Geology and Coal Reserves of the Kermit and Varney Area, Kentucky

GEOLOGICAL SURVEY PROFESSIONAL PAPER 507

Prepared in cooperation with the Kentucky Geological Survey, University of Kentucky

Huddle and Englund   GEOLOGY AND COAL RESERVES OF THE KERMIT AND VARNEY AREA, KENTUCKY   Geological Survey Professional Paper 507

Geology and Coal Reserves of the Kermit and Varney Area, Kentucky

By JOHN W. HUDDLE *and* KENNETH J. ENGLUND

GEOLOGICAL SURVEY PROFESSIONAL PAPER 507

Prepared in cooperation with the Kentucky Geological Survey, University of Kentucky

A study of the principal coal beds and Pennsylvanian stratigraphy in parts of Martin and Pike Counties, Kentucky.

UNITED STATES GOVERNMENT PRINTING OFFICE, WASHINGTON : 1966

UNITED STATES DEPARTMENT OF THE INTERIOR

STEWART L. UDALL, *Secretary*

GEOLOGICAL SURVEY

William T. Pecora, *Director*

Library of Congress catalog-card No. GS 65-328

For sale by the Superintendent of Documents, U.S. Government Printing Office
Washington, D.C. 20402

CONTENTS

ILLUSTRATIONS

[Plates in pocket]

TABLES

GEOLOGY AND COAL RESERVES OF THE KERMIT AND VARNEY AREA, KENTUCKY

By JOHN W. HUDDLE and KENNETH J. ENGLUND

ABSTRACT

The Kermit and Varney areas include about 109 square miles of coal-bearing rocks of Pennsylvanian age in Pike and Martin Counties, Ky. These areas were mapped cooperatively with the Kentucky Geological Survey, because preliminary reconnaissance coal-reserve studies indicated large reserves of undeveloped bituminous coal. Geologic and structure maps for each quadrangle were made by field and photogeologic mapping. Seven stratigraphic sections prepared from core and sample descriptions, measured sections, and drillers' logs show the lithology and persistence of rock units.

Pennsylvanian rocks of the Kermit-Varney area include the Lee Formation, between 350 and 450 feet thick, and the overlying Breathitt Formation, about 1,800 feet thick. The top of the Breathitt Formation has been removed by erosion, and most of the formation below the Alma coal is below stream level. In well samples and nearby areas, the Lee Formation is composed mainly of conglomeratic sandstone consisting largely of quartz grains and pebbles and contains very little matrix. Drillers' logs and samples show that the lower part of the Breathitt Formation contains about 70 percent shale and 30 percent sandstone. In surface sections and cores the middle part of the Breathitt Formation contains 50–60 percent sandstone, and the upper part, more than 60 percent sandstone. Sandstone in the Breathitt Formation is generally composed of 60–70 percent quartz grains and 5–12 percent matrix. Cementing materials include siderite, calcite, and quartz in the form of overgrowths. The matrix consists of quartz, clay, and chlorite; it is difficult to distinguish matrix from mashed fragments of reworked unconsolidated Pennsylvanian sediments. Fragments of reworked incompletely consolidated Pennsylvanian rock in slightly younger rock are characteristic of the Breathitt Formation. They include tiny fragments in the matrix, peat mats, shale and siltstone pebbles, siderite grains. and ironstone nodules. Many of these fragments are for the most part mashed around other grains, indicating they were soft and easily deformed when deposited.

The Lee and Breathitt Formations were deposited in a near-shore environment under both marine and continental conditions. Coal, seat rock, and some sandstone and shale units were mainly fresh-water continental deposits. Other sandstone, siltstone, and shale units were deposited in marine or brackish water. In particular, the shale, siltstone, or sandstone which contain ironstone and calcareous nodules and overlie coal beds are likely to be marine or brackish-water deposits.

Crossbedding is the most common sedimentary structure, and slump structures are common. Abundant molds, casts, and coaly compression films of the cortex of tree trunks and branches representing ancient log jams are common in the lower part of sandstone deposits. Log jams, standing stumps and trunks of trees, and the reworking of previously deposited sediments all suggest rapid deposition locally. The massive sandstone units probably represent channel-fill deposits, distributary channel deposits, and bars on a deltaic alluvial plain.

Invertebrate fossils are present locally in the roof rock of most coal beds in the Kermit-Varney area. Brachiopods, including lingulas, spirifers, and productids, are the most common fossils. Persistent marine zones in the area include the Campbell Creek Limestone of White (1885), and Elkins Fork Shale of Morse (1931), the Kendrick Shale of Jillson (1919), the marine zone over the Whitesburg coal, the marine zone over the Fire Clay rider coal bed, the Magoffin Beds of Morse (1931), and the marine zone over the Broas coal bed. These zones are used as key beds in the correlation of coal beds in the area.

Major geologic structures in the area include the Paintville-Warfield anticline and associated faults, the Eastern Kentucky syncline in the Kermit quadrangle, and the Brushy Fork syncline in the Varney quadrangle.

Twelve coal beds contain reserves of high-volatile bituminous coal in beds more than 14 inches in thickness in the Kermit and Varney quadrangles. Reserves in each bed are reported by thickness and reliability categories for each quadrangle, and for the Pike and Martin County parts of the Varney quadrangle. The Kermit quadrangle is estimated to contain original reserves of about 489 million short tons of coal in beds more than 14 inches thick; the Varney is estimated to contain about 861 million tons. Remaining reserves of coal in beds thicker than 28 inches amount to about 480 million tons in the 2 quadrangles. Gas, oil, and sand are the other mineral resources of the area.

INTRODUCTION

LOCATION AND AREA

The greater part of Kermit and Varney quadrangles, in Martin and Pike Counties, Ky., is in the Eastern Kentucky coal field (fig. 1). The part of Kermit quadrangle mapped in this study lies wholly in Martin County, Ky., and includes about 50 square miles. The part of the quadrangle east of Tug Fork of the Big Sandy River in West Virginia has an area of about 8½ square miles and was not mapped. The Varney quadrangle straddles the Martin-Pike County line along the ridge between the Tug Fork and Levisa Fork drainages. It includes about 59 square miles. Few trails cross the divide, and there were no roads across it in the Varney quadrangle in 1960. The only towns in the Kentucky part of the Kermit quadrangle are Warfield, Beauty, and Lovely. Kermit, W. Va., across the river from Warfield, is about 21 miles northwest of Williamson, W. Va. In 1960 there were several

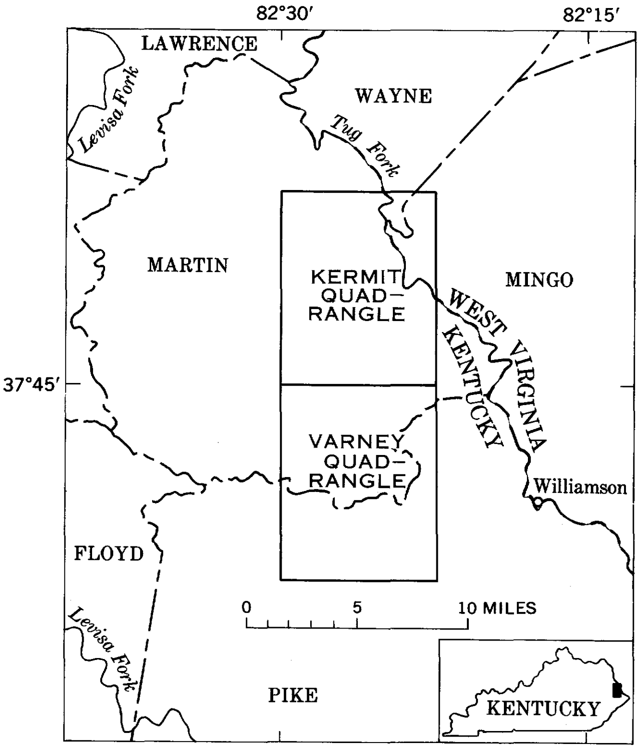

FIGURE 1.—Index map showing the location of the Kermit and Varney quadrangles, Kentucky.

rural post offices in the Varney quadrangle but no towns. Inez, the county seat of Martin County, is about 3 miles west of the Kermit quadrangle. State Route 40 crosses the northern part of the Kermit quadrangle and is the only through road in either quadrangle. All other State-maintained roads follow the streams, but most of these roads end before crossing the drainage divides.

Access to the southern part of the Varney quadrangle is by paved road over Rich Gap from U.S. Route 119 into the left fork of Brushy Fork of Johns Creek. U.S. Highway 52 in West Virginia is the only through road along Tug Fork. A spur line of the Norfolk and Western Railway crosses Tug Fork at Warfield from the main line along Tug Fork in West Virginia. Lumber and coal are shipped from Warfield.

The main route into the southern part of the Kermit and northern part of the Varney quadrangle is along Wolf Creek and its main tributaries, Emily Creek, Pigeonroost Fork, and Meathouse Creek.

PURPOSE AND SCOPE OF INVESTIGATION

The Kermit and Varney areas were mapped as a cooperative project of the Kentucky Geological Survey and U.S. Geological Survey. The project was undertaken after a general study of the Eastern Kentucky coal field (Huddle and others, 1963) showed that the area in northern Pike and southern Martin Counties probably contained more undeveloped coal than any other area of equal size in eastern Kentucky. As a part of the fieldwork necessary to prepare an estimate of the coal reserves of the Eastern Kentucky coal field (Huddle and others, 1963), E. J. Lyons did reconnaissance mapping in the Kermit and Varney areas. He measured and correlated the coal beds at nearly 200 localities, mainly in the Kermit area, in April 1955. Huddle and Lyons examined and described the cores from holes drilled for the Big Sandy Co. in the Varney and Meta areas in 1957. Detailed mapping in the Varney area was done during October and November 1958 by J. W. Huddle, assisted by A. C. Meisinger, and during October and November 1959 by Huddle. Harley Barnes started the mapping in the Kermit area in the fall of 1959, and this mapping was finished by Huddle in the spring of 1960. As the fieldwork was being completed an extensive core-drilling program was started by several coal companies; fieldwork was continued intermittently until the drilling program was completed and all the cores examined. Cores lying on the ground at the drilling sites were examined by J. W. Huddle, K. J. Englund, D. C. Alvord, W. F. Outerbridge, J. M. Schopf, and T. Schopf between April and December 1960.

A few samples of thin coals were taken for analysis, and plant-bearing cores were collected for study by J. M. Schopf. Coal reserves were calculated by Flora K. Walker. Additional altitudes and coal thicknesses measured in adjoining quadrangles were supplied by W. F. Outerbridge, C. L. Rice, and D. E. Wolcott. Mary G. Sheldon prepared the core descriptions for publication. Several of the illustrations were prepared by E. R. Landis.

Fieldwork in the Kermit and Varney quadrangles consisted of measuring and describing coal outcrops at mines, roadcuts, natural exposures, and cores at more than 500 localities and of tracing benches formed by coal beds and shale. Stratigraphic sections were described from cores and outcrops in the Kermit, Varney, and nearby quadrangles. Most of the altitudes were determined by aneroid barometer, but some were determined by hand level, photogrammetrically on a Kelsh plotter, and from a few transit traverses run by land-holding corporations.

In the office, records of more than 400 oil and gas wells were studied for data on the character of the sandstone units in the Breathitt and Lee Formations and the continuity of coal beds. Samples from eight wells were studied; thin sections of the Breathitt Formation from a measured section and drill cores were studied by R. A. Sheppard, C. S. Ross, J. W. Hosterman, and J. W. Huddle. J. M. Schopf examined the cores for plant fossils, especially spores, in an effort to correlate the coals in the upper part of the Breathitt Formation.

Photogrammetric methods were tried in the Kermit-Varney area in an effort to increase the speed and accuracy of geologic mapping of the Pennsylvanian rocks. Aerial photographs and ordinary stereoscopes proved unsatisfactory, because a bench could not be consistently traced from a gap around a point and back to the corresponding bench on the opposite side of the gap. Numerous benches 30–50 feet apart made tracing uncertain where good vertical control was lacking. A Multiplex plotter was tried in the hope that the floating dot would provide vertical control to guide bench tracing, but the results were inconclusive because of the low magnification and high K-factor, which did not permit altitude determinations closer than ±10 feet. By using a Kelsh plotter which has larger magnification and a smaller K-factor than the Multiplex plotter, it was possible to trace benches, and to check correlations, field traverses, and many barometer altitudes with an accuracy of ±5 feet. Whenever benches are distinct, outcrop position can be plotted more accurately with the Kelsh plotter than can be shown on the 1:24,000-scale base maps. In the heavily wooded areas where benches are indistinct, the floating dot aids in tracing benches and makes it possible to recognize benches at the same altitude on opposite sides of the ridge or valley. Use of the Kelsh plotter did not speed up mapping; however, used in conjunction with field mapping it can, by doubling or tripling the amount of specific observation, achieve greater accuracy than can be plotted on the 1:24,000-scale topographic maps. If there is time and there are adequate aerial photographs and if Kelsh plotters are easily available, use of the plotters aids the geologic mapping of the Pennsylvanian rocks of eastern Kentucky and improves accuracy. The Broas and Peach Orchard coal beds were mapped primarily by Kelsh plotter.

ACKNOWLEDGMENTS

The cooperation of the mine owners and residents of the Varney and Kermit quadrangles greatly aided the fieldwork for this report. We wish to thank the many people who gave permission to examine outcrops and prospect openings on their properties and especially those who served as guides to particular outcrops. We are indebted to the following companies for logs of diamond-drill holes, prospect and mine information, and for permission to publish many of these data: Big Sandy Co., Burning Springs Collieries, Cline & Chambers Coal Co., Federal Gas Oil & Coal Co., Island Creek Coal Co., Pocahontas Land Corp., Princess Coals, Inc., South-East Coal Co., Warfield Mining Co., and Webb Coal & Mining Co. We benefited greatly from our discussions of coal-bed distribution and correlation with O. S. Batten, Dennis K. Scott, Douglas Crickmer, C. L. Helmick, Ken Fairchild, Gordon Little, and Rufus Reed. We thank Mr. Douglas Crickmer, Pocahontas Land Corp.; Mr. David L. Francis, Princess Coals, Inc.; and Mr. J. L. Hamilton, Island Creek Coal Co.; for the privilege of examining the cores of diamond-drill holes as drilling progressed. This information contributed greatly to the value of this report. We appreciate the assistance given us by Mr. W. W. Hagan and Mr. Preston McGrain, of the Kentucky Geological Survey. H. R. Wanless generously loaned his field notes for the Beauty and Bent Mountain stratigraphic sections that he measured in 1937.

TOPOGRAPHY AND GEOMORPHOLOGY

The Kermit-Varney area lies between Tug and Levisa Forks of the Big Sandy River in the highly dissected Kanawha section of the Appalachian Plateaus. The lowest point, about 580 feet above sea level, is where the north edge of the Kermit quadrangle crosses Tug Fork. Here the hill tops are slightly higher than 1,200 feet, but in the southern part of the area the hills rise above 1,760 feet. The height of the hills above the valley floors ranges from about 400 feet in the northern half of the Kermit quadrangle to about 800 feet in the southern half of the Varney quadrangle.

Principal streams of the area are tributaries of the Tug Fork, these include Elk, Wolf, and Big Creeks and Blacklog Fork. Brushy Fork of Johns Creek drains the southern part of Varney quadrangle. Most of the stream valleys are narrow. Along Tug Fork an alluvial terrace about 40 feet above normal creek level has a maximum width of about 1,500 feet. Only a small area is flooded annually, and the towns of Warfield, Lovely, and Kermit, built on the terrace, are rarely flooded. The maximum stage reported at Kermit is 43.4 feet and occurred before 1915 (Wells, 1959, p. 262). Alluvial deposits are about 80 feet thick as shown in gas wells and are 23 feet below bottom of the river in drill hole DH 60 (pl. 1).

Terraces and flood plains extend almost to the heads of the major streams and range in width from a few feet to 1,000 feet. Two levels of sandy terrace deposits are prominent along the lower part of Wolf Creek and on Brushy Fork, particularly near Heenon. At Apple Orchard Church the higher terrace is composed of 15–20 feet of sand that is exposed in the roadcut and also underlies the cemetery. The two terraces are distinct near major streams, but they seem to merge upstream. The stream fall ranges from about 10 feet per mile along Wolf Creek to about 80 feet per mile along Emily Creek from the 1,000-foot contour to the junction with Wolf Creek.

A few of the stream crooks in the Kermit-Varney area have slip-off slopes and cut bluffs, which seem to have grown laterally as they were entrenched. The crooks are not regular as one would expect if they were derived from normal meanders on an old erosion surface. There is no clear evidence that the drainage pattern was derived from a previous erosion cycle. Wolf Creek may be migrating southward (downdip) on the Warfield anticline and fault. Most of the small tributaries are longer on the north side of Wolf Creek than they are on the south side.

A knob similar to the core of a cutoff meander is associated with a high terrace and an abandoned part of Wolf Creek Valley at Pilgrim in the Kermit quadrangle. Apparently Wolf Creek flowed through the valley now abandoned west of the knob at Pilgrim. It seems too large to have been formed by present streams. The divide in the abandoned valley is an alluvial fan from the drain to the north. It seems probable that a crook in Wolf Creek was cut off as Wolf Creek eroded into Emily Creek Valley or Holty (called Pipe Mud on map) Branch and abandoned the former valley west of the knob. The stream adjustment apparently occurred as the highest terrace was forming.

The smallest tributaries are short and steep, and their floors and those of the next larger streams are no wider than the stream channel. The streams flow on bedrock in some places, but generally there is a veneer of alluvium composed of boulders, sand, and clay. Alluvial fans are common along the main streams at the mouths of short tributaries. These fans generally displace the main stream channel to the opposite side of the valley. Many of the small tributaries are choked with debris from landslides and other gravity movements of mantle rock. Locally, such tributaries are said to have a "backbone" if the accumulation of debris in the center of the drain has deflected streams to both sides of the debris train. Typically the valley heads are rounded and amphitheatrelike, because of sapping by springs and landslides.

The valley walls have a modified cliff-and-slope type of topography consisting of alternating benches and slopes. The sandstone, where massive, tends to form cliffs in the upper half of the valley walls but forms only steep slopes in the lower half. Cliffs are somewhat more prominent on the northern slopes than they are on the southern slopes. Thin-bedded sandstone and shale units tend to form moderate slopes, and the benches tend to form at the tops of sandstone units where the more easily eroded shale, coal beds, and thin-bedded sandstone occur. Mantle on these steep slopes tends to slide when it is near the head of the valley or near the stream channel, especially if the unit is underlain by a coal bed which acts as a aquifer. Landslides involving large trees are so common that landsliding is considered to be one of the principle processes shaping the landscape. The process may have been speeded up by the removal of timber in the early 1900's, but it was effective in the virgin forest and is responsible for much of the secondary topographic detail. Stream terraces, debris-choked tributaries, "backbones," and large alluvial fans may have formed mainly during the Pleistocene when the area had periods of higher rainfall and more rigorous climate than it has at present.

The ridges are fairly narrow and sinuous. The knobs and ridges immediately underlain by sandstone tend to be sharp and rocky. Knobs underlain by shale or thin-bedded sandstone tend to be rounded and soil covered. The depth of weathering under the ridges was determined by the examination of diamond-drill core. Alteration of clay ironstone to limonite, dark-brown iron-oxide stain in sandstone beds, olive-colored shale, and soft white clays are evidence of weathering and probably were produced by circulating ground water. In 14 diamond-drill holes the minimum depth of weathering below the surface is 77 feet, and the maximum depth is 267 feet. Not all the rocks are affected to these depths, and gray unaltered sandstone zones are common. These zones are apparently impervious to ground water. In nine holes the weathering extended below the first coal zone and associated underclay, which apparently did not stop the vertical circulation of ground water.

PREVIOUS INVESTIGATIONS

Although the presence of coal, oil, and gas in the Kermit-Varney area has been known for many years, little detailed geologic work had been done previously within the areas. The earliest work in the area was by Crandall (1905), who made a reconnaissance of the Big Sandy Valley. Much of this work was concentrated in the Levisa Fork, where he continued to use the coal-bed nomenclature set up in his earlier work (1877) in Carter, Boyd, and Lawrence Counties. He used a combination of numbers and local coal-bed names. Crandall (1905, p. 37) set up a standard section for Middle Fork of Rockcastle Creek in the Inez area, just west of the Kermit area, and he designated the coal beds in this section by letter (table 4) and used letters and names for nearby areas. In the 1905 report he gives numerous sections and sketch maps showing the approximate locations of measured sections. C. N. Brown (1900) prepared a report on the mineral resources of the Big Sandy Valley for the U.S. Army Corps of Engineers and based it in part on fieldwork he did as an assistant to Crandall and in part on later independent work. He used Crandall's coal-bed names and letters and estimated the coal reserves of Martin County. Little information was given in the area of the Kermit and Varney areas. Phalen (1908) described the geology and coal resources of the Kenova 30-minute area to the north of Kermit-Varney area. He used names for coal beds and correlated sandstone beds with named units in Ohio and Pennsylvania.

Crandall in 1910 amplified his discussion of the coal beds in the Big Sandy Valley, gave additional coal sections and analyses, and made tentative correlation with the coal beds in Carter, Boyd and Lawrence Counties. After additional commercial development in the Big Sandy coal field, Hoeing in 1913, using both company information and personal observations, described more coal sections and gave additional coal analyses for the general area. Some beds in the Varney and Williamson quadrangles along Big Creek were described. In places, Hoeing confused the coal beds he called Alma and Thacker and suggested that the Warfield coal be correlated with the Eagle or No. 1 Gas coal of West Virginia. Hoeing described the structural features of the area, named the Paint Creek Uplift, and mentioned the Warfield anticline and associated fault in the Kermit quadrangle.

The part of West Virginia adjoining the Kermit quadrangle was described by Krebs and Teets (1913) and Hennen and Reger (1914). Hennen and Reger established coal-bed correlations in the Kermit area by tracing certain marine zones and coal beds. Wallace and others (1954) improved the correlations of West Virginia coal beds by the study of numerous core-hole logs. They demonstrated that the Warfield is not the No. 2 Gas of West Virginia as previously supposed, but the Alma coal bed. The Hennen and Reger (1914) report, as revised by Wallace and others (1954), is the basis for the use of central West Virginia coal-bed names in the Kermit-Varney area. The nomenclature of the West Virginia County reports are not entirely consistent, and it would be surprising if all the coal beds have been correctly traced into Mingo County, W. Va., from central West Virginia. However, the tracing of key beds as the method of correlating these complex rocks has not been improved on.

Most of the Kermit-Varney area was included in Hudnall's (1927a) report on Martin County. This report resulted from 2 months of fieldwork in 1921. The coal beds were mapped primarily to work out the geologic structure to aid in the search for oil and gas. Structure-contour maps were published for both Pike and Martin Counties in 1923 (Hudnall 1923a, b). Considering the short time spent in the field and the fact that the study of coals was a side issue, Hudnall's (1927a) report is very good. The section labeled "A" on the head of Meathouse Creek (1923a) and the general section on the plate in the 1927a report have been used as key sections for this report. Hudnall used as key beds the Fire Clay coal, with its distinctive flint-clay parting, and the Fossil Limestone (Magoffin Beds of Morse, 1931), and worked out the stratigraphic sequence. Several coal-bed correlations were corrected by Hudnall, but unfortunately he used different and uncorrelated coal-bed terminology in the text, in the illustrations, and on the structure map. Lack of a consistent nomenclature makes Hudnall's preference of coal-bed names difficult to determine. The map in the 1923a report stresses Hazard district coal-bed names; the generalized sections in the 1927a report stress West Virginia and northern Kentucky coal-bed names. The Hudnall reports give bed measurements, a few graphic coal sections, and the estimated reserves for eight coal beds.

The Pike County part of the Varney quadrangle was included in a study of the coal beds of Pike County by Hunt and others (1937). This report includes a map showing four coal beds in the Varney area on a planimetric base at a scale of 1: 62,500 taken from the U.S. Geological Survey Williamson topographic quadrangle. Structure contours were drawn on the Pond Creek coal bed. Dowd and others (1951) used Hunt's data in preparing an estimate of the coal reserves of Pike County. Locally, Hunt's report is consistent and correct in the correlation of coal beds or zones, but regionally dependence on intervals between coal beds as the chief means of correlation and the failure to recognize the southward thickening of the Breathitt Formation led to several errors in correlation as shown by Harris (in Huddle and others, 1963).

Wanless (1939, 1946) made regional studies of the Pennsylvanian rocks in Kentucky and adjacent States. His investigations consisted principally of measuring numerous stratigraphic sections and summarizing and analyzing the geologic literature. Wanless established a reasonable correlation of coal beds throughout eastern Kentucky, primarily by using graphic sections and by reemphasizing and demonstrating the persistence of several key beds, including the Magoffin Beds of Morse, the Kendrick Shale of Jillson (1919), and the Fire Clay coal bed. The sections he measured near Beauty in the Kermit quadrangle and the Bent Branch section in the Meta quadrangle were used to establish the coal-bed names for this report. McFarlan (1943) in the "Geology of Kentucky" used Wanless' correlations (1939) in a summary of the Pennsylvanian stratigraphy of eastern Kentucky. The stratigraphic nomenclature established by Wanless was also used in a report on "Coal Reserves of Eastern Kentucky," by Huddle, Lyons, Smith, and Ferm (1963).

777-057 O—66——2

GENERAL GEOLOGY OF THE PENNSYLVANIAN ROCKS

ROCK TYPES

The rocks exposed in the Kermit and Varney quadrangles belong to the Breathitt Formation of Middle Pennsylvanian age (pls. 1, 2). Relatively few rock types are present, and these are cyclically repeated throughout the formation. It is therefore advantageous to describe the lithology of these rocks here rather than repeat rock descriptions in stratigraphic discussions. Sandstone, shale, and siltstone, in that order, are the most abundant rock types, as shown on plates 3–8. Other rock types—coal, seat rock, flint clay, limestone, and ironstone—are less abundant but characteristic of the Breathitt Formation. All rocks grade laterally and vertically into other rocks, and except for local disconformities at the base of channel-fill deposits, gradational contacts are normal. The Breathitt Formation overlies the Lee Formation of Early Pennsylvanian age; the basal part of the Breathitt is not exposed in the area. Rocks between the top of the Lee Formation and the Alma coal bed consist of 30 percent sandstone and 70 percent shale, according to drillers' logs of gas wells. Rocks between the Alma coal bed and the Magoffin Beds of Morse are 57 percent sandstone and 43 percent shale. Rocks above the Magoffin Beds are 64 percent sandstone and 36 percent shale. These percentages of sandstone were determined by the study of 21,500 feet of core.

The color of Pennsylvanian rocks is almost exclusively shades of gray, ranging from very light gray in sandstone to black in the coal beds. The quartz and clay minerals give a primary light-gray tone; generally dark colors are due to organic matter. Abundant siderite imparts a slightly brownish tone to some rocks. Some shales are slightly bluish in cast. Flint clay is brownish in many places. Mica flakes and carbonaceous matter are abundant on many bedding planes and may give the rock a dark-banded appearance. The carbonaceous matter consists mainly of plant fragments, generally unidentifiable, but includes spores, fusain, vitrain, and shreds of cuticle. The weathered color of the rock is almost exclusively shades of grayish brown due to oxidation of iron compounds such as siderite and pyrite. Some black shale and some seat rock weather very light gray, almost white. Very light gray weathering shale chips are locally useful in locating the Magoffin Beds of Morse, and very light gray weathering underclays are useful in locating coal beds.

SANDSTONE

Sandstone in the Breathitt Formation ranges in grain size from very fine to coarse (figs. 2–4). Coarse-grained sandstone is relatively rare but is locally present in the upper part of the Breathitt above the Broas coal bed. In a few places coarse sandstone beds contain a few very small pebbles of quartz, but conglomeratic sandstone with abundant quartz pebbles was not found in the Kermit and Varney quadrangles. Conglomeratic sandstone containing numerous quartz pebbles is present in the Inez and Thomas quadrangles to the west and in Mingo County, W. Va., to the east. Pebbles and grains of reworked Pennsylvanian sediments are exceedingly common in both the sandstone and the finer grained rocks of the Breathitt and the Lee Formations. Indeed, reworked sediments seem to be the principal source of matrix in the clastic sediments. Shale chips (fig. 2), siderite grains (fig. 4), and irregular chunks of banded coal (fig. 3) are present in most sandstone beds and in some shale beds. Sorting by grain size ranges from very poor to excellent; the best sorting is in some of the very fine grained sandstone.

Beds in sandstone range from thin to very thick laminae; however, nearly all units are made up of thinly laminated to laminated sets of planar and cross strata, many of which are obscure. Some sandstone beds are a single grain in thickness.

Fossil tree trunks, branches, and pieces of bark form "coal spars" in most fine- to medium-grained sandstone units and are associated with conglomerates composed of ironstone pebbles and claystone chips. "Coal spars" are thin lenses of vitrain and banded

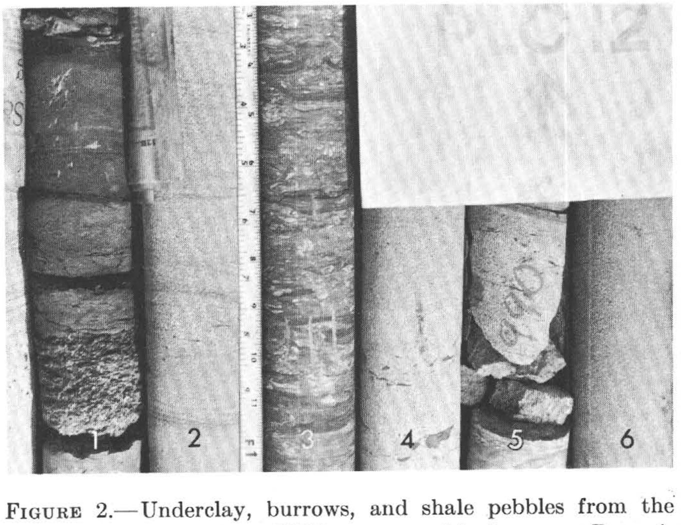

FIGURE 2.—Underclay, burrows, and shale pebbles from the Breathitt Formation, Williamson coal-bed zone. Row 1, dark- and medium-gray underclay with typical fracture due partly to abundant Stigmarias. Row 3, disturbed bedding due to animal burrows in a mixed light- and dark-gray shale and sandstone with calcareous and sideritic cement (Elkins Fork Shale of Morse, 1931). Row 4, shale pebbles (clay galls) in sandstone. The irregular shape is due partly to original shape of the pebble and partly to compression of soft claystone. Core from DH 35, Varney quadrangle, Kentucky. Ruler in inches and tenths of feet.

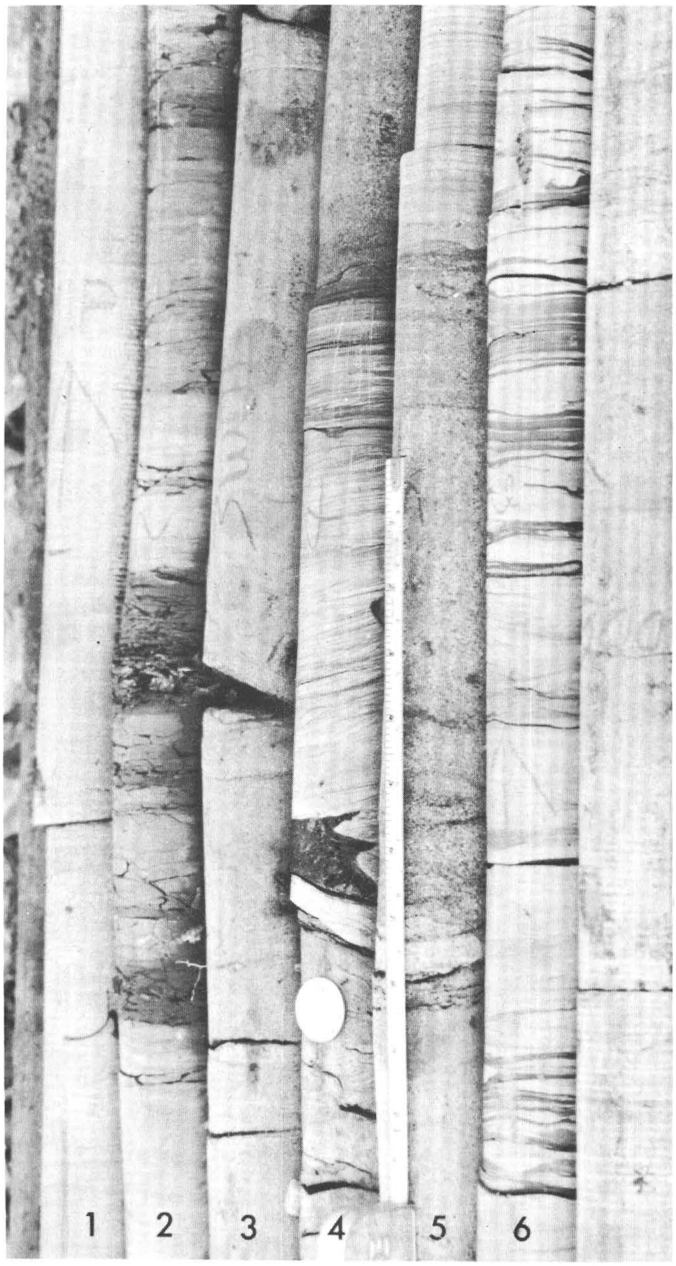

FIGURE 3.—Coal spars, underclay, and interbedded sandstone and shale in cores from the Breathitt Formation. Row 4, coal spar, above the coin, composed of bright-banded coal which interfingers into sandstone. This coal spar probably was deposited as a chunk of peat which was later compressed and coalified. Assuming that the sandstone at the tips of the coal fingers was not compressed, the peat must have been compacted to about one-half its original thickness. Row 6, very fine grained sandstone and shale, interbedded and rippled, above the Broas coal bed. Row 2, light- and dark-gray seat rock with Stigmarias. Core from DH 33, Varney quadrangle, Kentucky.

coal generally lying at angles to the bedding and cross-bedding of the sandstone (fig. 3 below coin). Most of the vitrain laminae represent plant parts which were compressed and coalified after deposition. The lenses of banded coal represent peat mats, eroded, transported, deposited, and later compressed and coalified. These are common in sandstone at about the stratigraphic position of a coal bed (pl. 5, column 27).

The mineral composition of the sandstone units in the Breathitt Formation was determined by Richard A. Sheppard (written commun., 1961). He made visual

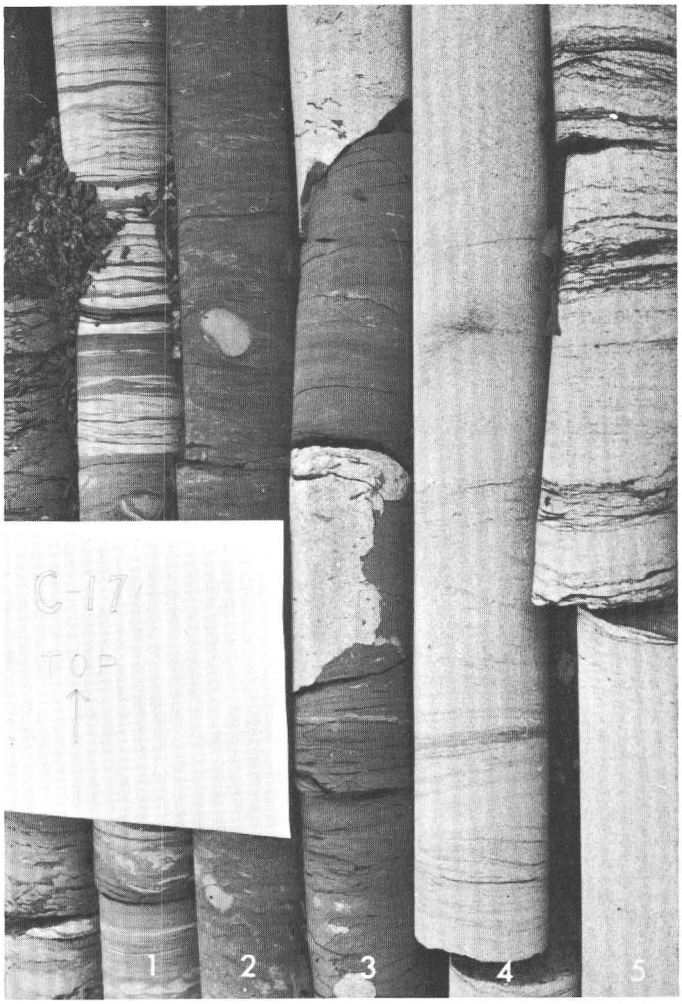

FIGURE 4.—Slump and burrows in the Breathitt Formation. Row 1, interbedded and rippled very fine grained sandstone and shale above the Broas coal bed. Row 2, dark-gray fine- to medium-grained argillaceous micaceous poorly sorted and bedded sandstone with ironstone nodules and areas of calcareous and sideritic cement. The bedding was disturbed by both slump and animal burrows. Row 3, slump contact between medium-grained sandstone above and sandy siltstone below which contains a block of medium-grained sandstone which was caught in the slump and squeezed while still unconsolidated. Row 4, fine-grained sandstone with faint gentle cross-laminations of mica flakes, siderite grains, and carbonaceous grains. Row 5, medium-grained sandstone with similar laminations of mica and carbonaceous grains, and thin lenses of gray shale. Core from DH 50, Varney quadrangle, Kentucky.

TABLE 1.—*Description of sandstones in the Breathitt Formation,*

[x indicates presence

Locality and stratigraphic position	Detrital grains [1]	Matrix	Cement	Grain composition by visual estimate, in percent: Quartz	Feldspar	Rock fragments	Chert	Muscovite	Biotite	Chlorite	Zircon	Tourmaline	Sphene [2]	Garnet	Apatite	Pyrite	Magnetite	Glauconite	Hypersthene	Carbonaceous matter
Samples collected above the Upper Broas coal bed																				
No. 20.[4] Roadcut at Rich Gap	92	8	0	73	3	12	1	1	<1	<1	<1	------	------	<1	------	------	------	------	<1	<1
DH 18.[5] 55 ft above Upper Broas coal bed. Pls. 1, 3.	88	12	0	65	3	15	1	2	<1	<1	<1	<1	<1	<1	<1	------	------	------	------	<1
DH 18. 81 ft above Broas coal bed. Pls. 1, 3.	88	8	4	68	2	14	2	1	------	<1	<1	<1	<1	<1	------	------	------	------	------	------
Average	89	9	1	69	3	14	1	1	<1	<1	<1	<1	<1	<1	<1	------	------	------	<1	<1
Samples between Taylor and Broas coal beds																				
DH 18; 138 ft. Sandstone seat rock above Upper Peach Orchard coal. Pls. 1, 3.	80	20	0	67	1	4	2	5	------	<1	<1	<1	<1	------	<1	<1	<1	<1	------	------
DH 18; 150 ft. Sandstone above Upper Peach Orchard coal bed. Pls. 1, 3.	87	12	<1	69	6	8	1	1	<1	1	<1	<1	<1	<1	<1	------	------	<1	x	------
DH 18; 158 ft. Sandstone above Upper Peach Orchard coal bed. Pls. 1, 3.	89	10	<1	65	4	15	1	2	<1	<1	<1	<1	<1	------	<1	------	------	------	------	------
No. 19. Base of sandstone above Upper Peach Orchard coal bed.	88	11	1	66	3	15	1	1	<1	------	<1	<1	<1	------	------	------	<1	------	------	------
DH 18; 218 ft. Top sandstone above Lower Peach Orchard coal bed. Pls. 1, 3.	88	12	0	63	2	15	------	------	------	2	<1	<1	<1	<1	<1	<1	<1	------	------	<1
DH 18; 266 ft. Base of sandstone above Lower Peach Orchard coal bed. Pls. 1, 3.	86	5	9	68	4	7	2	1	<1	<1	<1	<1	<1	<1	<1	------	------	<1	------	------
No. 18. Top of sandstone above Buffalo Creek coal bed. Pls. 1, 3.	88	12	0	67	4	10	2	2	1	<1	<1	<1	<1	<1	<1	------	------	<1	------	------
No. 17. Base of sandstone above Buffalo Creek coal bed.	93	6	1	71	5	12	1	2	<1	<1	<1	<1	<1	------	<1	------	<1	------	------	------
DH 25. Sandstone 23 feet ± above Winifrede coal bed. Pls. 2, 5.	88	5	7	70	3	6	1	2	<1	<1	<1	<1	<1	------	<1	------	------	<1	------	------
DH 18; 318 ft. Near top of sandstone above Winifrede coal bed. Pls. 1, 3.	86	12	2	73	3	6	1	1	<1	1	<1	<1	<1	------	------	------	------	------	------	------
DH 18; 324 ft. Sandstone above Winifrede coal bed. Pls. 1, 3.	84	8	8	68	7	5	1	1	<1	<1	<1	<1	<1	------	<1	<1	------	------	------	------
DH 18; 366 ft. Near base of sandstone above Winifrede coal bed. Pls. 1, 3.	81	4	15	62	6	9	2	<1	<1	<1	<1	------	<1	------	------	------	------	------	------	------
No. 16. Sandstone above Winifrede coal bed.	84	6	10	50	2	5	2	3	<1	<1	<1	<1	<1	<1	<1	------	------	------	------	------
No. 15. Base of sandstone above Young? coal bed.	87	10	3	65	5	10	2	2	<1	1	<1	<1	<1	------	<1	------	<1	<1	------	------
No. 14. Salt Lick beds of Morse (Wanless, 1937).	89	10	1	62	5	12	1	3	4	<1	<1	<1	<1	<1	------	------	------	<1	------	------
No. 13. Base of sandstone above Magoffin Beds of Morse (1931).	84	8	8	65	4	10	4	3	<1	<1	<1	<1	<1	<1	<1	------	<1	------	------	------
Average [6]	86	9	5	67	5	9	2	2	<1	<1	<1	<1	<1	<1	<1	------	<1	<1	<1	------
Samples between the Fire Clay coal bed and the Magoffin Beds of Morse																				
No. 12. Base of sandstone over Hamlin coal bed.	88	11	<1	67	5	8	2	3	1	1	<1	<1	<1	<1	<1	------	<1	------	------	------
No. 11. Sandstone 6 ft above Fire Clay rider coal bed.	65	0	35	55	2	2	2	3	<1	<1	<1	<1	<1	------	------	------	<1	------	------	------
No. 21. Sandstone between benches of Fire Clay rider coal bed.	87	12	1	62	3	5	2	6	5	2	<1	<1	<1	<1	<1	------	------	<1	------	------
No. 10. Base of sandstone above Fire Clay coal bed.	88	12	0	64	10	8	1	3	<1	<1	<1	------	<1	<1	<1	------	<1	------	------	------
Average	82	9	9	62	5	6	2	4	2	<1	<1	<1	<1	<1	<1	------	<1	<1	------	------

See footnotes at end of table.

based on thin section examination by Richard A. Sheppard

of secondary material]

Grain composition by visual estimate, in percent—Continued				Matrix	Cement	Kind of rock fragments	Grain size (mm)	Roundness [3]	Remarks
Siderite (detrital)	Limonite, secondary	Leucoxene, secondary	Sericitized matrix						
Samples collected above the Upper Broas coal bed—Continued									
------	x	x	------	Quartz, clay, chlorite	------	Siltstone, shale	0.4	0.4	Sutured quartz grains. Fresh feldspar.
------	x	x	------	do	------	do	.6	------	Quartz sericitized, replaced by sericite; poor sorting; shale chips.
------	x	x	------	Quartz, clay	Quartz, siderite	Shale, siltstone, schist, igneous rock.	.6	.3	
------	x	x	------	------	------	------	.5	------	
Samples between Taylor and Broas coal beds—Continued									
------	x	x	------	Quartz, clay	------	Siltstone, shale	0.1	0.2–0.3	Nearly all grains surrounded by matrix. Stigmarias.
------	x	x	------	do	Siderite	Shale, siltstone, detrital siderite.	.3	.3	
------	x	x	x	do	do	------	------	------	Difficult to distinguish squashed rock fragments from matrix. Plagioclase sericitized.
------	x	x	------	Quartz, clay, chlorite	Quartz	Siltstone, shale, quartzite	.4	.3	Sutured quartz. Some crystal faces on quartz grains.
x	x	x	------	do	------	Carbonate, shale	.07	.3–.4	Siderite grains abundant along ripple lamination less than 2 mm.
------	x	x	x	Quartz, clay	Siderite and quartz	Shale, siltstone, igneous rock.	.4	.3	Cement consists of 3 percent oxidized siderite and 6 percent quartz overgrowths. Feldspar sericitized.
------	x	x	------	Quartz, clay, chlorite	------	Siltstone, shale	.3	.3	Difficult to distinguish detrital matrix from squashed shale fragments.
------	x	x	------	Quartz, clay	Siderite	Quartzite, schist, shale, siltstone, volcanic rock.	.3	.3–.4	Most feldspar fresh. Many coaly fragments.
x	x	x	------	do	Quartz, siderite, calcite	Shale, siltstone, igneous rock.	.5	.3–.4	Abundant detrital siderite. Order of cementation siderite, quartz, and calcite.
------	x	x	------	do	Siderite	Shale, siltstone	.3	.3	
------	x	x	x	do	Quartz, calcite	Shale, siltstone, detrital siderite, igneous rock.	.3	.3	Quartz crystal faces in voids later filled by calcite. Plagioclase sericitized.
x	------	------	------	do	Calcite, quartz	Shale, siltstone, volcanic rock.	.5	.3	Calcite later than quartz overgrowth. Kaolinite crystals.
20	x	x	------	Clay, quartz, chlorite	Calcite	Siltstone, shale, coal	.3	.3–.4	Calcite replaces quartz. Siderite spherulites molded around other grains. They were plastic when deposited as detrital grains.
------	x	x	------	Quartz, clay, chlorite	Calcite, siderite	Siltstone, shale	.2	.3	
------	x	x	x	Clay, quartz, chlorite	Calcite	do	.3	.4	Difficult to distinguish detrital matrix from squashed shale fragments. Feldspars sericitized.
------	x	x	------	Quartz, clay	Calcite, siderite	do	.2	.4	Contains silty shale fragments as large as 5 mm. Most feldspar grains are unaltered.
------	x	x	------	------	------	------	.4	.3	
Samples between the Fire Clay coal bed and the Magoffin Beds of Morse—Continued									
------	x	x	------	Quartz, clay, chlorite	Siderite	Siltstone, shale	0.3	------	Difficult to distinguish detrital matrix from squashed shale fragments. Biotite altered. Quartz strained, carbonate replaces detrital grains. Patches of carbonate have radial structure.
------	x	x	------	------	Carbonate, some siderite	do	.1		
------	------	x	------	Quartz, clay, siderite	Siderite	do	.1	0.3	Concentration of heavy minerals, mica, and carbonaceous grains on bedding planes.
------	x	x	x	Quartz, clay, chlorite	------	do	.3	.4	Shale fragments as large as 8 mm alined parallel to bedding. Many feldspar grains are sericitized.
------	x	x	x	------	------	------	.2	.2	

TABLE 1.—*Description of sandstones in the Breathitt Formation, based*

Locality and stratigraphic position	Detrital grains [1]	Matrix	Cement	Grain composition by visual estimate, in percent																
				Quartz	Feldspar	Rock fragments	Chert	Muscovite	Biotite	Chlorite	Zircon	Tourmaline	Sphene [2]	Garnet	Apatite	Pyrite	Magnetite	Glauconite	Hypersthene	Carbonaceous matter
Samples between the Warfield and Fire Clay coal beds																				
No. 9. Base of sandstone above Upper Whitesburg coal bed.	92	6	2	76	8	2	<1	3	<1	1	<1	<1	<1	<1	<1	<1	<1	------	------	------
No. 8. Base of sandstone above Lower Whitesburg coal bed.	88	12	0	65	6	8	2	3	1	1	<1	<1	<1	<1	<1	------	<1	<1	------	------
Sandstone [7] below Lower Whitesburg coal bed.	87	12	<1	65	5	12	1	3	<1	1	<1	<1	<1	<1	<1	<1	------	<1	------	<1
No. 7. Base of sandstone above Kendrick Shale of Jillson (1919).	88	12	0	63	6	10	1	2	1	<1	<1	<1	<1	------	<1	------	<1	------	------	------
No. 6. Base of sandstone above Elkins Fork Shale of Morse (1931).	80	5	15	58	5	10	3	2	<1	<1	<1	------	<1	------	<1	------	<1	------	------	------
No. 5. Base of sandstone above Van Lear coal bed.	82	8	10	64	4	8	1	2	<1	1	<1	<1	<1	------	<1	------	<1	------	------	------
Average [6]	86	9	5	66	6	9	1.5	2.5	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	------	<1
Samples below Warfield coal bed																				
No. 2. Sandstone seat rock below Alma coal bed.	82	8	10	63	6	4	------	7	<1	1	<1	<1	<1	------	<1	------	------	------	------	------
No. 1. Sandstone about 20 ft below Alma coal bed.	88	8	4	74	4	2	3	2	<1	------	<1	<1	<1	<1	<1	<1	<1	------	------	------
Average [6]	88	8	4	74	4	2	3	2	<1	------	<1	<1	<1	<1	<1	<1	<1	------	------	------
Average all units [6]	85	9	5	66	4	9	1.6	2.2	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1

[1] Percentage of total derived by visual estimate.
[2] Sphene includes rutile and other nonopaque titanium-bearing minerals.
[3] Roundness determined visually from chart (Krumbein, 1941, pl. 1).
[4] Numbered sample collected in roadcuts along U.S. Highway 119 from Sidney to Rich Gap, Belfrey and Meta quadrangles, Kentucky. (Section measured by H. R. Wanless, written commun., 1936), from 3 ft above base of sandstone units unless otherwise noted.

estimates of mineral composition in thin sections of samples taken from cores and outcrops along U.S. Highway 119 between Sidney and Bent Mountain, Ky., in the Meta and Belfry quadrangles. The results of thin section analysis are shown in table 1.

