Geology and Coal Resources of the Elk Valley Area Tennessee and Kentucky

GEOLOGICAL SURVEY PROFESSIONAL PAPER 572

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By KENNETH J. ENGLUND

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A study of the resources, principally coal, and a description of the structural geology at the southwest end of the Cumberland overthrust sheet

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GEOLOGY AND COAL RESOURCES OF THE ELK VALLEY AREA, TENNESSEE AND KENTUCKY

By Kenneth J. Englund

ABSTRACT

The 240-square-mile area described in this report includes the Ivydell, Jellico West, Ketchen, and Pioneer 7½-minute quadrangles in Scott and Campbell Counties, Tenn., and McCreary and Whitley Counties, Ky. Elk Valley, the source of the area name, is centrally located.

The quadrangles of this report are in the Cumberland Mountain section of the Appalachian Plateaus province, except for the southeast corner of the Ivydell quadrangle which is in the Valley and Ridge province. That part of the area in the Cumberland Mountain section lies within the gently folded Cumberland overthrust sheet where the principal streams flow parallel to ridges that fringe the blunt southwest end of the Middlesboro syncline. Northwest and southwest of the Cumberland overthrust sheet, the Cumberland Mountain section is characterized by dendritic drainage patterns that were incised into relatively flat-lying rocks.

The rock formations exposed in the Elk Valley area range from the Newala Dolomite of Early Ordovician age to the Hignite Formation of Middle Pennsylvanian age. Approximately the lower third of this sequence consists of carbonate rocks of Early and Middle Ordovician age that crop out in the extreme southeast corner of the area. The middle third of the sequence is composed of alternating beds of shale and carbonate rocks of Late Ordovician to Early Mississippian age that crop out in narrow belts of upturned beds on the limbs of the Middlesboro syncline and along the Pine Mountain fault zone. Strata in the upper third of the section consist principally of sandstone, siltstone, shale, and coal of Late Mississippian and Pennsylvanian age, which are at the surface in most of the report area. These upper strata are largely of continental origin and vary more laterally than do the underlying formations of marine origin. The sequence totals about 8,300 feet in thickness and has been divided into 25 mapped formations. An additional 3,500 feet of underlying strata in the subsurface has been assigned to six formations that range in age from Early Cambrian to Early Ordovician. Unconsolidated surficial deposits of Quaternary age locally cover the bedrock.

The gentle southeasterly dip of strata, away from the Cincinnati arch, is terminated in the Elk Valley area by faulting and folding at the periphery of the Cumberland overthrust sheet. During late- or post-Paleozoic deformation of the Appalachian geosyncline the overthrust sheet was displaced northwestward by overthrusting on the Pine Mountain fault and by strike-slip movement along the Jacksboro fault. The thickness and character of formations on opposite sides of the Jacksboro fault indicate approximately 11 miles of movement at the southwest end of the overthrust sheet. Because of southeastward thickening of the stratigraphic section, northwestward movement of the overthrust sheet has placed a relatively thicker section of rocks opposite its counterpart across the Jacksboro fault. As a result of this thickening and subsequent displacement, beds cropping out in the Middlesboro syncline of the overthrust sheet are about 500 feet higher than their correlatives in the autochthonous plate. Northwest of the Cumberland overthrust sheet, deformation occurs principally along the high-angle Terry Creek fault, which strikes N. 40° W. from the junction of the Pine Mountain and Jacksboro fault zones.

Coal has been mined commercially in the Elk Valley area since the early 1880's. Most of the coal produced during the first 60 years came from large underground mines and was shipped by rail. In recent years the proportion of coal produced from strip, truck, and auger mines has increased rapidly, and in 1962 approximately 63 percent of the coal was mined by strip methods.

Coal in the Elk Valley area is of high-volatile A bituminous rank and occurs in at least 36 beds, of which 17 are of commercial importance. Analyses, on an as-received basis, of channel samples collected from the principal coal beds show that the composition of the coal ranges from 1.9 to 10.3 percent ash, 48.3 to 56.7 percent fixed carbon, 35.8 to 40.2 percent volatile matter, 0.6 to 4.5 percent sulfur, and 2.3 to 5.2 percent moisture. The heating value ranges from 12,980 to 14,010 Btu.

Original coal reserves in the Elk Valley area total more than 1 billion tons, of which approximately 3 percent is in beds more than 42 inches thick, 35 percent in beds 28–42 inches thick, and 62 percent in beds 14–28 inches thick. About 40 percent of the total reserve is in the Swamp Angel coal bed and its correlative, the Kent coal bed. About 58,500,000 tons, or 5½ percent, of the total tonnage has been mined or lost in mining, mostly from the Jellico, Blue Gem-Rich Mountain, Swamp Angel-Kent, and Rex coal beds. Assuming 50 percent recovery, the remaining recoverable reserves are about 505 million tons.

