples. It appears in six forms—striated cubes, octahedrons, pyritohedrons, spherulites, irregular masses, and tiny rootlets and plant structures. While the heavy minerals were being separated, a record was kept of the relative amount of pyrite in each sample; in most cases there is more pyrite in the finer grained underclay than in the coarser underclay. The well developed crystal forms of the pyrite show it to be authigenic. (Authigenic minerals are those that have formed independently in sedimentary rocks and are not to be confused with overgrowths that have formed on pre-existing minerals). The pyrite owes its origin to a reduction of iron salts by organic compounds. In many of the more weathered outcrops, the pyrite has been altered to limonite.

Zircon is present in 72% of the samples. Most of the crystals are simple combinations of prism and pyramid; all are colorless, and zoning is common in many crystals. Doubly terminated zircons are abundant and average about 7 to 10 microns in length. These crystals could be either authigenic or detrital as their small size and extreme hardness of 7.5 would have allowed them to be transported a considerable distance without showing evidence of wear. Well-rounded zircons are found in the presence of euhedral zircons. If some of the zircons have formed authigenically, the presence of overgrowths on other zircons would be expected. No overgrowths were noted. As zircon is an accessory mineral in almost all classes of igneous rocks, the well rounded examples may have been derived from reworked pre-existing sediments.

Tourmaline is present in 67% of the samples. It appears as irregular fragments, well-rounded grains, euhedral crystals, and as overgrowths on other well-worn or fragmental tourmaline grains. In many instances, the euhedral crystals are hemimorphic, *i.e.,* they display different forms at opposite ends of the crystal (Fig. 2). Varieties of tourmaline found in this underclay are brown, tan, olive-drab, pink, or colorless.

Most of the irregular fragments probably were derived from an iron-rich source as they are darker and have deeper pleochroic colors than do the euhedral varieties. In general, the euhedral crystals are pink and do not display strong pleochroic colors. The pleochroic color of the overgrowths generally is lighter than that of the covered older grain.