The sandstone averages 66 percent quartz, 4 percent feldspar, 9 percent rock fragments, 9 percent matrix, 5 percent cement, and 7 percent other minerals. These sandstones are perhaps best classified as subgraywackes. The percentage of quartz, feldspar, and rock fragments is well within the range of subgraywacke; but the percentage of matrix, 0–20 percent, is generally below the 15- to 75-percent matrix of a normal subgraywacke. The difficulty in classification arises from the fact that much of what might be called matrix is clearly recognized in thin section as tiny particles of reworked Pennsylvanian shale and siltstone. Sheppard reports that there is a complete gradation from matrix to easily distinguished particles of shale and siltstone. If the reworked particles are considered matrix for the purpose of sandstone classification, most of the sandstone in the Breathitt Formation here described is subgraywacke.

Quartz, feldspar, rock fragments, and mica are the most abundant grains in the sandstone of the Breathitt Formation (table 1). Quartz composing from 50 to 73 percent of the rock occurs mainly as discrete subrounded to rounded grains. Many of the larger grains show strong strain shadows and sutured contacts, indicating probable metamorphic origin. Other quartz grains lack distinctive characteristics. The feldspars were not identified, but in most thin sections feldspar without twinning or with Carlsbad twins is more common than the plagioclase feldspar with polysynthetic twinning. Both fresh and weathered feldspar is present; no significant difference in the grain size or amount of weathering of the feldspar was found from the base to the top of the section sampled. The most abundant rock fragments *on thin section examination by Richard A. Sheppard*—Continued

Grain composition by visual estimate, in percent—Continued				Matrix	Cement	Kind of rock fragments	Grain size (mm)	Roundness [3]	Remarks
Siderite (detrital)	Limonite, secondary	Leucoxene, secondary	Sericitized matrix						
Samples between the Warfield and Fire Clay coal beds—Continued									
------	x	x	x	Quartz, clay	Calcite, siderite	Siltstone, shale, volcanic rock.	0.2	0.3	Siderite spherulites squashed and replaced by mica. Mica flakes deformed by compaction. Feldspar sericitized.
------	------	------	x	Quartz, clay, chlorite	------	Siltstone, shale	.3	.3-.4	
------	x	x	x	Quartz, clay	Calcite	Siltstone, shale, volcanic rock.	.3	.3	Difficult to distinguish detrital matrix from squashed shale fragments. Crinkled muscovite parallel to bedding; sericitized feldspar.
------	x	x	x	Quartz, clay, chlorite	------	Siltstone, shale, schist, volcanic rock.	.4	.3	Difficult to distinguish matrix from squashed shale fragments. Biotite altered. Feldspar sericitized.
------	x	x	x	Quartz, clay	Calcite, siderite	Siltstone, shale, volcanic rock.	.4	------	Calcite luster mottling; idiomorphic siderite; carbonates replace detritals; Feldspar sericitized.
------	------	------	------	Quartz, clay chlorite	Siderite	Siltstone, shale	.2	.3-.4	Siderite cement in granular patches.
------	x	x	x	------	------	------	0.3	0.3	
Samples below Warfield coal bed—Continued									
------	x	x	------	Clay, chlorite	Siderite	Shale	0.1	0.4	Lamination marked by change in grain size. Abundant Stigmarias. Feldspar sericitized.
------	x	x	x	Quartz, clay	Siderite, calcite	Siltstone, shale	.1	.4	Siderite rhombs; calcite patchy; about one-half of feldspar grains sericitized.
------	x	x	x	------	------	------	0.1	0.4	
<1	x	x	x	------	------	------	0.3	0.3	

[5] Sample from core of diamond-drill hole at depth below surface indicated. Logs shown on pls. 3, 5.

[6] Seat rock excluded from average.

[7] Sample from roadcut at south edge of Kermit, W. Va.

are reworked grains of Pennsylvanian shale and siltstone. Rock fragments from pre-Pennsylvanian rocks and detrital chert probably constitute 3–5 percent of the sandstone units. These older rock fragments include schist, volcanic, and other igneous rock. No significant variation in the stratigraphic distribution of these rock fragments was noted. Muscovite is the dominant mica in most samples, but chlorite and biotite are nearly as abundant. Mica flakes are most abundant on the bedding planes and range in size from very fine grains to coarse flakes.

Accessory minerals seen in the thin sections include zircon, tourmaline, sphene, garnet, apatite, pyrite, magnetite, siderite, glauconite, and hypersthene. These minerals seem to occur randomly, and no stratigraphic significance of shape, color, or abundance was found. Sphene, as used here, includes rutile and other nonopaque titanium-bearing minerals. Most of the heavy-mineral grains are rounded, but a few are euhedral. The siderite grains were derived mainly from reworked Pennsylvanian sediments. Many siderite grains were soft when deposited but were mashed around other grains during compaction of the sandstone. The glauconite present in ten samples suggests a marine origin for these sandstone units or the reworking of marine rocks. Small particles of carbonaceous matter, common in Breathitt sandstone units along bedding planes, represent coalified partly decayed plant trash and spores. Carbonaceous fragments were found in four thin sections.

Secondary minerals include limonite, leucoxene, and sericite. Both quartz and feldspar are sericitized.

The matrix of most of the sandstone in the Breathitt Formation is composed of clay, silt-sized quartz grains, and finely divided carbonized plant fragments. Much of the matrix was probably derived from the reworking of unconsolidated Pennsylvanian sediments, as indicated by the presence of shale and siltstone fragments and siderite grains, many of which were soft when they were redeposited. The clay fraction of the matrix has not been studied by X-ray methods. Patterson and Hosterman (1962, p. F46) report that illite and kaolinite are the dominant minerals and that chlorite and mixed-layer clay minerals are present in the matrix of Breathitt sandstone in the Haldeman and Wrigley quadrangles, Kentucky. Thin sections from the Kermit-Varney area show authigenic development of sericite, chlorite, and kaolinite crystals in the matrix of sandstones, especially in the seat rocks. Kaolinite crystals have been found in both outcrop and core samples of sandstone.

The amount of cementing material in the thin sections of sandstone of the Breathitt Formation (table 1) ranges from 0 to 35 percent. The most abundant cementing materials are siderite and calcite. Quartz cement occurs principally as overgrowths on quartz grains and rarely fills the voids between grains. Pyrite is abundant enough to form a cement only very locally. Most of the limonite in the samples came from the weathering of siderite and pyrite. In several slides it was difficult to distinguish the detrital grains of siderite and the siderite cement. Many of the detrital siderite grains can be recognized by random orientation and distortion of radial structure. The sequence of cementing materials varies from sample to sample.

Local concentrations of siderite and calcite cement form concretionary masses in many sandstone units. Commonly the masses with calcite and siderite cement are finer grained than the sandstone above and below. These cemented zones occur anywhere within the sandstone unit (pls. 3–5), but they are more abundant near the middle. In outcrops they are prominent near the tops of the units; on weathering, they form smooth rounded hard, resistant masses that have a distinctive yellowish-brown color. Some of the well-cemented masses are spherical or ellipsoidal, giving the appearance of a concretion, but they lack concentric structure or a nucleus. The concentration of calcite and siderite in these masses is postdepositional. Sedimentary structures including bedding, crossbedding, and ripple marks, are preserved undistorted. The amount of cementing material is estimated to range from 10 to 40 percent. In thin sections the grains appear to be floating in cement. These zones of calcareous sandstone "concretions" are too numerous and too random to be useful in correlation. The cementation was apparently random in the consolidating sediment and was not confined to a particular stratigraphic horizon.

SILTSTONE

Siltstone and silty shale are very common in the Breathitt Formation, and there is a complete gradation from very fine grained sandstone through siltstone to silty shale. Well-sorted siltstone is rare and occurs only as thin beds or laminae a few grains thick. Most siltstone is argillaceous and sandy (fig. 4). Field identifications of very fine grained sandstone, siltstone, and silty shale are difficult to make and often nonobjective. Many siltstones contain almost 50 percent of organic matter, siderite, and calcite separately or in combination. Quartz, muscovite, and feldspar are the most common mineral grains in the clay matrix. The proportion of grains to matrix and of quartz to other minerals retains the same order of magnitude as found in the sandstone units. These siltstones could be classified as subgraywackes if they were composed of sand-sized grains.

Siltstone from the rock overlying the Broas coal, collected from a depth of 117 feet, in DH 18 was studied in thin section by R. A. Sheppard (written commun., 1961). The average grain size of the siltstone is 0.03 mm, and the laminae are 0.5–2.0 mm thick. The content of fragments ranges from 20 percent in the shale layers to 80 percent in the siltstone layers. The siltstone laminae are discontinuous and show very small scale slump and flow-cast structures. A postdepositional sideritic nodule seems to have grown along a siltstone layer. The rock contains the following minerals in decreasing order of abundance: quartz, muscovite, feldspar, chlorite, biotite, sphene, zircon, tourmaline, and glauconite. Carbonaceous fragments are abundant, and poorly preserved plant stems are present on some bedding planes.

SHALE

Most of the shale exposed in the Kermit-Varney area is moderately fissile and contains abundant elongate flattened nodules and thin lenses of ironstone. This type of shale commonly occurs in the rocks overlying coal beds and may contain abundant plant fossils. Shale beds of the Breathitt Formation range from very argillaceous to silty and sandy. Continuous or discontinuous silt and sand laminae are common (fig. 4). Interbedded small-scale crossbedded siltstone or sandstone layers are also common. Some sandy and silty shale beds lack fissility and weather to irregular chunks, as do the calcareous shales. Many shales, particularly the sandy and silty ones, appear to be massive in cores when fresh, but in outcrops they tend to weather spheroidally and form closely spaced joints locally known by the term "hill seams" or "pencil weathering." Calcareous shale generally contains brackish-water or marine invertebrate fossils, and many contain plant fossils as well. The black shales generally contain abundant finely divided plant material, and they grade locally into cannel coal. Some of these black shales are very fissile and some are massive. Most black shales contain unrecognizable plant trash and spores; a few contain good plant fossils or marine invertebrates. Pyrite is common in the black shales, and ironstone nodules are present. Some dark shale is calcareous; but where it is calcareous, it generally contains calcareous fossils, and the calcareous matter in the shale may be finely divided shell matter. Many black shales are silty and contain large authigenic mica flakes on the bedding planes.

Schultz (1958) and Glass (1958) have shown that there are more kaolinite and mixed-layer clay minerals and less illite and chlorite in the shales below a coal bed than there are in the shale above the coal bed. This is presumed to be related to the environment of deposition, that is, subaerial or submarine. Shales below the coal bed are generally thin and siltier than those above, and they tend to be more massive.

The clay mineralogy of shale in the Breathitt Formation in the Kermit-Varney area probably is similar to shale described by Patterson and Hosterman (1962) in the Wrigley-Haldeman area. They found that shale in the Lee Formation contains chiefly illite and kaolinite, fine-grained quartz, appreciable quantities of mixed-layer clay minerals, and a trace of chlorite.

COAL

All coal beds in the Kermit-Varney area are of high-volatile bituminous rank and range in thickness from vitrain laminae representing the coalified trunk, stem, or cortex of a plant to beds several feet thick. Petrographically most of the coal is dull to moderately bright attrital coal with thin vitrain bands. Much of it is splint coal, and most of the rest is common banded coal. Cannel coal is present locally in the Broas, Taylor, Fire Clay rider, and Fire Clay coal beds. These cannel coals appear to grade from low ash coals to black organic-rich shale. Some of the cannellike shales with conchoidal fracture and slaty cleavage contain lingulas and were apparently deposited in brackish water. Most of the coal beds contain partings of sandstone, shale, or underclay; coal rash, interbedded vitrain bands, and shale are common near the base and near the top of several coal beds. Calcite, gypsum, and pyrite are common on the cleat face in most of the coal beds, and the Williamson, Taylor, and Broas coal beds contain abundant disseminated pyrite. The total number of coal beds or zones present in the Kermit-Varney area is not known, because most of the coal beds, even those most persistent regionally, are lenticular and grade or finger into other sediments. Splits and riders are generally present and wherever a thick sandstone is replaced laterally by shale or siltstone, coal beds are present. These may represent persistent coal zones in other areas or be very local (pls. 3–8). Coal as an economic resource is discussed and described on pages 46–51.

SEAT ROCK

Seat rock generally is found just below a coal bed. Lithologically it may be clay, shale, siltstone, sandstone, limestone, or any other rock found in coal-bearing sequences. Commonly, seat rocks are composed of clay and are called underclay (figs. 2, 3), but in the Kermit-Varney area most of the seat rocks are silty or sandy (fig. 5). Generally, seat rock lacks lamination and grain orientation, shows no sign of bedding, has a soillike fracture, and contains traces of roots. Most of the roots are stigmarian (fig. 5), but other kinds may be present. All seat rocks have served as the soil or substratum in which plants were rooted, but the retention of soillike characteristics depends on the length of time they served as a soil and the subsequent diagenetic history. Most seat rocks are less than a foot thick, but some are many feet thick. The maximum thickness found in the Kermit-Varney area is 8 feet 10 inches in drill hole DH 15. Seat rocks are subjected to several different chemical environments during their formation. Starting as water-logged soils, they are subjected to organic acids during the accumulation of the overlying peat and to different chemical conditions during compaction, coalification of peat, and subse-

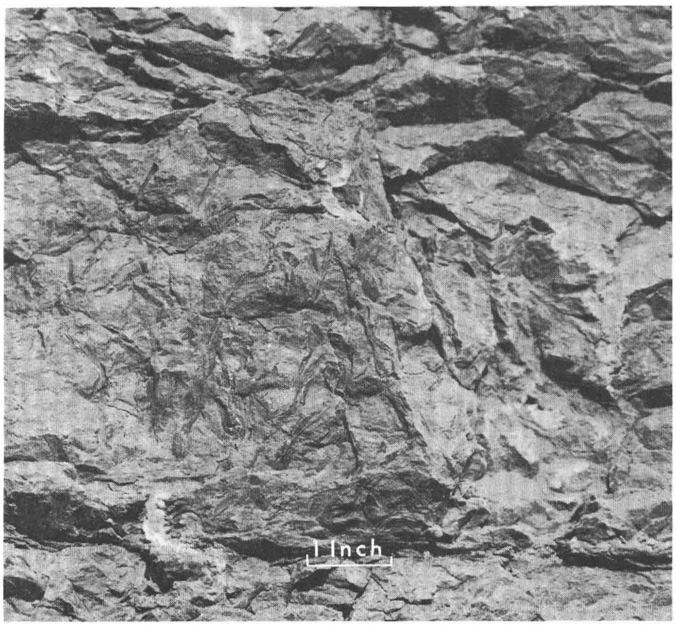

FIGURE 5.—Siltstone seat rock with Stigmarias and typical fracture. A horizontal compressed stigmarian axis or "root" lies near the bottom of the photograph. Many of the smaller roots which cut the seat rock at various angles grew from this axis. Below Winifrede coal bed at the road junction on U.S. Highway 119, east side of Bent Mountain, Meta quadrangle, Kentucky.

quent weathering. At times silica, carbonate, and alkali are dissolved out and at other times added to the seat rock. Depending on the amount of particular elements available in the substratum, plants may remove and deplete a seat rock of potassium, aluminum, silica, or other elements. Most seat rock contains illite, kaolinite, and mixed-layer clay minerals, some of which were present in the rock when the original sediment was deposited, some developed while the seat rock served as a soil, and some were developed diagenetically. Commonly, siderite or calcite accumulated near the base of a seat rock.

A thin section of a siltstone seat rock, beneath the Fire Clay rider coal bed on Johnson Rockhouse Fork of Pigeonroost Fork in the Varney quadrangle was described as follows by R. A. Sheppard (written commun., 1961):

Quartz, 91 percent (includes some cement); mica, 7 percent; shale fragments, less than 1 percent; sphene, tourmaline, zircon, and apatite, all less than 1 percent. The average grain size of this rock is 0.04 mm. Laminae composed of spores and other carbonaceous matter are disrupted by stigmarian roots. The fact that the laminae have not been destroyed suggests that the rock did not serve as a soil very long even though the mineralogy is very different from the other siltstones of the same area. The high percentage of quartz and mica and lack of matrix are noteworthy.

Sample No. 2 in table 1 is from the seat rock below the Alma coal bed and is a sandstone with considerably more matrix and siderite cement than the siltstone below the Fire Clay rider coal bed. Sample No. 14 contains Stigmarias and also contains a high percentage of mica. This specimen is weathered brown. The sample from drill hole DH 18, at a depth of 138 feet, is also a seat rock and contains a high percentage of muscovite or sericite. Mica is unusually abundant in all these seat rocks.

Underclays are generally light gray to very light gray in color and weather to a soft plastic clay. When fresh, many are hard nonlaminated in the upper part, but grade downward into shale or other rock with normal bedding. The clay mineralogy of typical eastern Kentucky underclay has been studied by Schultz (1958) and Patterson and Hosterman (1962). They find that the clay minerals present are mainly illite, kaolinite, mixed-layer clay minerals, and quartz. Kaolinite is the most abundant mineral in underclay of the Breathitt Formation described by Patterson and Hosterman (1962). The refractory quality of the clay in the Kermit-Varney area has not been tested.

Flint clay, a hard crystalline variety of clay with conchoidal fracture, and semiflint clay occur locally in the underclay beds of the Buffalo Creek coal and younger coal beds. Flint clay also forms a distinctive parting in the Fire Clay coal bed; locally it forms lenses less than one inch in length in the Williamson coal bed. As seen in the cores of diamond-drill holes, the flint and semiflint clays in the seat rocks of the Buffalo Creek and younger coal beds range in color from light to dark brown or gray; a few are greenish gray. The dark colors are due to the presence of organic matter. Most of the flint clay contains quartz sand grains and siderite spherulites. Flint clay grades upward and downward into underclay or other types of sedimentary rock and ranges in thickness from a few inches to a few feet. These flint and semiflint clays from the upper part of the Breathitt Formation were examined with a hand lens at the drill-hole sites, but they were not sampled or studied in the laboratory.

The flint-clay parting in the Fire Clay coal bed is a refractory underclay or true fire clay. The flint clay is generally brown to dark brownish black, 4–6 inches thick, and is present in the lower third of the coal bed. Locally, the coal above or below the flint clay is absent, and in a few areas of eastern Kentucky there is no coal above or below the flint clay. The flint-clay parting is absent in the Fire Clay coal at some localities in the Kermit-Varney area but is generally present in the Varney quadrangle.

Samples from the flint clay parting of the Fire Clay coal at Hazard, Ky., and the Windrock coal bed (correlative of the Fire Clay coal bed) of Tennessee were studied and described by Höehne (1957). He reports that the rock is a dense claystone composed of kaolinite, illite, quartz, siderite, and zircon and includes plant tissues, spores, and other carbonaceous matter. Most of the kaolinite is in the poorly crystallized clay matrix, but kaolinite crystals or "worms" and pellet structures are common (Höehne, 1957, pls. 13–15). Clearly recognized basal cleavage is present in both large and small crystals. Thin slivers and etched detrital grains of quartz are the most abundant constituents other than kaolinite.

The flint-clay parting of the Fire Clay coal in the Sandy Hook quadrangle, Ky., contains about 90 percent kaolinite and 10 percent angular quartz silt and sand grains, according to Patterson and Hosterman (1962). The clay also contains traces of mixed-layer clay minerals and organic matter.

Three samples of the flint-clay parting of the Fire Clay coal were studied in thin sections. A specimen collected on Crooked Fork of Rockhouse Fork in the southeast corner of the Varney quadrangle is a light-brown flint clay typical of the parting in much of the Hazard mining district of eastern Kentucky. The estimated composition of the specimen, as shown in thin sections, is as follows: Clay matrix 85 percent;

angular grains of quartz 10 percent; plant tissue retaining cellular structure 5 percent; grains of zircon and rutile, 0.01–0.3 mm in length, less than 1 percent. Many of the quartz grains are splinters 0.1–0.5 mm in length and have a length-to-width ratio of 10 to 1. The largest grain seen was 0.33 by 1 mm. The other quartz grains are etched and partly replaced by kaolinite and sericite. The clay matrix contains a few worm-shaped kaolinite crystals ranging in length from 0.1 to 0.3 mm. Some of the kaolinite crystals are replaced along the margins and in the cleavage planes by a carbonate, probably siderite; elsewhere in the slide, siderite replaces clay matrix.

Thin sections of the flint-clay parting in the Fire Clay coal from Hobbs Fork of Pigeonroost and from the Left Fork of Brushy are darker in color, almost black, and contain more organic matter, more abundant pellets of kaolinite in a clay matrix, and fewer detrital grains of quartz, zircon, and rutile than the sample from Crooked Fork. Zircon grains range in length from 0.02 to 0.13 mm and quartz grains from 0.1 to 1 mm. Splinters of quartz range from 0.02 to 0.23 mm in length. Many quartz grains are partly replaced by kaolinite or sericite. The contact between the quartz and the replacing mineral is sharp in some grains and serrate in others. Kaolinite occurs as wormlike crystals that replace not only the quartz grains but also the general clay matrix. A later generation of kaolinite forms clear veins cutting through everything else in the slide.

Thin-section examination demonstrates that the flint-clay parting in the Fire Clay coal is derived from a sediment composed of a clay matrix with detrital grains of quartz, zircon, and rutile. The clay matrix and quartz grains were replaced by one or more generations of kaolinite crystals, and kaolinite crystals have grown within plant tissues. Siderite has also replaced clay matrix and kaolinite. Feldspar or relic structures of feldspar were not seen, but were reported by Höehne (1957). He regards the quartz splinters as newly formed crystals grown in the clay because they are long, fragile, and could not have been transported. He also reports evidence of quartz replacing kaolinite crystals. In the slides that Huddle examined there is no clear evidence of authigenic quartz crystals. All the quartz splinters could be interpreted as residues of larger grains which had been replaced by kaolinite, sericite, or siderite. Some quartz splinters lying parallel to the margins of kaolinite crystals could be interpreted either as the relic of a quartz grain, as an authigenic crystal replacing kaolinite along a straight contact, or as relic shards. Höehne's examples (1957, pls. 13–15) of quartz replacing kaolinite make it seem probable that the sequence of solution and replacement in the Fire Clay parting was not everywhere the same. Locally, alternating conditions permitted the repeated formation of kaolinite, solution and precipitation of quartz, and the precipitation of siderite, but the sequence of mineralization differed.

LIMESTONE

Limestone is rare in the Breathitt Formation in the Kermit-Varney area. It occurs most commonly in shale as nodules and concretions 2–3 feet in diameter and ellipsoidal in cross section. Locally, limestone forms beds or lenses a few feet in diameter and less than 2 feet thick in the Magoffin Beds of Morse and other marine shale units. The limestone is light to medium gray, aphanitic in texture, and contains less than 10 percent detrital silt-sized grains and clay minerals. In places the Magoffin includes a thin bed of limestone composed of fragments of crinoid stems and other fossils. Many of the limestone concretions in other marine or brackish shale zones of the Breathitt Formation contain a large percentage, 20–40 percent, of silt- and sand-sized grains. Siderite nodules or layers generally are present in limestone concretions from the Elkins Fork Shale of Morse. Both siderite and pyrite are common in many concretions, and sphalerite and galena are in places present in septarian concretions. Many concretions have cone-in-cone structure and septarian veins. Sandy and silty laminae extend through many concretions without distortion, and the shale surrounding these concretions is generally warped around the concretion because of compaction of sediments after the concretion formed. Marine fossils are found in some concretions, but they are not common.

Two concretions and one limestone sample were studied in thin section by R. A. Sheppard (written commun., 1961). One of the concretions was collected on Millstone Creek, a tributary of Bent Branch in the Williamson quadrangle a short distance east of the Varney quadrangle. Sheppard reports that this concretion consists of 97 percent very fine grained anhedral carbonate, probably calcite, and 3 percent angular silt-sized detrital grains including quartz, muscovite, sphene, and carbonaceous fragments. The rock shows concentric concretionary layers. Another sample also showing concentric structure was collected 13 feet above the Taylor coal bed in a cut on a trail to the gas well east of the trail junction at 870 feet near the head of the Meathouse Creek in the Varney quadrangle. Sheppard reports that this sample contains 10 percent detrital fragments, 2 percent carbonate pellets, and 88 percent matrix or cement. The matrix is a mosaic of fine-grained anhedral carbonate, probably calcite. The detrital material is silt and fine sand grains concentrated along bedding planes. These include quartz, muscovite, carbonaceous fragments, feldspar, rock fragments, biotite, sphene, zircon, chlorite, and tourmaline. Subhedral to euhedral iron sulfide occurs in streaks parallel to the bedding. The carbonate pellets are oxidized on the weathered surface and are therefore probably siderite.

A sample of typical crinoidal limestone from the Magoffin Beds was collected on a logging road on the hillside above a gas well in the right tributary of Collins Branch in the Kermit quadrangle. Sheppard (written commun., 1961) says that this rock contains 40 percent fossil fragments, 1 percent quartz, 1 percent collophane, 1 percent oolites, and 57 percent matrix or cement. The granular carbonate matrix alters to iron oxide on weathering and probably consists of a mixture of siderite and calcite. A carbonate mineral, probably mainly siderite, partly replaces fossil fragments and quartz. The quartz grains are angular and average 0.1 mm in size. Collophane and granular carbonate form the nuclei of the oolites. The collophane is composed of fragments of phosphatic brachiopods, probably Lingulas and orbiculoids, and some are partly replaced by iron sulfide. The fossil fragments are mainly crinoid stems and brachiopods, with rounded edges; their maximum size is 18 mm. Huddle identified holothuroid sclerites and ostracodes in the thin section.

IRONSTONE

Clay ironstone, consisting mainly of siderite with a mixture of calcite, dolomite, and ferroan-dolomite with clay and siderite spherulites are common. When fresh, this material is dull, light gray or brown, and weathers to yellow and red brown. Ironstone concretions occur as ovoid nodules less than an inch in diameter to lenses several yards across and range in thickness from less than 1 inch to about 1 foot. Large nodules commonly have septarian veins of calcite, barite, dolomite, or siderite; a few have crystals of sphalerite, galena, and pyrite. Some have white powdery veins of dickite (Allen Heyl, written commun., 1960). Some nodules appear to be discrete and to have formed on the bedding surface before other shales above were deposited. Other nodules clearly formed after the sediments were deposited but before compaction, because they enclose uncompacted laminae, have indistinct boundaries grading outward, or replace fossils. Most ironstone nodules are in shale, but some are in siltstone and sandstone. The latter seem to have grown around nuclei and are composed of siderite and calcite. Some sandstone contains large amounts of siderite cement. The weathered part of similar beds was used for iron ore in the Ashland, Ky., area. These sandstones are typically dark gray, poorly sorted, poorly bedded, contain large unoriented mica flakes, and include 10–30 percent of siderite and calcite cement and clay matrix. These iron-rich sandstones generally contain marine or brackish-water fossils.

The clay ironstone and iron-rich sandstone are characteristic of rocks above coal beds. In contrast, siderite in the lower part of seat rocks consists of generally small individual spherulites scattered through the rocks; or where the spherulites are very abundant, they join to form irregular masses elongate vertically through the bed and following the Stigmarias rather than parallel to bedding planes, as are the clay ironstone nodules in roof shales. These irregular masses differ in appearance from the ovoid nodules in the rocks above the coal beds. Siderite spherulites in underclays are the probable source of the reworked grains in the sandstones.

BEDDING AND OTHER SEDIMENTARY STRUCTURES

Differences in the distinctness of bedding, lamination, grain orientation, and other sedimentary structures in the rocks of the Breathitt Formation are more significant than differences in grain size for local correlation and interpretation. Individual beds range from laminae a single silt-grain thick to beds as much as 10 feet thick. Bedding range from clear and sharp through indistinct laminae to mottled and mixed beds. Some beds have poorly oriented grains. Massive poorly bedded poorly sorted rocks include dark-gray sandstone, thick siltstone, and silty shales; some of these were deposited without apparent bedding, others were mixed by slump, burrowing organisms, or roots after deposition.

Other prominent sedimentary structures in the Breathitt Formation are crossbedding, ripple marks, current lineation, load casts, fluting, and cut-and-fill structures (figs. 3, 4, 6, 7, 8).

Crossbedding is the most prominent structure in sandstone of the Breathitt Formation. As shown in cores, nearly all the thick sandstone units have gently inclined crossbedding, and many thin units have very small-scale crossbedding. As shown in figure 6, the crossbedding is complex with dips in several directions. Individual crossbedding units range in thickness from less than 1 inch to about 10 feet. In Billy Lowe Branch (fig. 6) the crossbed sets are 1–3 feet thick. They are similar to those shown by Potter and Glass (1958, p. 18). No systematic observations of crossbedding directions were made, but casual observation gives the impression of a general northwest direction of sediment transport. Cross laminae in the Breathitt sandstone units generally are marked by an accumulation of mica flakes, coaly plant fragments, vitrain, fusain, and siderite grains. Rarely, shale chips and clay ironstone pebbles are concentrated along the surfaces of the cross laminae. The sorting is too poor in

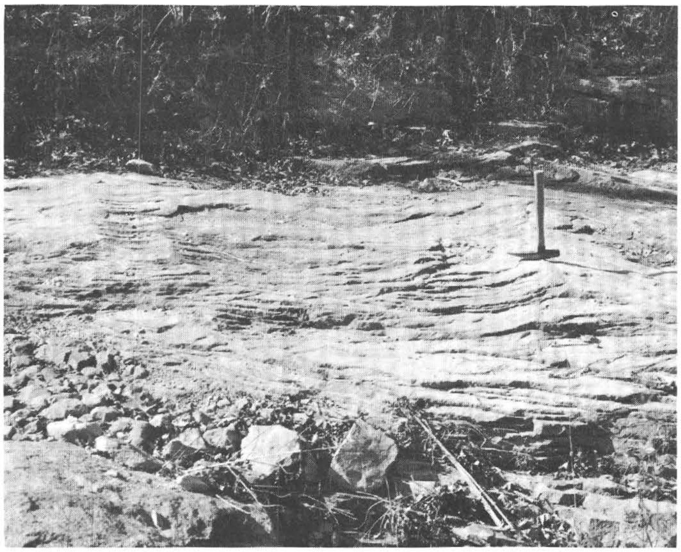

FIGURE 6.—Medium-scale trough-type crossbedding in the sandstone overlying the Upper Whitesburg coal bed. Billy Lowe Branch, Varney quadrangle, Kentucky.

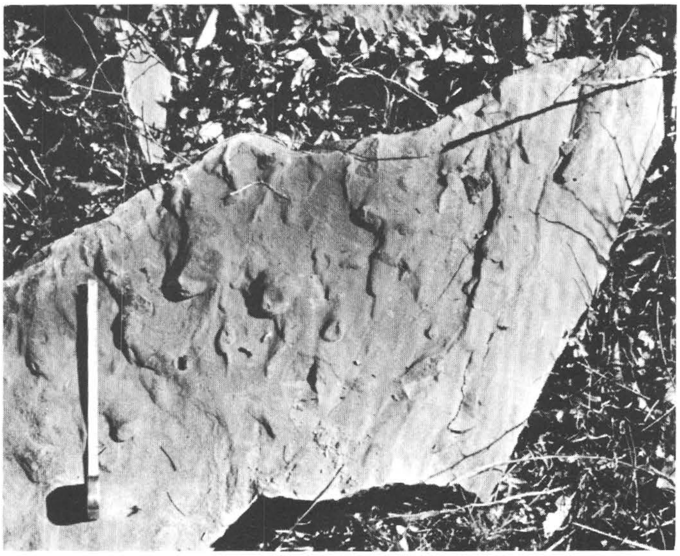

FIGURE 7.—Load casts or modified flute casts on the bottom of a sandstone slab from the Breathitt Formation, Big Creek, Williamson quadrangle, Kentucky.

most of the sandstones to show bedding by grain-size change. Consequently, some apparently massive sandstone units may be crossbedded even though the structure is not obvious. Probably most of the crossbedded sandstone was deposited rapidly, especially that with standing tree trunks and channel fills with abundant coal spars representing log jams.

Ripple marks are abundant in the very fine grained sandstone and the shale-siltstone-sandstone units. Ordinary asymmetric or symmetric ripple marks are rare. The common types of ripple marks are crossbedded ripple lenses of sandstone or siltstone in shale and thin wisps of shale marking ripples in siltstone or very fine grained sandstone. There is a complete gradation from discontinuous ripple lenses of sandstone in shale to sandstone with ripples marked by faint traces of shale. Hamblin (1961) described the structure seen in ripple lenses as micro-cross-laminations. He considered these as miniature trough-type crossbedding and a variety of ripple mark. They occur in sets that form beds ranging in thickness from a few inches to several feet. Micro-cross-lamination develops if deposition exceeds erosion just enough so that only the crests of ripples are cut off before burial by the next ripple migrating down current (Hamblin, 1961, p. 399). The basic crescent shape of the cusp ripple lens gives the troughlike form of the micro-cross-lamination set. On the bedding surfaces

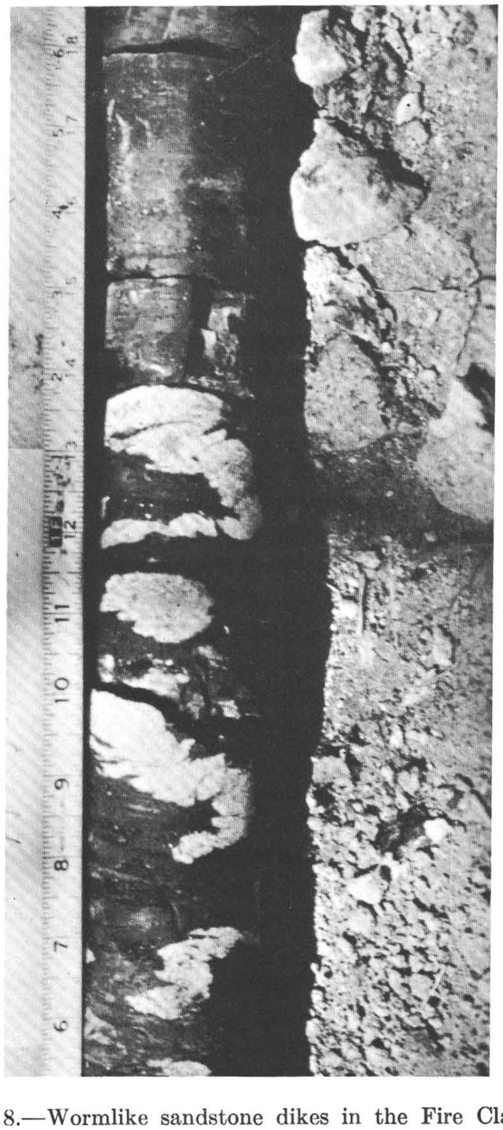

FIGURE 8.—Wormlike sandstone dikes in the Fire Clay rider coal bed, probably contorted when the peat was compacted. Core from DH 20, Varney quadrangle, Kentucky.

truncated ripples appear as confused ripples, rib and furrow structures, or arcuate wavy laminations. They are very common in the sandstone beds in the transitional zone between the Lee and the Breathitt Formations and in the upper part of the thick sandstone units of the Breathitt Formation. Micro-cross-lamination is characteristic of the very fine siltstone and fine-grained sandstone, especially the well-sorted beds composed mainly of quartz grains and containing little matrix. Probably these beds were winnowed, and the matrix was largely removed.

Sandstone ripple lenses in shale are also common in the Breathitt Formation in the Kermit-Varvey area. A complete gradation from shale with a few thin stringers of siltstone or shale, through discontinuous lenses of sandstone, interbedded sandstone and shale with micro-cross-laminations, to sandstone with wisps of shale are shown by core samples. In weathered outcrops the ripples are easily seen in the thin slabs of wavy siltstone which thicken and thin irregularly, representing poorly preserved interference and cusp ripples. Ripple lenses in shale may have been formed by currents strong enough to carry stringers and lenses of sandstone across clay surfaces without eroding the clay (Potter and Glass, 1958, p. 22), or they may have formed by occasional currents or storm waves that winnowed the upper few inches of previously deposited sediments in areas of slow deposition.

Current lineation, fluting, and drag grooves are very rare. Faint lineation shows on some siltstone slabs. The base of the sandstone overlying the Peach Orchard coal at the mine 800 feet south of DH 57 in the southeastern corner of the Varney quadrangle has large prod marks and grooves. The groove casts trend northwest and are deepest at the southeast end, indicating a current flowing in a northwest direction.

Load casts occur in some of the interbedded thin sandstone and shale units. These load casts are formed by the pressing of the sandy layer into the shale while the sediments were still soft (fig. 7). Some features resembling load casts were probably formed during rapid dewatering of the sandstone and during consequent compaction and flow. Many of these features are at definite stratigraphic positions.

Disturbed bedding and small-scale slump structures are much more common than load casts. Contorted and twisted bedding is common at several horizons (figs. 4, 8) and may be related to movement along a depositional slope. Most shale and siltstone beds beneath or between thick sandstone units have been strongly distorted, folded, faulted, and mixed;this is well shown in cores (fig. 4). These structures are due to compaction beneath channel sandstone units and differential compaction within the channel or slump along the channel edges where erosion undercut the previously deposited sediments. Channel sandstones have sharp slickensided contacts with distorted beds below. Differential compaction has also caused small-scale thrust faulting in the Williamson coal bed (fig. 10) and near the Three Forks School on Petercave Fork in the Fire Clay rider coal bed. Sandstone dikes through the Fire Clay rider coal bed were found in DH 20 (fig. 8) and in an 8-inch coal bed above the Campbell Creek Limestone of White (1885) in DH 33.

Disturbed bedding also was caused by burrowing organisms and plant roots, as well as by the compaction of plant stems or water-logged sediments. In the Kermit-Varney area relatively persistent zones disturbed by burrowing organisms are found in the Campbell Creek Limestone of White, the Elkins Fork Shale of Morse, Kendrick Shale of Jillson, Magoffin Beds of Morse, and in the marine rocks above the Broas coal beds. These disturbed beds range in thickness from about 6 inches to about 2 feet. Generally, they are calcareous, ferruginous, and contain abundant carbonaceous matter. Lamination in some beds is almost normal with only a few burrows perforating the laminae, but in others the bedding is completely churned, mottled in color, and individual burrows are hard to distinguish (figs. 2, 4). Commonly, the animals worked through a bed to a particular plane, turned, followed bedding, and then worked upward. Burrows extending to the sediment interface are considered worm burrows. Burrowing types of pelecypods are present in most of the marine zones. Holothurian sclerites are common in the Kendrick Shale and are found in the Magoffin Beds (Summerson and Campbell, 1958), and holothuroids may have been responsible for some of the disturbed bedding. Zones of animal burrows are indicated in the core descriptions and on plates 3–8. Fossils are scarce in many of the burrowed beds, but fragments of Lingulas and orbiculoids are present in some places.

Cut-and-fill structures are common in Pennsylvanian rocks in many regions. Washouts of coal beds have been reported from many parts of the world. Small-scale washouts or scour seem to be relatively rare in the Kermit-Varney area, but large-scale channel cutting is very common. Much of the complication of cross-bedding in the Breathitt Formation is due to variability in direction of the currents which carried and deposited the sediments in the previously scoured channels. Many of the channel fills are composed of sandstone; but, locally, all other types of rocks of the Breathitt Formation, including coal, occur in channel fills.

The undersurfaces of many channel sandstone bodies are marked by well-defined flutes and rounded scoops. Some of the flutings are parallel to the side of the channel; other fluting and the irregular patterns formed by scoops trend across the channel. The scoops were eroded by turbulent currents in many places, but load casts were caused by the pressing of sandstone into the underlying shale during compaction of the shale by the weight of the overlying sandstone.

SHAPE OF SEDIMENTARY DEPOSITS

Nearly all the beds in the Breathitt Formation are lenticular. Generally, where the contacts are gradational, the boundaries of sedimentary deposits are indistinct. Channel fills, however, have erosional contacts and sharp contacts where the channel fill and the enclosing rocks are different. In the Kermit-Varney area many channel sandstones occupy channels cut in other channel-fill sandstones, and the trends and shape of individual channels are difficult to determine.

In Indiana and Illinois, Pennsylvanian channel-fill sandstones have been traced considerable distances (Friedman, 1960, Hopkins, 1958, and Wanless, 1946). Hopkins describes the channel phase as massive crossbedded sandstone more than 20 feet thick with disconformable base and the sheet phase as thin-bedded sandstone with gradational base below. Sandstone channel fill can be traced relatively easily with subsurface information in a formation composed mainly of shale. Sheet-phase sandstones are more difficult to trace in the subsurface. In Tennessee, Wilson and Stearns (1960) describe blanket and digitate sandstones in the Lee Formation. The blanket sandstones of Tennessee are massive, quartzose, crossbedded, and average 100 feet in thickness. The digitate sandstones are described by Wilson and Stearns as consisting of massive fingers with webs of thin persistent sandstone between fingers. In Kentucky, Adkison (1957) shows a suggestion of channel pattern in the rocks just above the Fire Clay coal. Similar studies are needed elsewhere in eastern Kentucky. Availability of numerous cores offered the possibility of such a study in the Kermit-Varney area, but time was not available for it. The written logs are given on pages 53–78 to make the information available for this type of study. Drillers' logs of gas wells have not been widely used for a study of sandstone body shapes in eastern Kentucky (fig. 9).

The correlation of coal beds shown on plates 6–8 delimit large stratigraphic units. Those beds below the Magoffin Beds seem to be more persistent and mark more easily recognized units than those above. This section below the Magoffin Beds is composed of sandstone, 57 percent, and thick shale units, 40 percent. The sections above the Magoffin (pls. 3–5) show a higher percentage of sandstone, about 64 percent, and thinner less persistent shale units. The sandstone units are clearly channel-in-channel deposits above the Magoffin; they are not easily separated in cores and are almost impossible to distinguish in drillers' logs of gas wells and core holes. Variation in bedding and grain size suggests the compound structure of the channel-in-channel sandstone units in the logs of some core holes. The upper part of most massive channel sandstone contains a few feet of fine-grained to very fine-grained sandstone or siltstone that is interbedded with shale or siltstone and ripple marked. The amount of shale at the top of these channel sandstones ranges from wisps no thicker than a knife edge to layers a few inches thick. This shale normally grades upward into shale and siltstone, but several logs show that the overlying beds were removed and fine- to medium-grained sandstone of a different channel-fill overlies the very fine-grained sandstone in the top of the lower sandstone. Channel-in-channel sandstone is shown in many roadcuts, but the outcrops are not sufficiently numerous to determine the trend. The recurrence of clay chips, ironstone pebbles, coal, and shale also indicate erosion of contemporary rocks and repeated channel cutting.

An example of the difficulty of determining the shape of sandstone deposits is shown in the widespread occurrence of sandstone (pls. 6–8) just below the Magoffin Beds or Taylor coal bed. This is a complex sandstone locally representing one or more of the following: The sandstone over the Fire Clay coal bed, the sandstone over the Fire Clay rider coal beds, and the sandstones above and below the Hamlin coal beds. The sandstone above the Fire Clay rider coal is thick and extensive. In parts of the Hobbs Fork area in the Varney quadrangle a single sandstone unit seemingly occupies the interval between the Fire Clay rider and Taylor coal beds, but locally one or more Hamlin coal beds are present. Here the sandstone splits into an upper and lower unit. This splitting can be interpreted as two (or more) channel-fill sandstones and associated sheet sandstone, the youngest sandstone occupying a channel through the older channel fills where it cuts through the widespread Hamlin coal zone; or it can be interpreted as a single migrating channel with scattered sandstone sheets at the margins of coal swamps and on either side of the main channel. A migrating channel is the more likely explanation of the Fire Clay, Fire Clay rider, and Hamlin coal sequences than channel-in-channel deposition. A thorough consideration of this problem was not made.

Another type of sandstone-channel deposit that may be present in eastern Kentucky is the deposit formed by a delta distributary which extends from the mouth of the distributary out onto the submarine part of the delta. Such distributary deposits are linear sandy deposits built up above the general surface of the submarine delta. They are, therefore, a load on the soft wet sediments below and tend to sink into older finer grained beds. The sandstone bodies formed are similar to sandstone fills of erosional channels. The abundance of slump structures, such as those seen in figure 4, suggest that some of the channellike sandstone bodies in the Kermit-Varney area may be delta distributary-type subsidence channels rather than the channel-fill type. Probably bars and channel-island deposits are also present, both fluvial and marine.

Abundant "coal spars" in the thick sandstone bodies frequently represent log jams. This can be recognized by the vitrain, molds and impressions of trunk, bark, and stems jumbled at all angles into the sandstone. The coal spars composed of chunks of banded coal, however, indicate the erosion of a peat bed. Figure 3 shows such a piece of banded coal which was compressed when it was coalified. The thickness of the original block of peat is shown at the ends of the fingers of coal, and the amount of compression of the peat to form coal is indicated by the difference of thickness here and in the main block. Chunks of banded coal in sandstone are commonly found at positions of coal beds. The larger the fragments are, the more likely they indicate the position of a coal bed. Rounded coal pebbles are very rare. Wanless (1939, p. 51) regarded rounded coal pebbles as diagnostic of the sandstone above the Coalburg coal (Peach Orchard).

The lenticular nature of the coal beds is well shown on the isopach maps of the coal beds of the Taylor and Fire Clay rider. Swamp patterns are not clear from the small area studied. Extreme variation in the lithologic character of equivalent beds can be demonstrated in the interval between Fire Clay to Fire Clay rider which is coal and shale about 10 feet thick in the Big Creek area, and which, to the southwest, is as much as 60 feet of sandstone. Rapid deposition of the intervening rocks is indicated by standing trees in the rocks between the Fire Clay rider splits on the Left Fork of Brushy Fork. Extreme variation in lithology is also clearly present in the Buffalo Creek to Peach Orchard interval, but this is difficult to study because the correlation of the coal beds is so tenuous. The principal shale units likewise change laterally, and the principal marine zones used as key beds vary in rock type, so much that they cannot be described as distinct lithologic units and given formal stratigraphic names. Nearly all marine zones contain the same kind of fossils regionally, but may have distinct faunas locally. They are not distinct paleontologically, and therefore they are not truly faunal zones with characteristic genera or species. The lithology ranges from shale to sandstone with limestone, siderite, and septarian concretions; the bedding ranges from remarkably even and uniform laminae to nonbedded worm rock and ferruginous sandstone to massive silty shale without obvious internal bedding or orientation of particles. Limestone occurs only in concretions and lenses that have a maximum diameter a few tens of feet. The rock in the roof of the Upper Broas coal is a distinctive interrippled sandstone and shale in the northern half of the Varney quadrangle and the southern part of the Kermit quadrangle. This rock locally contains Lingulas and worm borings, and is probably brackish water or normal marine in origin. To the south and west this rock is replaced by more common types of shale and sandstone and is not distinctive. In thickness the unit ranges from less than 1 foot to more than 20 feet and is lenticular.

CYCLOTHEMS

In the Kermit-Varney area, as in other coal-bearing areas, rock sequences are cyclic. Currently these cyclic sequences are called cyclothems. Commonly, cyclothems consist of a sandstone at the base followed by shale, seat earth, coal, and shale with ironstone nodules and marine or brackish-water fossils. Often the cycles are incomplete, and members of the usual sequence are absent. In some cyclothems, and locally in many, other rocks may be added to the sequence or one of the usual members may be replaced by another rock.

Cyclothems have long been recognized in the Pennsylvanian rocks of the Appalachian region, by Stout (1931) in Ohio and Reger (1931) in West Virginia. Hoeing (*in* Crider, 1916, pl. 1) and Wanless in 1946 (p. 129) have pointed out the rapid thickening of section from Ohio southward and the intercalation of numerous coal beds. To account for larger number of cycles, Wanless reasoned that the rate of sedimentation and completeness of record increased southward. Wanless recognized a repetition of the following sequence: (1) Sandstone grading upward into shale or siltstone, locally containing plant fossils; (2) underclay; (3) coal, commonly including several benches as much as 20 feet apart; and (4) shale with limestone overlying the coal zone and containing plant fossils and marine or brackish-water invertebrate fossils.

In the Eastern Interior coal basin, cyclothems have been used for correlation and classification of Pennsylvanian strata, but they are now considered to be a type of classification separate from the rock-stratigraphic classification (Kosanke and others, 1960). Wanless (1955) placed principal emphasis on the tracing of key beds, especially coal beds and limestone beds, by means of electric logs and well records throughout the Eastern Interior Basin. In the Kermit-Varney area, peculiarities in certain beds of a cyclothem are useful in local correlation, and unusual features of cyclothems are very helpful in solving local correlation problems.

Cycles of sedimentation or rhythmic sedimentation is a necessary consequence of the formation of several coal beds. The mere fact that seat rocks and coal beds are associated means that, if coals are repeated in the section, the seat rock-coal couple will give a cyclic appearance to the section. Logically, certain other facts of coal bed accumulation and preservation make the repetition of beds inevitable. For a peat bed to be preserved it must be buried, which implies a subsiding basin and one in which sediments are accumulating. Only a few environments lead to the formation of water-logged swampy areas, and only a few environmental conditions can be expected as a swampy area subsides and sediments bury peat. The sediment will be marine if subsidence is rapid enough to permit the sea to invade the area, and brackish or fresh water if the rate of deposition exceeds the rate of subsidence. It follows that a normal peat-forming sequence starts with the deposition of sand or shale, subsidence to form water-logged soils, accumulation of peat, subsidence and deposition of marine or fresh-water rocks, generally shale or sandstone. Thus, the fact that there are several coal beds in a section, and a few rock types common in coal-bearing rocks, makes cycles inevitable however these cycles are caused.

Wilson and Stearns (1960) have postulated that the bulk of the strata of Pennsylvanian age equivalent to the Lee Formation in northern Tennessee are marine, and that the rocks exhibit a cyclothemic sedimentation controlled by eustatic sea-level changes. They regard the cyclothem concept as a stratigraphic tool for local and regional time-rock correlation, but they do not propose it as a basis for naming mappable rock units. Their interpretation was based on ideas presented by Wheeler and Murray (1957) advocating a glacial control theory of cyclothems. The cyclothem proposed by Wilson and Stearns (1960) starts "arbitrarily" with a coal beneath a blanket marine sandstone with slight basal unconformity. Just above the sandstone is another coal overlain by a shale with varying quantities of interbedded sandstone. Another coal zone is commonly present beneath the next blanket sandstone. Although this cyclothem is certainly repeated in the Lee Formation of Tennessee, the correlation of cycles to sea-level variation, assumes that coal beds, sandstone, and shale are blanket deposits and are virtually time lines with lithologic breaks paralleling time lines. This requires a greater regularity and continuity of the sediments and persistence of coal beds than has yet been demonstrated and seems to be an over simplification of the sedimentational history. The cycle that Wilson and Stearns (1960) describe is similar to the one above the Magoffin shale shown on plates 3–5. The percentage of sandstone is probably similar.