Exploration for oil and gas in the Elk Valley area has resulted in the drilling of three unproductive test holes. Several anticlinal flexures in the area have not been tested. The intertonguing relations of the Carboniferous rocks are also noteworthy because stratigraphic traps may exist in these rocks.

Mineral resources that have been developed commercially in the report area, in addition to coal, include limestone, iron ore, shale, and clay; of these, only limestone is currently (1962) exploited.

INTRODUCTION

LOCATION AND EXTENT OF AREA

The Elk Valley area is centrally located in the southern Appalachian coal field of eastern Kentucky and Tennessee (fig. 1). It occupies about 240 square miles in Campbell and Scott Counties, Tenn., and in the southernmost parts of McCreary and Whitley Counties, Ky. (lat 36°22′30″–36°37′30″ N., long 84°07′30″–84°22′30″ W.) (fig. 2), and includes the Ivydell, Jellico West,

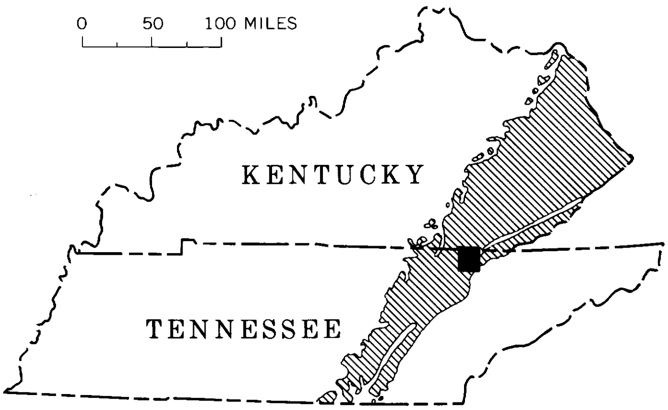


FIGURE 1.—Index map showing the area of this report (black) in the eastern Kentucky and Tennessee coal fields (shaded).

Ketchen, and Pioneer 7½-minute quadrangles. These quadrangles form a rectangular area west of a line between the cities of Jellico and La Follette, Tenn. Elk Valley, a broad strike valley along the trace of the Pine Mountain fault zone, is the source of the area name.

PREVIOUS INVESTIGATIONS

The earliest geologic investigations in the Elk Valley area were made by Safford (1869, p. 141–142) and consisted of observations along the Pine Mountain fault zone. An early geologic map was published in the Briceville folio (Keith, 1896b), which included the area of the Pioneer and Ivydell quadrangles; but because of the small scale (1:125,000) and inadequate portrayal of the topography, much of the areal geology was necessarily generalized. Crandall (1889) and Miller (1910) described coal beds at several localities in Whitley County, Ky.

The distribution and correlation of coal beds in the northern Tennessee coal field was systematically studied by Glenn (1925). Wanless (1946) described several stratigraphic sections of Pennsylvanian rocks in the Jellico West, Pioneer, and Ivydell quadrangles and correlated the coal beds with those in other parts of the southern Appalachian coal field. Rodgers' geologic map (1953) of east Tennessee shows the distribution of pre-Pennsylvanian formations southeast of Cumberland Mountain in the southeast corner of the Ivydell quadrangle. Recent investigations in the report area include coal-reserve studies by the U.S. Bureau of Mines (Williams, Gibbs, Crentz, and Miller, 1956; Williams, Gibbs, Crentz, Miller, and Reynolds, 1956) and reconnaissance geologic mapping (Wilson and others, 1956).

PRESENT INVESTIGATIONS

Geologic mapping in the quadrangles that compose this report area was undertaken primarily for an ap-