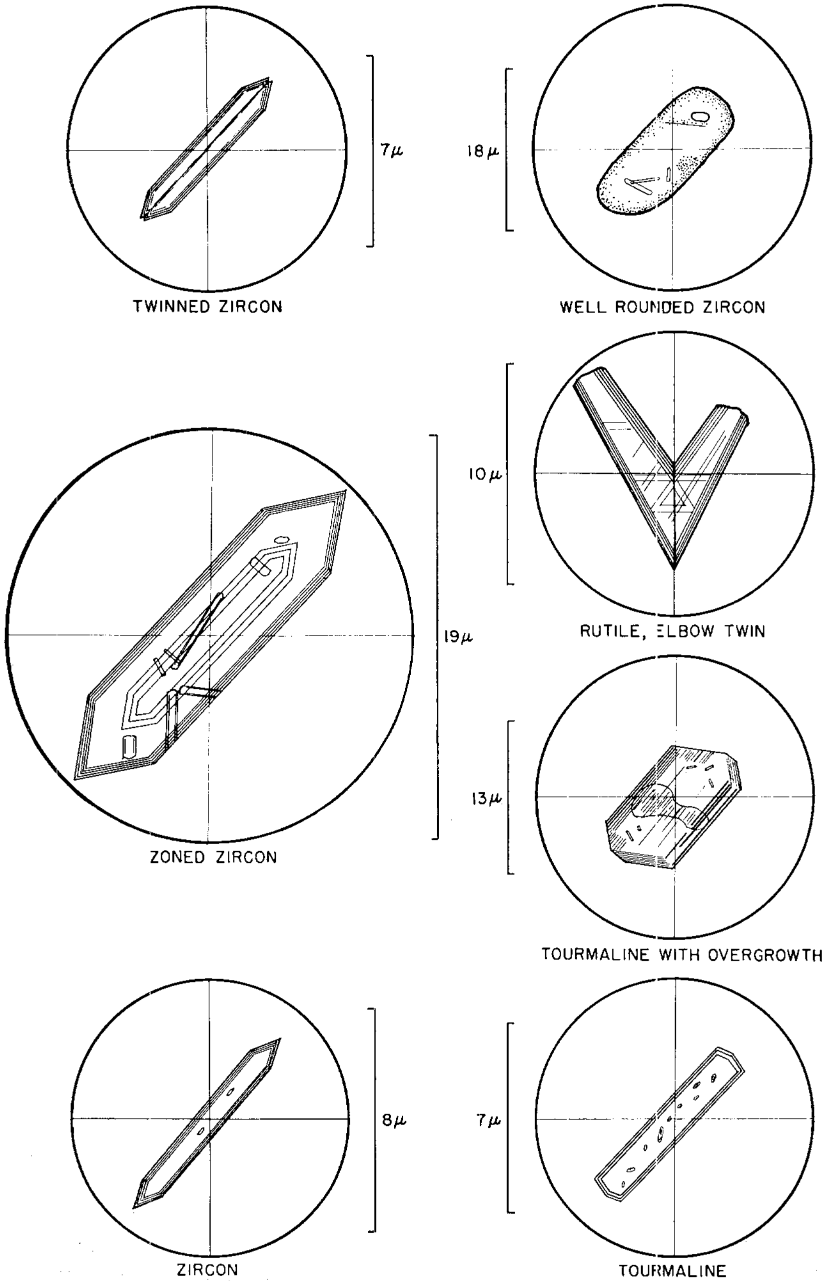

FIG. 2.—Common heavy minerals of the underclay of the Illinois No. 2 Coal.

Spencer (1955) thought that the euhedral varieties of tourmaline had formed authigenically. He stated that the material necessary for the formation of tourmaline, which is a complex boron aluminum silicate, could easily be obtained from the underclay. The boron would be released from decaying plant material, and the aluminum and silicon derived from many of the silicate minerals of the underclay itself. On the other hand, tourmaline is a mineral common in metamorphic and acid dike rocks and the euhedral tourmaline as well as the well rounded and fragmental pieces could have been derived from either source and, like euhedral zircon, may have undergone transportation without showing wear because of its hardness (7 to 7.5) and extremely small size (7 to 8 microns).

Krynine (1946) listed the "resistance coefficient to abrasion" of various minerals, compared with tourmaline, as follows: tourmaline, 850-900; chalcedony, 510; quartz, 245; and orthoclase, 150. It is apparent that tourmaline can undergo considerable transportation and abrasion and yet show very little wear in comparison with these other resistant materials. The well-developed crystal form of those grains possessing overgrowths tends to support Spencer (1955) in his belief that some of the tourmaline overgrowths formed in place in the underclay whereas other tourmaline was transported from other areas. The rounded forms apparently have undergone many cycles of erosion.

Limonite is present in 62% of the samples and is found as coatings on grains and as irregular, resinous, rounded masses. It is probably produced by the weathering of pyrite. In many instances it coats and stains other minerals, sometimes completely masking them. Only a few heavy mineral samples were treated with acid to remove the iron present.

Rutile is present in 43% of the samples. Generally, it appears as irregular, broken fragments, or as elbow twins. It is rusty red in color and commonly occurs in igneous and metamorphic rocks. Almost all grains or crystals observed show some signs of wear.

Ilmenite is present in 10% of the samples. It appears as black, irregular, pitted grains.

Leucoxene is present in a few samples. These samples were coated with limonite and had to be treated with hydrochloric acid to remove the iron. The leucoxene appears as rounded or oblong grains, dull, grayish-white in color. It may have been formed as a decomposition product of ilmenite.

Chlorite was recognized in one sample by its characteristic Berlin-blue interference color. The crystals were small and irregular in shape.

Much of the unidentifiable mineral present resembled mica flakes of a pale greenish-yellow color and may be the product of a much-weathered biotite. Optical properties could not be determined on these flakes.

Summary and Conclusions

Pettijohn (1957: 516) listed the persistent heavy minerals frequently found in the late Paleozoic sediments as rutile, zircon, tourmaline, garnet, biotite, apatite, ilmenite, magnetite, staurolite, and monazite. My study, like those of Grim and Allen (1938), Spencer (1955), and Wahl (1957), shows very similar assemblages with only slight variations.

The heavy minerals commonly present in this underclay are muscovite, pyrite, zircon, tourmaline, and rutile, an assemblage of very stable minerals. Some of the well-rounded tourmaline grains show that they must have undergone many cycles of erosion, whereas others show the sharp, euhedral form. The euhedral crystals may be authigenic or may have been transported without showing signs of wear. The extremely small size of the crystals and their great hardness could have protected them from wear during transportation. However, some of the euhedral tourmaline crystals are actually overgrowths on old, well-worn tourmaline grains. Still other euhedral tourmaline grains are definitely not overgrowths, and their euhedral form strongly indicates their authigenic origin. Their optical properties suggest a chemical composition different from that of the rounded and fragmental tourmaline.

A greater percentage of pyrite is found in the finer than in the coarser grained sections. It is authigenic and is found in the form of rootlets, plant structures, and euhedral crystals. This indicates that reducing conditions prevailed during underclay deposition. The circulation was probably poorer in the finer-grained sections, resulting in the higher content of pyrite in these sections today.

The stable heavy minerals and the presence of well worn and fragmental minerals suggest that the underclay was in part a transported sediment. Some of the heavy minerals have undergone many cycles of transportation and deposition.

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