Wilson and Stearns (1960, p. 1462) did not divide the upper part of the Pennsylvanian, which would include the rocks equivalent to the Breathitt Formation in the Kermit-Varney, into cyclothems because of the lack of blanket sandstone beds; but they suggested that these rocks as well as the formations equivalent to the Lee Formation (except for coal beds) were deposited in relatively deep sea. They assume the same kind of eustatic advance and retreat of the sea for the Lee Formation in Kentucky. The differences in lithology between the Lee Formation and the Breathitt seem to require different depositional conditions. The relatively clean sandstones of the Lee Formation are reasonably explained as marine. They are very different, in bedding charasteristics as well as in mineral composition, from the dirty sandstones of the Breathitt Formation and its equivalents. No marine fossils have been found in the channel phases of Breathitt sandstone units, but no diligent search for them has been made. The apparent channel-in-channel structure of the Breathitt sandstone suggests anastomosing shifting stream channels, locally, perhaps in distributaries on the submarine part of a delta, but certainly not deposits in water deeper than 600 feet. An alternate interpretation of the clean sandstones suggested by Englund and Smith (1960), from evidence gathered in mapping the Lee Formation in northern Tennessee and along the Kentucky-Virginia border, is that the Lee sandstone represents a regressive marginal marine sandstone deposit. It is probable that the Lee Formation is a composite body of sandstone or conglomerate, with tongues extending into shales and siltstones and lenses of conglomerate. That the younger quartzose sandstone units in the lower and middle parts of the Lee Formation extend farther westward than the older sandstone is clearly shown by Wilson, Jewell, and Luther (1956) and by Englund and Smith (1960). Study of numerous records of drillers' logs and a few sample logs by Mitchum (1954) and by the present writers fails to demonstrate the blanket nature of Lee Formation sandstone and shale units. Sample studies and drillers' logs show that there are shale units in the quartzose sandstone and conglomerate units, but they do not show persistent shale units over extensive areas. This problem deserves further study, because the existence of persistent blanket units cannot be regarded as proved or disproved (fig. 9).

The existence of cyclic sedimentation in the Appalachian regions is unquestionable, and we agree with Wanless (1946) and Wilson and Stearns (1960) that cyclothems should not be used as a basis for classification in Tennessee and eastern Kentucky for rock-

777–057 O—66——4

stratigraphic or time-rock units, but this conclusion is reached by different lines of reasoning. We question the value of the cycles as a means of correlation, except locally, and regard the persistence of cyclothems as not firmly established in this area.

If it could be demonstrated that cyclothems were due to episodic changes of sea level, either eustatic or diastrophic, they would provide regional basis for correlation. Neither the diastrophic theory advocated by Weller (1956) nor the glacial control theory advocated by Wheeler and Murray (1957) and Wilson and Stearns (1960) has been demonstrated. Both require persistent coal beds and marine beds and would lead to correlations which are much more certain than the writers have been able to prove by mapping in eastern Kentucky and northern Tennessee. Because coal-bed persistence and correlation are so essential to these hypotheses, the field evidence for the persistence of coal beds in the Kermit-Varney area should be considered.

PERSISTENCE OF UNITS WITHIN THE BREATHITT FORMATION

Lithologic units in the Breathitt Formation of eastern Kentucky seem to lack the regional persistence of some Pennsylvanian strata in other coal basins of the United States. In the Eastern Interior coal basin many thin units can be widely traced (Wanless, 1955, Siever, 1957), and in western Pennsylvania the main coal beds of the Allegheny Formation seem to be regionally persistent (Ferm and Williams, 1960). The difference between these findings in the Eastern Interior coal basin, western Pennsylvania, and those described by Huddle and others (1963) in the eastern Kentucky part of the Appalachian coal basin is one of degree. In eastern Kentucky there seems to be a slightly greater local variation and somewhat less regional persistence. The proof of this conclusion must await the accumulation of considerably more data than are now available. It is expected that the cooperative mapping program of the Kentucky Geological Survey and U.S. Geological Survey will map and establish the persistence of certain beds.

Coal beds.—The lateral persistence of most coal beds in eastern Kentucky has not been proved. The only coal which has been traced over a wide area is the Fire Clay coal bed. Its peculiar flint-clay parting and its stratigraphic position between the Kendrick Shale and the Magoffin Beds permit positive identification in most areas in eastern Kentucky. The identity of the Fire Clay coal bed is well established from Tennessee northward to the Sandy Hook and Williamson areas in Kentucky, but it has not been traced into West Virginia where its equivalent probably is the Chilton coal. Because of the relation of the Whitesburg and Williamson (Amburgy) coal beds to the Fire Clay coal bed and to the marine zone in the Kendrick Shale, these coal beds are widely recognized and their correlation is satisfactorily established. However, as has been pointed out (p. 14), the flint-clay parting is generally in the lower third of the coal bed, but it is in the underclay at some places and in the roof shales elsewhere. If the flint-clay parting represents a time zone such as that of an ash fall, the associated coal bed is not everywhere of exactly the same age. The persistence of beds in the Upper Elkhorn coal zone is less well known, and in spite of the extensive mining, the number of beds and their relationship to each other is still a puzzle which additional study and mapping might solve. The Fire Clay rider coal is also widespread and recognizable because of its relation to the Fire Clay coal. The coal beds above the Magoffin Beds have been correlated by probability based on inadequate data. Their continuity is not established, and the number of beds and their relationship is a problem that will require much additional study and will not be solved by geologic mapping alone.

The generalized geologic section used in this report is based in part on accumulated knowledge and in part on provisional correlations that were used as a working hypothesis. Local correlations which may be wrong are thought to have been compensated for regionally. There is a rapid thickening of the section in West Virginia (Thomas Arkle, Jr., written commun., 1959) from Charleston south to Princeton and in Kentucky from Martin County southward to Harlan County. Many coal zones in the southernmost exposures may not be represented to the north in the Kermit-Varney area. Furthermore, it is possible that there have been systematic errors in the correlations of coal beds from Harlan to Martin Counties and that all the coals in Harlan County are older than the Buffalo Creek of Martin County. These errors might be made because the actual rate of thickening is greater than that assumed. Consequently, the coal beds to the south may be so widely separated stratigraphically that they cannot be positively correlated with coals in the same general zone to the north. Probably the coal beds above the Magoffin Beds recur within the same general coal zone over a wide area, but this has not been established in eastern Kentucky by either mapping, paleontology, or study of measured sections. To establish correlation, sections and core holes to the stratigraphic horizon of the Fire Clay coal or below and spaced 1–5 miles apart are needed. These data combined with mapping can establish correlations. Spore studies also would be helpful.

Sandstone.—Sandstone units in the Breathitt Formation vary extremely in thickness within short distances, because they commonly occur as both channel phases and sheet phases; but regionally they recur at about the same stratigraphic positions. The Whitesburg sandstone beds recur in many areas and have a lithologic similarity, characteristic disconformable base, and a type of crossbedding that is familiar to geologists acquainted with the stratigraphy. These sandstone beds lie between the Kendrick beds and the Lower Whitesburg coal, between the Lower and Upper Whitesburg coal beds, and between the Upper Whitesburg coal and the Fire Clay coal beds. Other sandstone beds which recur at many localities are the sandstone units above the Fire Clay coal bed and above the Magoffin Beds. Thick sandstone units are common above the Magoffin Beds, but the correlation of the coal beds between the sandstone units is not established well enough to determine the extent or distribution pattern.

Shale and limestone.—Shale units of the Breathitt Formation are thicker and more persistent below the Magoffin Beds than they are above. Even in the lower part of the section, however, there is a tendency for rapid change in lithology from shale to silty or sandy beds. Concretions in a shale unit may vary from common to rare in areas a few miles apart. Probably most of these shale units were deposited in marine or brackish water. In many areas the discontinuity of shale units is due to erosion and replacement of the shale by channel sandstone. Shale units may be thick and easily mappable along one drainage and absent or too thin to map in adjacent drainages. Dark shale just above the Lee Formation is one of the most persistent lithologic types in eastern Kentucky and is shown in drillers' logs of most gas and oil wells which have been examined in the Kermit-Varney area and elsewhere (fig. 9). Probably these dark-gray shale units are not continuous or everywhere the same age, because they apparently interfinger with sandstone of the Lee Formation and seem to be younger northward. Similar shale units recur throughout the Breathitt Formation, and they cannot be traced on the basis of distinctive lithology. The named units are those which contain fossils and large calcareous concretions at one or more localities (table 2).

TABLE 2.—*Principal marine zones and their equivalents*

	Mingo County, W.Va.	Eastern Kentucky				Kermit-Varney area
Conemaugh Formation	Hennen and Reger, 1914	Hudnall, 1927b	Morse, 1931	Wanless, 1939	Huddle, 1953	
Breathitt Formation		Conemaugh Flint Ridge Limestone Kanawha Flint=marine zone above Hindman coal bed.	Flint Ridge Flint Lost Creek Limestone	Flint Ridge Flint Lost Creek Limestone	Flint Ridge Flint Marine zone above Hindman coal bed.	Zone with Lingulas
	Kanawha Flint				Marine zone above Flag and Fugate coal beds.	Zone with Lingulas and animal burrows above Broas coal bed.
					Marine zone above Hazard and Prater coal beds.	Pelecypods above Upper Peach Orchard coal beds.
	Buffalo Creek Limestone.	?----------?----------?	Salt Lick Beds	Salt Lick Beds	Salt Lick Beds	
	Fossil Limestone (reported by Hudnall, 1927a).	Fossil Limestone (above second coal above Fire Clay coal bed).	Magoffin Beds (above Taylor and Copland coal beds).	Magoffin Beds	Magoffin Beds	Magoffin Beds of Morse 1931.
					Marine zone above Fire Clay rider coal bed.	Marine zone above Fire Clay rider coal bed.
				Marine zone above Whitesburg coal bed.	Marine zone above Upper Whitesburg coal bed.	Marine zone above Upper Whitesburg coal bed. Marine zone above Lower Whitesburg coal zone.
	Dingess Limestone	Kendrick Shale	Kendrick Shale (above Amburgy and Williamson coal beds).	Kendrick Shale =Dingess Limestone	Kendrick Shale	Kendrick Shale of Jillson (1919).
	Seth Limestone		Elkins Fork Shale	Elkins Fork Shale	Marine zone above Little Caney coal bed.	Elkins Fork Shale of Morse (1931).
			Dwale Shale (above Prestonsburg No. 1 coal bed).	?----------?--------?	Marine zone---------? above Grassy coal bed.	Dwale Shale of Morse.
	Campbell Creek Limestone.	Fossil zone Shale over Lee Formation.		Marine zone equivalent to Campbell Creek Limestone. Cannelton Limestone equivalent. Eagle Limestone equivalent. Dwale Shale		Campbell Creek Limestone of White.
Lee Formation		Zone with lingulas in shale between Rockcastle and Corbin Members of Lee Formation. Fossil zone below sandstone members of Lee Formation.				

Marine zones.—Marine fossils in the Breathitt Formation reported by many of the Kentucky Survey geologists from shale, siltstone, sandstone, and limestone (table 2) and the "Fossil limestone" (probably Magoffin) were widely used for correlation before the marine zones were named. Jillson in 1919 proposed the name Kendrick Formation for the fossiliferous shale on Cow Creek near Prestonsburg in Floyd County. Crandall (1905, p. 53) may have been describing the same bed on Clarks Branch of Buffalo Creek. Hudnall in 1927b listed the following marine fossil zones: (1) Below the Pottsville Conglomerate (Lee Formation of this report), (2) between the Corbin and the Lee Sandstones, (3) shale over the Pottsville Conglomerate, (4) Campbell Creek Shale between the Wayland coal and the Pond Creek coal, (5) Kendrick (Dingess) Limestone in the shale over the Amburgy coal (Williamson of this report), (6) Fossil Limestone, above the Limestone coal or second coal above the Fire Clay coal bed, (7) Kanawha Black Flint over the Hindman coal bed. Morse (1931) described and named seven beds (table 2) containing marine or brackish-water fossils and described the faunas. Wanless (1939, 1946) made extensive use of these marine zones and correlated the Magoffin Beds with the Upper Mercer limestone of Ohio and the Winifrede Limestone of West Virginia. Summerson (1942) discussed the correlation of both marine and fresh-water shales of eastern Kentucky and adjacent States. Huddle (1953, fig. 23) shows 12 marine zones between the Elkhorn coal zone (Grassy coal) and the Flint Ridge Flint of Morse (1931). All these marine zones contain the same kind of fossils. *Lingula* and *Orbiculoidea* are common at most of the horizons and may indicate brackish-water deposits. Brachiopod faunas including Spirifers and productids are common in the more marine facies; locally, cephalopods, pelecypods, and gastropods are abundant in marine faunas. Crinoid stems are most common in the Magoffin Beds, but they may occur in the Kendrick and perhaps in other zones. Fresh-water pelecypods are uncommon.

Summerson and Campbell (1958) described holothuroid remains from the Kendrick Shale. Similar remains are found in the Magoffin Beds and may be present at other horizons, especially in beds which have numerous burrows. Although it is difficult to distinguish all these beds, except possibly the Magoffin, there is no doubt that many of the roof shales are marine and that marine fossils recur at the same horizon at many places. It is likely, however, that the water was shallow because, as can be seen by a study of plates 3–5, the fauna of the Magoffin Beds within the Kermit-Varney area ranges all the way from pelecypods in black shale through normal marine brachiopods to probable brackish-water-laid gray shale with *Lingula*, *Orbiculoidea*, and beds of sandstone with burrows. This variation in fauna as well as sediment type in a relatively small area seems to indicate shallow rather than deep water. Even the most widespread marine horizon, the Magoffin Beds, is not everywhere present. It was not deposited in some areas, it is represented by underclay or coal in some areas, and it was eroded and replaced by other sediments in other areas. It is possible that the Magoffin Beds as now recognized by Huddle and others (1963) is really two or three closely spaced marine horizons at which crinoidal limestones occur. Present evidence is not sufficient to rule out the possibility that there are Magoffin-like limestone beds above the Fire Clay rider coal, above the Hamlin coal, above Taylor or Copland coal (true Magoffin of Magoffin County), and at the position of the Salt Lick Beds of Morse (1931). Certainly marine zones are not unique, and correlations based merely on the presence of fossils are questionable. Locally, marine zones may not mark major changes in depositional environment but merely local changes in delta distributaries, bars, and similar features. Major marine invasions are widespread and useful markers, even if not specifically identified by their lithology or fossils. These widespread zones, marked by marine or brackish-water fossils, are characteristic of the more regular Breathitt Formation units below the Magoffin Beds.

CONDITIONS OF DEPOSITION

GENERAL

Rapid gradation from one sedimentary rock into another, the recurrence of similar rocks, and the presence of cyclothems in the Breathitt Formation suggest deposition in a fresh-water or marginal-marine environment. This suggestion is supported by the presence of bedding and structures such as micro-cross-laminations and burrowed beds of a low-energy environment, in the same sequence of rocks with strongly cross-bedded sandstones with coal spars and locally derived pebbles indicating a high-energy environment. Paleontologic evidence confirms this suggestion by the presence of fresh-water coal beds, seat rocks, plant fossils, and fresh-water, brackish-water, and normal marine invertebrate fossils. Considered separately, all this evidence of fresh-water and marginal-marine environments of deposition can be ascribed to other environments; but considered as a group, they invite comparison with modern flood-plain, delta, and tidal-flat environments.

Rocks, sedimentary structures, and fresh-water, brackish, and marine faunas similar to those found in the Breathitt Formation have been described in recent delta and tidal flat areas and from older rocks in many areas. Moore and Scruton (1957, p. 2750) describe bedding, associated structures, and rock types similar to those of the Breathitt Formation in Recent nearshore sediments along the gulf coast of Texas and in the Mississippi delta. Even, continuous, and discontinuous laminated sediments are characteristic of areas with rapid deposition and few bottom-dwelling organisms. Such laminated sediments form much of the Mississippi delta sediments. Other regular beds and laminae are considered by Moore and Scruton to be due to both primary deposition and secondary winnowing. Irregular mottling and irregular laminations are common in the Gulf Coastal Plain sediments of Texas, and there is a complete gradation from regular to irregular laminae, as to mottled beds and finally to completely churned and mixed sediments. Beds of sediments originally deposited without internal structure are also present. Thus in the Recent sediments of the Gulf of Mexico, primary and secondary sediments lacking internal bedding or orientation of grain are similar to the massive siltstones and silty shale of the Breathitt Formation. The Recent sediments are massive because of rapid primary deposition or because of secondary churning and winnowing by organisms; the same causes are ascribed to the Pennsylvanian beds with similar structures in the Kermit-Varney area. Burrowed beds are forming today in the Gulf of Mexico in both the sounds and the open gulf. In the sounds the depth of water ranges from 4 to 20 feet and the open gulf from 15 to 350 feet. Presumably the beds in the Breathitt Formation having similar lithologies and internal structures were deposited in water less than 350 feet, but such structures can form in deeper water.

Bedding types and structures similar to those found in the Breathitt Formation have been described and figured from Recent Wadden Sea tidal zone sediments in the Netherlands by Straaten (1951, 1954 a, b) and from many older rocks. Potter and Glass (1958, pls. 7, 8) compare similar structures from the Pennsylvanian of Illinois with those from the Wadden sea. Moore and Scruton (1957, fig. 15) reproduce photographs of burrowed beds from Pennsylvanian rocks in Illinois, Missouri, and Oklahoma. Greensmith (1956) described burrows from the Carboniferous of England. Micro-cross-lamination has been reported by Hamblin (1961) from the Precambrian Keweenawan Series and from younger rocks including the Pottsville of Pennsylvania. The bedding types and sedimentary structures found in the Kermit-Varney area are common to many in the Appalachian coal field, and although the structures have local causes, they are due to conditions that were repeated many times and in many places during the Pennsylvanian.

BREATHITT FORMATION

The general lithology, sedimentary structures, and faunal content of the Breathitt Formation suggest the following conditions of deposition.

The Breathitt Formation in the Kermit-Varney area was deposited in a marginal marine area—probably a delta lobe which was never very far above or below sea level and an adjacent shallow marine shelf. Seat rocks, coal beds, and channel-fill sandstones formed in swamps and migrating stream channels on the delta lobe. Locally, streams built levees, bars, and fingers of sandstone into the shallow seas. Beach deposits and well-sorted marine sandstone beds are common only in the Lee Formation, whereas most of the sandstone units in the Breathitt Formation are stream deposits. Calcareous shale, limestone, and some fissile shale with abundant ironstone nodules are marine and probably were deposited in lagoons and shallow-water open-sea areas. Black shale, massive silty shale, and siltstone beds with both regular and irregular laminations only suggest deposition in closed or nearly closed basins: swamps, ponds, and lagoons. The common association of beds with even and uneven laminae, ripple lenses of sandstone, micro-cross-laminations, mottled and burrowed beds corresponds to the structures found on modern tidal flats. No evidence of deep-water deposits was found in the Kermit-Varney area.

ORIGIN OF THE PARTING IN THE FIRE CLAY COAL BED

The origin of the flint-clay parting in the Fire Clay coal bed is a special problem, and the conditions under which it was deposited have not been determined. It is difficult to explain how such a thin relatively uniform unit generally 2–4 inches in thickness can be so widespread, extending from northern Tennessee throughout eastern Kentucky and into West Virginia. Generally, it is in the lower third of a coal bed, but locally, it occurs in the underclay below the coal. The growth of kaolinite crystals in the clay matrix seems to require the removal of potassium and, perhaps, sodium and calcium from the original sediment; this removal would seem to require considerable time for weathering and circulation of swamp waters, which makes the preservation of peat below the flint clay unlikely. It is true, however, that the coal below the parting is generally a splint coal in the Kermit-Varney area and elsewhere in eastern Kentucky, composed of only the plant parts most resistant to decay. The coal below the parting is very impure at many localities. This is also true of the Index coal which has a thick flint-clay parting at West Liberty, Ky. The presence of detrital grains of igneous and metamorphic quartz, quartzite, zircon, and rutile in a clay matrix seems to require the deposition of a sediment on peat in a swamp. The zircon and rutile may be less rounded than grains in the sandstones above and below the Fire Clay coal bed.

The uniqueness of the parting and its widespread distribution seem to require an unique origin. The growth of kaolinite crystals might be partly explained if the original sediments were degraded illitic clay and the whole sediment deficient in potassium. This could speed up the formation of kaolinite and make the preservation of peat below more likely. Possible origins of the flint clay parting include the following: (1) The original sediment, which forms the flint-clay parting, was brought into the swamp by a temporary marine invasion or an exceptional flood; (2) the precipitation of kaolinite from solution in an ordinary shale parting was caused by an unusual chemical condition in the swamp; or (3) the clay is altered airborne sediment, perhaps a volcanic ash.

A marine invasion would easily explain the wide distribution; but it seems improbable because it is not an unique event, and other marine invasions of coal-forming swamps have produced coal balls, black shales with fossils, and limestone beds but not flint clay. Also, according to Allen and Johns (1959) and Keller (1956), kaolinite is not formed under marine conditions. An exceptional flood affecting the whole swamp area from Tennessee to West Virginia could have spread the sediment over a wide area, but this does not easily explain the relatively uniform thinness of the flint clay. Precipitation from solution of a highly kaolinitic clay under unusual chemical conditions in the swamp seems possible, but it does not account for the detrital grains of quartz. An ash fall explains uniqueness and distribution easily. It would also explain the fresh grains of zircon and rutile in the thin sections. Nelson (1959) reported a "bentonite" from a coal bed below the Pardee coal bed in southwestern Virginia. This is the position of the Fire Clay coal bed, and Nelson's sample may be the flint-clay parting. C. S. Ross (oral commun., 1961) examined Nelson's material and concurs in the volcanic origin. Ross (written commun., 1961) also examined the thin sections of flint clay described in this report from the parting in the Fire Clay coal bed. He found areas in these slides which strongly resemble bentonite and collapsed pumice structure and other areas which were ambiguous. Some of the areas resembling pumice contained plant tissues. These plant tissues are probably stigmarian roots. Ross reports that although the structure of the flint clay resembles the pellet structure of some sedimentary clays, it is not precisely the same.

The origin of the flint-clay parting in the Fire Clay coal in the Kermit-Varney area remains in doubt, but the simplest and most probable explanation is that it is a highly altered water-laid volcanic ash fall.

PENNSYLVANIAN ROCKS

The Pennsylvanian rocks in the Eastern Kentucky coal field include a complex of interbedded, intertonguing shale, siltstone, and sandstone units which grade into one another They are divisible into three main units: the Lee Formation, a basal unit composed mainly of relatively clean quartz sandstone (orthoquartzite); the Breathitt Formation, a middle unit of shale and sandstone with considerable matrix (subgraywacke); and the Conemaugh Formation, an upper unit which includes a few red beds as well as shale, limestone, and sandstone. This nomenclature follows that of Wanless (1939) and Huddle and others (1963). The Breathitt Formation contains most of the commercial coal; the Lee and Conemaugh Formations contain only a few commercial coals in Eastern Kentucky. The Lee and Breathitt Formations are not everywhere the same age and are in part contemporaneous.

Englund and Smith (1960) have shown that the Lee Formation interfingers with the Pennington Formation along Cumberland and Pine Mountains in the Middlesboro area. Recent geologic work by Dobrovolny and others (written commun., 1960) in the Ashland area suggest that the Lee sandstone interfingers with fossiliferous Pennington of Mississippian Chester age in the Ashland area, confirming an opinion expressed earlier by J. C. Ferm and K. J. Englund (oral commun., 1956). The channel deposits at Heidelberg, Ky. (McFarlan, 1943, fig. 7, p. 97) and another Livingston, Ky., exposed along U.S. Highway 25, are clearly unconformable on several members of the Pennington. Englund regards these as disconformities below channels that eroded through part of the Lee Formation and into the Pennington rocks. He considers the normal relationship between the Pennington and the Lee Formation to be interfingering here as well as elsewhere in Eastern Kentucky. The combination of a gradational and interfingering contact coupled with local disconformable contacts below channels could explain the difficulty experienced for many years in placing the contact between the Lee and the Pennington in both outcrops and well records. This information will aid greatly in interpreting many of the puzzling correlation problems that have arisen in Eastern Kentucky. A new look at the well records will probably show zones of interfingering and may show that gas in the Maxon and Salt sands of drillers is stratigraphically controlled.

Along the western margin of the Eastern Kentucky coal field the Lee Formation is divided into several named members including the Beattyville Shale Member near the base, the Rockcastle Sandstone

Member, and the Corbin Sandstone Member. Englund and others (1961), in the Ewing quadrangle south of Pine Mountain, raised the Breathitt Formation to group rank. The names used and their approximate equivalents in other areas are shown in table 3.

In Virginia the Wise Formation includes most of the Breathitt Formation equivalents and is separated by the Gladeville Sandstone from the Norton Formation below. The Gladeville Sandstone has not been mapped in Kentucky, but it may be mappable in part of Letcher and Pike Counties. The Lee Formation is not exposed in the Kermit-Varney area, and the members have not been formally named.

The Breathitt Formation has not been divided into named members north of Pine Mountain. Wanless (1946) used Tennessee names for part of the area in a regional report. The rocks in the Breathitt, however, are generally divisible into three indistinct lithologic units that are informally designated as lower, middle, and upper. The contact between the Lee and Breathitt Formations lies in a transitional zone of shale interbedded with orthoquartzitic and subgraywacke sandstones. The top of the Lee Formation is drawn at the top of the highest orthoquartzitic sandstone. The lower unit of the Breathitt Formation lies between the top of the Lee Formation and the base of the Upper Elkhorn coal zone or Alma coal (table 3). This unit consists mainly of dark-gray shale (more than 60 percent in the Kermit-Varney area) with ironstone concretions and calcareous sandy concretions. It contains several relatively persistent sandstone beds 20–100 feet thick and some coal beds, especially to the south and east of the Kermit-Varney area. The middle unit, extending from the base of the Upper Elkhorn coal zone to the Magoffin Beds of Morse (50–60 percent sandstone in the Kermit-Varney area), contains regular coal-bearing zones including Fire Clay coal bed, and marine shales 0–100 feet thick. Typically, there is a repetition of sandstone, seat rock, coal, and marine shale in the middle unit. The upper unit generally contains more sandstone and less regular cycles and less continuous coal beds than the middle unit. In the Kermit-Varney area the upper unit has more than 60 percent sandstone. Only the middle and upper units are exposed in the Kermit-Varney area.

Marine zones in the Breathitt Formation of eastern Kentucky are key beds that have been used to unravel the complex stratigraphy of the formation. The marine zones, both formally and informally designated ones that have been used in classification and correlation, are shown in table 2. Jillson (1919) was the first to formally name one of these marine beds when he proposed the name Kendrick Shale, but the Magoffin Beds had long been known informally as the "Fossil limestone" before the name "Magoffin" was applied by Morse (1931). Unfortunately, all these marine zones are not lithologically persistent or distinct from the adjacent beds and do not correspond to the definition of beds in the code of Stratigraphic Nomenclature (Am. Comm. Stratigraphic Nomenclature, 1961), nor do they correspond to a biostratigraphic unit. They are not characterized by any genus or group of fossils, and the same zone may be represented by worm burrows in one area, Lingulas in another, pelecypods in another, and articulate brachiopods in still another. Marine zones could be designated by reference to the subjacent coal bed name, such as "marine zone over the Whitesburg coal." Such a nomenclature has the advantage of coupling the coal with the marine zone, but certainly is awkward. In this report names are used informally because they are convenient, and no new names are proposed.

TABLE 3.—*Formation names used in eastern Kentucky and West Virginia*

Ewing quadrangle, Kentucky		Kermit-Varney area, Kentucky		West Virginia	
BREATHITT GROUP	BRYSON FORMATION	BREATHITT FORMATION	Broas coal bed	KANAWHA FORMATION	Stockton coal bed
	HIGNITE FORMATION Magoffin Beds(?) of Morse (1931)		Magoffin Beds of Morse		Winifrede Limestone (Hennen, 1914)
	CATRON FORMATION Wallins Creek coal bed		Fire Clay coal bed		Chilton coal bed
	MINGO FORMATION Harlan coal bed		Alma coal bed		Alma coal bed
	HANCE FORMATION				
Naese Sandstone Member LEE FORMATION		LEE FORMATION		Nuttal Sandstone Member NEW RIVER FORMATION	
				Flattop Mountain Sandstone Member POCAHONTAS FORMATION	

The Conemaugh Formation has been entirely eroded from the Kermit-Varney area and is not discussed in this report. The Lee Formation is not exposed in the area and is described from well samples and records, as is the lower part of the Breathitt Formation. The oldest rock exposed in the Kermit-Varney area is about 30 feet below the Alma coal near the mouth of Collins Creek in the Kermit quadrangle.

The classification and correlation of the Pennsylvanian rocks in the Kermit-Varney and adjacent areas is shown in table 4. The lithologic characteristics of the Breathitt Formation are shown in the columnar sections on plates 3–8. Only part of the Breathitt Formation is exposed in the area; the upper part of the formation has been removed by erosion, and the part below the Alma coal is almost wholly below stream level.

Most of the sandstone units in the Breathitt Formation have been named as formations in the West Virginia Geological Survey county reports. In the following discussion references to these names and their authors are made because the Kermit-Varney area is adjacent to West Virginia, and correlations across the Tug Fork should be possible. The authors do not advocate the use of these names because the sandstones appear to be discontinuous, and although often recurring at the same horizon, they are not truly blanket deposits which are mappable. The lack of continuity and lack of need for the names persuaded the authors not to adopt these bed names for this report.

LEE FORMATION

The Lee Formation, as shown in the logs and samples from oil and gas wells, consists of sandstone and shale. The sandstones are orthoquartzitic, composed mainly of fine to coarse quartz grains that have little matrix and local quartz pebbles. Where the Lee Formation crops out near Paintsville and in Pine Mountain in southern Pike County, Ky., it is strongly crossbedded, contains lenses of shale and coal, and the individual sandstone units have disconformable basal contacts. Scattered quartz pebbles as well as pebbles arranged along the crossbedding planes are common. Generally the grains are medium to coarse in size, although parts of the formation are fine to medium grained. Sorting is generally poor. In outcrops, outside the Kermit-Varney area, the Lee sandstone weathers brown, but in well and core samples it is a clean very light gray friable sandstone. Thomas (1949) describes samples from Carter and Boyd Counties which have secondary quartz crystal overgrowths on grains and contain enough matrix to reduce permeability. This was seen in some of the well samples examined. Commonly the sandstones of the Lee Formation contain salt water and are known to the drillers as the "Salt sands."

The shape and distribution of sandstone in the Lee Formation were studied mainly by the use of drillers' graphic logs of gas wells. Many logs were available in the U.S. Geological Survey log file, which were collected by J. F. Pepper and others (1954) for their study of the Berea Sandstone; other logs were obtained from the United Fuels Gas Co., and Kentucky-West Virginia Gas Co. About 1,000 well logs were collected for the area; about 400 of these logs were used to lay out 5 principal sections across the Kermit-Varney area. Samples from 12 wells were examined, but samples from only 3 wells included Pennsylvanian rocks cut by the drill. Logs at a scale of 1 inch=30 feet were used to correlate units exposed at the surface with units found in diamond-drill holes and in drillers' logs of gas and oil wells. The logs plotted at 1 inch to 100 feet were used in the study of sandstone and shale bodies in the Lee Formation and in determining the thickness of the formation. Drillers' logs are not individually reliable, but they do show accurate trends. Enough logs are available to give a mass effect, and the study of samples confirmed findings made from drillers' logs.

The mass effect of the logs strongly suggests that the Lee sandstone units finger out northward and interfinger with the red and gray shales of the Pennington Formation. The rocks between the Greenbrier Limestone and the base of the Chattanooga Shale are regular and easily correlated; but the rocks above the Greenbrier are variable, and only when the logs are laid out in order and properly spaced do the Upper Mississippian and Pennsylvanian rocks make a pattern. Three north-south lines, each with 30–40 logs, all showed the northward thinning of the Pennsylvanian rocks and the overlap of sandstone members in the Lee Formation. The westernmost line of logs was chosen to prepare a diagrammatic stratigraphic section, figure 9. Fifteen well logs and two core-hole records from the 40-log layout were selected as guides in constructing the diagram.

The boundary between the Pennington and Lee Formations is gradational and indistinct. The Pennington Formation consists of gray shale, red shale, sandstone, and limestone. The red rocks do not form a consistent pattern, but apparently interfinger with the Maxon sand of drillers and the lower sandstone member of the Lee Formation. As shown on figure 9, the Maxon sand pinches out northward. Red beds occur above the lower sandstone member of the Lee Formation in the northern part of the Kermit quadrangle. Locally, dark shales and coal beds are reported by drillers in the upper Pennington Formation.

The Lee Formation thins from about 600 feet at the southern edge of the Varney quadrangle to about 300 feet at the northern edge of the Kermit quad-

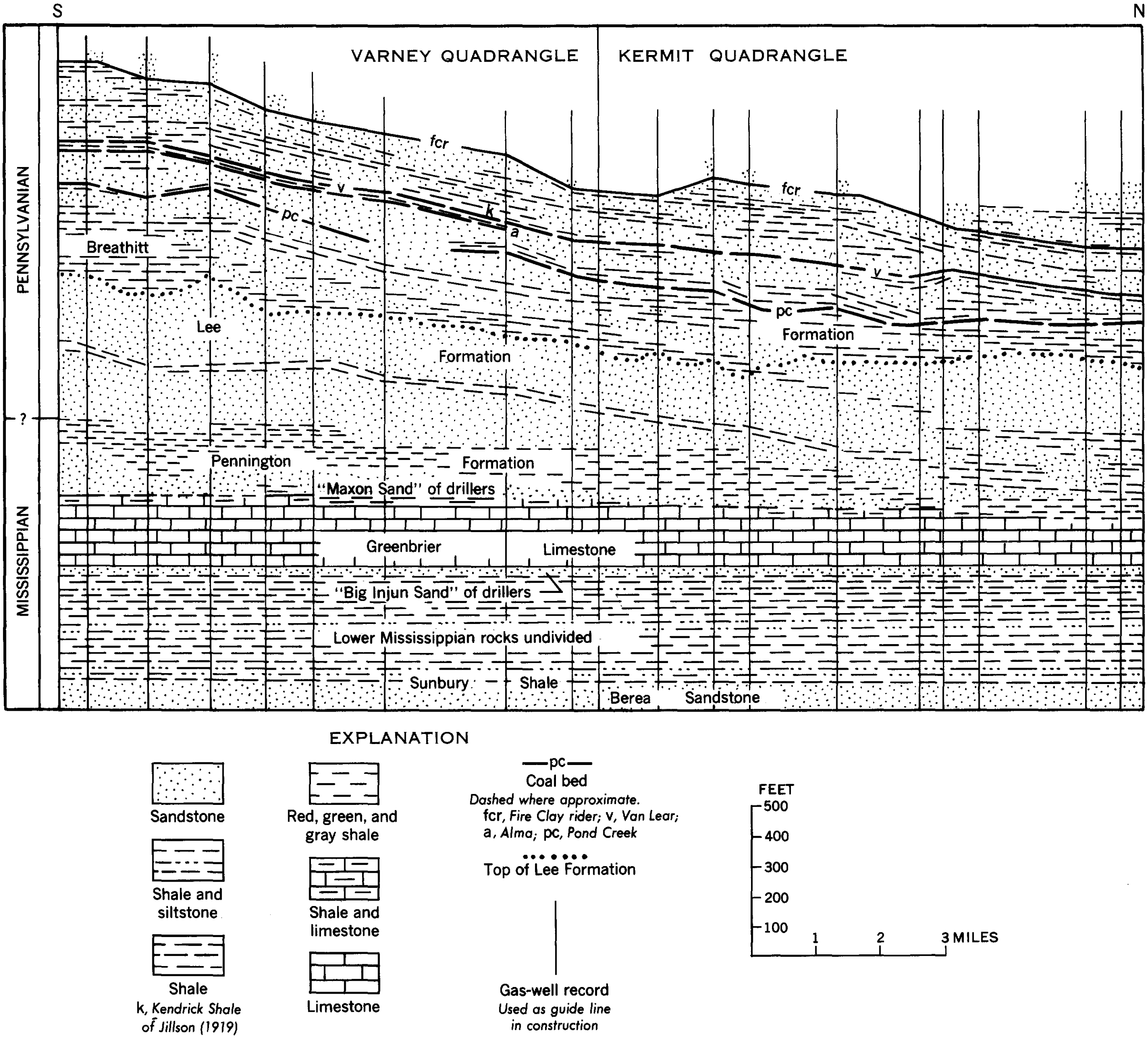

FIGURE 9.—Diagrammatic section along the west side of Kermit and Varney quadrangles showing the northward thinning of the Lee and Breathitt Formations. Based on drillers' logs of gas wells.

rangle. Apparently it consists of three sandstone members which are separated by thin shale units. The line at the top of the Lee Formation is drawn arbitrarily at the top of the massive sandstone. Fingers of the Lee sandstone tongue southward into the Breathitt Formation, and the sandstone members overlap northward.

The lower member of the Lee Formation has an average thickness of 300 feet in the southern part of the Varney quadrangle. It thins to about 200 feet in the northern part of the Varney quadrangle and, in places, pinches out in the southern third of the Kermit quadrangle, but continues north to the northwest corner of the quadrangle as shown on figure 9. Along the west side of the Kermit quadrangle the shale between the lower and middle sandstone members of the Lee Formation is generally between 15 and 50 feet thick. In a few wells, drillers have reported coal which probably occurs in local pockets. In the northern part of the Kermit quadrangle, the shale unit may interfinger with red and gray shales and marine limestones of the Pennington Formation.

777-057 O—66——5

The middle sandstone member of the Lee Formation ranges in thickness from 0 to 300 feet along the west edge of the quadrangle. In other cross sections it seems to be continuous with the upper sandstone member. The distinctness of the upper sandstone member is therefore questionable. The upper sandstone is the youngest part of the Lee and seems, as shown on figure 9, to finger into the shale of the lower part of the Breathitt Formation. On the outcrop in Johnson County these transitional beds from Lee to Breathitt Formation are thin- to medium-bedded orthoquartzitic sandstones with little matrix. Beds as much as 10 feet thick have steeply inclined crossbeds. The thickness of the upper sandstone member ranges from 0 to 300 feet.

Isopach maps of the lower and middle sandstone members of the Lee Formation in the Varney quadrangle show no regional trends. None were drawn for the Kermit quadrangle.

BREATHITT FORMATION

The Breathitt Formation (Campbell, 1898) consists of shale, sandstone, siltstone, coal, seat rock, and a few beds of calcareous shale, limestone, and ironstone. It lies conformably on the Lee Formation and grades and fingers into the Lee laterally as shown on figure 9. In the Kermit-Varney area the maximum thickness is about 1,800 feet; but the top of the formation has been removed by erosion, and none of the overlying Conemaugh Formation is preserved.

For purposes of description and to provide units for a colored geologic map, the Breathitt Formation has been divided into five units. These units were chosen to correspond as nearly as possible to the formations in the Breathitt Group in the Ewing quadrangle, Kentucky (table 3). The formation names were not used because there is still doubt about the correlation of beds used as boundaries. The correlation of the Wallins Creek and Fire Clay coal beds is well established. The correlation of the Alma with the Harlan is probable, as is the correlation of the Magoffin Beds of Morse in the Kermit-Varney area and the Ewing quadrangle. The correlation of the Broas coal with any coal in the Bryson Formation is very doubtful.

STRATA BETWEEN THE BASE OF THE BREATHITT FORMATION AND BASE OF THE ALMA COAL BED

The strata between the base of the Breathitt Formation and base of the Alma coal bed are approximately equivalent to the Hance Formation of southeastern Kentucky. They range in thickness from 200 to 780 feet. Except for the rocks just below the Alma coal bed exposed near the mouth of Collins Creek in the Kermit quadrangle, these rocks are known only from cores and samples from bore holes and from the logs of gas and oil wells. The interval generally includes a shale near the base, a sandstone below the Pond Creek coal bed, the Pond Creek and rider coal beds, the Campbell Creek Limestone of White (1885), and a sandstone below the Alma coal bed. These units are shown in the graphic sections (pls. 6–8).

A study of gas-well logs shows a unit composed mainly of shale 200–300 feet thick in the basal part of this interval. This is the lowest widespread unit in the Breathitt Formation. Within and above the basal shale unit many well logs record thin sandstone beds, especially in the southern part of the Varney quadrangle. A widespread sandstone below the Pond Creek coal is 30–120 feet thick in the Varney quadrangle and in the southern third of the Kermit quadrangle, but it is generally absent to the north. Coal is reported in a few wells in the southern third of the Varney quadrangle less than 100 feet above base of the Breathitt Formation. Generally the first coal recorded is 160–300 feet above the base of the Breathitt Formation. The correlation and extent of these beds are unknown.

Logs of core holes drilled for coal, especially DH 13 and 24 (pl. 6) supply considerably more information about the sequence from 80 feet below the Pond Creek coal to the Alma coal than is gained from the gas-well logs. DH 13 cored interbedded shale and sandstone containing Lingulas and animal burrows, 60–70 feet below the Pond Creek coal bed. This may represent the Cannelton Limestone (Stockton) of White (1903, p. 586) described from Mingo County, W. Va., southeast of the Kermit-Varney area, by Hennen and Reger (1914, p. 195–197). The Cannelton Limestone is described as sparingly fossiliferous by Wanless (1939, p. 79). DH 1, 2, 13, and 24 (pl. 6) cored a coal zone comprising 2 thin coal beds separated by 15–20 feet of shale and sandstone at the approximate position of the Powelton coal bed of West Virginia (Hennen and Reger, 1914, p. 192–195). Coal, without a seat rock, is reported from DH 59 (pl. 8), 20 feet below the Pond Creek. This may be the Powellton coal, but correlation is uncertain. The concretionary limestone and calcareous shale overlying the Powellton coal grades upward into interbedded shale and ripple sandstone and is probably marine, even though no fossils were found. It was not reported in West Virginia.

The name Pond Creek was used by Hunt and others (1937, p. 19) for the coal bed mined on Pond Creek by the Fordson Co. in the Williamson quadrangle and is used in this report. Other names for the same coal bed include Lower Elkhorn (Wanless 1939, p. 99; Hunt and others 1937, p. 19) Campbell Creek, and No. 2 Gas of West Virginia (Hennen and Reger, 1914, p. 185–190). It has been miscorrelated with the Warfield by Hunt and others (1937, p. 19), Wanless (1939, p. 107), and Dowd and others (1951).

The Pond Creek and the Pond Creek rider coal beds are traceable in the core logs with reasonable assurance through most of the Varney quadrangle and the southern part of the Kermit quadrangle as shown in the graphic sections (pls. 6–8). The Pond Creek coal is recorded in the cores of coal prospect diamond-drill holes and in drillers' logs of gas wells in the northern part of the Meta quadrangle which adjoins the Varney quadrangle on the south and in the southern part of the Varney quadrangle. The coal bed thins northward. A shale 50–100 feet thick in the stratigraphic position of the Pond Creek coal is recorded in logs of gas wells in the Kermit quadrangle and the northern part of the Varney quadrangle.

The rock between the Pond Creek and its rider bed ranges in thickness from 3 to 30 feet and consists of sandstone, shale, and siltstone. The relationship of the rider to the main coal bed is not everywhere clear, and the rider may be a split of the main seam. Furthermore, recognition of coal beds within this zone is uncertain locally because DH 59 (pl. 8) reveals a coal bed only 20 feet below the Pond Creek, and DH 13 (pl. 6) indicates four splits of the Pond Creek and its rider coal.

The Campbell Creek Limestone of White (1903, p. 599) consists of discrete siliceous or silty lenticular, calcareous, and sideritic concretions, as large as 4 feet in diameter, that occur locally in calcareous silty shale. As described by Hennen and Reger (1914, p. 185) in Logan and Mingo Counties, W. Va., the name Campbell Creek Limestone refers only to the concretions. In this report the name is used informally to refer to both the concretions and the enclosing rocks, above the Pond Creek coal zone, which are generally shale and siltstone. The unit ranges in thickness from 0 to 80 feet and averages about 30 feet. Burrows and plant fossils were found in three of the cores (pls. 6, 7), and the rocks probably were deposited in marine or brackish water. Ironstone concretions are common, and some of the shale in calcareous. In a few cores thin coal beds and seat rock as well as plant-bearing shale are associated with the ironstone and calcareous concretions. Lenses of sandstone are recorded in several cores; some of these lenses have calcareous and sideritic cement.

The strata between the Campbell Creek Limestone of White (1885) and the Alma coal bed consist mainly of sandstone ranging in thickness from 3 to 120 feet. Apparently this persistent sandstone consists of two or more channel-fill and associated sheet-phase units. Sheet-phase beds are described from the cores of DH 14, 20, 33 and 58 and are suggested by some of the drillers' logs especially DH 55 and 56. This sandstone may correlate with the Logan Sandstone of Hennen and Reger (1914, p. 178–179) in Logan and Mingo Counties, W. Va. Locally, it may include the equivalent of an older sandstone body which was called the Peerless Sandstone by Krebs and Teets (1914, p. 281). In the type area in Kanawaha County, W. Va., the Peerless lies between the Campbell Creek coal and the Little Alma coal bed. Possibly the coal bed above the Campbell Creek Limestone of White in DH 33 is the local equivalent of the Little Alma coal bed. If this correlation is correct, the equivalent of the Peerless Sandstone would be 15 feet thick in DH 33 and 35 feet thick in DH 48.

STRATA BETWEEN THE BASE OF THE ALMA COAL BED AND THE FIRE CLAY COAL BED

The strata between the Alma and Fire Clay coal beds are 200–330 feet thick and are approximately equivalent to the Mingo Formation of the Middlesboro area, Kentucky, as named by Ashley and Glenn (1906, p. 33) and as used by Englund and others (1961). The base of rocks approximately equivalent to the Mingo in the Kermit-Varney area is the base of the widespread Upper Elkhorn coal zone of eastern Kentucky. The Upper Elkhorn coal zone, which includes the Alma coal at the base, is overlain by the Elkins Fork Shale of Morse. The Upper Elkhorn coal zone ranges in thickness from 30 to 50 feet over most of the Kermit-Varney quadrangles, but it is as much as 120 feet thick in the southern part of the Varney quadrangle. The Upper Elkhorn coal zone contains 2–5 coal beds, some of which may be splits or riders of one or more of the main coal beds. These beds were numbered 1, 2, and 3 by Hunt and others (1937, p. 20–22). These numbers together with one-half numbers for intervening beds are used locally by coal companies.

In the Kermit-Varney area persistent coal beds lie at both the top and the base of the Upper Elkhorn zone as here defined. The bed at the base is the Alma; the top bed is either the Van Lear rider coal bed or the Van Lear if the rider is absent. The name Van Lear has long been used in Johnson County, Ky., and is used by Hauser (1953, 1958) in his reports on the Paintsville and Prestonsburg quadrangles.

The Alma coal bed and the rocks just below it are the oldest part of the Breathitt Formation exposed in the Kermit and Varney quadrangles. Crandall (1905, p. 44, 1910, p. 37), following local usage, used the name Warfield for the coal bed mined near Warfield, and across Tug Fork at Kermit, W. Va. The name Alma coal (Hennen and Reger, 1914, p. 177–178) is more widely used than Warfield and is chosen for use in this report. The exposures of the Alma coal bed in Collins

Branch and along Tug Fork between Warfield and Lovely (Kermit quadrangle) occur along the highest part of the Warfield anticline, and the bed is repeated at the mouth of Buck Branch on Wolf Creek by the Warfield fault. Elsewhere in the Kermit and Varney quadrangles the Alma coal bed is below stream level. Core drilling has demonstrated that the Alma coal is thick in only one small area (pl. 12) and that the bed is both thin and split in most of the Varney quadrangle. In the core holes shown on plates 6–8, the Alma coal bed is traced with reasonable assurance.

The correlation of the Alma coal bed with beds in adjacent areas is difficult because the coal cannot be traced on the surface. Generally the Alma coal bed at Warfield has been correlated with the Lower Elkhorn and Pond Creek coal bed in Kentucky and the No. 2 Gas or Campbell Creek of West Virginia (Wanless, 1939, p. 107). Wallace and others (1954), however, using information obtained by core drilling correlated the Warfield coal bed with the Alma coal bed of Hennen and Reger (1914, p. 177–178) in West Virginia. A study of the cores drilled in the Kermit-Varney area and adjacent area confirms the correlation of the Warfield coal bed with Alma and indicates a correlation with the Upper Elkhorn No. 1 of Hunt and others (1937) and Harris (in Huddle and others, 1963).

The main units in the interval between the Alma coal bed and the Fire Clay coal bed are: the Upper Elkhorn coal zone, Elkins Fork Shale of Morse, sandstone above the Elkins Fork, Williamson and rider coal beds, Kendrick Shale of Jillson, sandstone over the Kendrick, Dingess and Whitesburg coal zones, marine zone over the Whitesburg coal, and the sandstone above the marine zone. These units are shown graphically on plates 6–8.

Near Warfield a channel sandstone 20–40 feet thick overlies the Alma coal bed. This sandstone, which is shown in several cores on plates 6–8, and in DH 5 and 10, occupies the approximate position of the Lower Cedar Grove Sandstone of Hennen and Reger (1914, p. 175). In the DH 2 the Alma coal bed is apparently completely removed and replaced by one or more sandstone deposits. However, the driller may have missed the seat rock representing the position of the Alma coal bed in DH 2.

In several cores represented in section 5 and in cores from DH 4 and 6, the rock just above the Alma coal is shale and siltstone that contain ironstone concretions, plant fossils, worm burrows, and slump zones. The shale is probably the Dwale Shale of Morse, from which he reported Lingulas. Morse (1931, p. 296) proposed the name Dwale for the shale over the Prestonsburg No. 1 coal bed at Dwale in the Harold (7½-minute) topographic quadrangle. Probably the Prestonsburg No. 1 coal is the Alma, but the correlation is not firmly established. If, however, the Van Lear coal bed of this report is the Prestonsburg No. 1 coal bed, the Dwale Shale is a synonym of Elkins Fork Shale of Morse. The Dwale is a synonym of the Campbell Creek Limestone of White if the Prestonsburg No. 1 coal is the Pond Creek coal bed, which is also possible.