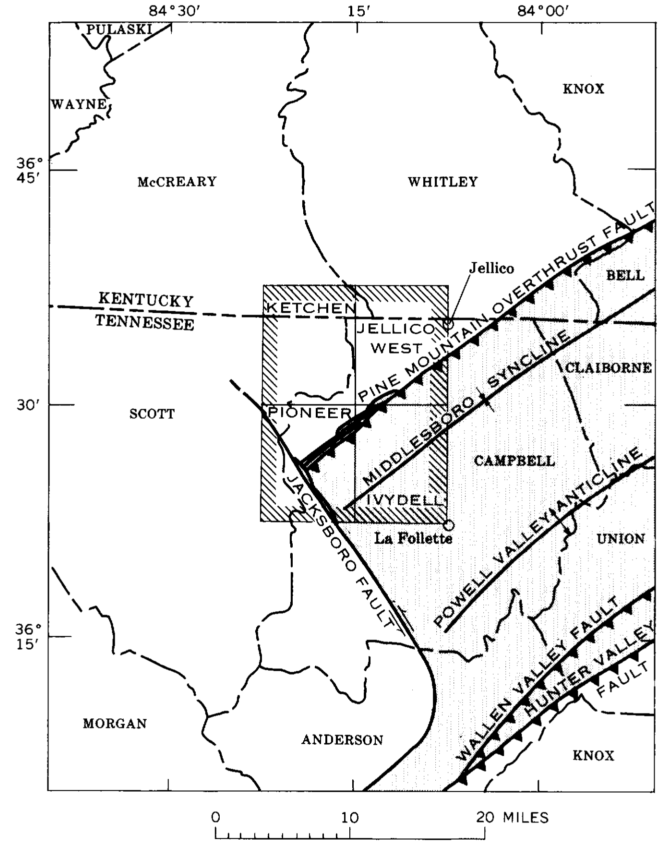


FIGURE 2.—Index map showing the area of this report (ruled pattern) and major structural features in the southwestern part of the Cumberland overthrust sheet (shaded).

praisal of the distribution, thickness, and quality of coal resources in conjunction with a study of the structural relations at the southwest corner of the Cumberland overthrust sheet. Fieldwork began in the fall of 1952 and consisted of periods of about 4 months in each quadrangle. The Pioneer quadrangle was mapped with the aid of E. D. Patterson; the Ivydell quadrangle was mapped in the fall of 1953 and the spring of 1954 with the assistance of J. A. Van Lieu. Preliminary coal maps were published for the two quadrangles (Englund, 1957, 1958). Geologic mapping of the Ketchen and Jellico West quadrangles continued intermittently from the fall of 1956 to the spring of 1958. The fieldwork was completed in the fall of 1962 with the mapping of subdivisions of the Lee Formation. A geologic quadrangle map (Englund, 1966) was prepared for the Ketchen quadrangle. A. O. DeLaney aided in the final phase of the fieldwork and in the compilation of maps and illustrations.

Most of the report area was mapped on topographic quadrangle sheets at a scale of 1:24,000. Areas of complex faulting and folding necessitated additional detail, and enlarged maps at a scale of 1:12,000 were used locally. In the field, aerial photographs were utilized to plot location points, to determine access into remote parts of the quadrangles, and to study topographic trends that reflect geologic features. Most of the altitudes of coal outcrop lines and contacts were established by aneroid barometer traverses, and readings were corrected for atmospheric and temperature variations. Other altitudes were determined by hand leveling or by reference to mine maps. All available exposures of coal beds in mines, prospects, roadcuts, and natural outcrops were described, and additional information relating to coal was obtained from mine maps and drill records. The measurement of stratigraphic sections was supplemented by study of all available cores and cuttings from test holes in the report area and nearby localities.

TOPOGRAPHY

The quadrangles of this report lie entirely in the Cumberland Mountain section of the Appalachian Plateaus province, except for the extreme southeast corner of the Ivydell quadrangle which is in the Valley and Ridge province. The part of the area lying northwest and southwest of the Cumberland overthrust sheet is characterized by dendritic drainage patterns and deep V-shaped valleys that were carved into nearly flat-lying beds of shale, siltstone, and sandstone. Flat land is limited to narrow flood plains bordering the larger streams and to benches on hill slopes formed by the differential erosion of weak shale beds and resistant sandstone beds. The area west of the Cumberland overthrust sheet is drained by Jellico and Elk Fork Creeks, which flow northeastward into the Cumberland River, and by southwestward-flowing tributaries of New River. Altitudes range from about 950 feet on Elk Creek to slightly more than 2,700 feet on Braden Mountain. Local relief ranges from 1,000 to 1,400 feet.

The Cumberland overthrust sheet in the southeastern part of the report area is bounded on the northwest by Elk Fork Creek and on the southwest by Cove Creek. Elk Fork Creek flows through Elk Valley which was cut largely into the contorted and faulted shale of the Pine Mountain fault zone. This valley is as much as a mile wide, and its relatively flat bottom land is interrupted only by disconnected erosion remnants of cherty dolomite known locally as the "lones." From Elk Gap at the head of Elk Valley, Cove Creek flows southeastward in a narrow gorge parallel to the trace of the Jacksboro fault zone.