The correlation of the coal bed or beds in the Upper Elkhorn coal zone between the Alma and Van Lear coal beds is uncertain. An upper split of the Alma or a rider bed is present in some cores, and a lower split of the Van Lear coal, or a separate coal bed, is present in a number of cores. These coal beds, or one of them, might be regarded as the Upper Elkhorn No. 2 of Hunt and others (1937) and as the Lower Cedar Grove of West Virginia, but regionally they are probably splits of either the Alma below or the Van Lear above, and perhaps locally are splits of both. Detailed paleontologic studies of the spores and petrographic studies of the coal might solve this problem. The names "Alma rider" and "Lower Van Lear" are used in this report to designate coal beds within the Upper Elkhorn coal zone. The lower split of the Van Lear is a persistent, thin coal as shown on plates 6–8. Probably this split joins the main bench where the Van Lear is thickest. Shale, siltstone, and sandstone occupy the interval between the lower and upper splits of the Van Lear. The Van Lear coal bed was seen at only a few localities, mostly along the road in the cuts north and west of Warfield. It was mined at one locality on the south side of Wolf Creek east of the mouth of Buck Branch in the Kermit quadrangle.

The Van Lear rider coal at the top of the Upper Elkhorn coal zone lies 5–50 feet above the Van Lear coal bed and just below the Elkins Fork Shale of Morse. The rider coal apparently is split again in DH 44 (pl. 7). The strata between the Van Lear and the rider coal beds are generally shale, siltstone, and seat rock, but in the southern part of the Varney quadrangle a channel sandstone occupies part of the interval. To the south in Pike County this rider coal is above a thick sandstone and may be the coal bed commonly called Upper Elkhorn No. 3½ coal bed in places, but in other places the Upper Elkhorn No. 3½ is the Williamson coal. Owing to the southward thickening of the section, it is possible that the coal here called the Van Lear rider is the Upper Elkhorn No. 3, and the Van Lear of this report is the Upper Elkhorn No. 2 of Hunt and others 1937 in south-central Pike County. Harris (in Huddle and others, 1963) has pointed out this possibility.

The Van Lear coal bed of this report is probably equivalent to the Upper Elkhorn No. 3, Little Caney, and Darby coal beds of Kentucky. These correlations are tenuous because these names have not been used consistently. The regional continuity of the Upper Elkhorn coal zone is reasonably well established, but the individual beds are difficult to correlate.

The Elkins Fork Shale of Morse overlies the Van Lear rider coal bed or, where the rider is absent, the Van Lear coal bed. It is exposed in Elkins Fork and Big Creek in the Varney quadrangle and along the Tug Fork and Elk Creek north of Warfield in the Kermit quadrangle. Along Highway 40 between Beauty and Warfield, it ranges in thickness from 0 to 75 feet and consists mainly of shale with some siltstone and sandstone beds. The unit is calcareous in part and contains numerous ironstone concretions. Morse (1931, p. 297) designated the type section at the Elkins Fork school in the Williamson quadrangle (15-minute). In 1954 the school building was being used as a church; the school is shown by a church symbol on the 1954 edition of the Varney topographic quadrangle map. The building was torn down about 1960, and road construction has concealed the beds from which Morse collected fossils. Huddle found only a few poorly preserved pelecypods in siltstone in the roadcut at the type locality. Well-preserved productids and other brachiopods are abundant in shale and poorly bedded sandstone exposed in the roadcut opposite the Dunkard Church on Elkins Fork north of the mouth of the Rockhouse Fork. The shale is well exposed at several places along Elkins Fork and its tributaries and in the roadcuts. Generally the unit is mainly silty or sandy shale, but in places, as in DH 35, channel sandstone is present. There are strongly rippled beds in DH 20 and poorly bedded ferruginous sandstone with many burrows are common. Large discoidal concretions of limestone, 2–6 feet in diameter, are sparse but distinctive, because persistent beds of ironstone 0–3 inches thick extend across the concretions and into the enclosing rock. Similar ironstone beds have not been found in other concretions in the Kermit-Varney area. Fossils were found in DH 24, 33, and 35.

The fauna of the Elkins Fork Shale, as pointed out by Morse (1931, p. 297), is generally dominated by a single species of productid, although other brachiopods and some mollusks are present. A species of *Linoproductus* is very abundant on Elkins Fork in the Varney quadrangle and in the bed of Sycamore Creek at the mouth of Jerry Fork in the northeastern corner of the Broad Bottom quadrangle. A similar abundance of linoproductids was found by D. E. Wolcott in the Elkins Fork Shale in Bent Branch near BM 892 in the Meta quadrangle. Marginiferas are also common at these localities. Lingulas were found in the Elkins Fork north of Warfield, but at many localities no fossils were found. Locally, the Elkins Fork Shale is distinguished from other marine beds in the area by the calcareous concretions with bedded ironstone, by the abundance of productids, and by burrowed beds, although these features are not distinctive regionally. The Elkins Fork Shale in this area is about 50 feet below the similar marine Kendrick Shale, with which it is easily confused. It probably correlates with the Seth Limestone of Krebs and Teets (1914), according to Wanless (1939, p. 43).

The core samples containing burrows (DH 58) may belong in the Elkins Fork Shale, or they may be from the blanket phase of the channel sandstone to the north. The Elkins Fork Shale and overlying rocks are well exposed in the roadcuts along Tug Fork north of Warfield. A thin coal bed and seat rock lie just below the channel sandstone (as in DH 24) at the top of the Elkins Fork Shale at most places, but they are cut out locally by a disconformable channel sandstone. Possibly the channel sandstone is disconformable on the Elkins Fork Shale locally, and elsewhere interfingers with it in the interchannel area where sheet deposits were laid down. However, the local presence of a coal bed at the top of the Elkins Fork suggests that the Elkins Fork is a separate and an older lithologic unit than the interchannel or sheet phase of the channel sandstone.

In the Kermit quadrangle and northern part of the Varney quadrangle the rock overlying the Elkins Fork Shale is a channel sandstone, but it apparently grades into a siltstone and shaly sandstone in the southern third of the Varney quadrangle. It is generally 20–40 feet thick, but is as much as 80 feet thick locally. There are good exposures of this sandstone along Big Creek in the Varney quadrangle. It was named the Upper Cedar Grove Sandstone by Hennen and Reger (1914, p. 169), who report that it forms a prominent bench below the Williamson coal along Tug Fork in Mingo County, W. Va. This sandstone is overlain by the Williamson coal bed and seat rock.

The Williamson is a thick coal bed containing abundant pyrite in the eastern edge of the Varney quadrangle where it has been extensively mined; it is easily recognized by the large quantities of acidic rusty water and rusty stain on the coal and dumps. Figure 10 shows the rocks above and below the Williamson coal and a small thrust fault in the coal bed. In the rest of the Varney and Kermit quadrangles the Williamson either is split or, as is more probable, there is a rider coal. Shale or siltstone 0–25 feet thick generally separates the Williamson and its rider, but sandstone occupies the interval in DH 13, 20, 24, and 44. The name Williamson, which was given the bed by Hennen

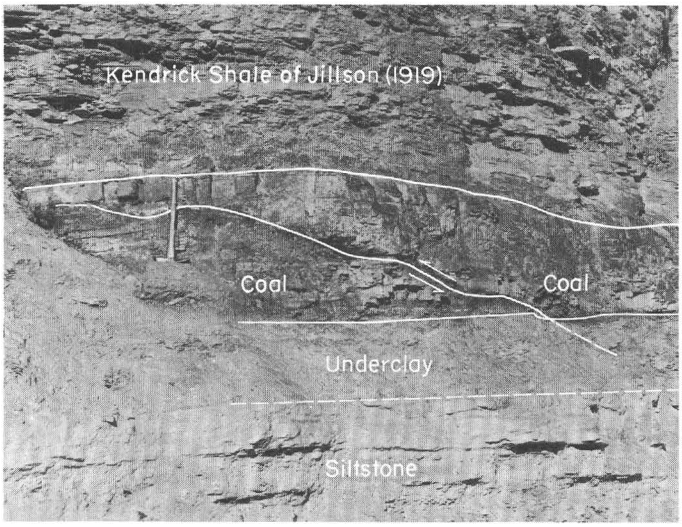

FIGURE 10.—Small thrust fault in the Williamson coal bed exposed in roadcut on Big Creek north of BM 682 on bend in road. Varney quadrangle, Kentucky.

and Reger (1914, p. 166–168), is used in this report because it is a valid local name. It is equivalent to the Amburgy, Cannel City, Gun Creek coal beds of eastern Kentucky (Huddle and others, 1963).

Strata between the Williamson and the Dingess coal beds include primarily the Kendrick Shale of Jillson and the channel sandstone called Williamson Sandstone by Hennen and Reger (1914, p. 165). The Kendrick Shale of Jillson is correlated with the Dingess Limestone of Hennen and Reger (1914, p. 165–166).

The Kendrick Shale ranges in thickness from 0 to 45 feet in the Kermit-Varney area. It is well exposed in Elk Creek and Blacklog Fork in the Kermit quadrangle and in Big Creek and Brushy Fork near the mouth of its Left Fork in the Varney quadrangle. At these localities it is primarily a silty calcareous shale with thin to massive poorly laminated sandy beds.

A sample of sandy limestone with abundant animal burrows from the Kendrick Shale was collected in a roadcut east of Heenon near BM 724 in the Varney quadrangle. A thin section of the sample was examined by R. A. Sheppard (written commun., 1961), who reports that the rock is composed of 56 percent matrix or cement, 40 percent detritals, 5 percent fossil fragments, and less than 1 percent each of oolites, carbonate pellets, and collophane. The granular carbonate cement, probably calcite, completely surrounds and partly replaces detrital quartz grains and fossils. The detrital grains are concentrated in irregular patches, owing to the activities of burrowing organisms which mixed detrital-rich and carbonate-rich laminae. The average grain size is 0.1 mm. Detrital grains, in the order of decreasing abundance, are quartz, feldspar, muscovite, chert, siltstone and shale fragments, chlorite, carbonaceous fragments, sphene, zircon, tourmaline, and garnet. The fossils found include brachiopods, pelecypods, ostracodes, and holothuroid sclerites including hooks, wheels, and sieve platelike types. The rock in hand specimen presents a massive appearance, and individual burrows are not easily traced.

A sample of a Kendrick Shale concretion from the forks of Brushy Fork in the Varney quadrangle was also studied in thin section by R. A. Sheppard (written commun., 1961). He reports that the nodule consists of 20 percent detrital grains, 11 percent fossil fragments, and 69 percent matrix or cement. The matrix consists of finely granular carbonate, probably calcite, irregular coarsely granular iron-oxide-stained carbonate, probably siderite, with minor amounts of clay and pyrite. Pyrite replaces some fossils fragments. The detrital material includes, in decreasing order of abundance, angular quartz, feldspar, muscovite, chert, siltstone and shale fragments, chlorite, biotite, sphene, zircon, and tourmaline. The average grain size is 0.07 mm. The fossils include brachiopods, pelecypods, ostracodes, and holothuroid sclerites. Some fossils are filled with coarsely granular calcite. Collophane, probably from phosphatic brachiopods, forms about one percent of the rock.

Fossils are abundant in the Kendrick Shale locally, but generally the rock contains only a few *Lingula* or *Orbiculoidea*. Abundant calcareous brachiopods and other fossils were found at the Kendrick type locality (Jillson, 1919, p. 96–104; Morse, 1931, p. 293–361). Summerson and Campbell (1958) described holothurian sclerites from the Kendrick Shale at the type locality. Fossils are abundant at several localities in the southern and eastern parts of the Varney quadrangle. Along Big Creek a poorly sorted ferruginous dark-gray sandstone, 1–2 feet thick, lies on or within 3 feet of the top of the Williamson coal. This sandstone bed generally is calcareous, contains pyrite, fusain, plant trash, and Lingulas, orbiculoids, and, locally, Spirifers and other calcareous brachiopods. This fossiliferous sandstone aids in the identification of the Williamson coal in the Big Creek area. Massive silty slightly calcareous shale containing abundant *Chonetes* and other fossils is exposed in the roof rock at the entrance to several of the old truck mines along Big Creek.

E. L. Yochelson (written commun., 1960) identified the following fossils from a collection (18333–PC) made from the rock in the roof of the Williamson coal at a truck mine on the east side of Big Branch opposite the mouth of Elkins Fork:

Orbiculoidea	*Astartella*?
Derbyia	*Aviculopecten*
Chonetes	Bellerophontacean gastropod indet.
Linoproductus	*Trepospira*?
Marginifera	"*Glabrocingulum*", indet. mollusk (possibly a gastropod)
Neospirifer	Coiled nautiloid cephalopod, undet.
Composita	Pseudorthoceroid cephalopod, undet.
Composita? (small)	Large pelecypod or cephalopod fragment, indet.
Brachiopods? indet.	
Sanguinolites	
Sanguinolites or *Allorisma*	
Sanguinolites? (small)	
"*Schizodus*"	

At Forks of Brush Fork of Johns Creek (18332–PC) the following were identified by E. L. Yochelson (written commun., 1960):

Orbiculoidea	*Aviculopecten*? "*Pteria*"
Derbyia	Bellerophontacean gastropod indet.
Chonetes	*Straparolus* (*Euomphalus*?)
Linoproductus	*Trepospira*
Marginifera	*Glabrocingulum*?
Composita	"*Strobzeus*"
Composita? (small)	Gastropod, indet.
Neospirifer	Coiled nautiloid cephalopod, undet.
Wellerella	Pseudorthoceroid cephalopod, indet.
Brachiopod, undet.	Ammonite cephalopod, indet.
Sanguinolites or *Allorisma*	Plant fragments, indet.
Sanguinolites? sp. (small)	
"*Schizodus*"	
Aviculopecten	

Abundant moderately well-preserved plants were collected at this locality.

E. L. Yochelson (written commun. 1960) reports:

These collections appear to represent a marine shallow-water nearshore environment. The bases for this speculation are

1. The collections contain marine fossils, particularly productoid brachiopods.
2. The collections are composed predominately of mollusks, not brachiopods. Other typical marine elements, such as corals, bryozoans and echinoderms, are absent. From comparisons with paleogeography, as interpreted in other areas for the late Paleozoic, there is some reason to think that assemblages dominated by mollusks characterize shallow water conditions. In addition, a few of the cephalopods retain color markings, a further indication of shallow water.
3. The relatively coarse nature of the sediment suggests near shore deposition.

The slit-bearing gastropods, *Trepospira* and bellerophontaceans, suggest a bottom that was firm enough for the animals to crawl around on without much stirring of sediment. That is, it was not an ooze. On the other hand, it was easy for burrowing clams to dig into. The diet of the clams would have been limited to food particles that could be drawn into the shells through the siphons. The large number of burrowing clams in the assemblage suggests that the water was relatively rich in nutrients; this also suggests shallow-water conditions.

The Williamson Sandstone of Hennen and Reger overlying the Kendrick Shale ranges in thickness from 0 to 60 feet; generally only the channel phase is exposed, and the base is disconformable on the Kendrick Shale or Williamson coal bed. However, at many roadcuts and mine entrances along Big Creek the Kendrick Shale seems to grade upward through silty and sandy shale to sandstone. The channel-phase sandstone is crossbedded and contains shale and ironstone-pebble conglomerate. Abundant coal spars that represent log jams are generally present in the basal parts, and calcareous masses or "concretions" are common throughout.

The first coal above Williamson coal bed has been called the Dingess coal in this report, a name proposed by Hennen and Reger (1914, p. 164). As shown on plates 6–8, the Dingess is generally a thin coal bed and is absent in DH 39. In much of the area it is separated from the overlying Lower Whitesburg coal by 10–15 feet of thin-bedded sandstone, but locally only shale occupies the interval. The sandstone between the coals is called the Naugatuck Sandstone by Hennen and Reger (1914, p. 163), and they report 20–40 feet of Naugatuck Sandstone in Mingo County, W. Va. In the area near DH 33 (pl. 7) there appears to have been an almost continuous peat-forming swamp from the time of deposition of Dingess coal until Upper Whitesburg peat accumulation ceased. Possibly all the Whitesburg and the Dingess coal beds are splits of the same bed, but to the south they are separated by 30–60 feet of rocks and need individual designation. The zone of the Whitesburg coals is widely traceable throughout eastern Kentucky (Huddle and others, 1963).

The Lower Whitesburg coal of this report is probably the Hernshaw coal of Hennen and Reger (1914, p. 156–163, coal section given on p. 164) and is in or near the Kermit quadrangle. Generally it is a thin coal bed separated by plant-bearing shale, very thin coal laminae, seat rock, and siltstone from the more persistent Upper Whitesburg coal bed. The abundance of fossil leaves and thin vitrain compressions of trunks and stems in the dark-gray to black shale above the Lower Whitesburg is an aid in identifying the Whitesburg coal beds. *Lingula* and *Orbiculoidea* also are found in this shale at the roadcut opposite Rattlesnake Hollow of Little Rock Castle and along Kentucky Highway 40 roadcuts on Blacklog Fork, Kermit quadrangle. Plant fossils are abundant at no other zone below the Magoffin Beds of Morse in the Kermit-Varney area.

The Upper Whitesburg coal bed is generally a thin coal overlain by a sandstone. The Upper Whitesburg of this report is the Little Chilton coal of Hennen and

Reger (1914, p. 151). It is a persistent bed and has been mined for household use in the Long Branch and Billy Lowe Branch in the southwestern corner of the Varney quadrangle and extensively north of Wolf Creek in the Kermit quadrangle. On Brushy Fork in Varney and Meta quadrangles it is exposed in many roadcuts. Marine fossils were found above the Upper Whitesburg coal where the bed goes under Hobbs Fork in central Varney quadrangle. They are internal molds of pelecypods preserved as siderite concretions. Standing plant trunks and stumps are present on Long Branch over the Lower Whitesburg coal (fig. 11) at the Hobbs Fork locality mentioned above. Worm rock(?) was noted by Henen and Reger (1914, p. 164) above the Hernshaw coal in the southern part of West Virginia part of Kermit quadrangle. DH 23 (pl. 4) also shows "worm burrows." The presence of standing trees associated with coal beds and marine and brackish-water fossils seem to indicate shallow-water deposition. Hennen and Reger (1914, p. 155–156) reported a sandstone, the Hernshaw, between the Lower Whitesburg (Hernshaw coal) and Upper Whitesburg (Little Chilton) at the mouth of Parstey Big Branch near the eastern edge of the Kermit quadrangle just north of Tug Fork near Long Branch. Elsewhere in the Kermit-Varney area this sandstone seems to be thin or is absent.

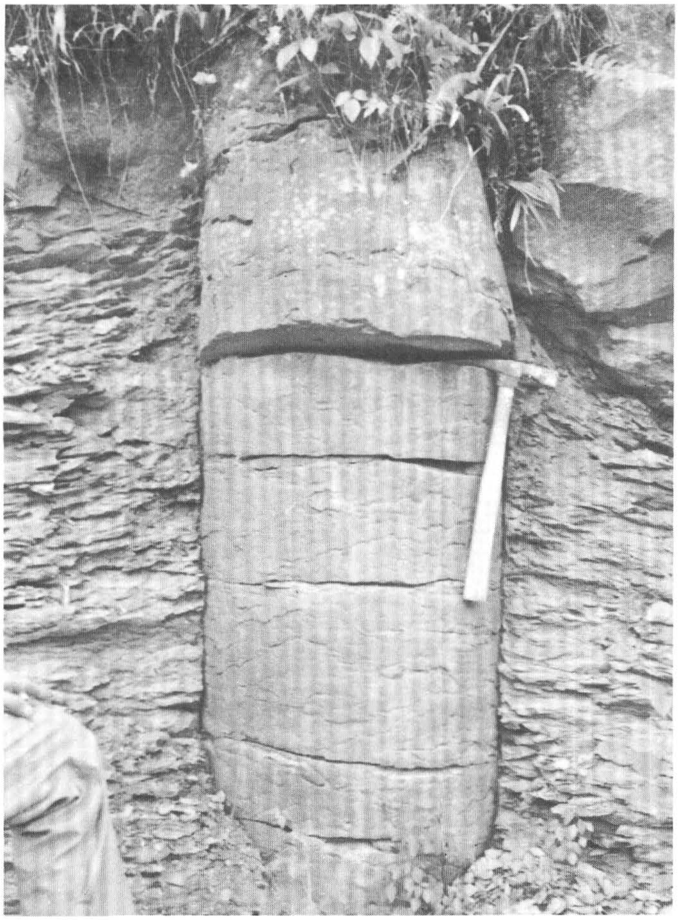

FIGURE 11.—Cast of an upright tree trunk. The tree was apparently rooted in the Lower Whitesburg coal bed and extends upward almost to the Upper Whitesburg coal bed. The cortex of the tree is preserved as a thin film of vitrain between the cast and the external mold. Note the differential compaction of the shale by overlying sandstone. Standing tree trunks indicate rapid deposition. Exposure in roadcut, Long Branch, Ky.

The rock over the Upper Whitesburg coal is generally a sandstone, called the Lower Chilton Sandstone by Hennen and Reger (1914, p. 150). This is one of the persistent sandstone horizons in eastern Kentucky. As shown on plates 4–7, the massive channel phase of this sandstone is present in the Beauty section and in DH 12, 20, 23, 33, 35, 44, and 58. The interchannel or sheet phase shown in DH 13 and 24 is composed of thin-bedded sandstone and shale with plant fossils and worm-burrow zones. The channel phase commonly crops out, but the interchannel phase is rarely exposed.

STRATA BETWEEN THE BASE OF FIRE CLAY COAL BED AND BASE OF MAGOFFIN BEDS OF MORSE (1931)

The strata between the base of Fire Clay and Magoffin Beds of Morse are approximately equivalent to the Catron Formation of southeastern Kentucky (Englund and others, 1961). They thicken southward from 60 to 140 feet. In the Kermit-Varney area most of the interval is occupied by sandstone. The interval includes the Fire Clay and Fire Clay rider coal beds, a marine zone over the Fire Clay coal bed, a sandstone over the Fire Clay rider bed, the Hamlin coal bed, and the Taylor coal just below the Magoffin Beds of Morse.

The Fire Clay coal bed is the most persistent recognizable bed in eastern Kentucky (Huddle and others, 1963). It is equivalent to the Hyden, Hazzard No. 4, Wallins Creek, Dean, and Poplar Creek coal beds in Kentucky; the Windrock in Tennessee; the Phillips in Virginia; and the Chilton in West Virginia. The Fire Clay and Fire Clay rider coal beds are near creek level and are easily traced in much of the Varney quadrangle and the southern part of the Kermit quadrangle.

The Fire Clay coal is a key bed because of its peculiar flint-clay parting. This parting is generally dark gray or dark brown and ranges in thickness from less than 1 inch to 6 inches. Everywhere in the Kermit-Varney area the flint clay is in the lower part of the coal bed, and at some localities it is at the bottom of the bed. The coal below the flint-clay parting is generally a dull attrital coal with few vitrain bands and contains a high percentage of ash at many localities. The flint-clay parting is enclosed in bony coal at many places and is difficult to distinguish between bony coal and flint clay. The conchoidal fracture, brown mottled color, pellet structure, and hardness are keys to the recognition of the flint clay. In the Kermit-Varney area the Fire Clay coal bed is sometimes mined for household use; but where mined, usually only the coal above the flint clay is taken. The Fire Clay coal bed was seen at a few localities in the tributaries of Elk Fork, but it is generally a thin coal with high ash and has not been much prospected in the areas where the Upper Whitesburg coal is conveniently mined for home use.

The rocks between the Fire Clay and the Fire Clay rider coal beds range in thickness from 2 to 40 feet and consist of shale, sandstone, and siltstone. Where the interval between the Fire Clay and the rider is small, the rider is split into several thin coal beds, and the intervening beds are separated by light- and dark-gray shales with abundant plants and stigmarian roots and underclays. The interval between the benches is 54 inches at locality 9 (Hunt and others, 1937, pl. 1) on Halfway Branch where the Fire Clay and benches of the rider were mined as one coal bed, in Peachtree Fork of Swinge Camp Branch on Hobbs Fork at locality 66, and eastward in the headwaters of Hobbs Fork and its tributaries. DH 13, 33, and 44 show a typical sequence of coal benches, shale, and siltstone between the Fire Clay and the rider. Locally 10–20 feet of channel-fill sandstone immediately overlies the Fire Clay coal, as is seen in the southern part of the Varney quadrangle (coal sections 82, 83, 84; DH 58, pl. 7).

The Fire Clay rider coal bed is a thick minable coal bed in the area near the forks of Brushy Fork, in Meathouse Creek, Petercave Fork, and Pigeonroost Fork in the Varney quadrangle and in the Wolf Creek area west of the mouth of Pigeonroost Fork in the Kermit quadrangle. Elsewhere, it is split into several beds, as is well shown in the cut along the road west of Varney on the Left Fork of Brushy. Here several sandstone, siltstone, and shale beds 1–10 feet thick intervene between coal beds. In the roadcuts east of Hurricane on Brushy School a sandstone containing trunks of trees separates the splits of the Fire Clay rider coal bed. This sandstone may be equivalent to the sandstone parting in the Fire Clay rider coal bed 1–3 miles northwest of the school and to the siltstone at locality 73. At some localities it is not possible to determine whether an individual coal bed is a split of the Fire Clay rider coal or one of the splits of the overlying Hamlin coal. The Fire Clay rider coal was called the Chilton rider coal by Henen and Reger (1914, p. 148).

Marine and brackish-water fossils occur in the rocks just overlying the Fire Clay rider coal. The rider coal crops out along the road on the Kentucky side of Tug Fork from the mouth of Long Branch (Kermit quadrangle) to a short distance south of Lovely and in roadcuts south of Kermit on Highway 52 in West Virginia. The rock in the marine zone above the Fire Clay rider coal is a dark-gray ferruginous silty shale and sandstone containing fragments of Lingulas, orbiculoids, plant material, and animal burrows. Fossil leaves are present over Fire Clay rider coal at the point the bed goes below Petercave Fork in the Varney quadrangle and along Meathouse Creek. At several cuts on the Kentucky side of Tug Fork, Spirifers and linoproductids are present in a light-gray sandstone which seems to have been modified by burrowing animals reworking an organic rich sand. This Spirifer-bearing bed is limonite-stained toward the base and is probably ferruginous. Orbiculoids occur in the silty shale above the Fire Clay rider coal in the roadcut at the junction near the Head of Emily Creek School (abandoned 1958) and in the tributary to the Left Fork of Brushy about one-half mile north of Hurricane on Brushy School. A diligent search probably would show an even more widespread distribution of brachiopods in the roof shales of the Fire Clay rider coal bed. This marine zone probably marks the inundation that ended the Fire Clay and Fire Clay rider coal swamps. The zone of marine fossils is widespread in eastern Kentucky (Huddle, 1953, fig. 23).

Sandstone comprises most of the interval between the Fire Clay rider coal bed and the Taylor coal bed. This sandstone, which ranges in thickness from 30 to 90 feet, forms a prominent bench in the tributaries of Pigeonroost Fork and crops out in the beds of many of the small tributaries. In much of the area the sandstone seems to be a single massive unit; but as suggested by bedding changes and by the presence of one of the splits of the Hamlin coal in the Beauty section, the sandstone is a compound channel sandstone. At least one and probably two splits of the Hamlin coal are present. These splits are less than 14 inches in thickness at nearly all localities. Possibly the Hamlin coal bed of this report is the Chilton "A" of Hennen and Reger (1914, p. 146–147). If this correlation is correct, the sandstone below the Hamlin coal beds would be the Upper Chilton Sandstone of Hennen and Reger (1914) and the upper part would be the Lower Winifrede Sandstone. Hennen and Reger (1914, p. 147) give an interval of 75–100 feet from the Chilton coal to the Chilton "A" coal. This interval suggests that the Chilton "A" is the Taylor coal of this report, and that the Upper Chilton Sandstone includes both the sandstone below the Hamlin coal bed and the sandstone above. This sandstone has two or more calcareous zones and several zones of "coal spars" and ironstone and shale-pebble conglomerates. The coal spar zones are at the position of the Hamlin coal beds in some core holes. The top of the sandstone

777-057 O—66——6

grades into the seat rock of the Taylor coal bed. Generally the upper 1–6 feet of the sandstone unit is fine grained, poorly bedded, and contains stigmarian roots. Very little argillaceous seat rock lies below the Taylor coal; generally not more than 4 inches can be classified as undercaly.

The Taylor coal (Hunt and others, 1937) immediately overlies a sandstone 30–90 feet thick and underlies the Magoffin Beds of Morse. It ranges in thickness from 0 to 43 inches. It is a multibedded seam with partings of shale, seat rock, and bony coal. Pyrite as nodules and as crystals disseminated through the coal is common. The Taylor was traced northward along Emily Creek to the mouth of White Oak Fork of Emily Creek. Between the mouth of White Oak and Pilgrim the interval between the Fire Clay and Taylor thins considerably. A similar change occurs along Pigeonroost Fork of Wolf Creek in the Kermit quadrangle. Here the Taylor is not positively correlated because the Magoffin Beds are absent at many localities, and the black fissile shale that forms the roof in Emily Creek and Pigeonroost Fork areas is also absent. The Taylor may have been confused with a Hamlin or younger coal bed at some localities. Where the Taylor coal is thick, it is composed of several coalesced beds. Locally the Taylor may include splits of the Hamlin coal bed. The Taylor coal bed is about the same position as the Copland coal of Morse (1931, p. 303) and probably is the Chilton "A" of Hennen and Reger (1914, p. 146–147).

STRATA BETWEEN THE BASE OF THE MAGOFFIN BEDS OF MORSE (1931) AND THE BROAS COAL BED

The rocks in the Breathitt Formation above the Taylor coal bed are probably equivalent to the Hignite and Bryson Formations of Ashley and Glen (1906) in southeastern Kentucky. This unit may contain rocks of Allegheny age (Wanless, 1939, p. 52); but the correlation is still in doubt, and the classification in West Virginia and Ohio is not in agreement. Collections of fossil leaves and spores made in the course of this field work have not been studied. The rocks above the Magoffin Beds are high on the hills in much of the Kermit-Varney area and in much of Kentucky. Consequently, they are poorly exposed, difficult to correlate, and not satisfactorily traced by mapping.

This interval includes the Magoffin Beds; the Trace Fork, Young(?), and Haddix coal zone and associated rocks; the Winifrede coal bed and overlying sandstone; the Buffalo Creek coal bed and overlying sandstone; and the Peach Orchard coal bed and overlying sandstone.

The Magoffin Beds of Morse (1931, p. 301–303) immediately overlie the Taylor coal bed and, as used in this report, probably include the Salt Lick Beds 35 feet above the Magoffin Beds, as described by Morse (1931, p. 303–304). The top is drawn either at the highest bed with animal burrows or marine fossils, or if fossils are absent, at the base of the first occurrence of seat rock or disconformable sandstone. The Magoffin Beds range in thickness from 0 to 85 feet in the Kermit-Varney area. Shale is the dominant rock type, but siltstone and sandstone beds are common; and the shale grades upward into sandy shale and sandstone. Generally the shale is calcareous in part and, locally, beds of limestone or zones of limestone concretions are prominent. Limestone lenses are well exposed in the beds of Lick Fork of Petercave and Rockhouse Branch of Pigeonroost Fork in the Varney quadrangle. Concretions composed of light-gray aphanitic limestone are common at many localities, but they are especially abundant on White Oak Fork of Emily Creek where the Taylor coal bed goes under drainage near the southern edge of the Kermit quadrangle. Some concretions are sideritic, and many contain septarian cracks filled with calcite and siderite. Siderite nodules and cement are common in sandy beds. A crinoidal limestone bed is present in the Magoffin Beds in much of eastern Kentucky, but it is rare in the Kermit-Varney area. The limestone concretions are generally 5–15 feet above the Taylor coal bed; fossils are common above and below, but are rare in the concretions.

Throughout the Varney quadrangle and south of Wolf Creek in the Kermit quadrangle a fossiliferous shale occurs near the base of the Magoffin. Generally it is less than 2 feet thick, massive, with conchoidal fracture, but locally it is fissile. Pyrite is abundant in the black shale, and many fossils are pyritized. Fusain and carbonized plant fragments are common, and some are impregnated with pyrite. Fossils collected in Wildcat Branch (20466–PC) identified by E. L. Yochelson and J. T. Dutro, Jr.:

Plant fragments, indet.	*Astartella* sp. indet.
Orbiculoidea sp. indet.	*Worthenia* sp. indet.
Pelecypod, indet. (perhaps a nuculoid).	*Straparolus* (Euomphalus) sp. indet.
Posidonomya? sp. indet.	Straight nautiloid cephalopod?, indet.

In the Kermit quadrangle along Emily Creek and in the Varney quadrangle along Little Caney and Hobbs Forks, the fauna is composed mainly of pelecypods. Only brachiopods, Lingulas, or orbiculoids, and plants were found in Meathouse Creek, on Manyard Fork, and in the head of Petercave Fork along Lick and Runyon Forks; at one locality on Petercave Fork only plant fossils were found. On Johnson Rockhouse Creek other brachiopods, pelecypods, and cephalopods were found in the black shale. The collection from the black shale (USGS 18894–PC) includes the following genera identified by E. L. Yochelson and J. T. Dutro, Jr.:

Plant fragments, indet.	Pelecypod (cf. *Posidonomya*)
Echinoderm debris, indet.	Pelecypod (cf. *Nuculopsis*)
Lingula sp. indet.	*Astartella* sp. indet.
Orbiculoidea sp. indet.	Straight nautiloid cephalopod, indet.
Rhipidomella sp.	Coiled nautiloid cephalopod, undet.
Derbyia sp. indet.	
Neospirifer sp.	
Composita sp. indet.	

The following fauna was collected from 3 feet of calcareous shales between the Taylor coal and the overlying black fissile shale, which is less than 1 foot thick in the bank near the mouth of Upper Twin Creek in the Kermit quadrangle (USGS 18895–PC). Identifications were made by E. L. Yochelson and J. T. Dutro, Jr.:

Crinoid tegmen plate, indet.	*Aviculopecten* sp. indet.
Derbyia sp. indet. (cf. *D. crassa* Meek and Hayden)	*Euphemites* n. sp.?
Linoproductus sp. indet.	*Knightites* (*Retispira*) sp. indet.
Marginifera cf. *M. missouriensis* Girty (of Morningstar)	*Knightites* (*Cymatospiria*?) sp. indet.
Neospirifer sp.	*Worthenia* cf. *W. tabulata* (Conrad)
Composita cf. *C. subtilita* (Hall)	*Trepospira* cf. *T. depressa* (Cox)
Crurithyris? sp. indet.	*Glabrocingulum* sp. indet.
Cryptacanthia? sp.	*Shansiella*? sp.
Nuculana cf. *N. bellistriata* (Stevens)	Straight nautiloid cephalopods, undet.
Nuculopsis ventricosa (Hall)	Coiled nautiloid cephalopods, undet.
Edmondia? sp.	Worm trails?, indet.
Astartella sp.	Plant fragments, indet.
Pelecypod, indet. (cf. *Schizodus*)	
Modiola? sp. indet.	
Posidonomya sp.	

Fossils were found in all the cores of the Magoffin Beds examined by Huddle, except from DH 37. Only a few specimens of phosphatic brachiopods and pelecypods were found in DH 23, 28 and 29. On the outcrop the fossils are present at most localities, but they are abundant at only a few. The best localities for collecting are as follows: Upper Twin Branch; in roadcuts along Emily Branch; in the roof shale of mine along Long Branch in the western part of the Naugatuck quadrangle; in the Long Branch tributaries which extend into the Kermit quadrangle; and in the shales over the Taylor coal at the mine just north of Fraley Church in the Kermit quadrangle. Most of the fossils are long ranging, and no difference in the fauna has been found between the Elkins Fork, Kendrick, and Magoffin marine beds.

Specimens of *Lingula*, oriented vertically in shale and apparently buried in living position in its burrow, are present in shale along the trail up the left branch of Bent Branch above the reservoir in the Varney quadrangle.

Generally the calcareous fossiliferous shale of the Magoffin Beds grades upward into sandstones which are fine to very fine grained and ripple marked or laminated. In DH 20 (pl. 5) these coarser grained rocks are calcareous and contain brachiopods, but in most cores animal burrows are the only fossils. In DH 57 (pl. 4) slumped beds are present, but the lack of burrows and other fossils makes the top of the Magoffin Beds indistinct. As shown on plates 4 and 5, the top of the Magoffin Beds is generally marked by seat rock, coal, and shale containing plant fossils. This coal horizon is tentatively correlated with the Trace Fork coal of Browning and Russell (1919, p. 44–45) in Magoffin County. In the Kermit quadrangle, as shown on plate 3, it is locally replaced by a sandstone. The relationship between the Trace Fork, Young(?), and Winifrede coal beds is not clear. The thick bed of coal in the head of Emily Creek, Swinge Camp, and Bent Branch area, which has been extensively mined, thins westward and appears to split into three beds, one of which is the Young(?) coal bed (Browning and Russell, 1919), of this report. The channel and blanket sandstone over the Trace Fork coal is well shown in the area crossed by plate 5, but it is thin or absent in those crossed by the sections on plates 3 and 4. The Young(?) coal bed of this report is correlated with the Haddix coal of the Hazard district (Englund, in Huddle and others, 1963). It is thin or absent in most of the area, but may join the Winifrede locally. The channel sandstone above the Young(?) coal bed cuts out both the Young(?) and Trace Fork coal beds in the area covered by section 1 (pl. 3), the southern end of section 3 (pl. 5), and much of section 2 (pl. 4). As shown in these sections the sandstone appears to include both strongly crossbedded channel and rippled thin-bedded blanket phases.

The Winifrede coal bed, as used in this report, is 85–150 feet above the Magoffin Beds of Morse and has been traced from the Bent Branch section of Wanless (1939, section for Pike County on pl. 4). The name is also used locally for the coal bed mined on Bent Branch at Hatfield, Ky., in the New Cinderella mine. Hudnall (1927a) used the name in the general section for Martin County. It is not certain that this is the same coal bed that was mined in the type locality in Kanawaha County, W. Va.; but no other local name is available, and a new name would serve little purpose. It is probably the same bed as the coal called Winifrede by Hennen and Reger (1914, p. 396) at locality 228 in the West Virginia part of the Kermit quadrangle, but mapping is needed to establish the correlation across Tug Fork. This mapping was not done because of the lack of time and a suitable topographic base map. This bed was included with the Peach Orchard coal reserves calculated by Huddle and others (1963). As shown on plates 3 and 5, the bed is widespread and easily correlated in the Kermit quadrangle and in the eastern part of the Varney quadrangle; but it is discontinuous in the western part of the Varney quadrangle (pl. 4), where it contains pockets of cannel coal and is locally cut out by channel sandstone.

A channel-fill sandstone 40–100 feet thick overlies the Winifrede coal bed in most of the Kermit and Varney quadrangles as shown on plates 3–5. Interchannel or sheet phases are thin-bedded sandstone, siltstone, and slumped beds in DH 11 (the channel-fill seems to be post-Buffalo Creek) and the shale in DH 41 and 57 on plate 4. The sandstone includes more than one channel phase on plate 5, DH 20 and occupies a channel cut through the Winifrede coal in DH 29 and 33 on plate 4. Locally, the sandstone is calcareous; generally it is crossbedded and contains coal spars, pebbles of shale, and ironstone derived from older still unconsolidated Pennsylvanian rocks. This sandstone may be the Upper Winifrede of White as used by Hennen and Reger (1914, p. 144) in Mingo County, W. Va. Here it is overlain by the Buffalo Creek coal, and there is no indication of a Buffalo Creek Limestone (Hennen and Reger (1914, p. 143).

The Buffalo Creek coal bed as used in this report follows Hudnall (1927a, p. 216). It is not certain that it is the Buffalo Creek of Hennen and Reger (1914, p. 142), which lies 60–80 feet above the Buffalo Creek Limestone. The Buffalo Creek Limestone may be the Winifrede Limestone of White (Magoffin Beds of this report), and if so, the Buffalo Creek coal of West Virginia may be the same as the Winifrede coal bed of Hennen and Reger (1914). Another possible correlation is Winifrede and Taylor coal beds. On plates 3–5 a coal bed at the position of the Buffalo Creek of Hudnall is widespread and is here tentatively correlated with the Buffalo Creek of Hennen and Reger (1914, p. 142). Apparently the Buffalo Creek coal is cut out by channel-fill sandstone in DH 9 and 11 (pl. 3). Sandstone 30–50 feet thick overlies the Buffalo Creek coal in DH 13, 17, 20, 50 and 57; this may be the Lower Coalburg Sandstone of Hennen and Reger (1914, p. 141). The rock logged between the Buffalo Creek and the Lower Peach Orchard coal bed in most of the cores is shale, siltstone, and thin-bedded fine-grained sandstone. The beds correlated with the Buffalo Creek and the Lower Peach Orchard in DH 21 and 38 are very close together and might be considered splits of the same seam. The Buffalo Creek and the Winifrede coals are very close together in DH 57, and they appear to be splits of the same seam. The true relationship between the Winifrede, Buffalo Creek and Peach Orchard coal beds is not known, and the correlation shown on plates 3–5 is not the only reasonable interpretation.

The name Peach Orchard was used by Hudnall (1927a, p. 218) for a multibenched coal bed, which he correlated with the Coalburg of West Virginia and with the type Peach Orchard of Lawrence County, Ky. The Peach Orchard coal in the Kermit-Varney area consists of lower and upper beds which are separated by a few feet of shale and seat rock in both DH 15 and 21 and many localities in the southern part of the Kermit and northwestern part of the Varney quadrangles. As much as 100 feet of channel-type sandstone separates the 2 beds in DH 38. In several places either the upper or the lower bed is cut out. Both beds seem to be absent in DH 9 and are thin or absent in much of the central part of the Varney quadrangle. In nearly all localities the Peach Orchard coal consists of several beds of coal separated by numerous partings ranging from less than an inch to several feet in thickness. Partings are seat rock, underclay, or shale with abundant plant material.

The Lower Peach Orchard coal bed of the Kermit-Varney area is probably the Little Coalburg coal bed of Mingo County, W. Va. The Upper Peach Orchard coal bed of this report is probably the Coalburg coal bed of Mingo County (Hennen and Reger, 1914, p. 138–141).

The Lower Peach Orchard Sandstone of Hudnall (1927a, p. 216) probably includes the sandstone over the Buffalo Creek coal (Lower Coalburg Sandstone of Hennen and Reger, 1914, p. 141), the sandstone between the Lower and Upper Peach Orchard coal beds, and, locally, the sandstone over the Winifrede coal bed (Upper Winifrede Sandstone of Hennen and Reger).

The Upper Peach Orchard Sandstone of Hudnall (1927a) overlies the Upper Peach Orchard coal bed, and is the Upper Coalburg Sandstone of White (1908, p. 468) as used in Mingo County, W. Va., by Hennen and Reger (1914, p. 137–138). The Upper Peach Orchard Sandstone may be the High Rock Sandstone of Browning and Russell (1919, general section) in Magoffin County. It is a massive sandstone that tends to form cliffs with long points and narrow saddles. The sandstone ranges in thickness from 5 feet in DH 26, plate 5, to 100 feet in DH 36, plate 4. In some areas as shown in DH 33, 34, 35 and 45, the Upper Peach Orchard Sandstone is almost continuous with the Lower Peach Orchard Sandstone. The most prominent cliffs occur where two or more sandstone units join. The lenticular shape of sandstone units and their tendency to join units above or below explains why many of the cliff-forming sandstones crop out discontinuously and are difficult to trace. The Upper Peach Orchard Sandstone is calcareous and sideritic in many places, contains numerous coal spars, is generally crossbedded, and contains several local conglomerate zones. There are both channel and blanket phases. The abundant coal spars suggest other probable coal zones. Locally, black shale with pelecypods (as in DH 33 and 34, pl. 4) and an associated seat rock seem to represent the Upper Peach Orchard coal bed.

BROAS COAL BED AND OVERLYING STRATA

The Broas coal and overlying rocks occur in the tops of the higher hills in the Kermit-Varney area. Only the thick sandstone units crop out, and most of the information about this interval has come from cores. Marine interbedded shale and sandstone form the roof rock of the Broas coal in much of the area. This marine zone is overlain by, and possibly interfingers with, a thick sandstone which has been correlated with the Homewood Sandstone of Pennsylvania by Hennen and Reger (1914, p. 136), but the correlation is questionable. Three coal beds occur sporadically in an interval 60–100 feet above the "Homewood Sandstone." Another thick sandstone unit overlies the three stray coal beds and underlies the Richardson coal bed. A thick massive sandstone above the Richardson coal beds, the East Lynn of Hudnall (1927a, p. 221), is the youngest rock unit exposed in the area.

The Broas coal was named informally by Crandall (1910) as the Broas "E" and was called Broas coal by Hudnall (1927a, p. 229) in the general section for Martin County. It is probably equivalent to the Stockton coal of West Virginia (Hennen and Reger, 1914, p. 137) and may be the same as the Torchlight coal of Lawrence County. It was correlated with the Torchlight and Francis coal beds by Huddle and others (1963); but these correlations were tentative, and a local name is preferred for this report. Wanless (1939, pl. 4) correlates the Stockton coal of West Virginia with the Hindman of the Hazard district. In the Kermit-Varney area the Broas coal bed is generally a multiple-bedded coal which is separated into main upper and lower beds by a parting a few inches thick or by 50 feet of channel-type sandstone as in DH 33 (pl. 4). About 35 feet of sandstone separates the Lower and Upper Broas coals in DH 50 and 52 in the southern part of the Varney quadrangle (pl. 4). Both splits are apparently absent in DH 27. The rocks between the Upper and Lower Broas coals in DH 30, 34, 35, 38, 43, 45 and 57 are calcareous thin-bedded sandstone or shale and seem to represent shallow-water or tidal-flat deposits. The rocks in DH 41 are similar to the roof rocks which are characteristic of the Upper Broas coal bed. As shown on plates 3–5, and on the isopach map (pl. 9), the interval between the Upper and Lower Broas increases generally southward to a maximum of about 50 feet in the central part of the Varney quadrangle.

The rock unit which forms the roof of the Upper Broas coal bed in most of the area ranges in thickness from 0 to 50 feet and averages about 20 feet. It is composed of interbedded shale and sandstone, with a characteristic bedding which is shown in figures 3 (row 6) and 4 (row 1). The sandstone is very fine or fine grained and ranges from less than 10 to almost 100 percent of the rock. The sandy phases of the unit have wavy argillaceous laminae which appear wispy on wet cores (for example, fig. 3). Beds range in thickness from less than 1 inch to about 2 feet. Sideritic and calcareous cement are abundant in some of the beds. Slump and animal burrows are common. Lingulas are present in black shale just over the coal at a mine on the northwest side of Flag Knob in the Varney quadrangle. The unit is present in the southern Kermit quadrangle and most of the Varney quadrangle, but the typical lithology is poorly developed in DH 9 and 15 (pl. 3). This roof rock is replaced by more normal channel sandstone in the Thomas and Inez quadrangles west of the Kermit-Varney area. It is lithologically similar to sediments described by Van Straaten (1954a) in the Wadden Sea and by Moore and Scruton (1957) in the Texas gulf coast and may represent tidal-flat deposition. These rocks seem to occupy the stratigraphic position of the Kanawaha Black Flint of Fayette and Kanawaha Counties, W. Va., which Hennen and Reger (1914, p. 137) report to grade into shale southward in Boone and Mingo Counties.

Sandstone ranging in thickness from 120 to 180 feet overlies the rock unit that forms the immediate roof of the Broas coal bed. In the Varney quadrangle the sandstone is disconformable on the rocks below and is locally split into units by one or more coal zones. Variation in bedding and grain size suggest that it is a complex sedimentary unit. It is generally crossbedded and contains abundant coal spars and zones of shale and ironstone pebbles. Slump zones occur at the thin shale breaks within the major sandstone units, and several calcareous zones are present. The occurrence of animal burrows in the sandstone (DH 13, and 17, pl. 3) suggest the northward continuation of the marine roof rocks of the Broas coal in the Kermit quadrangle and the lateral gradation of these interbedded shale and sandstone roof rocks into massive sandstone. This sandstone was called the Homewood by Hennen and Reger (1914, p. 136) and Hudnall (1927a, p. 219), all of whom considered it the top of the Pottsville Series. Wanless (1939, p. 49–50) correlated this sandstone with the Clarion Sandstone of Ohio (or with the Roaring Creek on pl. 4, 1939). It may be the Puncheon Creek Sandstone of Magoffin County (Browing and

Russell 1919, frontispiece). The lateral persistence and correlation of this sandstone is doubtful, and it is not called Homewood in this report.

Three coal beds are present in a zone 60–100 feet thick overlying the "Homewood Sandstone." These coal beds, though locally several feet thick, are discontinuous and difficult to trace. They remain only on the top of the highest hills in the southern part of the Kermit quadrangle and in the Varney quadrangle. Most of the information about these coals is from cores. The lowermost bed shown in DH 9, 15, and 20 (pl. 3) has been called Lower Clarion coal bed by Hudnall (1927a, p. 220 and plate opposite p. 219). The position of the Lower Clarion coal(?) is indicated by the seat rocks and plant fossil zones in DH 20, 21, 22, and 24 (pl. 5). It may be represented by seat rock in DH 41, 45, 50, and 52 (pl. 4). Shale with ironstone nodules and very fine grained even-bedded or ripple-bedded sandstone and seat rock comprise the rocks between the Lower Clarion coal and the next extensive coal bed, here called the Lower Richardson coal bed. Massive fine- to medium-grained sandstone intervenes between the Lower Clarion and Lower Richardson coal beds in DH 29, 35, and 45 (pl. 4). Slumped beds, calcareous zones, and plant fossils are present in some cores. It is not known whether the Lower Clarion coal bed represents a separate coal bed or merely the early stages of the coal swamp which formed the Richardson coal beds.

The Lower Richardson coal bed lies in the lower part of a coal zone which is called the Lower Kittanning in Ohio, the No. 5 Block in West Virginia (Wanless, 1939, p. 48), and the Richardson coal bed by Hudnall (1927a), in Martin County. The bed is recognizable in most of the core holes, but it seems to be absent in DH 38 (pl. 5), thin in DH 13, 17, and 20 (pl. 3), and thin in DH 41 and 52 (pl. 4).

The rocks between the Lower and Upper Richardson coal beds range in thickness from 20 to 60 feet. They are thicker and consist mainly of sandstone in the southern part of the Varney quadrangle and are thinner and more argillaceous in the northern part, and in DH 15 and DH 9 in the Kermit quadrangle (pl. 3). Possibly the two beds join farther north. Shale and siltstone overlie the Upper Richardson coal bed in DH 21 and 15. The Upper Richardson coal bed is shown in six cores in the southern part of the Kermit quadrangle and in the northern half of the Varney quadrangle. It is absent in DH 38 and has been eroded from the tops of the hills in much of the area.

A roof shale and seat rock were encountered by the drill about 40 feet above the Upper Richardson coal beds in DH 20 and 60 feet above in DH 15 (pl. 3). In other cores the rocks above the Richardson coal zone are fine- to coarse-grained sandstone, which is massive to crossbedded and contains coal spars and pebbles of shale and ironstone. Quartz pebbles were found in conglomeratic sandstone in the Inez quadrangle, but no quartz pebbles were found in the Kermit or Varney quadrangle. This is the East Lynn Sandstone of Hudnall (1927a, p. 221). It was originally named by Krebs and Teets (1913, p. 183–184) in Wayne County, W. Va., for the sandstone between the No. 5 Block coal and the overlying coal bed. The East Lynn Sandstone is fine to medium grained in all the cores examined and is not a lithologically distinct sandstone in the Kermit-Varney area. The East Lynn Sandstone of Hudnall is the youngest Pennsylvanian rock exposed in the area, but it probably is overlain by shale in some of the highest hills.

QUATERNARY DEPOSITS

Clay and argillaceous sand deposited along the valleys as flood plains, terraces, and alluvial fans are the only rocks younger than the Pennsylvanian Breathitt Formation in the Kermit-Varney area. Flood-plain and terrace deposits about 30 feet thick are exposed along the Tug Fork of the Big Sandy River, and deposits in the tributary valleys are thinner. A maximum thickness of 80 feet is reported in a drill hole on Tug Fork. Little gravel is exposed in the alluvium along Tug Fork, and gravel is rarely reported in drilling.

The weathering of the Breathitt Formation seems to supply principally clay and sand which is not well sorted when transported and redeposited as alluvium. Mica flakes and plant fragments are abundant in the alluvium. Alluvial fans are common at the mouths of tributaries to the principal streams. These fans were probably formed by exceptionally large flash floods due to very local storms. Boulders and large blocks of rock are found in the landslide trains and the alluvial ridges along valley axes formed by extreme floods in steep short valleys.

STRUCTURE

In the Kermit-Varney area the Pennsylvanian rocks dip northward at an average rate of 22 feet per mile (pls. 1, 2). This regional dip is modified by the Brushy Fork syncline, the Eastern Kentucky syncline, Warfield fault, and Paintsville-Warfield anticline.

The Warfield anticline, the dominant structure of the Kermit-Varney area, is a part of the Irvine-Paint Creek fault and Paintsville-Warfield anticline, structures which form the south side of the Allegheny synclinorium and the north side of the Eastern Kentucky syncline (fig. 12). The general geologic structure of eastern Kentucky has been described by McFarlan (1943, p. 136–148). Hudnall (1923a) showed structure of the Pennsylvanian rocks in the Martin County part of the

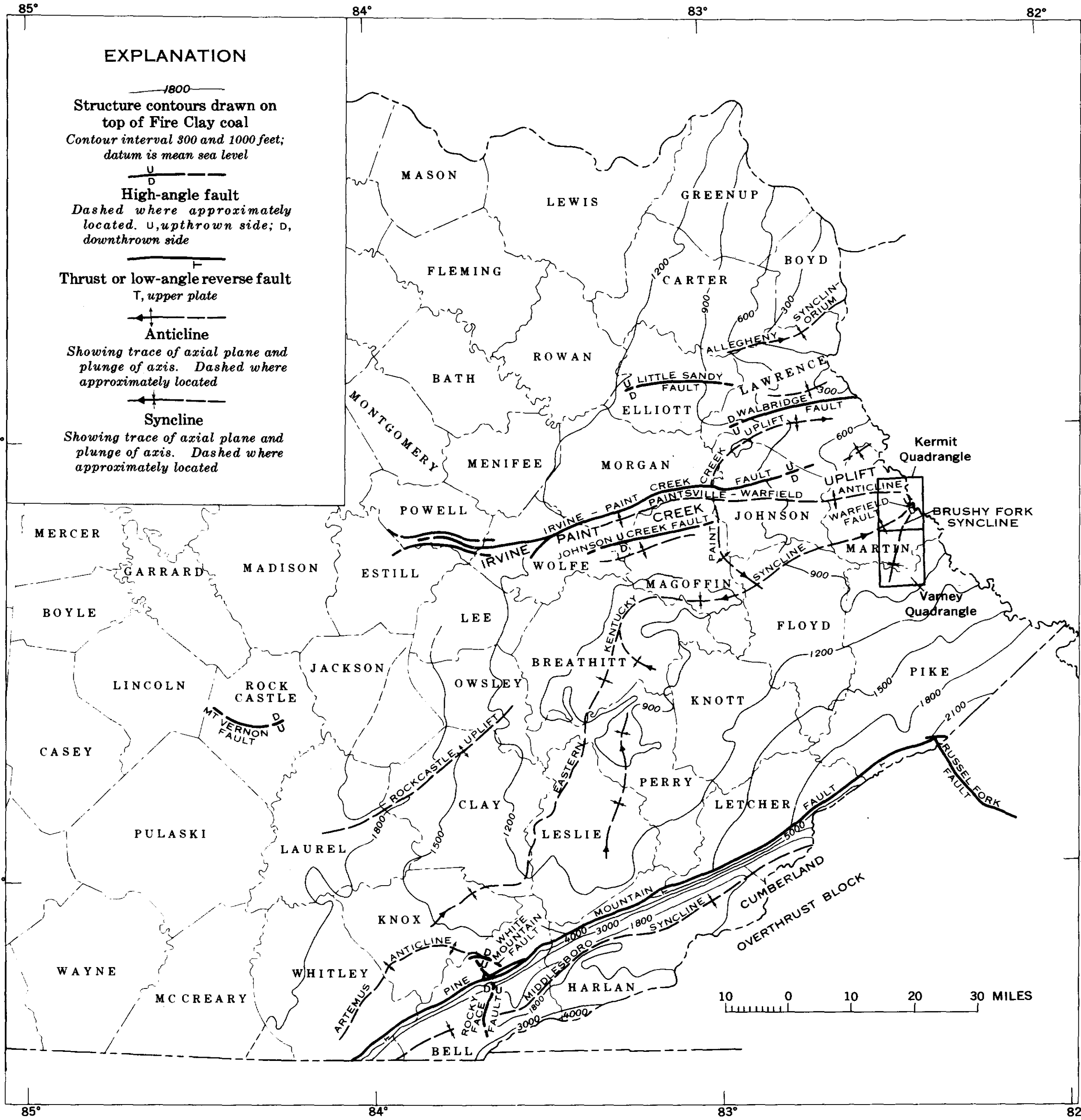

FIGURE 12.—Structure-contour map on the Fire Clay coal in eastern Kentucky. Adapted from McFarlan, 1950.

Kermit-Varney area by structure contours on the Fire Clay coal and subsurface structure by contours on the top of the Greenbrier Limestone (Hudnall, 1924). Hudnall (1923b) showed structure in the Pike County part of the Varney quadrangle by contours on the Van Lear coal bed; Hunt and others (1937) contoured on the Pond Creek coal bed. On plates 1 and 2 of this report, structure contours are drawn on top of the Taylor coal bed.

WARFIELD ANTICLINE

The anticline at Warfield, Ky., was mentioned by White in 1885; Krebs and Teets (1913) named it the Warfield anticline. It is the major anticline in Mingo and Logan Counties, W. Va., and is part of a major east-west structure. The Warfield anticline was traced northward and eastward into the Chestnut Ridge anticline of northern West Virginia and Pennsylvania by Hennen and Reger (1914, p. 32). Gardner (1915) called attention to the westerly extension in central and western Kentucky of the same major structure in the Irvine-Paint Creek fault, the Kentucky River fault system and the Rough Creek fault system.

In Mingo County, W. Va., the Warfield anticline is nearly symmetrical with dips slightly greater on the south side toward the Warfield fault. In the Kentucky part of the Kermit quadrangle the Warfield anticline is a prominent nose as far west as the Warfield fault extends; but where the fault dies out, the anticline becomes broader and dips are steeper on the south side. The dip, generally less than 5°, ranges from 200 to 300 feet per mile in the area just north of Wolf Creek west of the termination of Warfield fault. The production of oil in the Kermit quadrangle is for the most part confined to this zone of monoclinal southward dip; there is no apparent relationship of this structure to gas production. The Greenbrier and older rocks are involved in this fold, as shown by Hudnall (1924).

EASTERN KENTUCKY SYNCLINE

The eastern Kentucky syncline extends from Leslie County northward to Magoffin County and then eastward, parallel to the Irvine-Paint Creek fault, to Martin County. It follows Wolf Creek through the Kermit quadrangle (pl. 1) and joins the Coalburg syncline in Mingo County, W. Va. (Hennen and Reger, 1914, p. 34–36). This syncline, however, is not present on top of the Black shale (McFarlan, 1943, pl. 31). The Black shale of Devonian age dips uniformly southeast. The southeast flank of the eastern Kentucky syncline is formed by the rapidly thickening Lee and Breathitt Formations (McFarlan, 1943, p. 138). This rapid increase of interval between key beds in Pennsylvanian rocks south of the Paintsville-Warfield anticline was noted by Wanless (1939, p. 66).

BRUSHY FORK SYNCLINE

The Brushy Fork syncline (Hudnall, 1923b) extends south from the eastern Kentucky syncline along the Pigeonroost Fork of Wolf Creek and is the main structure of the Varney quadrangle. The irregular trend of the syncline is probably due to compaction folding. The Brushy Fork syncline, as shown on figure 12, follows the general trend of a structure farther south that is shown on the Pike County map by Hunt and others (1937). Preliminary structure-contour maps drawn by Huddle on the top of the Greenbrier Limestone and on the top of the Berea Sandstone, both of Mississippian age, show that the Brushy Fork syncline is confined to overlying Pennsylvanian rocks. The increase of northward dip in the southern part of the Varney quadrangle coincides with the southward thickening of section. The older Mississippian rocks dip southeast at about 40 feet per mile. A weak anticlinal nose extends southwest from the northeastern corner of the Varney quadrangle along the Pike-Martin County line.

WARFIELD FAULT

The Warfield fault of White (1908, p. 380, 402) is mainly in West Virginia. It extends from the headwaters of Mud Fork, about 3 miles east of Dingess in Mingo County, W. Va., west to Little Petercave Branch about 2 miles west of Lovely, Ky. As mapped by Hennen and Reger in West Virginia and by the authors in Kentucky, it is about 19 miles long. The fault plane is reported to have been encountered in a few entries in the Earlston and Burning Springs Collieries mines. The entrance of the Earlston mine (abandoned) in the Alma coal bed is at the Kermit toll bridge over Tug Fork, and the mined area extends west and south (pl. 12). "Steep" dips are reported near the fault, and open cracks occur at the surface above the mined area near the fault between Lovely and Buck Branch. The Webb mine and other truck mines near the mouth of Buck Branch reportedly encountered the fault plane. In 1959 Barnes and Huddle attempted to reach the fault plane in the Webb mine, but they were blocked by fallen rock.

There is little surface evidence of the Warfield fault in Kentucky. Local dips of 3°–8° along the extension of its trend in West Virginia suggest that it may be present. An offset of benches, formed by resistant sandstones, is apparent in the hollow north of Lovely. Sandstone beds in the ridge crest where the fault leaves this hollow are apparently offset, and a spring is present. The sandstone which crops out in Davis Branch may be cut off by the fault, but the exposure is poor. West of Davis Branch no offset benches or lineations were seen in air photographs. The apparent dip of the benches is southward 2°–4° without displacement. Benches on the south side of Little Petercave Branch are not broken. Benches on the north side are not distinct enough to determine displacement.

The best exposures of the Warfield fault in the Kermit quadrangle are in cuts of the Norfolk and Western Railway and U.S. Highway 52 on the West Virginia side of Tug Fork south of Kermit, W. Va., and opposite Lovely, Ky. The cut along U.S. Highway 52 is shown in figure 13. South of the fault the rocks dip about 4° south; north of the fault near Lovely, the rocks dip about 8° south. Hennen and Reger (1914, pl. 5) published a photograph of the fault in the Norfolk and Western Railway cut taken when the cut was fresh. This photograph shows crushed rocks on the south side of the fault. They reported the fault plane to be vertical (1914, p. 39) with a downward

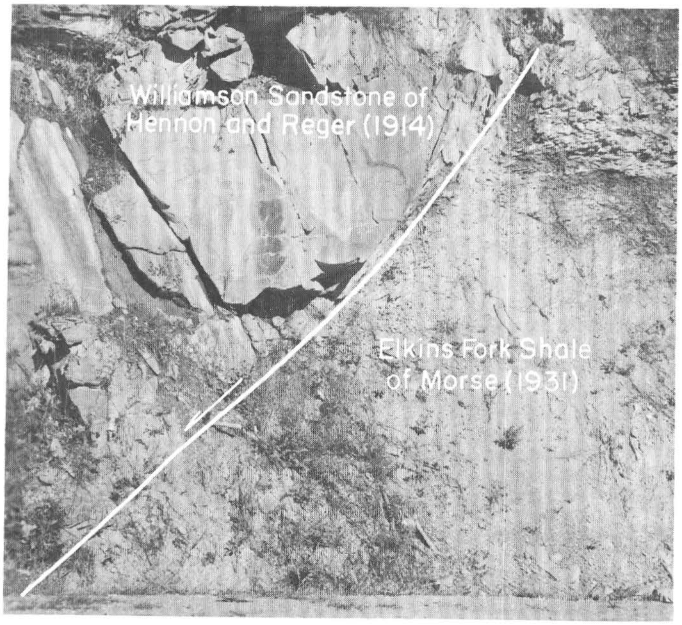

FIGURE 13.—Warfield fault in roadcut on U.S. Highway 52 in West Virginia, opposite Lovely, Ky.

displacement of 100 feet on the north side. Hudnall (1924, subsurface map of Martin County) shows 140 feet of displacement on the Greenbrier Limestone at Tug Fork and shows (Hudnall, 1923a) about 100 feet on Fire Clay coal bed. The railroad cut was considerably weathered and slumped in 1959 when examined by Huddle and Barnes. Siltstone and very fine grained sandstone are the predominant rocks on both sides of the fault. A sheared zone, 3–5 feet wide, has slickensides and is case hardened. The fault trace trends about N. 80° W., and the fault plane has a dip of 70°–85° N. The rocks on both sides of the fault plane, dip about 8° S. In the highway cut above the railroad, the trend of the fault plane is approximately east-west and it dips about 65° N. The sandstone over the Kendrick Shale, called Williamson Sandstone by Hennen and Reger (1914, p. 165), is faulted against the Elkins Fork Shale of Morse. The Elkins Fork Shale is repeated in the south end of the railway cut at Middle Burning Creek and in the north end of the cut at Lower Burning Creek. V-shaped fractures with minor offset in the Williamson Sandstone occur as much as 50 feet north of the fault. Gouge and slickensides form a zone about 3 inches thick at the fault surface.

The Warfield fault, as seen in the outcrops just described and in West Virginia, is a normal fault dipping to the north with the downthrown block on the north. The same direction of displacement is shown in the mines in the Alma coal and the outcrop pattern of the Alma coal. The general relationship of the rocks is shown in the cross section on the geologic map of the Kermit quadrangle (pl. 1). The same direction of displacement is shown on the Logan-Mingo County map of Hennen and Reger (1914) and on the surface and subsurface structure maps of Martin County, Ky., by Hudnall (1923a, 1924). Subsurface contours drawn on the top of the Berea Sandstone in Kermit quadrangle show that a fault, presumed to be the Warfield, is downthrown on the south side, the reverse of movement at the surface. This contouring is based on relatively recent well records, and the interpretation of displacement is reasonable. Most of the gas wells near the fault in Kentucky are old, and the well altitudes and records are poor. Consequently, the direction of displacement of the fault in the subsurface was not established with certainty. A possible explanation of the apparent anomaly is reversal of direction of movement on the fault in pre- and post-Pennsylvanian times. Another possible explanation is that the Warfield fault is part of a fault system of in echelon faults with a general graben structure. Both interpretations have been suggested for other faults in the eastern Kentucky area (A. C. McFarlan, oral commun., 1957).

The Irvine-Paint Creek fault has been described recently by Englund (1955, p. 12) and Adkison (1957). They show that the rocks on both sides of this fault dip in the same direction. The north side (upthrown) dips gently and the south dips more steeply. The Warfield fault shows similarly associated gentle and steeper dips. Hauser (1953) showed that in the Paintsville area the direction of movement of the Irvine-Paint Creek fault in both surface exposures and subsurface pre-Pennsylvanian rocks is the same. There is no evidence that older faults in eastern Kentucky have a reverse direction of movement at depth. It is probable that the Warfield fault consists of two more faults at depth, and that these faults are associated with a graben. Grabens are described by McFarlan (1943, p. 145–149) in the Kentucky River fault system. A careful study of the surface and subsurface data in West Virginia and Kentucky should be able to find the correct explanation for the reversal of movement.

The persistence of the structural trends from the Rough Creek fault zone in western Kentucky through the Warfield anticline to the Chestnut Ridge anticline of Pennsylvania, as pointed out by Gardner (1915), Lockett (1947), and Clark and Royds (1948), suggests that the structures in the Kermit-Varney area are part of a major continental structural feature. This tracing of structures from the Ozarks to Pennsylvania is vague and locally tenuous, but nevertheless regionally suggestive. Wanless (1939) and McFarlan (1943, p. 145) have called attention to the difference in Pennsylvanian rocks north and south of the Warfield anticline and the divergence of surface and subsurface formations to the south. The anticline is thought to have been progressively active during late Paleozoic time. Possibly it follows a Precambrian structure. Although the Warfield anticline is near the axis of thinning and change in lithology of the Pennsylvanian rocks, the thinning and change in character are gradual rather than abrupt. These changes might be explained by an arch along the Warfield anticline high enough to influence sedimentation in Pennsylvanian time. An alternate explanation is that the Warfield anticline may have developed at the northern edge of a wedge of Pennsylvanian sediments which localized structural movement. Both explanations may be partly correct. An old linear east-west structural element seems very probable, but evidence for its seeming northward swing and junction with the Chestnut Ridge anticline needs reexamination. The old east-west trend may have controlled the hinge faulting and folding which accompanied the depression of the basin in which the thick Pottsville rocks in West Virginia, Virginia, and southeastern Kentucky was accumulating.

JOINTS AND CLEATS

The strike of joints and cleats in rocks of the Breathitt Formation in the Kermit-Varney area varies widely. The strike of one cleat set is fairly consistent with 17 of 22 measurements ranging from N. 40° W. to N. 70° W. The strike of the second set shows more random distribution in a northeasterly direction, with approximately half falling in the range of N. 30° E. and N. 55° E. As shown by the table below, the cleat directions do not vary much from oldest and youngest coal beds. The main directions of cleats are about N. 45° E. and N. 55° W.

Joint and cleat directions

Coal bed	Cleat direction	Locality	Quadrangle
Broas coal	N. 55° E., N. 45° W	Hurricane Branch	Varney.
	N. 65° E., N. 45° W	do	Do.
	N. 20° E., N. 35° W	do	Do.
	N. 45° E., N. 55° W	Flag Knob	Do.
Peach Orchard	N. 35° E., N. 40° W	Pipe Mud Branch	Kermit.
	N. 50° E., N. 40° W	Maynard Hollow	Do.
	N. 60° E., N. 45° W	Head Elk Creek No. 17.[1]	Do.
	N. 30° E., N. 70° W [2]	Little Elk Creek	Do.
	N. 45° E., N. 40° W	do	Do.
Buffalo Creek	N. 10° E., N. 70° W	Head of John Young Branch No. 38.	Varney.
Winifrede	N. 70° E., N. 45° E	Emily Creek No. 35 [1]	Kermit.
	N. 25° E., N. 60° W	Emily Creek No. 43 [1]	Varney.
Taylor	N. 50° E., N. 50° W	Pigeonroost Fork No. 53.[1]	Do.
Fire Clay Rider.	N. 20° E., N. 4° E., N. 55° E., N. 85° E.; N. 50° W	Elkins Fork No. 70 [1]	Do.
Fire Clay: Upper bench.	N. 30° E., N. 45° W	Swinge Camp Branch	Do.
	N. 30° E., N. 55° W	do	Do.
Lower bench.	N. 10° E., N. 65° W	do	Do.
Williamson	N. 45° E., N. 0° E	Rockhouse Fork No. 101.[1]	Do.
	N. 0° E., N. 80° W	Big Creek	Do.
	N. 90° E., N. 20° W	do	Do.
Alma	N. 35° E., N. 50° W	Wolf Creek No. 80 [1]	Kermit.
	N. 80° E., N. 10° W	Webb Mine	Do.
	N. 70° E., N. 25° W	Webb Mine No. 82 [1]	Do.

[1] Locality number on pl. 1 or 2.
[2] Joints in sandstone roof.

ECONOMIC GEOLOGY

The principal mineral resources of the Kermit-Varney area are gas, coal, and oil. Sand, clay, and building stone are available for local use. Brine is present in the "Salt sands" and other horizons, but there are no chemical analyses to indicate whether or not they are sufficiently concentrated to be valuable or to contain unusual elements. Only the coal was studied in the preparation of this report.

COAL

Coal in the Kermit and Varney quadrangles occurs principally in 12 beds in the Breathitt Formation. Individual coal beds are almost 9 feet thick locally, and most beds average about 2½ feet thick. Available analyses (table 5; Fieldner and others, 1942, p. 22) indicate that the coal is of high volatile A or B bituminous rank, contains moderate amounts of sulfur, and yields a moderate amount of ash. Heat values on the as-received basis range from 12,200 to 15,050 Btu.

Coal-bed outcrop lines, mines, prospects, and drill holes used for structural control and for coal thicknesses are shown on plates 1 and 2. The coal beds at many of these control points are shown graphically on plates 10 and 11, and the thickness and areal distribution of coal in eight of the more widespread beds are indicated on plates 12–14.

Coal reserves in the 12 principal coal beds of the Kermit and Varney quadrangles are shown in table 6. On the basis of reliability of data, the reserves have been classified as follows: (1) As measured in areas within ¼ mile of a measured thickness, (2) as indicated within areas that are from ¼ to ¾ mile from point of observation or within ¾ mile of a point of partial exposure, and (3) as inferred in areas more than ¾ mile from point of observation and where the continuity of the coal can be inferred from geologic evidence. The coal has been further classified by thickness into the following: 14 to 28 inches, 28 to 42 inches, and more than 42 inches. All measurements used in calculating reserves exclude the thickness of partings.

Hudnall (1927a) estimated coal reserves for all of Martin County, and Hunt and others (1937) estimated reserves for Pike County. Huddle and others (1963) published the coal reserves of the Naugatuck and Williamson 15-minute quadrangles. The detailed geologic mapping done for this report proved larger coal reserves in more coal beds than was found earlier. Coal reserves reported in table 6 are 117 million tons larger for the Kermit quadrangle and 405 million tons larger for the Varney quadrangle than was estimated by Huddle and others (1963). Most of the additional coal reserves shown in table 6 for the Kermit quadrangle are in four coal beds not included in the previous estimate. Mis-

TABLE 5.—*Coal analyses*

Coal bed	Map locality (pls. 1, 2)	Source of data	Condition of sample[1]	Proximate analysis: Moisture	Proximate analysis: Volatile matter	Proximate analysis: Fixed carbon	Proximate analysis: Ash	Ultimate analysis: Sulfur	Ultimate analysis: Hydrogen	Ultimate analysis: Carbon	Ultimate analysis: Nitrogen	Ultimate analysis: Oxygen	Heat value (Btu)	Free swelling index	Ash softening temperature
Upper Richardson	Composite	(2)	A	2.49	37.09	52.57	7.85	0.71					12,980	2½	2800+
Do	DH 20	(3)		2.73	35.21	54.08	7.98	.81					13,221	4½	2800+
Lower Richardson	Composite	(2)	A	2.50	38.36	54.43	4.71	.74					13,580	3½	2800
Broas	DH 36	(4)	A	4.46	35.80	53.57	6.17	.95					13,120		2808+
			B		37.47	56.07	6.46	.99					13,732		
Do	Composite	(2)	A	2.23	38.64	52.24	6.26	1.11					13,432	3½	2724
Upper Broas	DH 20	(3)		2.45	41.17	50.17	6.21	2.21					13,515	4	2240
Lower Broas	18A	(4)	A	4.92	36.58	55.00	3.50	.71					13,352		2808+
			B		38.47	57.85	3.68	.75					14,043		
Do	19A	(4)	A	8.61	33.94	52.84	4.61	.69					11,958		
			B		37.14	57.82	5.04	.75					13,085		
Do	DH 17	(3)	A	2.82	36.58	53.06	7.54	.78					13,106	4	2800+
Upper Peach Orchard	DH 20	(3)	A	2.25	38.94	51.10	7.71	.76					13,307	4	2800+
Do	DH 17	(3)	A	2.44	37.76	50.66	9.14	.69					13,008	4	2800+
Lower Peach Orchard	Composite	(2)	A	2.23	37.92	50.98	8.81	.83					13,077	3¼	2800
Do	DH 36	(4)	A	4.16	34.62	40.49	11.73	.76					12,279		2808+
			B		36.12	51.64	12.24	.79					12,812		
Buffalo Creek	DH 38	(5)	A	4.2	38.0	54.0	3.8	1.9							
			B		39.6	56.4	4.0	2.0							
Winifrede	DH 20	(3)		2.95	40.52	53.17	3.36	.75					14,095	4½	2800+
Do	DH 27	(5)	A	2.0	37.7	50.7	9.6	1.4							
			B		38.5	51.7	9.8	1.5							
Do	DH 38	(5)	A	3.6	41.6	52.0	2.8	.8							
			B		43.1	54.0	2.9	.8							
4½-in. lump	(7)	(6)	A	4.6	38.7	50.7	6.0	.6					15,050		2960+
			B		40.4	58.1	6.3	.6							
2½–4½-in. lump	(7)	(6)	A	4.4	37.0	52.0	6.6	.6					15,000		2910+
			B		38.7	54.4	6.9	.6							
1¼–2½-in. lump	(7)	(6)	A	4.4	36.6	52.4	6.6	.8					14,960		2910+
			B		38.3	54.8	6.9	.8							
1¼-in. and slack	(7)	(6)	A	6.4	33.0	50.0	10.0	.9					14,920		2810
			B		35.3	53.3	11.4	1.0							
Winifrede	44A (8)	(4)	A	3.03	41.93	52.56	2.48	.76					14,167		2510
			B		43.24	54.20	2.56	.78					14,610		
Winifrede, 1¼-inch and slask.	44A (8)	(4)	A	2.92	42.45	52.58	2.05	.79					14,188		
			B		43.73	54.16	2.11	.81					14,615		
Taylor	DH 17	(3)		1.88	36.22	43.95	17.95	2.06					11,740	2½	2800+
Do	DH 27	(5)	A	2.3	39.2	52.2	6.3	.6					13,630		
			B		40.1	53.4	6.5	.7					13,940		
Do	DH 46	(4)	A	2.43	39.13	49.41	9.03	1.72					13,065		
			B		40.10	50.65	9.25	1.76					13,390		
Do	Near DH 39	(4)	A	2.06	38.70	50.75	8.49	1.12							3000
					39.51	51.82	8.67	1.14							3000
Do	Near DH 59	(4)	A	3.62	39.62	49.24	7.52	1.12					13,265		2980
Fire Clay rider:															
Upper Bench	73	(5)	A	2.5	42.5	44.0	11.0	7.7	5.2	68.9	1.4	5.8	12,840		
			B		43.6	45.1	11.3	7.9	5.1	70.7	1.5	3.5	13,180		
Middle Bench	73	(5)	A	3.1	35.9	47.4	13.6	2.0	5.0	68.3	1.5	9.6	12,200		
			B		37.1	48.9	14.0	2.0	4.8	70.5	1.5	7.2	12,590		
Lower Bench	73	(5)	A	3.7	38.1	49.1	9.1	1.1	5.4	72.2	1.5	10.7	12,960		
			B		39.6	50.9	9.5	1.1	5.2	74.9	1.6	7.7	13,450		
Fire Clay rider	Near DH 59	(4)	A	4.95	36.20	51.25	7.50	.77					13,135		2990
			B		38.09	54.02	7.89	.81					13,819		2990
Upper Whitesburg	DH 13	(5)	A	3.1	39.0	50.3	7.6	1.3	5.4	74.2	1.5	10.0	13,340		
			B		40.3	51.9	7.8	1.3	5.2	76.6	1.6	7.5	13,760		
Alma	DH 17	(3)	A	1.97	39.94	52.60	5.55	1.10					13,880	5½	2800+
Alma, 5-in. lump	Mine shaft at Beauty.	(6)	A	2.8	40.7	51.0	5.5	1.9					13,666		
			B		41.9	52.4	5.7	2.0					14,050		
2- by 5-in. lump	81	(6)	A	2.9	39.9	50.1	7.1	2.1					13,420		
			B		41.1	51.6	7.3	2.2					13,820		
2-in. and slack	81	(6)	A	4.2	37.0	48.0	10.8	2.5					12,640		
			B		38.6	50.1	10.3	2.6					13,190		
5-in. lump	81	(6)	A	2.7	41.2	51.3	4.8	2.0					13,850		
			B		42.4	52.7	4.9	2.1					14,240		
5-in. resultant	81	(6)	A	2.6	38.8	56.5	8.1	2.0					13,340		
			B		39.9	51.8	8.3	2.1					13,700		
Pond Creek	Composite	(2)	A	1.71	39.11	52.77	6.41	1.20					13,555	4	2800

[1] A, as received; B, moisture free.
[2] Average of several cores from Kermit-Varney area, analyzed for Pocahontas Land Corp. by a commerical laboratory.
[3] Analyses made for Island Creek Coal Co. by a commercial laboratory.
[4] Analyses made for Federal Gas, Oil & Coal Co. by a commerical laboratory.
[5] Analyses by U.S. Bureau of Mines, samples submitted by J. W. Huddle. Bureau of Mines Lab. No. G-58729, G-58730, G-58731.
[6] U.S. Bureau of Mines, Fieldner and others, 1944, p. 116; tipple samples of lump and slack.
[7] Winco Block Coal Co. mine, Naugatuck quadrangle Kentucky.
[8] Sample taken in New Cinderella mine, Cinderella Coal Corp.

TABLE 6.—*Estimated original and remaining [1] coal reserves*

[As of Jan. 1, 1960. In millions of short tons, covered by less than 1,000 ft of overburden]

Coal bed	Measured reserves, in beds of indicated thickness in inches				Indicated reserves, in beds of indicated thickness in inches				Inferred reserves, in beds of indicated thickness in inches				Total all beds
	14 to 28	28 to 42	>42	Total	14 to 28	28 to 42	>42	Total	14 to 28	28 to 42	>42	Total	
KERMIT QUADRANGLE													
Broas			3.6	3.6		0.6	4.5	5.1					8.7
Upper Broas	0.6			.6	2.2			2.2	1.2			1.2	4.0
Lower Broas	.2	0.4		.6	1.2	.2		1.4					2.0
Buffalo Creek	1.4			1.4	6.6			6.6	7.4			7.4	15.4
Fire Clay	2.1			2.1	12.2			12.2	11.0			11.0	25.3
Fire Clay rider	1.1	1.4		2.5	4.9	4.4		9.3					11.8
Peach Orchard	.6	3.0	8.1	11.7	3.9	20.7	14.3	38.9	2.4	3.0		5.4	56.0
Pond Creek	.5			.5	2.9			2.9	8.7			8.7	12.1
Taylor	5.3	5.7		11.0	37.7	15.5		53.2	5.8			5.8	70.0
Van Lear	2.3			2.3	13.3			13.3	42.6			42.6	58.2
Upper Whitesburg	10.1			10.1	28.7			28.7	21.3			21.3	60.1
Alma	1.5	.6	11.7	[2] 13.8	5.7	10.0	28.3	[3] 44.0	22.8	36.1	18.6	[4] 77.5	135.3
Williamson	.7			.7	2.5			2.5	3.4			3.4	6.6
Winifrede	3.4	.6		4.0	12.7	.8		13.5	2.9	2.6		5.5	23.0
Total Kermit	29.8	11.7	23.4	64.9	134.5	52.2	47.1	233.8	129.5	41.7	18.6	189.8	488.5
VARNEY QUADRANGLE													
Martin County													
Upper Broas	1.4	.5	13.1	[5] 15.0	3.0	3.2	7.4	[6] 13.6	.4	1.5	.4	[7] 2.3	30.9
Lower Broas	.5	1.0	.1	1.6	1.1	.4	.1	1.6	1.1			1.1	4.3
Buffalo Creek	4.0			4.0	9.8			9.8	6.9			6.9	20.7
Fire Clay	4.6	5.9	.7	11.2	16.1	25.1	.9	42.1	6.9	3.0		9.9	63.2
Fire Clay rider	5.4	10.0	.9	16.3	15.9	17.1	.8	33.8	2.0	1.0		3.0	53.1
Peach Orchard	.5	1.0	12.4	13.9	2.5	4.2	9.3	16.0	.5			.5	30.4
Pond Creek	2.0	2.8		4.8	11.3	16.7		28.0	15.1	7.4		22.5	55.3
Taylor	4.8	9.3	1.9	16.0	14.3	17.5	4.6	36.4	6.6			6.6	59.0
Van Lear	1.6	3.8		5.4	10.0	22.2		32.2	20.8	8.8		29.6	67.2
Upper Whitesburg	2.9			2.9	16.2			16.2	13.9			13.9	33.0
Alma	.8			.8	4.2			4.2	11.1			11.1	16.1
Williamson	.5	.7		1.2	2.8	4.6		7.4	6.3	1.4		7.7	16.3
Winifrede	2.6	4.6		[8] 7.2	4.3	4.0		8.3	.8			.8	16.3
Total Martin County	31.6	39.6	29.1	100.3	111.5	115.0	23.1	249.6	92.4	23.1	.4	115.9	465.8
Pike County													
Upper Broas	0.6	0.4	1.1	[9] 2.1	2.5	2.4	2.3	[10] 7.2	0.8	0.8	1.7	3.3	12.6
Lower Broas	.6	.6	1.6	2.8	.9	2.7	2.6	6.2	1.3		.8	2.1	11.1
Buffalo Creek	.7	.2		.9	2.9			2.9	1.8			1.8	5.6
Fire Clay	4.4	7.1		11.5	14.4	20.5		34.9	3.2	2.6		5.8	52.2
Fire Clay rider	1.4	2.8	11.7	15.9	5.2	10.2	10.3	25.7	2.4			2.4	44.0
Peach Orchard	1.1	.3	.7	2.1	3.0	1.4	.7	5.1	2.3	.3	.2	2.8	10.0
Pond Creek		2.9	2.8	5.7		20.1	16.7	36.8	4.5	22.5	36.3	63.3	105.8
Taylor	.9	1.0	1.2	3.1	4.4	5.6	2.9	12.9	.3		.5	.8	16.8
Van Lear	.5	2.2	1.6	4.3	5.0	20.4		25.4	16.7	10.1		26.8	56.5
Upper Whitesburg	4.2			4.2	15.5			15.5	7.0			7.0	26.7
Alma	.8			.8	3.6			3.6	5.5			5.5	9.9
Williamson	1.1	4.0	5.6	10.7	5.5	11.4	1.8	18.7	4.8	4.5		9.3	38.7
Winifrede	.2	1.6		[11] 1.8	1.5	1.1		2.6	.7			.7	5.1
Total Pike County	16.5	23.1	26.3	65.9	64.4	95.8	37.3	197.5	51.3	40.8	39.5	131.6	395.0
Total Varney quadrangle	48.1	62.7	55.4	166.2	175.9	210.8	60.4	447.1	143.7	63.9	39.9	247.5	860.8
Grand total	77.9	74.4	78.8	231.1	310.4	263.0	107.5	680.9	273.2	105.6	58.5	437.3	1,349.3

[1] Remaining reserves 1334.7 million tons.
[2] Includes 4.6 million tons of coal mined and lost in mining.
[3] Includes 6.1 million tons of coal mined and lost in mining.
[4] Includes 1.3 million tons of coal mined and lost in mining.
[5] Includes 0.9 million tons of cannel coal ranging in thickness from 6 to 17 in.
[6] Includes 0.4 million tons of cannel coal ranging in thickness from 6 to 17 in.
[7] Includes 0.2 million tons of cannel coal ranging in thickness from 6 to 17 in.
[8] Includes 2.6 million tons of coal mined and lost in mining.
[9] Includes 0.2 million tons of cannel coal ranging in thickness from 6 to 17 in.
[10] Includes 0.9 million tons of cannel coal ranging in thickness from 6 to 17 in.
[11] Includes 1.4 million tons of coal mined and lost in mining.

takes in correlation of coal beds lead Huddle and others (1963) to overestimate the amount of coal in the Fire Clay, Fire Clay rider, and Broas coal beds in the Kermit quadrangle. The coal mistakenly reported in these beds is reported in other beds in table 6. The Peach Orchard coal in the Varney quadrangle was also overestimated, based on the assumption that the bed extended through the central part of the quadrangle where subsequent drilling has proved it to be absent. Reserves of coal in the Broas, Pond Creek, Fire Clay, and Upper Whitesburg coal beds in the Varney quadrangle shown in table 6 agree well with the estimate of Huddle and others (1963), but reserves in other beds were greatly increased by using new information.

The following descriptions of coal beds are based on both surface and subsurface data. Surface data were obtained from coal outcrops, prospect pits dug by land and mining companies, and from numerous small mines which supply coal for local use. These shallow diggings or "house openings" commonly extend less than 100 feet in from the outcrop line; consequently, the amount of coal that has been removed is relatively insignificant in comparison with the total reserves in a bed. Additional surface data were obtained from small truck mines, most of which are abandoned, and from a few large abandoned underground mines that are in areas accessible to rail transportation. Maps of the large mines also furnish subsurface data and delineate exploited areas (pls. 12, 13). The bulk of subsurface data has been obtained from drillers' logs and core descriptions of diamond-drill holes that range in depth from 81 to 1,203 feet (pls. 3–8). The position of a coal bed is occasionally indicated on the drillers' logs of wells drilled for oil and gas.

COAL BEDS OF THE LEE FORMATION

Coal beds of the Lee Formation are in the subsurface at depths from about 400 to as much as 1,500 feet in the Kermit and Varney quadrangles. Information concerning these beds is limited to reports of coal in drillers' logs of wells drilled for oil or gas. Bed descriptions and reserve estimates are not included here because of the scarcity of data.

COAL BEDS OF THE BREATHITT FORMATION

Pond Creek coal bed.—The Pond Creek coal bed is the first coal of economic importance above the base of the Breathitt Formation in the Kermit and Varney quadrangles. It is entirely in the subsurface at a minimum depth of about 300 feet below the main streams. Although the Pond Creek coal is not mined, its extent and thickness are well delineated by core drilling. The bed attains a maximum thickness of slightly more than 50 inches near the south edge of the Varney quadrangle and thins gradually to 14 inches or less near the north edge. From an area of coal 14 to 18 inches thick in the southeast corner of the Kermit quadrangle, the bed appears to continue to thin northward. Locally, thin partings of impure coal or shale occur near the base or top of the coal bed. The estimated reserves of the Pond Creek coal total about 173 million tons, of which more than 30 percent is in the thickness category of more than 42 inches. Because of these large reserves of substantially thick coal, the Pond Creek coal bed probably contains the most important reserves for future development in the Kermit and Varney quadrangles.

Alma coal bed.—The Alma coal bed is the most extensively mined coal in the Kermit quadrangle. Outcrops of the bed are limited to small areas in the northeastern part of the quadrangle where the proximity of the bed to the surface is related to gentle warping and uplift of strata along the Warfield fault. Several square miles of the bed have been mined from the outcrop areas near the town of Warfield and on lower Wolf Creek. Here the bed was readily accessible by drift and slope entries, and large-scale development was aided by the availability of rail transportation along the Big Sandy River. Where mined, the coal bed is 31–61 inches thick and includes one or two thin partings of impure coal and shale in the lower part. The coal thins toward the northwest, but core drilling indicates that it is 28 inches or more in thickness to the south-central part of the Kermit quadrangle, and that from there to the south edge of the quadrangle it is 14–28 inches thick.

In the Varney quadrangle the Alma coal has been core drilled in at least 18 locations. Except for local areas along the north edge of the quadrangle and in the southern corner where the coal is from 14 to 28 inches thick, drilling indicates that most of the Alma coal is less than 14 inches thick. The estimated original reserves in the Alma coal bed total a little more than 161 million tons. Most of these reserves are in the Kermit quadrangle where about 9 percent of the coal is estimated to have been mined or lost in mining.

Van Lear coal bed.—The Van Lear coal bed is mainly in the subsurface, and data on the bed were obtained from 23 core holes The only area of outcrop is in the north-central part of the Kermit quadrangle where the bed is generally less than 14 inches thick. Because of the thinness of the bed and the scarcity of data, the outcrop line is not shown on plate 1. Southward from the outcrop area the Van Lear coal increases in thickness to about 20 inches, which it maintains into the the northern part of the Varney quadrangle. Prospecting by core drilling has located a pocket of coal that has an average thickness of 34 inches and a maximum of 43 inches, the pocket extends in a broad belt across the central part of the Varney quadrangle. Here the Van Lear coal bed is at a depth of 170–300 feet below drainage and usually contains a shale parting from 3 to 16 inches thick and a few thin partings of impure coal.

The total estimated original reserves of the Van Lear coal bed are nearly 182 million tons, of which nearly 40 percent is more than 28 inches thick.

Williamson coal bed.—The Williamson coal bed is relatively thin and of little commercial importance in most of the area of this report. It has been extensively mined in large railroad mines just east of the Varney quadrangle. It crops out near drainage level principally along Big Creek and several tributary streams on the east edge of the Varney quadrangle (graphic sections 98–102, 94, pl. 11). In several small mines in this area, the coal is from 30 to 61 inches thick and averages about 42 inches. These mines were operated for a short time, and the production is disregarded in the reserve computation. Mining is hampered by thin shale partings and abundant pyrite in the bed. Westward from the outcrop area an abrupt thinning to 14 inches or less and possible splitting of the bed are revealed by core drilling (pl. 13). Thin coal, mostly less than 14 inches thick, also extends northward into the Kermit quadrangle. It crops out near drainage level on Elk Creek where a few small mines show 15–17 inches of coal in a single bench (graphic sections 76 and 77, pl. 10). Nearly all the estimated original reserves, 61.6 million tons, in the Williamson coal bed are located in the eastern part of the Varney quadrangle.

Upper Whitesburg coal bed.—The Upper Whitesburg coal bed is a thin persistent bed occurring slightly above drainage level in most parts of the Kermit and Varney quadrangles. Because of favorable access to the coal outcrop, which usually is less than 100 feet above the valley floor, the bed is often mined as a source of fuel for local use. Commercial development is deterred by partings of shale and underclay and by the general thinness of the bed. In outcrops in the northern and central parts of the Kermit quadrangle, the Upper Whitesburg coal is 12–25 inches thick and average about 20 inches. The bed is entirely in the subsurface from the southern part of the quadrangle into the northwestern part of the Varney quadrangle. In these areas 15 widely spaced core holes indicate 4–22 inches of coal that has an average thickness of 18 inches. A similar range in thickness extends into the outcrop areas in the southern half of the Varney quadrangle. All the estimated original reserves, 119.8 million tons, of the Upper Whitesburg coal bed are in the 14- to 28-inch category. The amount of coal mined for local use is small and therefore is disregarded in the reserve calculation.

Fire Clay coal bed.—The Fire Clay coal bed is of minor commercial importance in the area of this report. Because of persistent partings and the variable thickness of the bed, development of the coal is limited to small mines which furnish coal for local use. However, the characteristic flint-clay parting in the bed is a useful key for the correlation of outcrop and core-hole sections. Outcrops of the Fire Clay coal follow the lower hill slopes bordering the main streams of the Kermit and Varney quadrangles. The bed occurs principally in the Varney quadrangle (pl. 14) and ranges in thickness from 14 to 42 inches in Brushy Creek and its tributaries, from 28 to 38 inches on tributaries of Big Creek, and from 25 to 37 inches on Pigeonroost Fork. Core holes in the intervening area indicate a comparable variation in the thickness of the coal, except for a maximum thickness of 47 inches in drill hole 39 (pl. 14). The coal thins northward and is 14–20 inches thick in the southern part of the Kermit quadrangle. In the Elk Creek area in the northwest corner of the Kermit quadrangle the bed contains 30 inches of cannel coal (graphic section 64, pl. 10). The total estimated original reserves of the Fire Clay coal bed in all categories are 140.7 million tons.

Fire Clay rider coal bed.—The Fire Clay rider coal bed occurs principally in the Varney quadrangle in a broad northwest-trending belt which extends into the southwest corner of the Kermit quadrangle (pl. 14). Its outcrop line on the lower hill slopes is well delineated by abandoned truck mines and numerous house openings. Most of these entries are shallow, and only a relatively small amount of coal appears to have been removed. The Fire Clay rider coal bed is 14–49 inches thick on Brushy Fork and its tributaries, 23–40 inches on Big Creek and its tributaries, and 21–37 inches in the Pigeonroost Fork area of the Varney quadrangle. In the Kermit quadrangle the coal is 16–38 inches thick in the Wolf Creek drainage. Data available from other parts of the Kermit quadrangle indicate a thickness of less than 14 inches. Partings of shale and impure coal are common in the Fire Clay rider coal (graphic sections 61–74, pl. 11), and areas of thin coal occur where individual benches of coal wedge out or where shale partings are abnormally thick. About 90 percent of the total estimated original reserves of 108.9 million tons is in the Varney quadrangle.

Taylor coal bed.—The Taylor coal bed is widely distributed and crops out in most of the area of this report (pls. 12, 13). Absence of the bed locally in the Kermit quadrangle and in the southern part of the Varney quadrangle may have resulted from erosion which preceded the deposition of the overlying sandstones. The coal has been mined at many localities for local use and at a few truck mines that are presently abandoned. The thickness of the Taylor coal bed increases southward in the Kermit quadrangle from an average of about 20 inches in the Buck Creek area to an average of about 28 inches on Wolf Creek and its tributaries. Southward thickening continues into the Varney quadrangle where the coal occurs in a broad northeast-trending belt that has a thickness mostly in excess of 28 inches and locally more than 42 inches. The coal contains partings of shale and impure coal, and at some localities the bed consists largely of dull impure coal. The Taylor coal bed contains a total estimated original reserve of 145.8 million tons, of which an insignificant amount of coal is mined and lost in mining.

Winifrede coal bed.—The Winifrede coal is the most extensively mined bed in the Varney quadrangle. A large area of coal has been depleted in the ridge between Emily Creek and Bent Branch in the northeast corner of the quadrangle. Here the coal averages about 40 inches thick and occurs in a belt of relatively thick coal that parallels the east side of the report area (pls. 12, 13). The bed wedges out westward and is absent in a north-trending belt that extends into the western part of the Kermit quadrangle. In the eastern part of the Kermit quadrangle the Winifrede coal crops out on the middle or upper hill slopes and averages about 18 inches thick. Thin partings of impure coal or shale commonly occur in the bed. House openings and truck mines have operated in the bed locally. About 9 percent of the total estimated original reserves of 44.3 million tons in the Winifrede coal bed has been mined or lost in mining.

Buffalo Creek coal bed.—The Buffalo Creek coal bed is of minor economic importance in the area of this report. Commercial development has been discouraged by the thinness of the bed and by the presence of impure coal and shale partings (graphic sections 29–38, pl. 11). Workings in the bed consist of a few small entries that provide coal for local use. The Buffalo Creek coal crops out in the upper hill slope in most of the Varney quadrangle and in the southern part of the Kermit quadrangle where the bed gradually wedges out northward. It attains a maximum thickness of 32 inches in a small pocket at the head of Middle Fork in the southeastern part of the Varney quadrangle. Core drilling indicated an average thickness of about 20 inches in the northern part of the Varney quadrangle. About 16 inches of coal has been cored in the southern part of the Kermit quadrangle. Nearly all the 41.7 million tons of estimated original reserves in the Buffalo Creek coal bed are in the 14- to 28-inch category.

Peach Orchard coal bed.—The Peach Orchard coal bed is widely distributed and crops out in the upper hill slopes throughout the area of this report. It is characteristically multibenched and contains partings of shale, underclay, and impure coal that range in thickness from a few inches to 3 feet or more (graphic sections 16–35, pl. 10; 19–28, pl. 11). The coal has been extensively prospected by shallow pits along the outcrop line and by core drilling. Workings in the coal consist mostly of small mines that supply coal for local use. A few truck mines have operated in the bed, but as only a relatively small amount of coal has been mined, it is disregarded in the reserve calculations. The Peach Orchard coal bed is thickest in a broad northeast-trending belt which extends from Meathouse Creek on the west side of the Varney quadrangle to Tug Fork on the east side of the Kermit quadrangle (pl. 12, 13). Most of the coal in this belt exceeds 42 inches in thickness and locally is as much as 9 feet thick, excluding partings. In the remainder of the quadrangle the coal is mostly from 28 to 42 inches in thickness and averages about 30 inches. Southward through the Varney quadrangle the coal thins and splits into two or more separate beds (pl. 4). In an area of reserves in the southern part of the quadrangle the coal is 14–63 inches thick. The estimated original reserves of the Peach Orchard coal bed total 96.4 million tons. Of this total, about 47 percent is in the thickness category of more than 42 inches.