Both creeks are bordered by linear ridges of massive conglomeratic sandstone which are the most conspicuous physiographic features of the area. These ridges, consisting of Pine Mountain on the northwest, Chestnut Ridge and Fork Mountain on the southwest, and Cumberland Mountain on the southeast, outline the Middlesboro syncline (fig. 2) of the overthrust sheet. Altitudes on Pine Mountain decrease northeastward from 2,360 to about 2,000 feet, and the altitudes along Chestnut Ridge, Fork Mountain, and Cumberland Mountain average about 2,000 feet.

The principal streams within the Middlesboro syncline flow in a direction parallel to these mountains and include Stinking Creek, which flows northeastward along Pine Mountain into the Cumberland River drainage, Titus Creek, which drains into Cove Creek, and Ollis Creek, which flows northeastward along Cumberland Mountain into Big Creek of the Tennessee River drainage. Tributaries of these creeks drain the central part of the syncline where dendritic drainage patterns are incised into relatively flat-lying rocks. The valleys are steep sloped, but in contrast to the physiography west of the thrust sheet, broad flat benches have formed on the uplands. Walnut Mountain, the highest point in the report area, rises about 900 feet above these uplands to an altitude of slightly more than 2,800 feet.

ACCESSIBILITY AND ROUTES OF TRAVEL

U.S. Highway 25W, a main north-south artery, passes through Jellico and La Follette on the east edge of the report area and provides access from Lexington and central Kentucky on the north and from Knoxville and east Tennessee on the southeast. From U.S. Highway 25W, two hard-surfaced all-weather roads extend southwestward to State Highway 63 in the southern part of the Pioneer quadrangle. One of these secondary roads passes through Elk Valley and the other follows Stinking Creek. Access along the larger streams is provided by gravel or dirt roads; travel into the mountainous or upland sections is limited in most places to four-wheel drive vehicles on mine or logging roads.

A freight line of the Southern Railroad in east Tennessee follows Cove Creek to Elk Gap where it passes through a tunnel and continues along Elk Valley to Jellico. The freight is principally coal that is loaded from several sidings along the route. The main line of the Louisville and Nashville Railroad serves La Follette, and a spur line extends into Jellico.

ACKNOWLEDGMENTS

The writer wishes to acknowledge the cooperation of the many mine operators and local residents who kindly contributed information and permitted examination of their mines and property during the fieldwork for this report. Special thanks are due to A. E. Price, E. Kyle Miller, W. G. Gilchrist, Jr., and I. C. Burroughs. Con-

ferences in the field with R. L. Miller, G. V. Cohee, and J. W. Huddle, of the U.S. Geological Survey, were very helpful.

STRATIGRAPHY

GENERALIZED DESCRIPTION

The Elk Valley area is underlain by marine and continental sedimentary deposits that range from Cambrian to Pennsylvania in age and that total approximately 11,800 feet in thickness. Of this total the basal 3,500 feet is only in the subsurface where its presence is indicated by the sequential relation of beds in the faulted and folded belt of east Tennessee, which borders on the southeast corner of the report area. The continuity of these beds northwestward into the subsurface is verified by oil and gas test holes.

Exposed rocks total about 8,300 feet in thickness and have been divided into 25 formations which include 11 members and numerous coal beds (pls. 1–4). Approximately the lower third of this sequence consists of carbonate rocks of Early and Middle Ordovician age which are exposed in the extreme southeast corner of the area. The middle third of the exposed section is composed mostly of alternating carbonate rocks and shale of Late Ordovician to Mississippian age that crop out in narrow belts of upturned beds on the limbs of the Middlesboro syncline and along the Pine Mountain fault zone. Strata in the upper part of the section consist principally of sandstone, siltstone, shale, and coal of Pennsylvanian age which are at the surface in most of the report area. The rocks of Pennsylvanian age are largely continental in origin and vary more laterally than the underlying rocks which are marine in origin. Unconsolidated surficial deposits of Quarternary age locally cover the bedrock.

CAMBRIAN SYSTEM

ROME FORMATION

The Rome Formation (Hayes, 1891, p. 143–146) of Early Cambrian age includes the oldest sedimentary rocks known in the general area of this report. Although the rocks occur only in the subsurface, data are available from nearby Bell County, Ky. (Englund and others, 1964), where the United Fuel Gas Co. Knuckles 2 oil and gas test penetrated about 1,200 feet of the Rome. Drill cuttings from this test show that the Rome consists mostly of greenish-gray, grayish-red, and medium-gray shale and siltstone with lesser amounts of fine- to medium-grained medium-gray limestone and light-gray fine-grained sandstone. Scattered glauconite grains were observed in both the limestone and sandstone. Rocks at the base of the drilled sequence were largely fine- to coarse-grained standstone with a few quartz pebbles. Deep oil and gas tests in other parts of eastern Kentucky (Thomas, 1960) indicate that the Rome Formation unconformably overlies a basement complex of Precambrian rocks. The total thickness of the formation may be as much as 1,500 feet in the report area.