Broas coal bed.—The Broas coal bed underlies the ridge tops in most of the Varney quadrangle and in the southern part of the Kermit quadrangle (pl. 15). It is a thick coal bed, but the presence of persistent partings and the fairly inaccessible hilltop location of the outcrop have limited development to a few small truck mines and house openings. Data from these workings are supplemented by extensive prospecting along the outcrop and by core drilling. The Broas coal bed is thickest in the ridges extending from the upper part of Wolf Creek in the Kermit quadrangle southward into the western part of the Varney quadrangle. Excluding the thickness of shale and impure coal partings, the coal in this area is 49–80 inches thick and averages about 60 inches. An increase in the thickness of partings to the east and southeast results in the splitting of the coal into two separate beds—the Lower Broas coal bed and the Upper Broas coal bed (pl. 4). Reserves are calculated individually for each of these beds (table 5). In the Kermit quadrangle core drilling indicates that the Lower Broas coal is 18–32 inches thick, the Upper Broas coal 21–27 inches thick. The Lower Broas coal increases in thickness southeastward in the Varney quadrangle from less than 14 inches to a maximum of 56 inches. Conversely, the Upper Broas coal bed thins to the east from a maximum of about 70 inches to less than 14 inches. It includes a bench of cannel coal as much as 17 inches thick in the western part of the quadrangle. Original estimated reserves in the Broas coal bed, including the lower and upper splits, total 76.6 million tons. About 50 percent of this total is in the thickness category of more than 42 inches.

Richardson coal beds.—The Lower and Upper Richardson coal beds occur in a few of the highest hill tops of the Kermit and Varney quadrangles. Each bed averages about 60 inches in thickness and commonly contains several partings of impure coal and shale (graphic sections 1–6, pl. 10). Because of the limited areal extent of the Richardson coal beds, the amount of reserves is small and is disregarded in this report.

NATURAL GAS

Natural gas was discovered in Martin County in 1881 (Jillson, 1937, p. 57). Drilling has continued intermittently through 1960 when the fieldwork for this report was done. According to McFarlan (1943, p. 361), carbon black was manufactured from 1891 to 1901, before the field was connected by pipeline to

Ashland, Ky. In 1912 a pipeline to central Kentucky was laid. The original field was on the Warfield anticline, extending from Inez through Warfield and into West Virginia. It has expanded from the early "Inez Field" to the "Martin County Field" and with the drilling of wells in the intervening area has now joined the larger "Big Sandy Gas Field." Early production came from the Maxon sand and Big Lime of Mississippian age, which yielded large initial open flows (Hunter, 1935, p. 943; Jillson, 1937, p. 52-53); as the gas was exhausted from the younger producing zones, wells were deepened to the Black shale of Devonian age (Ohio Shale). Maxon wells have a life of 10-12 years (Jillson, 1937, p. 53). Most of the production in 1960 came from the Ohio (or Chattanooga) Shale of Late Devonian age and from the Greenbrier Limestone of Mississippian age. According to Hunter (1955, p. B49), wells drilled to the Ohio Shale have an 85 percent chance of success in either the Greenbrier Limestone or the Ohio shale. Gas has also been produced from the Lee Formation (Salt sands of drillers) of Pennsylvanian age, the Pennington Formation (Maxon sand and Red Injun of drillers) of Mississippian age, the Berea Sandstone (Wier sandstone of drillers) of Early Mississippian age, and from Devonian and Silurian formations below the Ohio Shale. No relationship between the amount of gas produced from a well and its position on geologic structure has been found. Variation in the porosity and permeability of the producing formation probably determines the areas of gas accumulation (Hunter, 1955, B49).

PETROLEUM

Oil was discovered in 1897 (McFarlan, 1943, p. 193), and production declined until 1927. No production of oil was reported (Crawford, 1958, p. 34) between 1928 and 1934. A field discovered in 1935 north of Wolf Creek extends westward from the Kermit quadrangle into the Inez quadrangle. By 1939 the new field was almost completely developed by drilling. Initial production was 31-50 barrels per day per well. Production reached a peak in 1938 and declined progressively (Crawford, 1958, p. 38). The Maxon sand in the Pennington Formation of Mississippian age is the source of tbe oil, and the accumulation seems to be structurally controlled by the steeper south flank of the Warfield anticline and in the area where the associated Worfield fault dies out.

Oil was produced in 1960 in small quantities from many gas wells in the Kermit-Varney area. Most of this was wasted because it was worth less than collection costs.

There is little probability of other accumulations of petroleum in the Kermit-Varney area in rocks of Pennsylvanian and Mississippian age; these rocks have been tested by many wells drilled for gas. The rocks older than the Ohio Shale of Late Devonian age have not been widely tested and may contain commercial quantities of petroleum.

A deep test well, U-8610-T, drilled in the Inez quadrangle by the United Fuels Gas Co., reached a depth of 13,172 feet. This well, at the time of drilling, was the deepest test in Kentucky and is interesting because it shows the character of the older rocks with production potential. It was drilled in the eastern edge of the town of Inez about 1 mile west of the Kermit quadrangle. A log of this well reprinted from Thomas (1960, p. 20) follows.

U-8610-T
Jasper James, et al.
United Fuel Gas Co.
Martin County, Ky.

Carter Coordinates, 19-Q-84
Commenced Drig., 12-9-58
Completed Drig., 5-7-59
Elevation, 659.00′ Kelly Bushing

Breathitt Formation	0	426	Show gas and salt water, 6,735 ft.
Salt sand	426	882	Show gas, 9,122-9,128 ft.
Maxon sand	998	1014	Show gas and salt water 9,189 ft.
Big Lime	1088	1270	Drill stem test No. 1.
Berea sand	1736	1840	9,186-9,240 ft, 450 ft gas-cut mud.
Devonian (Brown) shale	1840	2808	Drill stem test No. 2.
Corniferous	2808	3502	9,040-9,844 ft, 6,800 cu ft gas, 400 ft.
Big Six sand	3502	3522	Gas-cut mud.
Clinton shale	3522	3902	Tested through 7⅝ in. casing.
Clinton sand	3902	3916	Perforation 7,257-7,264 ft.
Ordovician limestone	3916	6620	Results—sulphur and salt water.
St. Peter sand	6620	6668	Perforation 6,854-6,872 ft.
Knox dolomite	6668	7248	No results.
Rose Run sand	7248	7376	Plugged and abandoned.
Knox dolomite	7376	8374	
Conasauga Formation	8374	8614	
Rome Formation	8614		
Total depth	13,172 ft		

Samples are available at the Kentucky Geological Survey, Lexington, Ky.
Electric Logs are available at the Appalachian Logging Service in Pittsburgh, Pa.

SAND

Sand for general construction is dredged from Tug Fork and Wolf Creek in the Kermit quadrangle. Most of the sand is composed of fine quartz grains, but a few medium grains are generally present. Mica flakes are abundant, and there is less than 1 percent dark mineral grains. Sand dredged from Tug Fork contains appreciable quantities of coal grains derived from mining activities upstream.

CLAY AND SHALE

Clay is present in the Kermit-Varney area in shale and underclay in the Breathitt Formation and in alluvium. The Elkins Fork Shale, Kendrick Shale, and Magoffin Beds are the thickest shale units exposed and are the most promising sources of clay. The Elkins

Fork Shale is exposed in several roadcuts north of Warfield along Tug Fork. In the valleys of Elk Creek and Little Elk Creek both the Elkins Fork and Kendrick Shales are exposed. The shale in the Magoffin Beds is at road level and is exposed in roadcuts and creek banks along Emily Creek and White Oak Fork. The Kendrick Shale is exposed in roof of the Williamson coal bed along Big Creek in the Varney quadrangle at several truck mines and in roadcuts near the forks of Brushy Fork. The underclays are exposed below coal beds at many mines. Thick underclay partings in the Peach Orchard coal could be mined with the coal. Generally the underclays are too thin and too limited in quantity to offer much encouragement for commercial use. Probably both the shales and the underclays of the Breathitt Formation and alluvium from Tug Fork would be suitable for brick and tile, and some of the shale may bloat. The underclay probably is refractory. No samples of clay were collected for testing, and there are no reports of tests of Martin County clays in the Kentucky Geological Survey Reports between 1955 and 1960. Results of tests on refractory and bloating characteristics of clay in the Breathitt Formation, including samples from the Elkins Fork Shale, Kendrick Shale, and Magoffin Beds from nearby counties, are given in Kentucky Geological Survey Reports of Investigations by Floyd and Kendall (1955), McGrain (1957), McGrain and Kendall (1957), and McGrain, Kendall and Teater (1960). Probably these clays are similar in quality to those in Martin County and northern Pike County in the Kermit-Varney area.

Sandstone for the construction of foundations, chimneys, and local buildings has been quarried from sandstone beds in the Breathitt Formation. During the 1950's other building material largely replaced sandstone. All the sandstone in the Breathitt contains too much iron or other undesirable elements to supply high-silica sand. None of the sandstones in the Kermit-Varney area contain enough quartz pebbles to supply large quantities of pebbles to crush for coarse angular silica grains.

LIMESTONE AND IRONSTONE

Except for local lenses of limestone and scattered concretions, there are no readily available reserves of limestone or ironstone. The quantity is small everywhere. The best source of limestone in the area would be the Greenbrier Limestone, which is reachable by shaft. Near Warfield, where the Greenbrier Limestone is nearest to the surface, it is at a depth of 1,000–1,200 feet.

MEASURED SECTIONS AND SELECTED LOGS OF CORES FROM DIAMOND-DRILL HOLES

STRATIGRAPHIC SECTIONS

KERMIT QUADRANGLE

Section measured along pipeline trench from Emily Branch up a nose to knob at the head of Roost Branch

[Section starts 1,200 ft north of the mouth of Meade Branch and continues to the bench at the 1,200-ft contour. Measured by J. W. Huddle and Harley Barnes]

Pennsylvanian, Breathitt Formation.	Thickness Ft	Thickness in
Clay and blossom at hill crest	3	0
Blossom (clay mixed with powdery organic matter): Deeply weathered residue of the Lower Richardson coal bed	1	6
Claystone; weathered white, considerably weathered; partly concealed; grades upward to underclay	10	6
Claystone, somewhat shaly; deeply weathered to olive and limonite brown	27	0
Blossom: Lower Clarion(?) coal bed	10	0
Underclay, light-gray, silty; Stigmarias; seat-rock fracture; hard in lower part; grades upward to squeezed clay below blossom	1	10
Shale, silty, micaceous; weathered olive and limonite brown; poor shaly structure; includes 1 ft sandstone about 3 ft above base which is fine grained; grades upward to underclay	7	8
Sandstone, fine- to medium-grained, micaceous; weathered feldspar; thin bedded to massive; crossbedded in part; forms major bench	93	0
Siltstone, deeply weathered olive and limonite brown; shaly structure; includes claystone beds	19	0
Blossom: Upper Broas coal bed		10
Claystone, slumped(?), deeply weathered; probably underclay	4	6
Blossom: Lower Broas coal bed		4
Underclay, light-brownish-gray, considerably weathered; slicks and Stigmarias	1	2
Claystone, silty; weathered white and olive; few Stigmarias even at base; very little shaly structure; grades upward to underclay	6	0
Sandstone, micaceous, fine- to medium-grained, friable; weathered yellow brown; massive; some thin bedded and crossbedded; supports broad bench near hill top	56	0
Blossom, somewhat slumped: Upper Peach Orchard coal bed	1	8
Claystone, deeply weathered; probably underclay; alt 1,028 ft, barometer	1	1
Blossom, slumped		4
Claystone; blocky fracture, interbedded with siltstone near base; grades upward to seat rock; some Stigmarias and laminae at top	3	11
Sandstone, fine- to medium-grained; large-scale gentle crossbedding; thin to massive beds; ledge-former; plant stem fragments, clay galls, and ironstone conglomerate lenses	53	0
Blossom: Lower Peach Orchard coal bed		7
Seat rock; sandy and silty weathered white claystone; somewhat squeezed		5
Sandstone, medium-grained, medium- to thick-bedded; quartz and weathered feldspar; micaceous, chloritic; weathered buff to rust	37	0
Shale, silty; strongly stained with limonite; blocky fracture; suggestion of seat-rock fracture toward top; sparse Stigmarias	2	6

KERMIT QUADRANGLE—Continued

Section measured along pipeline trench from Emily Branch up a nose to knob at head of Roost Branch—Continued

Pennsylvanian, Breathitt Formation.	Thickness Ft	in
Sandstone, light-gray, fine- to medium-grained, micaceous; abundant carbonaceous fragments; beds 0.1–1 ft thick; thickest beds in upper part; weathered yellow brown	8	2
Blossom: Buffalo Creek coal		1
Underclay, silty; seat-rock fracture; abundant Stigmarias; weathered very light gray with light-brown streaks	1	10
Siltstone, micaceous; some poor shaly structure; weathered very light gray; scattered small plant stems; grades up into underclay	12	0
Partly concealed; lower part is thin bedded very fine grained sandstone and shaly sandstone	6	0
Sandstone, fine- to medium-grained, thick-bedded, micaceous; carbonate fragments; weathered light gray; feldspar, weathered rusty brown	53	0
Blossom: Winifrede coal bed		8
Underclay; slightly silty clay; Stigmarias; slumped	2	4
Siltstone with shaly structure, micaceous, thin-bedded; weathered olive; rippled below; upper part 1.5 ft solid ledge	3	4
Seat rock; light-gray micaceous siltstone; grades up to underclay; seat-rock fractures; weathered white; Stigmarias in upper part (no sign of blossom or black shale, exposure reasonably good)	3	4
Sandstone, medium-grained, poorly sorted, feldspathic, micaceous; thick bedded to medium bedded; abundant fusain chips and carbonaceous fragments	30	6
Blossom: Trace Fork coal bed		6
Underclay, brown and light-gray-mottled, silty; Stigmarias; seat-rock fracture	2	1
Claystone, medium-gray; blocky fracture; slight shaly structure; weathered light olive; considerably weathered	12	0
Siltstone, limonite-rich; Spirifers and other fossils		6
Shale, medium-gray, very silty, micaceous; abundant brown specks; weatherd olive; fossils include molds of gastropods, pelecypods(?), orthoceroids, Spirifers, and productids: Magoffin Beds of Morse (1931)	11	6
Limestone, medium-gray, silty; possibly a large concretion		6–9
Shale, fissile to massive, micaceous, deeply weathered; appears dark gray, weathered olive; abundant poorly preserved fossils; tiny purplish-brown specks along bedding planes	23	0
Blossom; probably includes some carbonaceous shale: Taylor coal bed; alt 753 ft	2	10
Siltstone, sandy, micaceous; weathered brown gray; Stigmarias and plant leaves	2	1
Sandstone, medium-grained; bedding massive in lower part, 0.3- to 1-ft beds in upper part; poorly sorted; quartz, weathered feldspar, mica, and carbonate grains; coarse carbonate fragments abundant in upper part; much mica on bedding planes	16	0
Concealed	5	6
Sandstone, fine-grained, thin-bedded; mica and carbonaceous fragments on bedding surfaces	5	6
Sandstone, medium-grained, massive, dirty; weathered medium yellow brown	4	0
Valley fill: coarse rubble, sandstone blocks, and mud	10	0

KERMIT QUADRANGLE—Continued

Section measured along Kentucky Highway 40, beginning at town limit of Beauty, 1,200 feet east of BM 722 feet and continuing to BM 945 feet at gap between Buck Creek and Blacklog Fork

[Measured by J.W. Huddle and Harley Barnes]

Pennsylvanian, Breathitt Formation.	Thickness Ft	in
Sandstone, light-gray, weathered brown, fine- to medium-grained, massive, crossbedded. Includes several channels and thin shale beds. Large masses (as much as 3 by 5 ft) of calcareous sandstone about 45 ft and 60–62 ft above bottom of unit. (BM 945 near American Legion Post 173 is about 60 ft above base of the sandstone.) Underlying coal and sandstone cut out by channel; edge of channel filled with slumped shale and siltstone with coal and shale at base (dip 5°–12°); bedding not disturbed within slumped material. Slump overlain by massive channel sandstone 0–6 ft thick up to position of Taylor coal bed	64	0
Underclay and blossom	1	0
Coal, deeply weathered: Taylor coal bed; alt 884 ft		8
Underclay, silty, weathered light-brown; blocky structure Stigmarias	1	2
Coal, weathered		5
Underclay, plastic, weathered brown		10
Shale, weathered olive, silty; Stigmarias; limonite stained	2	0
Sandstone, fine- to medium-grained; abundant plant stems in base; sharp, rolling contact	10	6
Siltstone, light-gray, laminated, weathered		6
Coal (½-in. clay seam in middle): Hamlin coal bed		2
Shale, weathered light-brown; plant stems		4
Coal		5
Underclay; light-gray soft plastic clays		7
Siltstone and very fine grained sandstone; large-scale wedge bedding; at top poorly bedded with abundant Stigmarias; spheroidal weathering	4	2
Siltstone, irregularly bedded; pencil weathering; poorly developed shaly structure	8	7
Sandstone, very fine grained; even laminae of mica and carbonaceous grains; dark-gray; weathered fissile	1	7
Sandstone, fine- to medium-grained; abundant plant stems with vitrain bands in basal foot; forms ledge; small-scale crossbedding; top is calcareous	10	6
Coal, platy; sharp contact with sandstone above; Fire Clay rider bed; alt 842 ft		2
Shale, deeply weathered; grades up into olive siltstone; Stigmarias and plant stems in upper part	14	4
Coal, weathered: Fire Clay coal bed; alt 827 ft	1	0
Bony coal, flint clay(?)		8
Underclay, light-gray, silty; mica flakes and Stigmarias	1	8
Sandstone, massive, crossbedded; Stigmarias in top 2 ft	32	0
Coal: Upper Whitesburg coal bed; alt 792 ft		2
Shale, soft clay, light-gray		4
Coal	1	1
Concealed	1	6
Sandstone, fine-grained; small-scale crossbedding; Stigmarias in top 1 in	21	0

KERMIT QUADRANGLE—Continued

Section measured along Kentucky Highway 40, beginning at town limit of Beauty, 1,200 feet east of BM 722 feet and continuing to BM 945 feet at gap between Buck Creek and Blacklog Fork—Continued

Pennsylvanian, Breathitt Formation—Continued	Thickness Ft	in
Sandstone, very fine grained; interbedded with shaly siltstone; grades upward into sandstone	2	0
Shale, silty, fairly fissile	7	0
Coal with ½-in. dark-gray fissile shale, parting ½ in. above base: Lower Whitesburg coal bed		11
Shale, light-gray with dark-gray and coaly laminae; abundant plant stems and Stigmarias; fissile	1	1
Coal		4
Siltstone; argillaceous in lower 2 ft; abundant Stigmarias; limonite-stained weathered olive	3	2
Sandstone, fine- to medium-grained, weathered, massive; large-scale crossbedding; calcareous concretionary masses in upper part; crossbedding outlined by mica and carbonaceous grain laminae; basal contact sharp, disconformable; with rolls and scoops, normal to dip of crossbedding and 1–2 ft in cross section	45	0
Shale, medium-gray, fissile; abundant plant trash on bedding plane; sharp contact with disconformable sandstone above. In next cut to southwest this unit is squeezed, contorted, and contains a tilted sandstone lens (penecontemporaneous deformation, but the underlying sandstone is undisturbed)	3	0
Sandstone, fine-grained; ironstone conglomerate in base with shale chips and abundant plant stems, mica-carbonaceous laminae; small-scale cross lamination; siltstone partings, several even beds ½–1½ in. thick; scattered calcareous masses; thins to 4 ft about 100 ft to the southwest	7	6
Claystone, weathered olive, silty, chunky; ironstone concretions; thins and disappears 100 ft to southwest	2	0
Sandstone, dark-gray, fine-grained, poorly sorted; unoriented mica and ironstone concretions; grades upward into clay	1	5
Coal, dull, attrital with abundant thin vitrain bands: Williamson rider coal bed; alt 700 ft		5
Shale, black, carbonaceous, fissile; also light-gray shale with vitrain streaks; ½-in. coal 0.1 ft below top		7
Underclay, light-gray, soft, weathered plastic		4
Siltstone, argillaceous, light-gray; shaly structure toward base; Stigmarias throughout but more abundant in upper part	4	0
Sandstone, very fine grained, light-gray; with siltstone and shale laminae; irregularly bedded; 150 ft to southwest unit increases to 5 ft with ripple bedding and small-scale crossbedding, sandstone and siltstone laminae	2	4
Shale and siltstone interbedded, light-gray; some plant trash	1	6
Coal with 0.02-ft shale parting: Williamson coal bed		1
Shale, abundant Stigmarias		1
Shale, medium-gray, chunky, silty layer; ironstone concretions and sparse Stigmarias	2	5

VARNEY QUADRANGLE

Section measured along road up the Middle Fork of Elkins Fork beginning about 1,000 feet below the mouth of Brushy Hollow Fork. Top of section in the gap between Middle Fork and John Young Branch

[Measured by J. W. Huddle and A. C. Meisinger]

Pennsylvanian, Breathitt Formation.	Thickness Ft	in
Sandstone, very fine-grained, thin-bedded, laminated; exposed in roadcut south of gap	7	0
Shale, black, coaly; vitrain bands: Young(?) coal bed; alt about 1,153 ft		6
Underclay, silty, medium-gray, hard; Stigmarias		11
Sandstone, fine-grained, weathered white; abundant Stigmarias; nonbedded	1	0
Underclay, slightly silty, gray mottled; limonite stain; Stigmarias		7
Siltstone and sandstone interbedded, very fine-grained; in thin even slightly rippled beds less than ½-in. thick; Stigmarias in top 1½ ft	14	6
Concealed	5	6
Shale, weathered olive, moderately thick-bedded	11	0
Sandstone, very fine-grained; calcareous concretions	7	1
Shale, silty, chunky; spheroidal weathering	4	0
Sandstone, medium-light-gray; thin-bedded in lower part; massive, dark gray, and calcareous in upper part	2	7
Siltstone, medium-light-gray; thin, platy, and nonlaminated layers 0.3 ft thick interbedded	4	0
Shale, medium-gray, weathered olive, chunky	8	6
Concealed	15	0
Shale, interbedded with thin even layers of siltstone weathered olive	2	0
Shale, light-gray; weathered olive; chunky: Magoffin Beds of Morse (1931)	8	0
Shale, weathered olive; few ironstones and limestone concretions; silty, blue gray; no fossils seen	13	6
Concealed	5	0
Shale, black, fissile; large mica flakes; plant stems; (represents Taylor coal bed)		2
Sandstone, black, fine-grained; bedding poor; large mica flakes		1
Sandstone, medium-grained, massive, finely crossbedded; fine grained in top few feet	34	0
Shale, black		2
Coal, laminated, bony in basal 3 in.: Hamlin coal bed; alt 1,015 ft by hand level from BM X 314	1	1
Underclay, silty, limonite-stained; abundant Stigmarias	3	2
Shale, medium-gray, silty, chunky, hard	6	0
Sandstone, very fine grained, platy, and calcareous; siderite concretions, 0.5 ft by 3 ft	3	0
Shale, chunky, silty; and wafer-thin siltstone beds; weathered olive	6	0
Concealed	5	0
Sandstone, light-gray; thin slabby beds in lower part, massive in middle, ripple lamination in upper part	11	0
Concealed; collapsed mine entrance	5	0
Coal blossom smeared by road scraper: Fire Clay rider coal bed	1	0
Clay, plastic	1	0
Shale, soft, fissile, weathered olive	12	4
Coal blossom and underclay	3	0

VARNEY QUADRANGLE—Continued

Section measured along road up the Middle Fork of Elkins Fork beginning about 1,000 feet below the mouth of Brushy Hollow Fork—Continued

Pennsylvanian, Breathitt Formation—Continued	Thickness Ft	in
Shale, silty, massive, weathered olive, spheroidal; Stigmarias in top 6 in.; coal blossom in landslide above	9	6
Shale, light-gray; plant stems and leaves, pecopterid, Calamites; grades upward into massive siltstone; weathered olive	8	0
Coal, probably bony, hard, bright: Fire Clay coal bed; alt 962 ft		2
Coal, moderately bright, attrital; sparse, thick vitrain bands and fusain lenses		5
Coal, dull and bright attrital, hard; probably splint	1	4
Flint clay, moderately dark brown		5
Coal, dull attrital; one band of bright attrital near middle		10
Shale, light-gray, soft; Stigmarias		1
Concealed	17	0
Sandstone, fine grained; abundant mica flakes and carbonaceous fragments; shale chips in lower bed; crossbedded	30	0
Coal, bright attrital: Upper Whitesburg coal bed	1	3
Underclay, light-gray, limonite-stained; abundant Stigmarias		5
Sandstone, weathered olive, very fine grained, poorly bedded; abundant Stigmarias	1	10
Shale, deeply weathered olive	1	2
Coal blossom (in place)		10
Concealed	18	0
Coal blossom, slumped: Lower Whitesburg coal bed		2
Underclay, silty, nonplastic; abundant Stigmarias	2	0
Sandstone, very fine grained, poorly bedded; abundant Stigmarias		10
Shale, medium-gray, silty; ironstone nodules	5	5
Sandstone, thin-bedded, fine grained; massive in upper half; siderite grains, abundant mica, and carbonaceous laminae	11	0
Sandstone concealed	7	0
Coal blossom: Dingess coal bed		1
Underclay, light-gray		2
Coal, bony; vitrain bands		1
Shale, black, bony; vitrain bands		1
Underclay, light-gray, plastic; Stigmarias	1	0
Sandstone, very fine grained, weathered olive, nonbedded; Stigmarias	1	0
Underclay, light-gray, plastic; Stigmarias	1	0
Sandstone, very fine grained, weathered olive, nonbedded; Stigmarias	1	0
Shale, silty, weathered olive; Stigmarias	3	0
Sandstone, very light gray, fine-grained; abundant white matrix; ironstone-pebble and shale-chip conglomerate at base; thin slabby beds in basal 3 ft massive above	23	0
Shale, light- to medium-dark-gray, silty, chunky; abundant small ironstone nodules in a zone. Shale and sandstone; very fine-grained thin interbedded sandstone; probably siderite cement; large flat calcareous sideritic silty concretions; rippled siltstone wafers; Kendrick Shale of Jillson (1919)	8	0

VARNEY QUADRANGLE—Continued

Section measured along road up the Middle Fork of Elkins Fork beginning about 1,000 feet below the mouth of Brushy Hollow Fork—Continued

Pennsylvanian, Breathitt Formation—Continued	Thickness Ft	in
Siltstone, medium-dark-gray, poorly bedded; mottled, with limonite stain; irregular ironstone nodules, gradational upward; marine fossils, Spirifers, and fragments of *Lingula*		6
Coal: Williamson coal bed (or rider?)	1	11
Underclay, medium-gray, plastic; Stigmarias		1
Sandstone and siltstone grades upward light-gray; weathers limonite brown; abundant Stigmarias; nonbedded	2	11
Concealed	2	10
Sandstone, very fine grained, weathered olive, thin-bedded, rippled; exposed in creek bed	3	6

DRILLERS' LOGS

Drill hole 4

Cline & Chambers Coal Co., McCarr, Ky., DDH 6
July 24–28, 1959
Location: West bank of Wolf Creek in old road at stream bend 2,100 ft southeast of Buck Branch, Kermit quadrangle, Martin County, Ky.
Altitude: 616 ft, barometer

Pennsylvanian, Breathitt Formation.	Thickness Ft	in	Depth Ft	in
Surface	32	8	32	8
Sandstone	28	3	60	11
Blue shale: Kendrick Shale of Jillson	30	4	91	3
Sandstone		3	91	6
Coal: Williamson rider coal bed		7	92	1
Fire clay	1	4	93	5
Shale	19	6	112	11
Coal: Williamson coal bed		10	113	9
Slate		4½	114	1½
Coal		9½	114	11
Slate	1	6	116	5
Coal		1	116	6
Shale	3	1	119	7
Coal		2	119	9
Shale	5	3	125	0
Sandstone	46	1	171	1
Shale		7	171	8
Coal: Upper Van Lear coal bed	1	3	172	11
Shale	1	5	174	4
Sandy shale	19	1	193	5
Coal bone: Lower Van Lear coal bed	2	2	195	7
Fire clay	1	8	197	3
Shale	10	11	203	2
Coal: Alma coal bed	4	7	212	9
Fire clay	2	3	215	0

Drill hole 5

Cline & Chambers Coal Co., McCarr, Ky., DDH 3
June 18–19, 1959
Location: Davis Branch of Wolf Creek, Kermit quadrangle, Martin County, Ky.
Altitude: 697 ft

Pennsylvanian Breathitt Formation.	Thickness Ft	in	Depth Ft	in
Surface	10	0	10	0
Sandy shale	5	2	15	2
Blue shale	3	0	18	2

Drill hole 5—Continued

Pennsylvanian, Breathitt Formation—Continued	Thickness Ft	Thickness in	Depth Ft	Depth in
Sandstone	37	3	55	5
Sandstone: coal streak	3	2	58	7
Shale	1	0	59	7
Coal: Lower Van Lear coal bed	1	4	60	11
Fire clay		9	61	8
Sandy shale	5	10	67	6
Dark sandstone	10	9	78	3
Coal: Alma coal bed	4	5	82	8
Jack rock		6¼	83	2¼
Fire clay		10¾	84	1
Sandy fire clay	1	11	86	0

Drill hole 6

Cline & Chambers Coal Co., McCarr, Ky., DDH 5
July 23, 1959
Location: In road south of Wolf Creek 3,000 ft southwest of Lovely, Ky., Kermit quadrangle, Martin County, Ky.
Altitude: 636 ft, barometer

Pennsylvanian Breathitt Formation.	Thickness Ft	Thickness in	Depth Ft	Depth in
Surface	10	0	10	0
Shale	9	6	19	6
Sandstone	41	1	60	7
Coal: Lower Van Lear coal bed	1	3	61	10
Fire clay	1	8	63	6
Shale	9	9	73	3
Coal: Alma coal bed	5	1½	78	4½
Fire clay	2	7½	81	0

Drill hole 7

Cline & Chambers Coal Co., McCarr, Ky., DDH 1
June 10–12, 1959
Location: Road curve shown on topographic map 600 ft south of Wolf Creek bridge at Lovely, Ky., Kermit quadrangle, Martin County, Ky.
Altitude 632 ft, barometer

Pennsylvanian Breathitt Formation.	Thickness Ft	Thickness in	Depth Ft	Depth in
Surface	12	5	12	5
Sandy shale	9	2	21	7
Sandstone	24	5	46	0
Sandy shale		9	46	9
Coal: Upper Whitesburg coal bed	1	9	48	6
Fire clay	2	6	51	0
Dark shale	15	0	66	0
Coal: Lower Whitesburg coal bed		7	66	7
Fire clay	1	5	63	0
Gray shale	4	0	72	0
Coal: Dingess coal bed		2	72	2
Fire clay	3	0	75	2
Gray shale	8	8	83	10
Fire clay	1	10	85	8
Sandy shale	16	4	102	0
Sandstone	24	0	126	0
Black shale	11	8	137	8
Coal slate: Williamson rider coal bed		11	138	7
Gray shale	7	6	146	1

Drill hole 8

Cline & Chambers Coal Co., McCarr, Ky., DDH 2
June 15–17, 1959
Location: At stream junction 704 ft of Big Branch of Wolf Creek, Kermit quadrangle, Martin County, Ky.
Altitude: 705 ft, barometer

Pennsylvanian, Breathitt Formation.	Thickness Ft	Thickness in	Depth Ft	Depth in
Surface	5	0	5	0
Sandy shale	6	0	11	0

Drill hole 8—Continued

Pennsylvanian, Breathitt Formation—Continued	Thickness Ft	Thickness in	Depth Ft	Depth in
Black shale	2	7	13	7
Sandstone	14	3	27	10
Dark sandstone	1	8	29	6
Coal slate streak: Williamson rider coal bed		4	29	10
Fire clay		5	30	3
Coal slate streak	1	0	31	3
Fire clay	1	0	32	3
Sandstone	1	4	33	7
Black shale	3	8	37	3
Coal: Williamson coal bed		5	37	8
Fire clay	2	2	39	10
Sandy shale	33	8	73	6
Blue shale	4	8	78	2
Sandstone	28	6	106	8
Sandstone; coal streaks	5	0	111	8
Sandstone	12	3	123	11
Coal: Upper Van Lear coal bed		4¼	124	3¼
Bony coal		1¾	124	5
Slate		½	124	5½
Bony coal		3½	124	9
Fire clay		10	125	7
Sandy shale	7	0	132	7
Blue shale	6	6	139	1
Sandy shale	17	11	157	0
Coal: Lower Van Lear coal bed		10	157	10
Black slate		9	158	7
Slate coal streak	1	7	160	2
Sandy shale	9	6	169	8
Dark sandstone	3	7	173	3
Coal: Alma coal bed	2	6¼	175	9¼
Slate		¼	175	9½
Coal		¾	175	10¼
Slate		¾	175	11
Coal	1	11¼	177	10¼
Jack rock		1	177	11¼
Sandstone		5	178	4¼
Shale		4	178	8¼
Coal		9½	179	5¾
Fire clay	2	1¼	181	7
Sandy shale	2	5	184	0

Drill hole 10

Cline & Chambers Coal Co., McCarr, Ky., DDH 4
June 19–22, 1959
Location: Flat north of BM 634 on Wolf Creek about 4,000 ft northeast of the mouth of Pigeonroost Fork, Kermit quadrangle, Martin County, Ky.
Altitude: 643 ft, barometer

Pennsylvanian, Breathitt Formation.	Thickness Ft	Thickness in	Depth Ft	Depth in
Surface	15	0	15	0
Sandy shale	9	0	24	0
Coal: Williamson coal bed		4	24	4
Slate		8	25	0
Coal		4	25	4
Fire clay	1	0	26	4
Sandy shale	4	1	30	5
Sandstone	21	7	52	0
Sandstone coal streaks	2	0	54	0
Sandstone	5	5	59	5
Blue shale	3	0	62	5
Sandstone	6	8	69	1
Dark sandstone	13	9	82	10

Drill hole 10—Continued

Pennsylvanian, Breathitt Formation—Continued	Thickness Ft	Thickness in	Depth Ft	Depth in
Coal: Upper Van Lear coal bed		2	83	0
Slate		9	83	9
Slate coal		4	84	1
Coal		3	84	4
Fire clay	1	4	85	8
Sandy shale	9	9	95	5
Bony coal: Lower Van Lear coal bed		11	96	4
Slate		8	97	0
Coal		6	97	6
Slate	1	2	98	8
Coal		9	99	5
Fire clay	1	2	100	7
Sandy shale	4	0	104	7
Dark sandstone	11	6	116	1
Coal: Alma coal bed	3	10½	119	11½
Jack rock		3½	120	3
Fire clay		9	121	0
Sandy fire clay	1	0	122	0

CORE DESCRIPTION OF DRILL HOLES

Drill hole 13

Pocohontas Land Corp. diamond-drill hole 6, July 1960
Location: On ridge between Upper Twin Branch and Pigeonroost, Kermit quadrangle, Martin County, Ky.
Altitude: 1,245 ft, barometer
Core description by company engineers modified by J. W. Huddle and W. F. Outerbridge, Sept. 16, 1960

Pennsylvanian, Breathitt Formation.	Thickness Ft	Thickness in	Depth Ft	Depth in
Soil and loose rock	10	8	10	8
Sandstone, brown; clay streaks	17	6	28	2
Sandstone, gray; weathered brown; fine-grained	5	0	33	2
Coal: Upper Richardson coal bed		5½	33	7½
Shale, black, fissile		4	33	11½
Coal		7½	34	7
Bone		1	34	8
Coal	1	10	36	6
Shale, gray, coaly; abundant plants and stigmarian roots	2	9	39	3
Coal		2½	39	5½
Bone		3½	39	9
Coal		6	40	3
Shale, gray, soft; siltstone laminae	7	5	47	8
Shale, dark-gray		7	48	3
Coal		8	48	11
Underclay, soft	4	7	53	6
Coal	4	11½	58	5½
Slate		½	58	6
Coal		½	58	6½
Underclay, brown, hard; abundant stigmarian roots	3	1½	61	8
Shale, silty; grades down to very fine grained ripple-marked sandstone; stigmarian roots in upper part	3	2	64	10
Sandstone, gray, fine- and medium-grained; occasional cross laminae marked by abundant mica flakes and carbonaceous fragments	26	11	91	9
Shale, dark-gray; siderite layers; black fissile shale at base with plant stems and leaves vitrain	1	8	93	5

Drill hole 13—Continued

Pennsylvanian, Breathitt Formation—Continued	Thickness Ft	Thickness in	Depth Ft	Depth in
Position of Lower Richardson coal bed; underclay, stigmarian roots, and hard silty siderite grains	2	1	95	6
Shale and sandstone laminae; plants and "worm" burrows		10	96	4
Brown underclay		5	96	9
Underclay, black		8	97	5
Shale with "worm" burrows and silty patches		6	97	11
Sandstone, very fine grained; with very thin indistinct distorted shale laminae	4	10	102	9
Sandstone, brown; fine-grained in upper part, fine- to medium-grained below; ironstone and chert pebbles; sparsely laminated	57	10	160	7
Sandstone, brown, fine-grained; coal spars, vitrain laminae and coal fragments, ironstone and coal pebbles	3	10	164	5
Sandstone, brown, fine-grained	5	8	170	1
Shale, dark-gray, sandy; with sandstone lenses	1	7	171	8
Sandstone, gray, fine- to medium-grained; coal pebbles	5	1	176	9
Shale, gray, with very fine grained ripple-marked sandstone laminae; ironstone pebbles in upper part	2	5	179	2
Sandstone, gray, fine- to medium-grained; coal spars; cross-lamination in basal 2 ft	15	5	194	7
Sandstone with ironstone pebbles ¼ to 2 in. long, ¼–½ in. thick		7	195	2
Sandstone, gray, fine- to medium-grained; vitrain layers and cross-lamination	3	1	198	3
Shale, medium-gray, with discontinuous siltstone laminae, 2 ft 11 in; light-gray underclay 16 in. at base	3	6	201	9
Sandstone, very fine grained; with angular shale chunks, laminae, swirls; ironstone pebbles	1	5	203	2
Sandstone, gray, very fine grained; siderite grains; sparse cross-lamination	3	5	206	7
Shale, gray, with discontinuous disturbed siltstone laminae; "worm" burrows and ironstone nodules	1	8	208	3
Sandstone, gray; very fine grained and ripple marked in upper 2 ft; fine grained below with abundant cross beds, siderite grains marked by mica flakes, and carbonaceous fragments	17	4	225	7
Shale, gray, sandy	3	0	228	7
Coal: Broas coal bed (upper)		3¾	228	10¾
Bone		1	228	11¾
Coal		5½	229	5¼
Bone		1	229	6¼
Coal	1	6¼	231	½

Drill hole 13—Continued

Pennsylvanian, Breathitt Formation—Continued	Thickness Ft	Thickness in	Depth Ft	Depth in
Siltstone, gray, hard; stigmarian roots; very thin indistinct laminae at base	2	2½	233	3
Sandstone, very fine grained; with occasional shale laminae, disturbed in part	2	10	236	1
Coal: Broas coal bed (lower)		4½	236	5½
Bone		2½	236	8
Coal	1	2	237	10
Underclay, light-brown, micaceous; silty chips and stigmarian roots	1	8	239	6
Siltstone and seat rock, hard, gray; stigmarian roots	1	4	240	10
Sandstone, gray, fine-grained; calcareous, 279–284 ft; light gray, fine grained in upper 1 ft; fine to medium grained, cross laminated; sparse laminae marked by abundant mica flakes and carbonaceous fragments; vitrainized plant stems; 1 ft 4 in of siltstone and sandstone at 9 ft below top of unit	54	4	295	2
Sandstone, gray; round and flat ironstone pebbles		10	296	0
Shale, gray, with layers of siderite; plant trash	4	4½	300	4½
Coal, bony: Upper Peach Orchard coal bed		1	300	5½
Coal		5	300	10½
Shale, dark-gray		11¼	301	9¾
Coal, bony	1	1½	302	11¼
Coal		7½	303	6¾
Bone		4½	303	11¼
Shale, carbonaceous	1	1	305	¼
Coal	1	3	306	3¼
Shale		1½	306	4¾
Coal		3½	306	8¼
Bone		4	307	¼
Underclay		8¾	307	9
Shale, gray, silty; scattered stigmarian roots; sharp basal contact	1	9	309	6
Sandstone, gray, fine to medium-grained; occasional cross laminae marked by abundant mica flakes and carbonaceous fragments; shale chips; vitrain coal spars and ironstone pebbles at base; fine-grained and calcareous at 329–332 ft; calcareous at 335–336 ft	45	9	355	3
Coal, bright and fusain; sharp irregular top, penecontemporaneous slump?: Lower Peach Orchard coal bed		9	356	0
Sandstone and carbonaceous shale; messy angular chunks		9	356	9
Sandstone, very fine grained in upper 3 ft; cross laminae and shale chips 9–10 in. below top of unit; fine- and medium-grained cross laminae below; brown shale chunk 1 ft above base	50	9	407	6
Coal, bright-banded: Buffalo Creek coal bed	1	4	408	10

Drill hole 13—Continued

Pennsylvanian, Breathitt Formation—Continued	Thickness Ft	Thickness in	Depth Ft	Depth in
Shale, underclay, greenish-gray, hard; stigmarian roots; grades down into unit below	2	8	411	6
Shale, gray; scattered stigmarian roots; siderite layers	1	7	413	1
Sandstone, gray, very fine grained, ripple-marked	4	10	417	11
Shale, dark-gray, hard, silty, micaceous		8	418	7
Sandstone, fine- and medium-grained, cross-laminated; medium to coarse-grained in basal 15 ft; coal spars at 436 ft; shale chips and coal spars 462–465 ft	67	5	486	0
Shale, dark-gray; plant leaves		5	486	5
Coal, bright-banded; Winifrede coal bed		11	487	4
Shale, dark-gray, carbonaceous; slickensides, plants, and stigmarian roots	1	0	488	4
Siltstone and sandstone, very fine grained; stigmarian roots in upper 1 ft; very thin indistinct shale laminae; vitrain bands	3	9	492	1
Sandstone, gray, fine-grained, cross-laminated	7	4	499	5
Sandstone with abundant vitrain coal spars and carbonaceous trash	1	7	501	0
Sandstone, very fine grained, cross-laminated	3	2	504	2
Shale and siltstone laminae with even small-scale crossbeds		9	504	11
Sandstone, very fine grained; with ripple-marked shale laminae, very thin, indistinct, and even	8	8	513	7
Sandstone, fine grained; with sparse laminae marked by abundant mica flakes and carbonaceous fragments; scattered vitrain coal spars	42	5	556	0
Sandstone with thick vitrain bands		10	556	10
Sandstone, gray, fine-grained	3	8	560	6
Sandstone with coal spars	7	2	567	8
Shale, sandy		2	567	10
Claystone, medium gray; conchoidal chunky fracture; grades down to black carbonaceous shale	4	1	571	11
Shale, dark-gray; marine fossils including poorly preserved brachiopods, probably *Composita*?; slickensides; Magoffin Beds of Morse		2	572	1
Coal, bony; Taylor coal bed	1	8	573	9
Underclay, hard, brown; stigmarian roots	2	6	576	3
Siltstone with laminae and crossbeds of very fine sandstone	2	5	578	8
Sandstone, very fine grained; ripple marked in upper 5 ft, fine and medium grained below; some crossbeds; calcareous, 585–588 ft and 594–596 ft	28	3	606	11
Coal, bony: Hamlin coal bed		6	607	5

Drill hole 13—Continued

Pennsylvanian, Breathitt Formation—Continued	Thickness Ft	Thickness in	Depth Ft	Depth in
Underclay, grading down into shale; stigmarian roots to base	5	7	613	0
Shale, medium-gray, with sparse siltstone laminae; calcareous in top 6 in	16	2	629	2
Shale, dark-gray; coaly with vitrain bands, plant fossils, and slickensides		10	630	0
Coaly, bony, banded: Fire Clay rider coal bed		9	630	9
Underclay, medium-gray; stigmarian roots; grades down to shale below		9	631	6
Shale, medium-gray, fissile; with ironstone; dark-gray carbonaceous shale beds	5	4	636	10
Shale, black, coaly		6	637	4
Coal		1	637	5
Underclay, medium-gray; with carbonaceous shale zones and slickensides	2	11	640	4
Siltstone, gray, laminated; ironstone nodules	1	2	641	6
Shale, gray, with laminae and lenses of very fine grained ripple-marked sandstone; underclay-type siderite in upper 6 in	5	2	646	8
Shale, dark-gray, carbonaceous, coaly; stigmarian roots and plants		9	647	5
Coal		3	647	8
Underclay		6	648	2
Shale, medium-gray; with siltstone laminae	5	2	653	4
Coal: Fire Clay coal bed		1	653	5
Shale, dark-gray		6	653	11
Coal		3	654	2
Bone		2	654	4
Coal	1	½	655	4½
Bone		6	655	10½
Coal		3½	656	2
Bone		2	656	4
Underclay, dark-gray	1	2	657	6
Shale, dark-gray; abundant plants and vitrain, ironstone nodules, few stigmarian roots	5	0	662	6
Sandstone, fine-grained, even-bedded; abundant ironstone nodules	3	8	666	4
Sandstone, fine-grained; disturbed bedding; "worm" burrows; siderite grains abundant	2	3	668	7
Shale, gray, 60 percent; sandstone layers and ripple-marked crossbeds, 40 percent	2	7	671	2
Sandstone, 80 percent very fine grained; ripple marked with 20 percent interbedded shale layers	2	3	673	5
Sandstone with shale streaks	4	0	677	5
Shale, medium-gray, with discontinuous siltstone laminae	5	2	682	7
Coal: Upper Whitesburg coal bed	1	10	684	5
Underclay, dark-gray, slickensided; stigmarian roots	1	5	685	10
Sandstone, very fine grained; ripple marked with interbedded shale layers; siderite grains, "worm" burrows; calcareous, 688–688⅓ ft	2	6	688	4
Shale, medium-gray, fissile; discontinuous siltstone laminae; few plant stems	7	6	695	10
Coal, bony, banded: Lower Whitesburg coal bed		6	696	4
Sandstone, gray, very fine grained, silty; stigmarian roots	2	7	698	11
Sandstone, very fine grained, with irregularly cross-laminated shale; ironstone nodules; white, weathering yellowish-brown	5	8	704	7
Sandstone, fine-grained, with cross laminae marked by abundant mica flakes and carbonaceous fragments; fine-grained calcareous sandstone from 705 to 708 ft 5 in	12	10	717	5
Shale, dark-gray; plants and stigmarian roots		3½	717	8½
Coal, bright-banded: Dingess coal bed		4½	718	1
Underclay, brown; weathered and dark; stigmarian roots; underclay-type siderite, hard, silty, somewhat like flint clay	2	4	720	5
Claystone, medium-dark brownish-gray, nonbedded; stigmarian roots	3	4	723	9
Sandstone, gray, fine-grained; fine to medium grained in basal 10 ft; upper 2 ft very thinly indistinctly bedded probably slump	34	0	757	9
Shale, medium dark-gray, fissile; scattered ironstone nodules at base: Kendrick Shale of Jillson	19	6	777	3
Coal, bony, bright-banded: Williamson rider coal bed		5	777	8
Shale, dark-gray, slickensided, carbonaceous; vitrain	1	2	778	10
Sandstone, very fine grained, with very thin indistinct contorted laminae, flow?	3	8	782	6
Siltstone, gray, sandy, laminated; crossbedded; calcareous from 785 ft 9 in. to 786 ft 3 in	4	11	787	5
Shale, medium-dark-gray, with siltstone laminae; siderite layers	6	10	794	3
Coal: Williamson coal bed		6	794	9
Coal, bony		8	795	5
Shale, medium-dark-gray; with silty discontinuous lamine and ironstone nodules, white clay in septarian veins, stigmarian roots; underclay-type siderite	9	3	804	8
Sandstone, very fine grained, with coal spars (vitrain), calcareous from 806¼ to 808½ ft	3	10	808	6

Drill hole 13—Continued

Pennsylvanian, Breathitt Formation—Continued	Thickness Ft	Thickness in	Depth Ft	Depth in
Sandstone, fine-grained; siderite grains, few cross laminae and coal spars	34	0	842	6
Sandstone, with abundant coal spars (vitrain bands)	3	9	846	3
Sandstone, fine-grained; very calcareous from 850 to 850½ ft; medium grained in basal 3 ft	14	8	860	11
Shale; 70 percent with interbedded very fine grained sandstone; ripple-marked laminae, 30 percent	8	2	869	1
Sandstone, very fine grained, ripple-marked	3	0	872	1
Sandstone, fine- to medium-grained; siderite grains; cross laminated	11	3	883	4
Sandstone with shale and ironstone pebbles		8	884	0
Sandstone, dark-gray; ironstone nodules; nonbedded: Elkins Fork Shale of Morse	5	1	889	1
Shale, black, fissile; plants, *Pecopteris*	4	11	894	0
Coal: Upper Van Lear coal bed	1	4	895	4
Fusain		1	895	5
Coal		5¾	895	10¾
Shale, dark-gray, carbonaceous	1	5¼	897	4
Coal	1	0	898	4
Shale, dark-gray, soft, carbonaceous		9	899	1
Coal		2	899	3
Underclay, soft, carbonaceous	1	3	900	6
Shale, dark-gray, sandy	18	3	918	9
Coal: Lower Van Lear coal bed	1	9½	920	6½
Shale, dark-gray, sandy		4½	920	11
Coal		10	921	9
Underclay		4½	922	1½
Shale, sandy	1	2½	923	4
Sandstone	9	0	932	4
Shale, gray		7	932	11
Coal: Alma coal bed		1	933	0
Shale, dark-gray		3½	933	3½
Coal	1	2½	934	6
Shale, dark-gray	1	3	935	9
Shale, sandy	15	5	951	2
Sandstone	3	6	954	8
Shale, gray, sandy	4	6	959	2
Sandstone with shale streaks	6	10	966	0
Sandstone, medium-grained	8	8	974	8
Shale with discontinuous siltstone laminae and siltstone beds, gray; ironstone nodules, few "worm" burrow beds; abundant plant trash	16	1	990	9
Sandstone with ironstone nodules and coal spars, calcareous large mica flakes, poorly preserved fossils, gastropods and *Lingula:* Campbell Creek Limestone of White		7	991	4
Sandstone, gray, fine-grained; ironstone pebbles and plant trash	1	0	992	4
Shale, greenish-gray, soft, fissile		3	992	7
Shale, black, fissile; pyrite; some vitrain bands		4	992	11
Coal, thick vitrain, fusian; pyrite lenses		2½	993	1½
Shale, dark-gray, carbonaceous		1½	993	3
Underclay, dark-gray, hard; stigmarian roots	1	3	994	6
Shale, sandy, with very fine grained sandstone laminae, horizontal, disturbed; underclay-type ironstone nodules	3	0	997	6
Coal: Pond Creek rider coal bed	1	6	999	0
Shale, black		2	999	2
Shale, dark-gray, hard, sandy; abundant stigmarian roots in upper part; siltstone lamainae below; ironstone nodules	4	6	1,003	8
Sandstone, gray, fine-grained, ripple-marked		10	1,004	6
Shale-siltstone laminae	2	7	1,007	1
Coal, impure		2	1,007	3
Coal, bright-banded, thin vitrain: Pond Creek coal bed		6	1,007	9
Seat rock, siltstone, light-brown; stigmarian roots	1	0	1,008	9
Underclay, light-grayish-brown; stigmarian roots, underclay-type siderite grains and nodules; grades down	2	5	1,011	2
Siltstone and interbedded fine-grained sandstone; siderite grains abundant	3	6	1,014	8
Shale, silty, and siltstone in discontinuous laminae; abundant intergrown ironstone nodules and poorly preserved plant leaves and stems; vitrain bands	7	7	1,022	3
Shale, dark-gray, carbonaceous; vitrain bands		5½	1,022	8½
Coal, and plant trash, bright-banded; with abundant medium vitrain bands; some fusain; and underclay partings	1	½	1,023	9
Shale, dark-gray, carbonaceous; abundant stigmarian roots	1	0	1,024	9
Shale, sandy, with stigmarian roots; very fine grained sandstone laminae disturbed by roots or "worm" burrows	2	10½	1,027	7½
Sandstone, fine-grained; crossbedded siderite shale laminae	9	11½	1,037	7
Shale, dark-gray, with discontinuous lenses and pods of siltstone and very fine grained white sandstone beds; ironstone grains and nodules	14	3	1,051	10
Shale, dark-gray, slickensided; plant stems and pyrite		4	1,052	2
Coal, banded; thick vitrain bands and calcite veins: Powellton coal bed		6	1,052	8
Shale, dark-gray, hard, silty; stigmarian roots abundant; elongate ironstone nodules (roof-type)	1	8	1,054	4
Coal with marcasite, bright-banded		2	1,054	6

Drill hole 13—Continued

Pennsylvanian, Breathitt Formation—Continued	Thickness Ft	Thickness in	Depth Ft	Depth in
Shale, dark-gray; plant fossils		1	1,054	7
Coal, bright-banded		1	1,054	8
Shale, dark-gray; plant fossils		1	1,054	9
Coal, bright-banded		1	1,054	10
Shale, dark-gray, carbonaceous; stigmarian roots and abundant plant leaves and stems		11	1,055	9
Sandstone, light gray; siltstone in basal 6 in	4	0	1,059	9
Sandstone, gray, fine-grained, ripple-marked; siderite grains; base erosional, contains siltstone pebble	1	8	1,061	5
Shale, gray, silty; scattered ironstone nodules; plant fossils in basal 2 in	2	0	1,063	5
Coal; abundant thin to medium vitrain		6	1,063	11
Sandstone, dark-gray; mottled white and gray; carbonaceous; beds disturbed; stigmarian roots	1	1	1,065	0
Sandstone, gray, fine-grained; with shale streaks; ripple-marked; few shale layers; stigmarian roots in upper 3 ft	13	7	1,078	7
Sandstone, 70 percent, and interbedded shale layers, 30 percent; in rippled pods; *Estheria*? and *Orbiculoidea*	13	0	1,091	7
Sandstone, with disturbed bedding, possibly due to animal burrows: Cannelton Limestone of White (1885)	4	0	1,095	7
Shale, dark-gray, ironstone nodules		5	1,096	0

Drill hole 20

Pocahontas Land Corp. diamond-drill hole 17, May 1960
Location: On ridge between White Oak Fork and Emily Creek, Varney quadrangle, Martin County, Ky.
Altitude: 1,445 ft, barometer
Core description by company engineers modified by J. W. Huddle, May 11, 1960

Pennsylvanian, Breathitt Formation.	Thickness Ft	Thickness in	Depth Ft	Depth in
Sandstone, weathered rusty, fine-grained, sparsely laminated; clay cement	55	0	55	0
Shale, gray, sandy, coaly; megaspores and ironstone nodules	2	0	57	0
Shale, soft	2	0	59	0
Shale, light-gray, nonbedded; stigmarian roots and ironstone	2	6	61	6
Shale with very fine sand-grain laminae	4	0	65	6
Sandstone, fine- to medium-grained, and clay; massive and limonite stained; laminae marked by abundant mica flakes and carbonaceous fragments	30	3	95	9
Coal: Upper Richardson coal bed		10½	96	7½
Shale		3	96	10½
Shale, carbonaceous		1½	97	0
Coal	1	3	98	3
Shale		4	98	7
Coal	2	8	101	3

Drill hole 20—Continued

Pennsylvanian, Breathitt Formation—Continued	Thickness Ft	Thickness in	Depth Ft	Depth in
Shale, black		3	101	6
Coal	1	5½	102	11½
Shale, gray, hard, silty, fissile; stigmarian roots in upper part; laminated below; some small-scale slump or load casts	5	0	107	11½
Coal		1½	108	1
Shale		1	108	2
Coal, bony		3	108	5
Underclay, shaly		3	108	8
Coal		3	108	11
Underclay, light-gray, hard, silty (flint clay?); stigmarian roots	2	0	110	11
Shale, light-gray; stigmarian roots	8	1	119	0
Shale, gray, sandy; siltstone laminae; small-scale slump	6	0	125	0
Sandstone, fine- to medium-grained; few laminae marked by abundant mica flakes and carbonaceous fragments; calcareous from 149½ to 150 ft	37	8	162	8
Coal: Lower Richardson coal bed		1	162	9
Sandstone, shale 1 in. at about 4 in. below top of unit	2	6	165	3
Underclay, gray, hard	1	6	166	9
Sandstone and shale slumped	2	5	169	2
Sandstone, white; laminae marked by abundant carbonaceous fragments		4	169	6
Sandstone, light-gray; few coal spars	25	6	195	0
Shale, light-gray, nonbedded; weathers to chips; underclay-type ironstone nodules	3	8	198	8
Coal, weathered; white film on cleats		7	199	3
Shale underclay; stigmarian roots; grades down into shale with roof-type ironstones in basal part of unit	1	8	200	11
Coal: Lower Clarion(?) coal bed		8	201	7
Seat-rock sandstone, white (ganister); Stigmarias		7	202	2
Shale, gray; nonbedded with stigmarian roots in upper part grading to siltstone at base of unit; few thin sandstone beds	3	7	205	9
Sandstone, fine- to medium-grained; with sparse laminae marked by abundant mica flakes and carbonaceous fragments; some crossbeds; coal spars at depth of 235 ft	49	3	255	0
Sandstone, medium-grained, with shale, ironstone (altered to limonite), and coal pebbles	1	6	256	6
Sandstone, fine- to medium-grained; coal spars; medium to coarse grained at depth of 300 ft; calcareous from 330 to 331 ft	77	0	333	6
Sandstone, very fine grained 10 percent; interbedded shale and ironstone beds or nodules	15	0	348	6
Coal: Upper Broas coal bed		7	349	1
Shale, black		1	349	2

Drill hole 20—Continued

Pennsylvanian, Breathitt Formation—Continued	Thickness Ft	Thickness in	Depth Ft	Depth in
Coal	1	7	350	9
Underclay, soft; stigmarian roots; underclay-type ironstone	1	9	352	6
Coal, bony		3	352	9
Underclay	3	4	356	1
Shale, gray; ironstone nodules	3	7	359	8
Coal: Lower Broas coal bed		8	360	4
Shale, dark-gray		1½	360	5½
Coal		4	360	9½
Shale, dark-gray		1	360	10½
Coal		1½	361	0
Underclay, dark-gray, soft; stigmarian roots		8	361	8
Underclay, nonbedded	1	6	363	2
Shale, sandy; stigmarian roots in upper part, bedded in basal part of unit	3	3	366	5
Sandstone, fine- to medium-grained; coal spars	67	9	434	2
Coal: Upper Peach Orchard coal bed		2¾	434	4¾
Bone		1¾	434	6½
Coal		3½	434	10
Bone		¾	434	10¾
Coal	1	3	436	1¾
Shale, black		¼	436	2
Underclay		3¾	436	5¾
Coal	1	8	438	1¾
Shale	1	¼	439	2
Coal		10¼	440	¼
Shale, black		1½	440	1¾
Coal		2½	440	4¼
Shale		4¾	440	9
Coal		1	440	10
Shale, gray, hard, nonbedded; stigmarian roots	2	10	443	8
Sandstone, fine- to medium-grained; coal spars and some crossbeds; 1 ft of shale 4 ft below top of unit	30	5¾	474	1¾
Coal, bony: Lower Peach Orchard coal bed		1	474	2¾
Coal		½	474	3¼
Shale		½	474	3¾
Coal	1	9½	476	1¼
Shale, dark-gray; includes some cannellike shale	2	4	478	5¼
Shale, sandy; stigmarian roots in upper part of unit	1	8¼	480	1½
Sandstone and shale interbedded; irregular inclined uneven beds		10	480	11½
Sandstone, fine- to medium-grained; coal fragment dips 10°	1	10½	482	10
Coal		2	483	0
Sandstone, fine- to medium-grained; some crossbeds; very fine grained and nonbedded in upper 1½ in.; white, doubtful stigmarian roots	32	10	515	10
Coal: Buffalo Creek coal bed		1½	515	11½
Shale, black, fissile; stigmarian roots	3	0	518	11½
Shale, sandy; stigmarian roots; coal laminae	2	10	521	9½
Shale, dark-gray, with vitrain bands		2½	522	0

Drill hole 20—Continued

Pennsylvanian, Breathitt Formation—Continued	Thickness Ft	Thickness in	Depth Ft	Depth in
Underclay, medium-gray, hard; stigmarian roots		9	522	9
Coal		6	523	3
Bone		¼	523	3¼
Shale, gray, fissile; stigmarian roots and plant leaves	1	3	524	6¼
Coal		10½	525	4¾
Shale, gray		¾	525	5½
Coal		3½	525	9
Shale, gray		¼	525	9¼
Coal		¼	525	9½
Shale		1	525	10½
Coal and shale		½	525	11
Shale		1½	526	½
Sandstone with indistinct bedding, fine-grained; some laminae; dark-gray ganister, in upper 3 in.; very fine grained in upper 2½ ft	23	½	549	1
Shale and sandstone; evenly laminated and ripple marked in upper part; very fine grained sandstone at base	2	6	551	7
Sandstone, gray, fine- to medium-grained; few vitrain laminae and coal fragments	8	8	560	3
Sandstone, including shale pebbles; coal spars	2	7	562	10
Sandstone, medium-grained; shale and ironstone pebbles and coal spars; some crossbeds	29	7	592	5
Coal, banded; black shale and vitrain		9	593	2
Sandstone and coal spars	1	8	594	10
Coal: Winifrede coal bed		9	595	7
Shale, gray		10½	596	5½
Coal	2	9	599	2½
Bone		¼	599	2¾
Underclay, gray, soft		1	599	3¾
Shale, dark-gray, with vitrain layers		4¼	599	8
Underclay, gray; stigmarian roots	1	3	600	11
Seat rock (ganister) sandstone with stigmarian roots		11	601	10
Shale, coaly		2	602	0
Underclay with stigmarian roots	1	5	603	5
Shale with stringer of siltstone	3	2	606	7
Shale, gray, fissile; ironstone nodules	2	4	608	11
Shale, gray		2	609	1
Coal, bony: Young(?) coal bed		1	609	2
Shale, gray; ironstone nodules (roof type)	1	5	610	7
Sandstone, fine- to medium-grained; some shale laminae; shale pebbles and coal spars; calcareous from 625 to 627½ ft	26	4	636	11
Shale, black, fissile		3½	637	2½
Coal: Trace Fork coal bed		11½	638	2
Shale with stigmarian roots; grades from nonbedded to contorted bedding in lower part of unit	2	2	640	4
Sandstone, fine-grained, poorly bedded	1	10	642	2

Drill hole 20—Continued

Pennsylvanian, Breathitt Formation—Continued	Thickness Ft	Thickness in	Depth Ft	Depth in
Shale and sandstone layers; ripple-marked thin shale beds and sandstone beds about 2 in. thick	2	6	644	8
Sandstone, very fine grained, laminated; siderite cement	3	5	648	1
Shale, dark-gray, hard; irregular fracture; ironstone nodules and abundant mica flakes; calcareous sandstone from 650 to 652½ ft: Magoffin Beds of Morse	6	3½	654	4½
Shale, dark-gray, fossiliferous: *Chonetes*, *Trepospira*, and others	5	2	659	6½
Sandstone, poorly bedded, with "worm" trails and burrows(?); few brachiopods	4	9	664	3½
Shale, mottled light- and dark-gray; with sandstone beds and siderite layers	5	9	670	½
Shale, gray; pelecypods and other fossils	11	3½	681	4
Shale, dark-gray; pelecypods	2	8	684	0
Coal: Taylor coal bed	1	3	685	3
Bone		1½	685	4½
Coal		4½	685	9
Shale, sandy, mottled dark- and light-gray	1	0	686	9
Sandstone, fine- to medium-grained; coal spars; sparse crossbeds; calcareous from 698 to 708 ft and from 718 to 723 ft	58	6	745	3
Sandstone and ironstone pebbles 1 in. long		11	746	2
Shale, dark-gray		3	746	5
Coal, bony: Fire Clay rider coal bed		7	747	0
Coal and contorted sandstone veins and inclusions		11	747	11
Underclay, gray; stigmarian roots	2	1	750	0
Underclay, light-gray, sandy	3	8	753	8
Shale, dark-gray, carbonaceous; coaly with stigmarian roots in basal part of unit		7½	754	3½
Underclay, sandy; sharp uneven basal contact	1	4½	755	8
Sandstone, light-gray, fine-grained; some laminae of mica and carbonaceous fragments	27	0	782	8
Sandstone, light-gray; coal spars	2	8	785	4
Coal, bony: Fire Clay coal bed		1½	785	5½
Sandstone, very fine grained, and interbedded shale laminae		8½	786	2
Bone		1½	786	3½
Coal		8¼	786	11¾
Bone, and flint clay 3± in		6	787	5¾
Coal		7¼	788	1
Claystone and sandstone laminae; stigmarian root grades into bed below	2	2	790	3
Sandstone and shale laminae; ripple marked	2	2	792	5

Drill hole 20—Continued

Pennsylvanian, Breathitt Formation—Continued	Thickness Ft	Thickness in	Depth Ft	Depth in
Sandstone, fine- to medium-grained; laminae marked by abundant mica flakes and carbonaceous fragments; coal spars and ironstone pebbles	38	¾	830	5¾
Coal: Upper Whitesburg coal bed	1	10½	832	4¼
Coal, bony		1½	832	5¾
Underclay, very soft; stigmarian roots	1	8¼	834	2
Shale, dark-gray, with sandstone streaks; disturbed bedding in upper part of unit, regular bedding below	12	0	846	2
Coal: Lower Whitesburg coal bed		10	847	0
Shale, gray, with ironstone nodules; 3 in. of coaly shale 5 ft below top of unit	9	4	856	4
Coal: Dingess coal bed		6	856	10
Sandstone, gray, very fine grained, argillaceous; underclay-type siderite and stigmarian roots; interbedded shale in basal 1± ft	3	1	859	11
Sandstone and shale laminae, irregular and indistinct	5	4	865	3
Sandstone, fine- to medium-grained; coal spars; some crossbeds	5	9	871	0
Shale, dark-gray, carbonaceous		5	871	5
Coal, bright-banded		1	871	6
Shale, gray, with regular continuous siltstone laminae; ironstone nodules	12	1	883	7
Shale, sandy		8	884	3
Shale, sandy; coal spars; slump		3	884	6
Shale and siltstone laminae, distorted		8	885	2
Coal banded fingering into sandstone		1	885	3
Sandstone, very fine grained; coal spars and squeezed lens of black coaly shale		9	886	0
Sandstone, very fine grained; coal spars	3	8	889	8
Sandstone, fine-grained; laminae marked by abundant mica flakes and carbonaceous fragments with crossbeds dipping about 6°	14	10	904	6
Sandstone with abundant laminae marked by abundant mica flakes and carbonaceous fragments; dips 30° probably due to slump	1	3	905	9
Shale, dark-gray, silty, slickensided; scattered sandstone stringers and ironstone nodules: Kendrick Shale of Jillson	10	0	915	9
Shale, with sandstone beds and twisted laminae; ironstone nodules		10	916	7
Sandstone with disturbed shale layers probably "worm" burrows; ironstone nodules, siderite grains, crinoid stems, shark tooth, and other fossils; dark-gray graywacke at base of unit	3	5	920	0
Coal: Williamson rider coal bed		5¼	920	5¼
Bone		5¼	920	10½
Coal		3½	921	2

Drill hole 20—Continued

Pennsylvanian, Breathitt Formation—Continued	Thickness Ft	Thickness in	Depth Ft	Depth in
Bone		2½	921	4½
Coal		3¼	921	7¾
Underclay, light-gray; stigmarian roots	1	2¼	922	10
Sandstone, very fine-grained, with 40 percent shale layers; sandstone in vertical dikes	3	3	926	1
Sandstone and shale interbedded; roof-type ironstone nodules	7	0	933	1
Sandstone, calcareous; siderite grains		8	933	9
Shale, gray, fissile; black at base of unit	4	6	938	3
Coal: Williamson coal bed	1	4	939	7
Bone		2	939	9
Coal		3	940	0
Underclay, light-gray, soft, slickensided; stigmarian roots and ironstone nodules	2	6	942	6
Sandstone and shale interlaminated with indistinct bedding	2	4	944	10
Sandstone, fine-grained; abundant laminae; some crossbeds	11	4	956	2
Sandstone, yellow; weathers rapidly; calcareous; siderite grains	4	1	960	3
Sandstone, fine-grained; grades down to medium-coarse grained at base; laminae indistinct, inclined in part, marked by abundant mica flakes and carbonaceous fragments; ironstone pebbles and coal spars in basal 2 ft	11	9	972	0
Shale with sandstone, evenly laminated; small-scale crossbeds	2	6	974	6
Sandstone, gray, medium-grained; laminae marked by carbonaceous fragments; coal spars; crossbeds	8	6	983	0
Sandstone, medium-grained; shale pebbles, siderite, and abundant coal spars	8	0	991	0
Sandstone, medium-grained; sparse crossbeds marked by abundant mica flakes and carbonaceous fragments	3	4	994	4
Sandstone, medium-grained; shale and ironstone pebbles		9	995	1
Sandstone and shale laminae, ripple-marked; abundant mica flakes and carbonaceous fragments	18	9	1,013	10
Sandstone; weathers yellow; fine-grained calcareous and sideritic		4	1,014	2
Sandstone and shale layers, ripple-marked; very thin beds	1	9	1,015	11
Shale, light-gray; abundant intergrown ironstone nodules	11	1	1,027	0
Shale, very dark gray fissile; plant trash, pyrite, and slickensides: Elkins Fork Shale of Morse	6	6½	1,033	6½
Shale, dark-gray, soft; probably stigmarian roots		3½	1,033	10
Coal: Upper Van Lear coal bed	1	6½	1,035	4½
Shale, light-gray; stigmarian roots		5½	1,035	10

Drill hole 20—Continued

Pennsylvanian, Breathitt Formation—Continued	Thickness Ft	Thickness in.	Depth Ft	Depth in.
Siltstone, light-gray; abundant stigmarian roots	5	4	1,041	2
Shale-light, and dark-gray, with sandstone laminae; plant stems and leaves	2	9	1,043	11
Coal, bright-banded: Lower Van Lear coal bed		9	1,044	8
Underclay, light-gray, soft; stigmarian roots	2	3	1,046	11
Shale, medium-gray, fissile; stigmarian roots in upper 1 ft, siderite pellets	18	0	1,064	11
Shale, mottled, sandy	5	10	1,070	9
Coal: Alma coal bed		½	1,070	9½
Bone		¾	1,070	10¼
Coal	2	2	1,073	¼
Coal laminae		2¼	1,073	2½
Shale		5	1,073	7½
Sandstone	4	2	1,077	9½
Shale, sandy	1	11½	1,079	9
Sandstone	1	3	1,081	0
Shale, soft, sandy		2½	1,081	2½
Coal		1	1,081	3½
Underclay		5	1,081	8½
Coal		7	1,082	3½
Underclay, hard	1	8	1,083	11½
Shale, gray	1	1	1,085	½
Shale, sandy	2	5	1,087	5½
Shale and sandstone laminae	2	1	1,089	6½
Shale, very sandy, calcareous 3 in		11	1,090	5½
Shale with sandstone streaks	30	4	1,120	9½
Shale, very sandy and calcareous	2	7	1,123	4½
Shale, dark-gray	9	9	1,133	1½
Shale, very sandy, calcareous; ironstone pebbles	1	9	1,134	10½
Shale, sandy	4	10	1,139	8½
Sandstone	7	8	1,147	4½
Shale, black		9	1,148	1½
Shale, dark-gray, with sandstone laminae	4	5	1,152	6½
Shale, very sandy, calcareous		8	1,153	2½
Shale, sandy	1	0	1,154	2½
Shale, gray	15	2	1,169	4½
Shale, soft		½	1,169	5
Coal: Pond Creek rider coal bed	1	6	1,170	11
Underclay, light-brown	1	10½	1,172	9½
Shale, gray	1	11	1,174	8½
Shale, dark-gray, soft		1	1,174	9½
Shale, dark-gray		3	1,175	½
Shale, gray, sandy	3	6	1,178	6½
Sandstone	3	3	1,181	9½
Sandstone, with shale laminae	4	6	1,186	3½
Shale, sandy	2	2	1,188	5½
Coal: Pond Creek coal bed		10½	1,189	4
Coal, bony		2	1,189	6
Shale, gray	1	½	1,190	6½
Shale, sandy	2	10½	1,193	5
Sandstone	1	3	1,194	8
Shale, sandy	1	4	1,196	0
Sandstone, calcareous	4	2	1,200	2
Shale, sandy	2	10	1,203	0

Drill hole 24

Pocahontas Land Corp. diamond-drill hole 3, August 1960
Location: On the ridge between the Left Fork of Petercave Fork and Rockhouse Branch of Pigeonroost Fork, Varney quadrangle, Martin County, Ky.
Altitude: 1,342-ft Level traverse by Pocahontas Land Corp.
Core description by company engineers, modified by J. W. Huddle and K. J. Englund, July 19, 1960

	Thickness Ft	Thickness in	Depth Ft	Depth in
Pennsylvanian, Breathitt Formation.				
Soil, loose rock, and gray soft shale	11	8	11	8
Sandstone, brown and gray, fine-grained, crossbedded; laminae marked by abundant mica flakes, carbonaceous fragments, and ironstone grains	30	4	42	0
Coal: Upper Richardson coal bed		10½	42	10½
Shale, dark, sandy		8	43	6½
Coal	1	¼	44	6¾
Bone		¾	44	7½
Coal	2	2	46	9½
Bone		7½	47	5
Coal		¾	47	5¾
Bone		2	47	7¾
Coal	1	9½	49	5¼
Underclay, soft	1	8	51	1¼
Coal		4½	51	5¾
Shale, black; stigmarian roots and plant stems		4½	51	10¼
Coal		4½	52	2¾
Underclay, dark to light-brown below; no silt	3	8¼	55	11
Shale, gray, fissile	2	4	58	3
Shale, sandy; very fine-grained sandstone in very thin indistinct laminae 2–7 in. thick in shale; calcareous 68 ft 10 in. to 69 ft 4 in	11	1	69	4
Shale, medium- and dark-gray; 10 in. of black shale at 78 ft; plant leaves and elongate ironstone nodules; one 2-in. sandstone bed	15	8	85	0
Shale, gray, soft		6	85	6
Coal: Lower Richardson coal bed	3	4	88	10
Underclay, light-gray, soft; grades down to silty underclay; 1-in. bone coal	4	2	93	0
Underclay, siltstone and shale; underclay with stigmarian roots 2 ft ±; siltstone 1 ft; gray shale, with ironstone nodules. Thin underclay 3 ft above base	10	5	103	5
Coal, bone		2	103	7
Shale, dark-gray, soft; stigmarian roots		3	103	10
Coal, bony		2	104	0
Shale, gray, soft, sandy; stigmarian roots disturb siltstone laminae	2	9	106	9
Sandstone, white; stained by limonite streak; fine-grained; very calcareous in 3-ft zone at base	5	8	112	5
Shale, gray; interbedded with 6-in to 2-ft beds of very fine grained ripple-marked sandstone	6	2	118	7
Shale, gray; elongate ironstone nodules	2	9	121	4

Drill hole 24—Continued

	Thickness Ft	Thickness in	Depth Ft	Depth in
Pennsylvanian, Breathitt Formation—Continued				
Shale, dark-gray, carbonaceous, fissile; plants	3	3	124	7
Shale, gray, sandy; top 2 ft black shale and sandstone irregularly laminated; black underclay grades down into the siltstone, which contains stigmarian roots	5	7	130	2
Sandstone, light-brown, fine-grained; scattered coal spars; few laminae of mica flakes and carbonaceous fragments; medium grained at base and includes plant stems	24	0	154	2
Shale, gray; 2-in. sandstone layer has dip of 5°–10°	1	3	155	5
Sandstone, light-brown, fine-grained; scattered coal spars; vitrain	2	3	157	8
Shale, gray, olive; plants		9	158	5
Sandstone, brown, medium- to coarse-grained; at 163 ft 4-in. bed of siderite pebbles, few coal spars, vitrain and attrital coal; calcareous zone 171–174 ft	30	4	188	9
Sandstone, light, medium- to coarse-grained; abundant coal spars	5	4	194	1
Sandstone, white, coarse-grained	5	8	199	9
Breccia; shale, sandstone, siderite and vitrain; brecciated by slump	3	1	202	10
Sandstone, light-brown, coarse-grained	7	11	210	9
Sandstone, white, fine-grained; scattered coal spar; cross-bedded	4	2	214	11
Sandstone, brown, coarse-grained	1	1	216	0
Sandstone, white, coarse-grained; vitrainized plant stems; crossbeds, marked by thick laminae containing abundant mica flakes and carbonaceous fragments	1	0	217	0
Sandstone, medium- to coarse-grained, light-brown; coal spars; ironstone pebbles, a few mica flakes, and carbonaceous fragment laminae	8	0	225	0
Sandstone, white, medium- to coarse-grained; coal spars; ironstone pebbles and shale chips in base	16	8	241	8
Shale and sandstone layers; ironstone nodules; "worm" burrows in top 2 ft; ripple-marked	8	10	250	6
Sandstone, very fine-grained, with a few very thin indistinct laminae and thin beds	7	5	257	11
Sandstone, white, fine-grained; about 1-ft calcareous zone at base	3	0	260	11
Shale, gray; elongate ironstone nodules	2	3	263	2
Shale, gray, with horizontal uneven siltstone laminae	11	6	274	8
Shale, gray, sandy; roof shale	4	8	279	4
Coal laminae: Broas Coal bed (both beds)		1½	279	5½
Coal		4½	279	10
Bone		1	279	11

Drill hole 24—Continued

Pennsylvanian, Breathitt Formation—Continued	Thickness Ft	Thickness in	Depth Ft	Depth in
Coal	2	5	282	4
Bone		4¼	282	8¼
Coal	1	8½	284	4¾
Shale		3	284	7¾
Coal		6	285	1¾
Underclay, light-brown; siltstone below; abundant stigmarian roots	1	2¼	286	4
Siltstone and shale, gray: 4 ft siltstone with abundant stigmarian roots and underclay-type of ironstone at top; 6 ft of ripple-marked very fine grained sandstone below; slump at base	10	3	296	7
Sandstone, gray, coarse-grained; coal spars	8	9	305	4
Sandstone, gray, medium-grained	4	1	309	5
Sandstone, gray, fine-grained; laminae marked by abundant mica flakes and carbonaceous fragments	3	7	313	0
Sandstone, gray, medium-grained, crossbedded	4	6	317	6
Sandstone, medium-grained, vitrain laminae	8	0	325	6
Sandstone, gray, medium-grained; coal spars	2	7	328	1
Sandstone, gray, medium grained	5	10	333	11
Shale, sandy; brown underclay; Stigmarias	2	8	336	7
Shale, dark-gray, silty, micaceous; plants		4	336	11
Coal: Upper Peach Orchard coal bed		3½	337	2½
Shale		8⅜	337	10⅞
Coal		¾	337	11⅝
Shale		⅜	338	0
Coal		2⅞	338	2⅞
Shale and coal		5⅞	338	8¾
Bone		¾	338	9½
Coal		5¾	339	3¼
Shale		1⅝	339	4⅞
Coal		⅝	339	5½
Shale		1⅜	339	6⅞
Coal		7¼	340	2⅛
Shale		3½	340	5⅝
Coal		10½	341	4⅛
Shale, gray; plants; no suggestion of underclay	1	10⅜	343	2½
Sandstone, gray, fine-grained; "worm" burrows at top	1	0	344	2½
Shale, gray, irregularly bedded		1½	344	4
Sandstone, very light gray; very thin indistinct ripple-marked laminae	1	6	345	10
Shale and sandstone, irregularly bedded	1	1	346	11
Sandstone, light-gray, fine- to medium-grained; very thin indistinct laminae to 4± ft; cross laminated; medium grained below 360± ft	20	0	366	11
Shale, gray; contains very fine grained ripple-marked sandstone and siltstone laminae and lenses from ½–1 in. in thickness	14	5	381	4

Drill hole 24—Continued

Pennsylvanian, Breathitt Formation—Continued	Thickness Ft	Thickness in	Depth Ft	Depth in
Shale, dark, soft, carbonaceous		4	381	5
Coal: Lower Peach Orchard coal bed	2	3	883	11
Shale, carbonaceous		6	384	3
Coal		3	384	8
Shale, dark, carbonaceous		1½	384	9½
Coal		3	385	½
Shale	1	5½	386	6
Coal	1	6½	388	½
Shale		1½	388	2
Coal	2	1½	390	3½
Shale		2½	390	6
Coal		6	391	0
Underclay and dark-gray soft shale, carbonaceous; carbonaceous shale; plants	4	0	395	0
Shale, black, carbonaceous	1	10	396	10
Underclay, light-gray; stigmarian roots to base	4	2	401	0
Sandstone, very fine-grained; shale laminae; calcareous zone 413 to 414 ft 9 in	16	3	417	3
Shale, gray; plant leaves and stems		6	417	9
Coal: Buffalo Creek coal bed		4¾	418	1¾
Shale		¾	418	2½
Coal	1	7	419	9½
Shale, dark-gray, sandy; stigmarian roots	1	8½	421	6
Shale, dark-gray, sandy; irregular beds of sandstone and black shale	7	10	429	4
Sandstone, white, medium-grained; abundant laminae	10	5	439	9
Sandstone, fine-grained, calcareous; weathers yellow-brown	2	7	442	4
Sandstone, medium-grained; scattered vitrainized plant stems	10	6	452	10
Sandstone, fine- to medium-grained; a few shale pebbles and coal spars	20	4	473	2
Coal; probably detrital block of coal: position of Winifrede coal bed	1	0	474	2
Sandstone, medium-grained; many coal spars; coarse-grained sandstone and siderite pebbles in basal 4 in	8	6	482	8
Shale, gray; elongate ironstone nodules; few siltstone laminae	4	0	486	8
Shale, dark, soft		2	486	10
Coal: Young(?) coal bed	1	10½	488	8½
Shale, gray	1	7½	490	4
Sandstone and shale mixed, disturbed; dikelets	2	1	492	5
Coal, bony		3	492	8
Shale, dark, with vitrain laminae		4	493	0
Underclay, brown and gray	1	2	494	2
Shale, gray, soft; underclay; stigmarian roots	3	8	497	10
Shale, gray, sandy; Stigmarias in upper part	4	0	501	10
Sandstone, with scattered coal spars and shale streaks; crossbedded; laminae marked by abundant mica flakes and carbonaceous fragments	22	8	524	6

Drill hole 24—Continued

Pennsylvanian, Breathitt Formation—Continued	Thickness Ft	Thickness in	Depth Ft	Depth in
Sandstone conglomerate; siderite pebbles		2	524	8
Shale, black, carbonaceous; underclay	1	7	526	3
Coal and bone: Trace Fork coal bed		6	526	9
Shale, black		4	527	1
Shale, gray; includes black thin plant-bearing beds	15	9	542	10
Sandstone, light, fine-grained; calcareous zone 546 ft 6 in to 547 ft 4 in: Magoffin Beds of Morse	5	5	548	3
Shale, dark-gray, calcareous; brachiopods at base in black fissile shale	12	10	561	1
Underclay, light-brown		4	561	5
Shale, dark, sandy; stigmarian roots at top; carbonaceous shale and plants below	5	7	567	0
Coal: Taylor coal bed	1	3½	568	3½
Shale, dark; underclay; stigmarian roots		4½	568	8
Underclay		5	569	1
Shale, gray; stigmarian roots throughout; underclay above grades down into shale	3	1	572	2
Sandstone, very fine grained; very thin indistinct shale laminae	3	5	575	7
Sandstone, fine- and medium-grained crossbedded	30	11	606	6
Sandstone with shale laminae; coal spars	3	10	610	4
Shale, gray, sandy; probably a transported "boulder"		8	611	0
Sandstone, fine- and medium-grained, laminated; crossbedded; shale pebbles	10	0	621	0
Sandstone, fine- to medium-grained; coal spars	5	2	626	2
Conglomerate composed of pebbles; sharp erosional contact at base		2	626	4
Shale, gray; even laminations of siltstone	1	1	627	5
Sandstone and shale breccia, slump	1	10	629	3
Sandstone and shale with ironstone pebbles; bedding disturbed	3	3	632	6
Sandstone, fine-grained; laminae, even, marked by abundant mica flakes and carbonaceous fragments	14	10	647	4
Coal: Fire Clay rider coal bed		4	647	8
Bone		½	647	8½
Coal		3½	648	0
Shale, dark-gray		1¼	648	1¼
Coal	1	7	649	8¼
Shale, dark-gray		3¾	650	0
Underclay, shaly; stigmarian roots	2	0	652	0
Shale, gray; includes sandstone layers ⅛ in. to 5 in. thick; stigmarian roots and underclay-type siderite	2	3	654	3
Sandstone, very fine grained; laminae marked by abundant mica flakes and carbonaceous fragments	3	4	657	7
Shale, gray, sandy	1	6	659	1
Shale, gray		7	659	8
Shale, black		1	659	9
Coal: Fire Clay coal bed	2	1	661	10
Shale, dark, carbonaceous	1	0	662	10
Underclay, light-brown	1	11	664	9
Shale and sandstone layers; burrows	3	4	668	1
Shale, sandy; mottled light and dark gray due to "worm" burrows	9	1	677	2
Siltstone; laminae gray in upper part	3	3	680	5
Shale, gray; plant leaves and stems	4	3	684	8
Coal: Upper Whitesburg coal bed	1	7	686	3
Underclay, brown, hard, silty		3	686	6
Shale, gray, soft; stigmarian roots	2	3	688	9
Shale, dark-gray to black, fissile; few siltstone laminae, very thin, incomplete	6	4	695	1
Coal: Lower Whitesburg coal bed		8	695	9
Underclay, hard, shaly, silty		8	696	5
Shale, light-gray; stigmarian roots in upper part	2	8	699	1
Sandstone, gray; fine-grained in upper 2½ ft; medium-grained below; cross laminated; coal spars	13	7	712	8
Coal, tightly attached to sandstone in roof: Dingess coal bed		3½	712	11½
Underclay, light-gray, brown, soft	1	1½	714	1
Shale, sandy; stigmarian roots; poor bedding	2	11	717	0
Sandstone, gray, fine-grained; laminated in upper part, includes shale bed 4 in. thick near the top, medium-grained below 733 ft; calcareous zone 730–733 ft	25	0	742	0
Sandstone, gray, fine- to medium-grained; coal spars		8	742	8
Sandstone, gray, medium-grained; coal spars and few shale pebbles 754–755 ft	12	7	755	3
Sandstone, gray; medium-grained with laminae ½–1 in. thick composed of abundant mica flakes and carbonaceous fragments	6	8	761	11
Sandstone, gray, medium-grained, massive	4	3	766	2
Sandstone, gray, medium-grained; shale pebbles		8	766	10
Sandstone, medium-grained, massive	10	9	777	7
Shale, medium-gray; ironstone nodules; basal 8 in. dark-gray argillaceous sandstone with *Lingula* fragments; Kendrick Shale of Jillson, 1919	3	0	780	7
Coal: Williamson rider coal bed		7	781	2
Shale, dark, carbonaceous, slickensided; stigmarian roots; underclay-type ironstone nodules		7	781	9
Shale, gray; includes discontinuous even-bedded and ripple-marked sandstone laminae	4	4	786	1
Sandstone, very fine grained, with thin shale streaks; ripple-marked	2	9	788	10

Drill hole 24—Continued

Pennsylvanian, Breathitt Formation—Continued	Thickness Ft	Thickness in	Depth Ft	Depth in
Shale, gray and dark-gray; plant leaves	3	5	792	3
Shale, black		2	792	5
Coal: Williamson coal bed		4	792	9
Underclay, gray; stigmarian roots	2	5	795	2
Shale, dark-gray, with sandstone laminae and "worm" burrows; underclay-type ironstone	13	6	808	8
Sandstone, light-gray, medium-grained; crossbedded; calcareous 811 ft 8 in. to 812 ft 11 in	25	5	834	1
Underclay, dark-gray		8	834	9
Coal		½	834	9½
Shale, sandy; sharp uneven base		1	834	10½
Underclay, medium-gray	1	4½	836	3
Shale, mottled, sandy; ironstone pebbles; burrows; Elkins Fork Shale of Morse	1	8	837	11
Sandstone, light, fine-grained, calcareous	1	6	839	5
Sandstone, fine-grained, with thin shale laminae and "worm" burrows	2	0	841	5
Shale, gray; scattered large irregular ironstone nodules	6	6	847	11
Shale, gray, calcareous; sandstone flecks; ripple-marked siltstone and very fine grained sandstone layers	9	5	857	4
Shale, gray, calcareous; includes discontinuous very fine grained sandstone and siltstone laminae and lenses; siderite nodules and "worm" burrows	28	3	885	7
Coal: Upper Van Lear coal bed	1	6½	887	1½
Shale, gray, slickensided; stigmarian roots		9½	887	11
Sandstone, very fine grained, with thin shale laminae; very thin indistinct laminae top 6 in.; ripple-marked and even laminae of shale and mica flakes	8	0	895	11
Shale, gray	2	8	898	7
Shale, dark-gray, ironstone nodules	1	8	900	3
Coal: Lower Van Lear coal bed		10	901	1
Underclay, dark-gray; abundant stigmarian roots		7	901	8
Underclay, light-gray to brown; stigmarian roots	1	4	903	0
Sandstone, light-gray, very fine grained; stigmarian roots	1	2	904	2
Shale, dark-gray; ironstone and sandstone lenses; "worm" burrows(?); discontinuous silty and sandy laminae	16	2	920	4
Shale, mottled, sandy; calcareous in lower part; plant fragments and coarse mica flakes	12	4	932	8
Coal: Alma coal bed		5	933	1
Shale, carbonaceous		4	933	5
Coal	1	4	934	9
Underclay, shaly; stigmarian roots		3	935	0

Drill hole 24—Continued

Pennsylvanian, Breathitt Formation—Continued	Thickness Ft	Thickness in	Depth Ft	Depth in
Shale, dark-gray; ⅛-in. ironstone bands; few stigmarian roots; vitrain bands and plant stems at base	4	9	939	9
Coal		2	939	11
Underclay with abundant stigmarian roots		7	940	6
Sandstone, fine-grained, with some shale streaks; top 1 ft 5 in. includes stigmarian roots and is poorly bedded; shale streaks and micaceous and carbonaceous laminae; gently crossbedded	42	5	982	11
Sandstone, calcareous; few coal spars, ironstone nodules and vitrain bands	2	4	985	3
Sandstone with a few laminae consisting of mica flakes and carbonaceous fragments not crossbedded; siderite pebble at base	12	6	997	9
Shale and siltstone laminae interbedded, gray; some ironstone nodules	29	10	1,027	7
Sandstone, medium-grained; few coal spars; laminae marked by carbonaceous fragments	2	7	1,030	2
Shale with some very thin ironstone beds; a few plant fossils: Campbell Creek Limestone of White	6	9	1,036	11
Shale and coal		1	1,037	0
Coal: Pond Creek rider coal bed		2½	1,037	2½
Shale, dark-gray to black, carbonaceous, slickensided		9½	1,038	0
Underclay, shaly; abundant stigmarian roots	1	6	1,039	6
Shale, sandy; irregular sandstone lenses; contorted	6	8	1,046	2
Sandstone, fine- to medium-grained; some coal spars; carbonaceous laminae	8	0	1,054	2
Shale, gray		2	1,054	4
Coal, banded; thin pyrite laminae: Pond Creek coal bed	1	0	1,055	4
Shale, dark, carbonaceous		3½	1,055	7½
Underclay and shale; abundant stigmarian roots (other plants?)		5½	1,056	1
Siltstone, gray; stigmarian roots; bedding irregular	2	0	1,058	1
Sandstone with micaceous and carbonaceous shale streaks and laminae; shale laminae 1/16–¼ in. thick, wavy	8	7	1,066	8
Shale with sandstone lenses, streaks, and laminae 1/16–¼ in. thick; ripple marked; calcareous zone 1087 to 1087 ft 7 in	22	11	1,089	7
Shale, gray, hard, calcareous; probably a concretion	1	8	1,091	3
Shale, gray, with sandstone streaks; siderite nodules and lenses	7	8	1,099	0
Coal: Powellton(?) coal bed		8	1,099	8

Drill hole 24—Continued

Pennsylvanian, Breathitt Formation—Continued	Thickness Ft	Thickness in	Depth Ft	Depth in
Shale, dark-gray, carbonaceous, silty; plant stems		10	1,100	6
Shale, gray, sandy; siltstone at top; Stigmarias and underclay-type siderite	4	5	1,104	11
Shale with sandstone; crossbedded laminae and lenses as much as ½ in. thick	1	9	1,106	8
Sandstone, fine-grained, with some shale streaks and lenses; ripple-marked; siderite grains in thin lenses	4	10	1,111	6
Sandstone with shale streaks and lenses	2	2	1,113	8
Shale and sandstone interbedded in equal proportions; thickness of most lenses half an inch; ripple-marked disturbed bedding at top	19	2	1,132	10
Shale, black		5	1,133	3
Sandstone, gray, very fine grained		9	1,134	0
Shale, dark-gray, silty		5	1,134	5

Drill hole 33

Pocahontas Land Corp. diamond-drill hole 8, June 1960
Location: On ridge between the Left Fork of Petercave Fork and Pigeonroast Fork, Varney quadrangle, Martin County, Ky.
Altitude: 1,440 ft, barometer
Core description by company engineers modified by J. W. Huddle, June 23, 1960

Pennsylvanian, Breathitt Formation.	Thickness Ft	Thickness in	Depth Ft	Depth in
Soil and loose rock	23	4	23	4
Sandstone, brown, weathered, medium-grained; liesegang rings	3	6	26	10
Sandstone, white	3	0	29	10
Sandstone, brown, weathered; no obvious crossbedding	5	10	35	8
Sandstone, white, medium-grained	1	2	36	10
Shale, gray; light-gray, underclay; stigmarian roots		8	37	6
Coal, bright, banded, with laminations of shale and iron sulfide		7	38	1
Shale, gray, soft; stigmarian roots in top 14 in	3	3	41	4
Shale, gray; weathered olive; sandy; crossbeds dip 10°; ironstone nodules and very fine grained siltstone and sandstone laminae, some distorted, especially at base, slump	4	5	45	9
Underclay		10	46	7
Coal: Lower Richardson coal bed	2	9	49	4
Underclay, light-brown, hard, micaceous; stigmarian roots	3	6	52	10
Shale, gray, sandy; stigmarian roots	2	10	55	8
Shale and very fine grained sandstone, poorly bedded and sorted	1	3	56	11
Sandstone, very fine grained, cross laminated; siderite grains and abundant mica flakes and carbonaceous fragments	14	10	71	9
Sandstone, brown; weathered fine- to medium-grained	5	7	77	4

Drill hole 33—Continued

Pennsylvanian, Breathitt Formation—Continued	Thickness Ft	Thickness in	Depth Ft	Depth in
Sandstone, fine-grained; sparse cross laminae marked by abundant mica flakes and carbonaceous fragments	2	4	79	8
Sandstone, brown, medium-grained; limonite nodules and shale chips at base	5	9	85	5
Sandstone, gray, very fine grained; indistinct bedding	2	2	87	7
Sandstone, brown, fine- to medium-grained, massive; shale chips at base	36	6	124	1
Shale, light-gray and weathered brown; includes squeezed masses of sandstone	1	7	125	8
Sandstone, light-brown, medium-grained	1	10	127	6
Sandstone, brown, weathered, medium- to coarse-grained	8	3	135	9
Sandstone and gray shale mixed; irregular masses of sandstone, probably slump	2	1	137	10
Sandstone, brown, medium- to coarse-grained, weathered, feldspathic, micaceous	7	5	145	3
Sandstone, brown, weathered, fine- to medium-grained; ironstone pebbles and feldspar and carbonaceous grains	13	0	158	3
Shale, gray; weathered olive; siltstone laminae; few limonite and ironstone nodules	1	6	159	9
Sandstone, brown, massive	12	7	172	4
Sandstone, white; ironstone nodules and cavities		5	172	9
Sandstone, brown, shale chips	2	7	175	4
Sandstone, white, laminated; crossbeds dip 5°	1	1	176	5
Sandstone, brown, weathered, fine- to medium-grained	3	1	179	6
Sandstone, white, fine- to medium-grained; ironstone pebbles at base	5	2	184	8
Sandstone, white, very fine grained; laminae marked by abundant mica flakes and carbonaceous fragments, horizontal, even	3	9	188	5
Sandstone, brown, medium-grained; limonite grains	2	1	190	6
Shale, gray, fissile; ironstone nodules; sandstone dikes or twisted tubes and faulted siltstone laminae	2	0	192	6
Sandstone, very fine grained and medium-grained; coal spars, carbonaceous fragment laminae, and ironstone pebbles	3	10	196	4
Sandstone, white, fine-grained, massive	5	6	201	10
Sandstone, white, and contorted shale streaks	2	5	204	3
Sandstone, white; coal spars and ironstone pebbles	14	3	218	6

Drill hole 33—Continued

Pennsylvanian, Breathitt Formation—Continued	Thickness Ft	Thickness in	Depth Ft	Depth in
Sandstone and shale; sandstone, black shale, and siderite nodules		8	219	2
Siltstone and sandstone; ripple-marked siltstone and very fine grained sandstone; thin bedded with minor distortion by flowage; calcareous at base	4	9	223	11
Sandstone, very fine grained, with some shale streaks	16	5	240	4
Sandstone, very fine grained; ironstone nodules, siderite, shale laminae and layers; ripple-marked	6	10	247	2
Coal: Upper Broas coal bed		¼	247	2¼
Sandstone		⅛	247	2⅜
Coal		1⅜	247	3¾
Shale		1½	247	5¼
Coal		3⅞	247	9⅛
Pyrite		½	247	5⅝
Coal		3	248	⅝
Pyrite		¼	248	⅞
Coal	1	2½	249	3⅜
Shale, dark		3	249	6⅜
Coal	2	8¼	252	2⅝
Shale, dark; coal streaks and underclay		11⅜	253	2
Shale, dark-gray, sandy; stigmarian roots; poor bedding; sandstone laminae at base	4	5	257	7
Sandstone, light-green, very fine grained to medium-grained, laminated; very thin coal spars	19	0	276	7
Sandstone, fine- to medium-grained; sparse coal spars; massive	14	11	291	6
Sandstone, medium-grained, massive, calcareous; fine-grained at 295–297 ft	13	5	304	11
Shale, dark-gray to black; plant stems and leaves		5	305	4
Coal, bright, banded: Lower Broas coal bed		5	305	9
Shale, dark-gray to black, hard; stigmarian roots		1	305	10
Underclay, dark-gray and brown; stigmarian roots	1	0	306	10
Shale, dark, nonbedded; stigmarian roots		10	307	8
Shale, dark, sandy, poorly bedded; indistinct sandy "beds"	1	0	308	8
Sandstone with coal spars; horizontal and cross laminae marked by abundant mica flakes and carbonaceous fragments	2	4	311	0
Sandstone, fine- to medium-grained	11	1	322	1
Shale, sandy, with distorted bedding		8	322	9
Sandstone, very fine grained in top 2 ft, medium-grained below; coal spars	22	6	345	3
Shale, dark-gray, black carbonaceous, fissile; pelecypods: position of Upper Peach Orchard coal bed	1	7	346	10
Shale, dark-gray; stigmarian roots	4	4	351	2

Drill hole 33—Continued

Pennsylvanian, Breathitt Formation—Continued	Thickness Ft	Thickness in	Depth Ft	Depth in
Shale, dark-gray	3	10	355	0
Shale, gray, with ripple-marked laminae of sandstone	3	9	358	9
Sandstone, gray, fine- to medium-grained, massive	20	10	379	7
Sandstone with abundant coal spars and ironstone pebbles	1	4	380	11
Sandstone, gray, fine- to medium-grained, massive	16	1	397	0
Coal: Lower Peach Orchard coal bed		2¼	397	2¼
Shale		½	397	2¾
Coal		3¼	397	6
Shale		3	397	9
Coal		4	398	1
Shale		1	398	2
Coal	1	4½	399	6½
Shale, dark		1½	399	8
Underclay		4½	400	½
Shale, dark		¾	400	1¼
Underclay, brown, slickensided, hard; possibly a flint clay	1	7¾	401	9
Shale, greenish-gray, with siltstone laminae, ironstone nodules; poor bedding; abundant stigmarian roots in upper part (under clay)	20	2	421	11
Coal: Buffalo Creek coal bed		7½	422	6½
Shale		¾	422	7¼
Coal		¼	422	7½
Shale		1	422	8½
Coal	1	1½	423	10
Underclay, dark-gray, hard, micaceous		4	424	2
Sandstone, very fine grained, poorly bedded; faint lamination	6	10	431	0
Sandstone, fine-grained, crossbedded	30	6	461	6
Sandstone, with coal spars	15	6	477	0
Sandstone, gray, fine- to medium-grained, massive; few laminae; at 513–522 ft it is calcareous and fine grained	68	3	545	3
Shale, gray, slickensided; plants; sandstone and ironstone nodules		11	546	2
Shale, black, fissile, coaly	1	0	547	2
Coal, laminated; and pyrite: Trace Fork coal bed		1	547	3
Shale, black	1	2	548	5
Coal, laminated, bright, banded		6	548	11
Shale, black, moderately fissile; stigmarian roots		3	549	2
Shale, gray, nonbedded; stigmarian roots	3	8	552	10
Sandstone, very fine grained, with shale streaks and ripple-marked layers; calcareous at 557–563 ft	10	6	563	4
Shale, dark-gray, plants and ironstone nodules; calcareous at 571–572 ft: Magoffin Beds of Morse	19	6	582	10
Shale, gray; ironstone nodules and a few brachiopods	15	8	598	6
Coal: Taylor coal bed	1	11½	600	5½
Shale, black		½	600	6

Drill hole 33—Continued

Pennsylvanian, Breathitt Formation—Continued	Thickness Ft	Thickness in	Depth Ft	Depth in
Sandstone, brown above; gray below; fine-grained beds indistinct flow laminae	29	10	630	4
Sandstone with laminae composed of clay, vitrain, and coaly fragments	2	10	633	2
Sandstone, fine- and medium-grained; calcareous and medium-grained at 633–635 ft	3	0	636	2
Sandstone, light-gray; coal spars	1	6	637	8
Sandstone, light-gray, fine-grained; calcareous at 642–643 ft	8	1	645	9
Sandstone, light-gray, fine- to medium-grained; siderite; shale and coal spars	7	4	653	1
Sandstone, fine- to medium-grained; few faint laminations indicate cross-bedding	16	0	669	1
Sandstone, fine- to medium-grained; shale and siderite nodules; slickensided	1	4	670	5
Sandstone, fine-grained	6	7	674	0
Shale, gray		1	677	1
Sandstone, fine-grained, massive	3	0	680	1
Shale, gray		1	680	2
Sandstone, gray, fine- to medium-grained; faint lamination; sharp erosional contact at base		11	681	2
Shale; faint silty and sandy laminations		6	681	7
Sandstone, fine-grained; faint laminations		2	681	9
Shale, medium-gray; ironstone nodules		4	682	1
Sandstone, fine-grained; faint cross-bedding	6	9	688	10
Shale, gray, with siltstone laminae and elongate ironstone nodules	3	6	692	4
Coal: Fire Clay rider coal bed	2	9½	695	1½
Shale, dark	1	0	696	1½
Coal		7	696	8½
Shale, dark-gray	2	9	699	5½
Coal		2	699	7½
Shale		2	699	9½
Coal	1	8	701	5½
Shale, black		1½	701	7
Coal: Fire Clay coal bed		8½	702	3½
Flint clay, brown	1	3½	703	7
Shale, dark-gray, sandy; carbonaceous zone in upper part	4	0	707	7
Sandstone, light, fine-grained; faint cross laminae	6	9	714	4
Shale, gray, sandy; with siltstone laminae		9	715	1
Sandstone, light, fine-grained; faint crossbedding	22	1	737	2
Sandstone with abundant coal spars and ironstone pebbles	1	11	739	1
Coal, bright, banded: Upper Whitesburg coal bed	1	0	740	1
Shale, dark-gray, sandy; stigmarian roots		4	740	5

Drill hole 33—Continued

Pennsylvanian, Breathitt Formation—Continued	Thickness Ft	Thickness in	Depth Ft	Depth in
Sandstone with shale, laminated, wavy, calcareous; very thin indistinct carbonaceous laminae	3	3	743	8
Shale, dark-gray, slickensided; plants		1	743	9
Coal, bright		2	743	11
Shale, very dark gray, slickensided		4	744	3
Underclay, medium- to dark-gray; stigmarian roots		8	744	11
Shale, dark-gray, coaly, slickensided; sandstone tubes	2	6	747	5
Shale, dark-gray; contains many discontinuous irregular siltstone layers and laminae; animal burrows	7	11	755	4
Shale, dark-gray to black, fissile, silty; no plants	3	4	758	8
Coal, bright, banded: Lower Whitesburg coal bed	1	0	759	8
Shale, dark, coaly; plants and slickensides; top 6 in. roof-type	3	9	763	5
Coal		4½	763	9½
Underclay, soft, light-gray and brown; green stigmarian roots; slickensides	1	6½	765	4
Shale, dark, roof-type	1	4	766	8
Underclay, soft		2	766	10
Shale, dark, slickensided; stigmarian roots, vitrain bands, and trash	2	7	769	5
Coal: Dingess coal bed		5	769	10
Underclay; mottled brown clay; stigmarian roots		6	770	4
Shale, gray, sandy; stigmarian roots throughout the upper 2 ft; contains underclay-type siderite and a sandstone bed with very thin indistinct laminae near the middle of the unit	3	11	774	3
Sandstone with shale and siltstone	3	4	777	7
Sandstone, light-gray, fine-grained; few very thin indistinct laminae; calcareous near base	13	0	790	7
Sandstone, fine-grained, calcareous; thick laminae marked by abundant mica flakes and carbonaceous fragments		5	791	0
Sandstone, medium-grained	11	10	802	10
Sandstone, medium-grained; abundant shale chips and ironstone nodules ¼ to 2 in across	5	0	807	10
Sandstone with laminae marked by abundant mica flakes and carbonaceous fragments; small shale chips	6	8	814	6
Shale, black, sandy, silty; fragments of Lingulas: Kendrick Shale of Jillson		10	815	4
Sandstone, light and dark, very fine grained, calcareous; "worm" burrows	1	4	816	8

Drill hole 33—Continued

Pennsylvanian, Breathitt Formation—Continued	Thickness Ft	Thickness in	Depth Ft	Depth in
Shale, black, micaceous, fissile, slickensided; sandstone bed near base; *Lingula*, and *Naiadites*?	2	0	818	8
Coal: Williamson rider coal bed		2	818	10
Shale, brown, hard, claystone		1	818	11
Coal		5	819	4
Underclay, greenish-gray, slickensided; stigmarian roots	3	8	823	0
Shale, green, with siltstone lamination; crossbedded and horizontal bedding	4	4	827	4
Sandstone, medium-grained; fine-grained very thin indistinct laminae in top 6 in.; sparse crossbedding	22	4	849	8
Sandstone, medium-grained; coal spars and ironstone pebbles	2	2	851	10
Coal: Williamson coal bed		2	852	0
Underclay grading down into gray sandy shale; stigmarian roots to base; black shale chips in lower part	2	9	854	9
Shale, dark, coaly; with sandstone streaks		2	854	11
Sandstone, fine-grained, shaly; with coal laminae; contact with underlying shale dips 30°		10	855	9
Shale, gray, sandy; inclined bedding; ironstone nodules and plant stems; sharp wavy base, probably slumped	1	3	857	9
Sandstone and shale irregularly laminated; shale chips; "worm" burrows: Elkins Fork Shale of Morse	1	11	858	11
Sandstone, very fine-grained, calcareous		6	859	5
Shale and sandstone; messy beds; "worm" burrows(?); ironstone-cemented areas	8	2	867	7
Shale, gray, sandy, slightly calcareous; ironstone nodules; thin lens of sandstone or siltstone; "worm" burrows	20	0	887	7
Shale, gray; few siltstone laminae; few ironstone nodules; *Orbiculoidea*	11	2	898	9
Shale, gray, slightly calcareous	1	10	900	7
Shale, gray, silty irregular fracture; pelecypods in basal 6 in	7	0	907	7
Shale, gray, sandy, calcareous; Marginiferas and other brachiopods		9	908	4
Sandstone, dark-gray argillaceous and ferruginous		4	908	8
Sandstone, gray, fine-grained; with some shale streaks; "worm" burrows to base of unit	3	5	912	1
Shale, gray; abundant silty laminae, some contorted by flowing, ripple-marks in lower two-thirds of unit	17	8	929	9
Shale, dark-gray, moderately fissile; ironstone nodules	4	5	934	2
Bone: Van Lear rider coal bed		2	934	4

Drill hole 33—Continued

Pennsylvanian, Breathitt Formation—Continued	Thickness Ft	Thickness in	Depth Ft	Depth in
Shale; dark-gray plant stems, *Lepidodendron:* vitrain bands		10	935	2
Shale, gray, silty; abundant stigmarian roots		8	935	10
Shale, green, sandy	4	8	940	6
Coal: Upper Van Lear coal bed	1	1½	941	7½
Shale, dark		½	941	8
Coal	1	1	942	9
Shale, gray		7	943	4
Sandstone, gray; very fine grained with very thin indistinct argillaceous laminae	7	1	950	5
Shale, gray, silty; ironstone nodules; irregularly fractured	5	5	955	10
Shale, black; plants and stems		4	956	2
Coal: Lower Van Lear coal bed		½	956	2½
Shale, black		1½	956	3½
Coal		9	957	½
Underclay, light-brown; abundant stigmarian roots	1	11	958	11½
Shale, gray, with irregular and wavy lenses and laminae of sandstone; ironstone nodules and "worm" burrows	9	4	968	3½
Shale, gray; consists of interbedded shale and sandstone laminae with crossbeds; dips 5°; stigmarian roots and "worm" burrows		7	968	10½
Sandstone, gray, fine-grained crossbedded; coal spars	6	10	975	8½
Coal: Alma coal bed		10½	976	7
Shale, dark, very fissile, slickensided; plant stems	1	5	978	0
Coal		8½	978	8½
Underclay, dark-brown; stigmarian roots		8	979	4½
Underclay, light-brown; stigmarian roots	1	2	980	6½
Shale and sandstone, very fine grained; 2½ ft sandstone at top nonbedded; laminated below	4	11	985	5½
Sandstone, gray, fine-grained; very thin indistinct laminae	4	2	989	7½
Shale, gray; contains siltstone laminae, and a 2-in. ripple-marked siltstone bed	2	9	992	4½
Shale, gray; includes crossbedded ripple-marked siltstone laminae	12	0	1,004	4½
Sandstone, gray, fine-grained, crossbedded	4	3	1,008	7½
Sandstone, fine-grained, with shale streaks; bedding contorted, probably due to flowage		6	1,009	1½
Sandstone, gray, fine-grained; shale chips at base	1	11	1,011	½
Sandstone with disturbed shale streaks, probably flow		5	1,011	5½
Sandstone, gray, fine-grained, massive	2	0	1,013	5½

Drill hole 33—Continued

Pennsylvanian, Breathitt Formation—Continued	Thickness Ft	Thickness in	Depth Ft	Depth in
Shale, gray, sandy, ripple-marked; laminae dip 5°, probably due to flowage	2	4	1,015	9½
Sandstone, gray, fine-grained; shale chips		10	1,016	7½
Shale, gray, sandy; bedding disturbed by flowage		11	1,017	6½
Sandstone, gray, fine-grained; shale chips		10	1,018	4½
Shale, gray, sandy; sandstone laminae		3	1,018	7½
Sandstone, fine-grained; few cross-bedded shale laminae and coal spars; siderite grains concentrated in cross-laminations	29	10	1,048	5½
Sandstone, fine-grained; coal spars; crossbedded laminae of mica flakes and carbon fragments	3	4	1,051	9½
Shale, light-gray; underclay-type siderite nodules		8	1,052	5½
Shale, gray		11	1,053	4½
Sandstone, medium-gray; abundant coal spars; 8 in. of coal at base contains wiggly sandstone dikes	2	0	1,055	4½
Shale, gray, sandy; dips 45°, probably due to slump		9	1,056	1½
Sandstone, gray, fine-grained; slump; coal spars, about 1 in. thick. Basal contact sharp, dipping 75°	2	5	1,058	6½
Shale, gray, with siltstone streaks and scattered ironstone pebbles; bedding even, regular	21	1	1,079	7½
Shale, gray, with sandstone laminae and beds 1–2 in. thick; ironstone nodules and "worm" burrows in a zone 1-ft thick at top; calcareous in part: Campbell Creek Limestone of White	6	6	1,086	1½
Sandstone, fine-grained; ironstone pebbles; shale bed half an inch thick and vitrain layers	1	0	1,087	1½
Sandstone with dark-gray shale a ¼–3 in. thick	2	3	1,089	4½
Siltstone seat rock, siderite grains, and stigmarian roots(?); nonbedded; grades down to shale	3	11	1,093	3½
Shale, medium-gray; ironstone nodules	2	6	1,095	9½
Shale, black, slickensided; plants		2	1,095	11½
Coal: Pond Creek rider coal bed		5	1,096	4½
Shale, gray and black, fissile; abundant stigmarian roots	2	8	1,099	½
Shale, sandy, with ripple-marked siltstone; laminated	2	9	1,101	9½
Cannel coal; conchoidal fracture: Pond Creek coal bed		5	1,102	2½
Coal		2	1,102	4½
Shale, dark-gray		5	1,102	9½
Coal, laminated		4½	1,103	2
Coal	2	½	1,105	2½
Bone		1½	1,105	4
Coal		4	1,105	8
Shale, black, hard		2	1,105	10
Underclay, gray, soft; stigmarian roots		5½	1,106	3½
Shale, dark	1	8½	1,108	0

Drill hole 35

Pocahontas Land Corp. diamond drill-hole 12, August 18, 1960
Location: On ridge between Petercave Fork and Meathouse Creek, Varney quadrangle, Martin County, Ky.
Altitude: 1,494 ft, barometer
Core description by company engineers modified by J. W. Huddle and D. A. Alvord, Aug. 21, 1960

Pennsylvanian, Breathitt Formation.	Thickness Ft	Thickness in	Depth Ft	Depth in
Soil and loose rock	5	6	5	6
Sandstone, brown	15	1	20	7
Shale, dark-gray	2	10	23	5
Shale, olive, weathered; siderite layers and carbonaceous beds	4	7	28	0
Coal, bright-banded; 2 in. of dull attrital coal or bone in the middle		11	28	11
Shale, black, canneloid		3	29	2
Shale, grayish-olive, weathered; siderite layers; scattered stigmarian roots in upper part	6	3	35	5
Shale, sandy; evenly laminated in beds as much as 0.02 ft thick; siderite layers		5	35	10
Shale, gray; ironstone nodules; sparse laminae of very fine grained sandstone	4	0	39	10
Coal: Upper Richardson coal bed	1	6	41	4
Shale		3½	41	7½
Coal	1	3	42	10½
Shale		4	43	2½
Coal	3	6	46	8½
Shale		2¼	46	11
Coal	1	7½	48	6¼
Shale		11	49	5¼
Coal		4½	49	9¾
Shale, gray, soft	2	9¼	52	7
Sandstone, gray, fine- to medium-grained	2	0	54	7
Shale and sandstone lenses and laminae as much as 0.03 ft thick		7	55	2
Sandstone, white, fine- to medium-grained; laminae of siderite grains; scattered ironstone pebbles and coal spars; very calcareous from 81 ft 7 in. to 85 ft	31	5	86	7
Shale, gray, with siderite layers; dark-gray zones with leaves	3	8	90	3
Sandstone very fine grained to medium grained; interbedded with very thin indistinct laminae of medium-grained sandstone marked by mica flakes and carbonaceous fragments	4	6	94	9

Drill hole 35—Continued

Pennsylvanian, Breathitt Formation—Continued	Thickness Ft	Thickness in	Depth Ft	Depth in
Shale, gray; interbedded with very fine grained ripple-marked sandstone and siderite layers	2	1	96	10
Shale, gray; sandstone lenses and laminae and siderite layers	7	0	103	10
Shale, black; chips		4	104	2
Coal: Lower Richardson coal bed	2	3	106	5
Underclay, light- and dark-gray; with dark carbonaceous zones and vitrain bands	2	7	109	0
Underclay, light- and dark-gray; coal zones 1–2 in. thick; siltstone and seat earth in basal 1 ft grading down into unit below	2	4	111	4
Sandstone, white, fine-grained; calcareous sandstone, 1 ft thick, 16 ft above base of unit; cross laminae of siderite grains; some laminae marked by abundant mica flakes and carbonaceous fragments	34	2	145	6
Shale, medium- and dark-gray, carbonaceous; ironstone nodules; scattered leaves and stigmarian roots	5	3	150	9
Sandstone with shale streaks; seat rock in upper 1 ft; limonite, after siderite nodules; very thin indistinct laminae; stigmarian roots; flow	8	4	159	1
Shale, dark-gray, with vitrain bands and plant stems	1	11	161	0
Sandstone, brown and gray, fine- to medium-grained; brown and calcareous from 183 to 185 ft; coal spars and ironstone and shale pebbles; medium- to coarse-grained in basal 15 ft	41	8	202	8
Shale, gray, weathered; slump structure; includes a siderite layer	2	6	205	2
Sandstone, fine- to medium-grained; coal spars and ironstone pebbles in basal part; abundant shale and siderite pebbles 8–10 ft below top of unit	18	8	223	10
Shale, gray, and siltstone laminae; slumped	2	5	226	3
Coal, bright-banded; probably slumped		4	226	7
Sandstone and shale mixed; slumped	1	9	228	4
Sandstone, medium-grained; abundant shale pebbles	2	0	230	4
Sandstone, very fine grained; cross-bedded and rippled laminae composed of abundant mica flakes and carbonaceous fragments	5	1	233	5
Siltstone, gray, squeezed		6	233	11
Sandstone, fine- to medium-grained; scattered coal spars and ironstone pebbles; siderite grains on cross laminae	20	0	253	11
Shale, gray; ironstone nodules; squeezed	1	3	255	2

Drill hole 35—Continued

Pennsylvanian, Breathitt Formation—Continued	Thickness Ft	Thickness in	Depth Ft	Depth in
Sandstone with shale pebbles and abundant ironstone nodules	1	0	256	2
Sandstone, fine- to medium-grained; abundant ironstone nodules; some coal spars	7	11	264	1
Sandstone and shale, interbedded, 50 percent of each; ripple-marked; ironstone nodules	32	3	296	4
Sandstone, very fine grained; very thin indistinct ripple-marked laminae	2	0	298	4
Coal: Upper Broas coal bed	4	7	302	11
Shale, dark-gray		2	303	1
Underclay, dark-gray	1	10	304	11
Underclay, very light-gray to gray, hard silty	1	2	306	1
Shale and sandstone interbedded, ripple-marked; beds range in thickness from laminae to 1 ft; very fine grained sandstone	15	9	321	10
Shale, dark-gray, carbonaceous		8½	322	6½
Coal, bright-banded: Lower Broas coal bed	1	½	323	7
Shale, dark-gray, carbonaceous		4½	323	11½
Coal, bright-banded		1½	324	1
Underclay, very light-gray, soft		8	324	9
Shale, light-gray, hard, silty; stigmarian roots	1	11	326	8
Sandstone, very fine grained, ripple-marked; siderite grain laminae	6	6	333	2
Shale, gray, with interlaminations of very fine-grained sandstone; ironstone nodules	2	8	335	10
Sandstone, fine- to medium-grained; upper 10 ft very fine grained and ripple marked; white, fine-grained to medium-grained, calcareous from 349 to 354 ft; some coal spars; ironstone pebbles from 346 to 348 ft	59	8	395	6
Sandstone, medium- to coarse-grained; coal spars and black shale pebbles; sharp contact at base	8	1	403	7
Shale, dark-gray, slickensided; conchoidal fracture		4	403	11
Underclay, gray; underclay-type siderite; some stigmarian roots in upper part	2	3	406	2
Coal, bright-banded		6	406	8
Shale, gray, slickensided; stigmarian roots		9	407	5
Coal, bony		7	408	0
Underclay, light-gray; stigmarian roots; carbonaceous zones and plant leaves and stems	5	11	413	11
Coal: Lower Peach Orchard coal bed	3	4	417	3
Shale, gray, soft		9	418	0
Underclay, light-brown, soft; flint clay patches	1	3	419	3
Shale, light-brown to greenish-gray; stigmarian roots	3	1	422	4

Drill hole 35—Continued

Pennsylvanian, Breathitt Formation—Continued	Thickness Ft	Thickness in	Depth Ft	Depth in
Shale, gray, interbedded with very fine-grained ripple-marked sandstone in laminae and beds as much as 4 in. thick	27	2	449	6
Sandstone, fine-grained; laminae marked by abundant mica flakes and carbonaceous fragments; coal spars	5	8	455	2
Coal, bright, with shale partings 0.01 ft thick	1	1	456	3
Seat-rock sandstone, very fine grained; very thin indistinct laminae		8	456	11
Sandstone, gray, fine- to medium-grained; mixed with claystone in upper part; fine-grained, calcareous from 472 to 473 ft; medium-grained, calcareous from 486 to 488 ft	35	7	492	6
Sandstone, medium-grained; thin coal spars and shale pebbles	13	11	506	5
Shale, gray, silty; ironstone layers; vitrainized plant leaves and stems	2	8	509	1
Shale, coaly		1	509	2
Underclay, light-brownish-gray; stigmarian roots		7½	509	9½
Shale, black, heavy, fissile, canneloid, fusain		11½	510	9
Shale, gray and black; plant leaves and stems, siderite, and vitrain bands	1	0	511	9
Shale, dark-gray, carbonaceous, coaly		1½	511	10½
Underclay, light-brown, silty, micaceous; stigmarian roots	1	5½	513	4
Shale, gray, interbedded with very fine grained ripple-marked sandstone 1–4 in. thick; *Pecopteris*	4	1	517	5
Shale, dark-gray, fissile; plant leaves	1	0	518	5
Coal: Winifrede coal bed		4½	518	9½
Underclay, light-brown, hard semiflint clay; stigmarian roots	1	10½	520	8
Sandstone and shale, interbedded (70 percent sandstone), very fine grained, ripple-marked; calcareous very fine grained sandstone from 532 to 533 ft	12	7	533	3
Shale, medium-gray, silty; siderite layers	6	5	539	8
Sandstone, fine-grained, with dark-gray shale laminae marked by abundant mica flakes and carbonaceous fragments; calcareous in upper part	3	6	543	2
Coal, splint, medium bright: Young(?) coal bed	1	4	544	6
Shale, dark-gray, carbonaceous slickensided; stigmarian roots, plant leaves and stems, and light-gray shale pods		5	544	11
Underclay, light- to medium-gray, soft; roof-type ironstone nodules	1	10	546	9

Drill hole 35—Continued

Pennsylvanian, Breathitt Formation—Continued	Thickness Ft	Thickness in	Depth Ft	Depth in
Shale with carbonaceous and interbedded vitrain layers		3	547	0
Shale, medium-gray, fissile (roof type); ironstone nodules; discontinuous siltstone laminae near base; scattered stigmarian roots in upper part of unit	5	0	552	0
Shale, dark-gray, carbonaceous; abundant vitrain laminae; plant leaves and stems		8	552	8
Underclay, gray and very light brown; underclay-type siderite	3	0	555	8
Shale, gray; abundant plants	2	6	558	2
Shale with abundant vitrain bands		2	558	4
Coal, splint and bright attrital: Trace Fork coal bed		10	559	2
Underclay, light-gray, soft; abundant stigmarian roots	1	6	560	8
Sandstone with stigmarian roots and underclay-type siderite		9	561	5
Shale and sandstone layers; cut by "worm" burrows	1	1	562	6
Sandstone, very fine grained; ripple marks of siderite grains and shale	2	6	565	0
Sandstone and shale in very thin even layers	9	8	574	8
Shale, medium-gray, moderately fissile; ironstone nodules; some siltstone laminae in upper 4 ft of unit	14	2	588	10
Shale, dark-gray, with marine fossils and vitrain laminae; crinoid stems; 3 in. rusty pyritic shale at base: Magoffin Beds of Morse. Position of Taylor coal bed	1	0	589	10
Underclay, brown and black, carbonaceous; stigmarian roots; grades down into shale		8	590	6
Shale, medium light-gray; stigmarian roots in upper 2 ft; chunky below	4	0	594	6
Sandstone, fine- to medium-grained; calcareous from 600 to 604 ft and from 609 to 612 ft	30	4	624	10
Sandstone, fine-grained, with coal and vitrain laminae		8	625	6
Sandstone, medium-grained	1	0	626	6
Shale, light-gray; plant leaves; grades down into sandstone below		5	626	11
Sandstone, fine- to coarse-grained; some cross laminae; fine-grained calcareous from 657 to 661 ft; siderite grains, clay galls, and vitrain laminae	51	11	678	10
Coal: Fire Clay rider coal bed		8	679	6
Shale		½	679	6½
Coal	1	1½	680	8
Underclay, light-brown; stigmarian roots and underclay-type siderite	1	10	682	6
Shale, dark-gray; scattered stigmarian roots	2	10	685	4

Drill hole 35—Continued

Pennsylvanian, Breathitt Formation—Continued	Thickness Ft	Thickness in	Depth Ft	Depth in
Sandstone, gray, very fine grained; shale laminae; ripple-marked	6	2	691	6
Coal, dull; thick vitrain bands		6	692	0
Underclay, black and bony in upper part; soft- and light-gray below, with abundant stigmarian roots		10	692	10
Siltstone, gray; scattered stigmarian roots; underclay-type siderite in upper part	6	7	699	5
Shale, gray; upper 2 in. dark-gray, with plants; remainder light-gray and soft; slumped and mixed with sandstone at base	1	2½	700	7½
Coal: Fire Clay coal bed		2	700	9½
Shale		5¼	701	2¾
Coal		9¾	702	½
Bone		4	702	4½
Coal		11½	703	4
Shale, carbonaceous		5	703	9
Sandstone, medium-light-gray, very fine grained; abundant stigmarian roots	2	3	706	0
Sandstone, fine-grained, nonlaminated	3	3	709	3
Siltstone, medium-gray, evenly laminated		2	709	5
Sandstone, fine- to medium-grained; some beds medium- to coarse-grained sandstone; crossbedded laminae of siderite grains	31	10	741	3
Shale and ironstone; white clay in very small limonite concretions after ironstone		6	741	9
Sandstone, fine- to medium-grained; vitrain layers and ironstone nodules		3	742	0
Coal, splint and bright-banded; firmly cemented to sandstone above: Upper Whitesburg coal bed	1	3	743	3
Underclay, light-brown, silty, hard, micaceous	1	8	744	11
Siltstone, laminated		9	745	8
Sandstone, fine-grained and ripple-marked to 753 ft; remaining part fine- to medium-grained; some crossbeds marked by mica flakes and carbonaceous fragments	20	11	766	7
Shale, dark-gray, with sandstone lenses and layers 0.01–0.03 ft thick	12	8	779	3
Coal, probably a pebble		1	779	4
Sandstone, fine-grained, with shale galls	1	0	780	4
Shale, medium-dark-gray; siderite laminae		8	781	0
Coal: Dingess coal bed		7½	781	7½
Shale		½	781	8
Coal		5	782	1
Shale		2½	782	3½
Coal		7½	782	11
Underclay		4	783	3

Drill hole 35—Continued

Pennsylvanian, Breathitt Formation—Continued	Thickness Ft	Thickness in	Depth Ft	Depth in
Sandstone, gray, very fine grained; stigmarian roots	3	3	786	6
Sandstone, fine-grained; scattered stigmarian roots; faint lamination	1	8	788	2
Siltstone, gray, with sandstone lenses		7	788	9
Sandstone, fine- to medium-grained; siderite grains and mica, carbonaceous fragment cross laminae; few coal spars	33	0	821	9
Shale, medium-gray, pebble		8	822	5
Sandstone, fine- to medium-grained, with shale pebbles	1	6	823	11
Shale, medium-gray, fissile		7	824	6
Sandstone, medium-gray, fine-grained; abundant small ironstone pebbles ½–1 in. thick; coal spars	2	2	826	8
Sandstone with ironstone nodules	1	2	827	10
Sandstone with coal spars		11	828	9
Shale, dark-gray, with dark-gray very fine-grained graywacke, and ironstone nodules in the basal part; *Lingula* fragments: Kendrick Shale of Jillson	1	10	830	7
Coal laminae with abundant pyrite: Williamson rider coal bed		5	831	0
Shale, gray, hard; stigmarian roots		4	831	4
Coal laminae with abundant pyrite		5	831	9
Underclay, light-gray and brown; hard in part; stigmarian roots		9	832	6
Shale, gray, with siltstone laminae and very fine grained ripple-marked sandstone lenses 0.3–1 ft thick	7	4	839	10
Shale, medium dark gray, with siltstone laminae and siderite layers; scattered plants	3	11	843	9
Coal: Williamson coal bed		2	843	11
Underclay, gray; abundant stigmarian roots: roof- and underclay-type ironstone nodules	3	5	847	4
Coal		2	847	6
Underclay, greenish-gray; ironstone nodules	2	7	850	1
Shale, greenish-gray; siderite grains and ironstone nodules	3	2	853	3
Sandstone, fine- to medium-grained; sharply disconformable at base; sparse coal spars; shale chips; crossbedding marked by siderite grains	33	5	886	8
Shale, gray, with disturbed siltstone laminae abundant in upper 10 ft	21	6	908	2
Sandstone, gray and white mottled, very fine grained, nonbedded; abundant ironstone nodules; "worm" burrows; calcareous and much mixed; calcareous brachiopods and *Lingula* from 910 to 913 ft. Elkins Fork Shale of Morse	32	11	941	1
Sandstone, fine-grained; few siderite grain laminae	8	8	949	9
Sandstone with coal spars and ironstone pebbles	3	7	953	4

Drill hole 35—Continued

Pennsylvanian, Breathitt Formation—Continued	Thickness Ft	Thickness in	Depth Ft	Depth in
Shale, gray, and siltstone, in discontinuous laminae; siderite layers	1	7	954	11
Shale, gray	1	8	956	7
Coal: Van Lear coal bed	2	4½	958	11½
Shale, gray		3	959	2½
Shale, gray, soft		2½	959	5
Shale, gray		2½	959	7½
Coal		11	960	6½
Underclay, greenish-gray; stigmarian roots; irregular ironstone nodules and grains	1	5½	962	0
Shale, gray, and siltstone evenly laminated; plants near base; scattered ironstone nodules	17	8	979	8
Sandstone, fine- to medium-grained; cross laminae marked by abundant mica flakes and carbonaceous fragments	12	8	992	4
Shale, gray, sandy, slump folds	1	2	993	6
Sandstone, gray, fine-grained; cross laminae of siderite grains	3	3	996	9
Sandstone with vitrain bands	2	0	998	9
Shale, dark-gray, sandy		7	999	4
Coal, bright: Alma coal bed		9	1,000	1
Underclay, brown		3	1,000	4
Coal		3	1,000	7
Underclay, light-gray, soft; stigmarian roots	1	1	1,001	8
Shale, dark-gray, carbonaceous; pyrite, vitrain layers, and plant stems	1	1	1,002	9
Coal, banded		3½	1,003	½
Shale, gray; stigmarian roots		2½	1,003	3
Shale, dark-gray; vitrain bands and plants		7	1,003	10
Coal, banded		2½	1,004	½
Underclay, brown; stigmarian roots		6½	1,004	7
Shale and sandstone, very fine-grained, ripple-marked; stigmarian roots in upper 1 ft	4	5	1,009	0
Shale, gray; siltstone laminae and plants	1	11	1,010	11
Coal with pyrite nodules		3	1,011	2
Shale, dark-gray; plants		2	1,011	4
Underclay, gray		3	1,011	7
Underclay and black shale with coal layers and vitrain bands	1	0	1,012	7
Underclay, shaly, very light brownish gray; stigmarian roots	3	10	1,016	5
Sandstone, fine- to medium-grained; cross laminae of siderite; mica and carbonaceous grains	24	1	1,040	6
Sandstone with vitrain laminae and coal fragments	1	6	1,042	0
Sandstone with some thin cross laminae marked by abundant mica flakes, carbonaceous fragments, and siderite grains	7	9	1,049	9

Drill hole 35—Continued

Pennsylvanian, Breathitt Formation—Continued	Thickness Ft	Thickness in	Depth Ft	Depth in
Shale, gray; scattered ironstone nodules; even interbeds of sandstone in upper 10 ft; irregular discontinuous layers of shale and very fine grained sandstone laminae; possibly some "worm" burrows: Campbell Creek Limestone of White	38	5	1,088	2
Shale, gray, fissile; some siltstone laminae and ironstone nodules	9	2	1,097	4
Underclay, light-brown, slickensided; stigmarian roots	1	7	1,098	11
Shale, dark-gray		3	1,099	2
Coal: Pond Creek coal bed	3	4	1,102	6
Shale, gray; siltstone laminae; stigmarian roots in upper part; sandstone in basal 2 in	5	6	1,108	0

Drill hole 60

Log of core from drill hole at centerline of Tug Fork at mile 36.56, approx 28.10 ft upstream from mouth of Wolf Creek, Kermit quadrangle, Ky. (Kentucky coordinates 557,800 ft N.; 2,967,500 ft E.). Drilled by U.S. Engineering Office, Huntington, W. Va., March 24–26, 1945
Altitude: 578.39 feet

Pennsylvanian, Breathitt Formation.	Thickness Ft	Thickness in	Depth Ft	Depth in
Sand; some silt and boulders	23	1	23	1
Sandstone, medium-hard; coal spars	16	3	39	4
Shale, soft, dark-gray; some core lost	1	8	41	0
Silty shale		6	41	6
Sandstone, gray, medium-grained, medium-hard; coal partings	2	5	43	11
Shale, dark gray, silty, medium-hard	16	2	60	1
Sandstone, gray, medium-hard; shale partings	1	11	62	0
Coal (probably Williamson coal bed)	1	1	63	1
Shale, medium-hard		9	63	10

REFERENCES

Adkison, W. L., 1957, Coal geology of the White Oak quadrangle, Magoffin and Morgan Counties, Kentucky: U.S. Geol. Survey Bull. 1047–A, p. 1–23.

Allen, V. T., and Johns, W. D., 1959, Clay-mineral environments in New England and Eastern Canada [abs.]: Geol. Soc. America Bull., v. 70, no. 12, pt. 2, p. 1560.

American Commission on stratigraphic nomenclature, 1961, Code of stratigraphic nomenclature: Am. Assoc. Petroleum Geologists Bull., v. 45, no. 5, p. 645–665.

Ashley, G. H., and Glenn, L. C., 1906, Geology and mineral resources of part of the Cumberland Gap coal field, Kentucky: U.S. Geol. Survey Prof. Paper 49, 239 p.

Brown, C. N., 1900, Report on the mineral wealth of the Big Sandy Valley from Louisa to the head of navigation: U.S. (War Dept.) Chief Engineer Ann. Rept., pt. 5 (U.S. 56th Cong., 2d sess., H. Rept. Doc. 2), p. 3413–3461.

Browning, I. B., 1921, Map of the structural geology of Johnson County, Kentucky: Kentucky Geol. Survey, ser. 6.

Browning, I. B., and Russell, P. G., 1919, Coals and structure of Magoffin County, Kentucky: Kentucky Geol. Survey, ser. 4, v. 5, pt. 2, 552 p.

Campbell, M. R., 1898, Description of the London quadrangle [Ky.]: U.S. Geol. Survey Geol. Atlas, Folio 47, 3 p., maps.

Clark, S. K., and Royds, J. S., 1948, Structural trends and fault systems in Eastern Interior Basin: Am. Assoc. Petroleum Geologists Bull., v. 32, no. 9, p. 1728–1749.

Crandall, A. R., 1877, Report on the geology of Greenup, Carter, and Boyd Counties (and a part of Lawrence) [Ky.]: Kentucky Geol. Survey Rept. Prog., v. 2, new ser., p. 1–77.

——— 1905, The coals of the Big Sandy Valley south of Louisa and between Tug Fork and the headwaters of the North Fork of Kentucky River: Kentucky Geol. Survey Bull. 4, 141 p.

——— 1910, Report on the coals of the Tug Fork region, Martin and Pike Counties, Kentucky: Kentucky Geol. Survey Rept. Prog. 1908–09, p. 36–54.

Crawford, T. J., 1958, Compilation of coal and petroleum data for Kentucky: Kentucky Geol. Survey, ser. 10, Rept. Inv. 1, 43 p.

Crider, A. F., 1916, The coals of Letcher County: Kentucky Geol. Survey, ser. 4, v. 4, pt. 1, 234 p.

Dowd, J. J., and others, 1951, Estimate of known recoverable reserves of coking coal in Pike County, Kentucky: U.S. Bur. Mines Rept. Inv. 4792, 34 p.

Englund, K. J., 1955, Geology and coal resources of the Cannel City quadrangle, Kentucky: U.S. Geol. Survey Bull. 1020–A, 21 p.

Englund, K. J., and Smith, H. L., 1960, Intertonguing and lateral intergradation between the Pennington and Lee Formations in the tri-state area of Kentucky, Tennessee, and Virginia [abs.]: Geol. Soc. America Bull., v. 71, no. 12, pt. 2, p. 2015.

Englund, K. J., Smith, H. L., Harris, L. D. and Stephens, J. G., 1961, Geology of the Ewing Quadrangle Kentucky and Virginia: U.S. Geol. Survey Quad. Map GQ–172.

Ferm, J. C. and Williams, E. G., 1960, Stratigraphic variations in some Allegheny rocks of Western Pennsylvania: Am. Assoc. Petroleum Geologists Bull., v. 44, no. 4, p. 495–497.

Fieldner, A. C., and others, 1942, Typical analyses of coals of the United States: U.S. Bur. Mines Bull. 446, 45 p.

——— 1944, Analyses of Kentucky coals: U.S. Bur. Mines Tech. Paper 652, 323 p.

Floyd, R. J., and Kendall, T. A., 1955, Miscellaneous clay and shale analyses for 1952–1954: Kentucky Geol. Survey, ser. 9, Rept. Inv. 9, 61 p.

Friedman, S. A., 1960, Channel-fill sandstones in the middle Pennsylvanian rocks of Indiana: Indiana Geol. Survey Rept. Prog. 23, 59 p.

Gardner, J. H., 1915, A stratigraphic disturbance through the Ohio Valley running from the Appalachian Plateau in Pennsylvania to the Ozark Mountains in Missouri: Geol. Soc. America Bull., v. 26, no. 4, p. 477–483.

Glass, H. D., 1958, Clay mineralogy of Pennsylvanian sediments in southern Illinois, *in* Swineford, Ada, ed., Clays and clay minerals: Natl. Research Council Pub. 566, p. 227–241.

Glass, H. D., Potter, P. E., and Siever, Raymond, 1956, Clay mineralogy of some basal Pennsylvanian sandstones, clays, and shales: Am. Assoc. Petroleum Geologists Bull., v. 40, no. 4, p. 750–754.

Greensmith, J. T., 1956, Sedimentary structures in the Upper Carboniferous of north and central Derbyshire, England: Jour. Sed. Petrology, v. 26, no. 4, p. 343–355.

Hamblin, W. K., 1961, Micro-cross-lamination in upper Keweenawan sediments of northern Michigan: Jour. Sed. Petrology, v. 31, no. 3, p. 390–401.

Hauser, R. E., 1953, Geology and mineral resources of the Paintsville quadrangle, Kentucky: Kentucky Geol. Survey, ser. 9, Bull. 13, 80 p.

——— 1958, Geology and mineral resources of the Prestonsburg quadrangle, Kentucky: Kentucky Geol. Survey, ser. 9, Bull. 22, 49 p.

Hennen, R. V., and Reger, D. B., 1914, Logan and Mingo Counties: West Virginia Geol. Survey County Repts., 776 p.

Höehne, Karl, 1957, Tonsteine in Kohlenflözen der Oststaaten von Nordamerika und Ostaustralien: Chemie Erde, v. 19, no. 2, p. 111–129.

Hoeing, J. B., 1913, The coals of the upper Big Sandy Valley and the headwaters of the North Fork of the Kentucky River: Kentucky Geol. Survey, ser. 4, v. 1, pt. 1, p. 79–261.

Hopkins, M. E., 1958, Geology and petrology of the Anvil Rock Sandstone of southern Illinois: Illinois State Geol. Survey Circ. 256, 49 p.

Huddle, J. W., ed., 1953, Guide to some Pennsylvanian sections in Morgan, Magoffin, and Breathitt Counties, Kentucky [field trip]: Lexington, Ky., Geol. Soc. Kentucky, 28 p.

Huddle, J. W., and Englund, K. J., 1962, Geology of the Kermit quadrangle, Kentucky: U.S. Geol. Survey Geol. Quad. Map GQ–178.

——— 1962, Geology of the Varney quadrangle, Kentucky: U.S. Geol. Survey Geol. Quad. Map GQ–180.

Huddle, J. W., Lyons, E. J., Smith, H. L., and Ferm, J. C., 1963, Coal reserves of Eastern Kentucky: U.S. Geol. Survey Bull. 1120, 247 p.

Hudnall, J. W., 1923a, Map of the structural geology of Martin County, Kentucky: Kentucky Geol. Survey, ser. 6.

——— 1923b, Map of the structural geology of Pike County, Kentucky: Kentucky Geol. Survey, ser. 6.

——— 1924, Sub-surface structural geologic map of Martin County, Kentucky: Kentucky Geol. Survey, ser. 4; repr., 1949, ser. 9.

——— 1927a, Coals of Martin County: Kentucky Geol. Survey, ser. 6, v. 26, p. 209–228.

——— 1927b, Marine invasions in eastern Kentucky in Pennsylvanian times: Kentucky Acad. Sci. Trans., v. 2, p. 44–46.

Hunt, C. B., and others, 1937, Coal deposits of Pike County, Kentucky: U.S. Geol. Survey Bull. 876, 92 p.

Hunter, C. D., 1935, Natural gas in eastern Kentucky, *in* Geology of Natural Gas; Tulsa, Okla., Am. Assoc. Petroleum Geologists, p. 915–939.

——— 1955, Development of natural gas fields of eastern Kentucky: Petroleum Engineer, v. 27, no. 5, p. B47, B49–50, B52.

Jillson, W. R., 1919, The Kendrick shale, a new calcareous fossil horizon in the coal measures of eastern Kentucky: Kentucky Dept. Geology and Forestry, ser. 5 [of Kentucky Geol. Survey], Mineral and Forest Resources Kentucky, v. 1, no. 2, p. 96–104.

——— 1937, Natural gas in eastern Kentucky: Louisville, Ky., Standard Printing Co., 237 p.

Keller, W. D., 1956, Clay minerals as influenced by environments of their formation: Am. Assoc. Petroleum Geologists Bull., v. 40, no. 11, p. 2689–2710.

Kosanke, R. M., Simon, J. A., Wanless, H. R., and Willman, H. B., 1960, Classification of the Pennsylvanian strata of Illinois: Illinois Geol. Survey Rept. Inv. 214, 84 p.

Krebs, C. E., and Teets, D. D., Jr., 1913, Cabell, Wayne, and Lincoln Counties: West Virginia Geol. Survey County Repts., 483 p.

——— 1914, Kanawha County: West Virginia Geol. Survey County Repts., 679 p.

Krumbein, W. C., 1941, Measurement and geological significance of shape and roundness of sedimentary particles: Jour. Sed. Petrology, v. 11, no. 2, p. 64–72.

Lockett, J. R., 1947, Development of structures in basin areas of north-eastern United States: Am. Assoc. Petroleum Geologists Bull., v. 31, no. 3, p. 429–446.

McFarlan, A. C., 1943, Geology of Kentucky: Lexington, Ky., Univ. Kentucky, 531 p.; repr., 1950.

McGrain, Preston, 1957, Sources of shale in Kentucky for lightweight aggregate production: Kentucky Geol. Survey, ser. 9, Rept. Inv. 12, 23 p.

McGrain, Preston, and Kendall, T. A., 1957, Miscellaneous clay and shale analyses for 1955–1956: Kentucky Geol. Survey, ser. 9, Rept. Inv. 13, 70 p.

McGrain, Preston, Kendall, T. A., and Teater, T. C., 1960, Miscellaneous clay and shale analyses for 1957–1959: Kentucky Geol. Survey, ser. 10, Rept. Inv. 3, 71 p.

Mitchum, R. M., Jr., 1954, Pottsville strata (Pennsylvanian) of part of the central Appalachian coal field [abs.]: Dissert. Abs., v. 14, no. 10, p. 1684–1685.

Moore, D. G., and Scruton, P. C., 1957, Minor internal structures of some recent unconsolidated sediments: Am. Assoc. Petroleum Geologists Bull., v. 41, no. 12, p. 2723–2751.

Morse, W. C., 1931, Pennsylvanian invertebrate fauna: Kentucky Geol. Survey, ser. 6, v. 36, p. 293–348.

Nelson, B. W., 1959, New bentonite zone from the Pennsylvanian of southwestern Virginia: Geol. Soc. America Bull., v. 70, no. 12, pt. 2, p. 1651.

Patterson, S. H., and Hosterman, J. W., 1962, Geology and refractory clay deposits of the Haldeman and Wrigley quadrangles, Kentucky: U.S. Geol. Survey Bull. 1122–F, p. 1–113 [1963].

Pepper, J. F., de Witt, Wallace, Jr., and Demarest, D. F., 1954, Geology of the Bedford Shale and Berea Sandstone in the Appalachian Basin: U.S. Geol. Survey Prof. Paper 259, 111 p.

Phalen, W. C., 1908, Economic geology of the Kenova quadrangle, Kentucky, Ohio, and West Virginia: U.S. Geol. Survey Bull. 349, 158 p.

Potter, P. E., and Glass, H. D., 1958, Petrology and sedimentation of the Pennsylvanian sediments in southern Illinois—a vertical profile: Illinois Geol. Survey Rept. Inv. 204, 60 p.

Reger, D. B., 1931, Pennsylvanian cycles in West Virginia: Illinois Geol. Survey Bull. 60, p. 217–239.

Schultz, L. G., 1958, Petrology of underclays: Geol. Soc. America Bull., v. 69, no. 4, p. 363–402.

Shepard, F. P., and others, eds., 1960, Recent sediments, northwest Gulf of Mexico; a symposium on Proj. 51 of Am. Petroleum Inst.: Tulsa, Okla., Am. Assoc. Petroleum Geologists, 394 p.

Siever, Raymond, 1957, Pennsylvanian sandstones of the Eastern Interior Coal Basin: Jour. Sed. Petrology, v. 27, no. 3, p. 227–250.

Siever, Raymond, and Glass, H. D., 1957, Mineralogy of some Pennsylvanian carbonate rocks of Illinois: Jour. Sed. Petrology, v. 27, no. 1, p. 56–63.

Stout, W. E., 1931, Pennsylvanian cycles in Ohio: Illinois Geol. Survey Bull. 60, p. 195–216.

Straaten, L. M. J. U. van, 1951, Texture and genesis of Dutch Wadden Sea sediments: Internat. Cong. Sedimentology, 3d, Netherlands 1951, p. 225–244.

——— 1954a, Composition and structure of recent marine sediments in the Netherlands: Leidsche Geol. Mededeel., pt. 19-p. 1–108.

——— 1954b, Sedimentology of recent tidal flat deposits and the *Psammites du Condroz* (Devonian): Geologie en Mijnbouw, new ser., v. 16, no. 2, p. 25–47.

Summerson, C. H., 1942, Some Pennsylvanian faunas of Tennessee, eastern Kentucky, and West Virginia [abs.]: Univ. Illinois, unpub. thesis.

Summerson, C. H., and Campbell, L. J., 1958, Holothurian sclerites from the Kendrick shale of eastern Kentucky: Jour. Paleontology, v. 32, no. 5, p. 961–969.

Thomas, G. R., 1960, Geology of recent deep drilling in eastern Kentucky, *in* 24th Ann. Mtg. Kentucky Oil and Gas Assoc. Proc.: Kentucky Geol. Survey, ser. 10, Spec. Pub. 3, p. 10–28.

Thomas, R. N., 1949, Salt sands of eastern Kentucky: Appalachian Geol. Soc. Bull., v. 1, p. 167–180.

Wallace, J. J., and others, 1954, Estimate of known recoverable reserves of coking coal in Mingo County, West Virginia: U.S. Bur. Mines Rept. Inv. 5068, 57 p.

Wanless, H. R., 1939, Pennsylvanian correlations in the Eastern Interior and Appalachian coal fields: Geol. Soc. America Spec. Paper 17, 130 p.

——— 1946, Pennsylvanian geology of a part of the Southern Appalachian coal field: Geol. Soc. America Mem. 13, 162 p.

——— 1955, Pennsylvanian rocks of Eastern Interior Basin: Am. Assoc. Petroleum Geologists Bull., v. 39, no. 9, p. 1753–1820.

Welch, S. W., 1958, Geology and coal resources of the Tiptop quadrangle, Kentucky: U.S. Geol. Survey Bull. 1042–P, p. 585–612.

Weller, J. M., 1956, Argument for diastrophic control of late Paleozoic cyclothems: Am. Assoc. Petroleum Geologists Bull., v. 40, no. 1, p. 17–50.

Wells, J. V. B., and others, 1959, Surface water supply of the United States 1957, Part 3–A. Ohio River Basin except Cumberland and Tennessee River Basins: U.S. Geol. Survey Water-Supply Paper 1505, 553 p.

Wheeler, H. E., and Murray, H. H., 1957, Base-level control patterns in cyclothemic sedimentation: Am. Assoc. Petroleum Geologists Bull., v. 41, no. 9, p. 1985–2011.

White, I. C., 1885, The geology of natural gas: Science, v. 5, p. 521–522; v. 6, p. 43–44.

——— 1903, The Appalachian coal field: West Virginia Geol. Survey, v. 2, pt. 2, p. 8–716.

——— 1908, Supplementary coal report: West Virginia Geol. Survey, v. 2 (A), 720 p.

Wilson, C. W., Jr., Jewell, J. W., and Luther, E. T., 1956, Pennsylvanian geology of the Cumberland Plateau: Tennessee Dept. Conserv., Div. Geology Folio, 21 p.

Wilson, C. W., Jr., and Stearns, R. G., 1960, Pennsylvanian marine cyclothems in Tennessee: Geol. Soc. America Bull., v. 71, no. 10, p. 1451–1465.

INDEX

[Italic page numbers indicate major references]