CONASAUGA SHALE

The Conasauga Shale (Hayes, 1891, p. 143–148) of Middle and Late Cambrian age is confined to the subsurface in the Elk Valley area; the nearest outcrops are in the vicinity of Lake City, Tenn., about 8 miles south of the Ivydell quadrangle. In the Rose Hill district of southwestern Virginia, about 40 miles to the northeast, Miller and Fuller (1954, p. 33) report that the Conasauga contains both Middle and Late Cambrian faunas. In the Knuckles 2 oil and gas test the formation is mostly greenish-gray shale with some interbedded grayish-red and medium-gray shale. Intercalated light-gray limestone, very fine grained sandstone, and glauconite grains were also evident in the drill cuttings. The Conasauga is estimated to be about 400 feet thick in the Elk Valley area, and, on the basis of its stratigraphic relations with adjacent formations where exposed, the lower and upper contacts are probably conformable.

MAYNARDVILLE LIMESTONE

The Maynardville Limestone of Late Cambrian age was named by Oder (1934, p. 475) from an outcrop belt at Maynardville, Tenn., about 19 miles east of the Ivydell quadrangle. The formation occurs only in the subsurface in the report area, but data are available from the Knuckles 2 test. Drill cuttings show that the Maynardville consists of light-olive-gray to olive-gray finely crystalline dolomite with a few thin beds of light-gray limestone. Scattered white chert nodules are also present. The contact with overlying beds may be conformable, but it is not readily evident in the cuttings. The Maynardville Limestone seems to be about 250 feet thick.

CAMBRIAN AND ORDOVICIAN SYSTEMS

KNOX GROUP

The Knox Group (Safford, 1869, p. 204) is a remarkably continuous sequence of dolomite and cherty dolomite about 2,100 feet thick. It ranges in age from Late Cambrian to Early Ordovician and is divided into four formations, including in ascending order, the Copper Ridge, Chepultepec, Longview, and Newala Dolomites. This nomenclature was previously used by Rodgers (1953, pl. 1) in the Powell Valley outcrop belt which passes through the southeastern part of the Ivydell quadrangle. In addition to this occurrence in the Cumberland overthrust sheet, the Knox is at a minimum depth of about 4,500 feet below the surface in the autochthonous block in the Elk Valley area. Because only the uppermost part of the Knox Group is exposed in the report area, the following descriptions of subdivisions are of outcrops in the Middlesboro South quadrangle (Englund, 1964a), on the Powell Valley outcrop belt about 23 miles northeast of the Elk Valley area.

COPPER RIDGE DOLOMITE

The Copper Ridge Dolomite (Ulrich, 1911, p. 635–636) of Late Cambrian age is in the subsurface in the Elk Valley area. Lithologically, it is divisible into two distinct units of about equal thickness. Approximately the lower half is thick-bedded medium to coarsely crystalline olive-gray to brownish-gray dolomite which emits a petroliferous odor from a freshly broken surface. This relatively dark-colored dolomite in the lower part of the formation contrasts sharply with the very light gray and light-olive-gray very finely to finely crystalline dolomite that predominates in the upper part. White to light-gray chert nodules occur throughout and are oolitic in the upper part of the formation. Large chert oolites, about one-eighth inch in diameter, occur near the top and are an aid in locating the top contact. Also included in the upper part of the formation is very fine grained to fine-grained quartz sandstone in beds as much as a few inches thick. The top contact is conformable with the overlying Chepultepec Dolomite which is marked by a persistent sandstone bed at its base. The Copper Ridge is about 750 feet thick in the Elk Valley area.

CHEPULTEPEC DOLOMITE

The Chepultepec Dolomite of Early Ordovician age was named in Alabama by Ulrich (1911, p. 549, 638–640) and was subsequently traced by numerous workers northeastward in the outcrop belts of eastern Tennessee and the southwestern Virginia. In the Powell Valley outcrop belt the Chepultepec consists of a lower sandy dolomite member and an upper argillaceous dolomite member. In addition to light-gray to light-olive-gray finely crystalline dolomite, the lower member contains very fine to medium-grained moderately quartzose dolomitic sandstone in beds as much as 10 feet thick. The abundance of sandstone in the lower member distinguishes it from the upper member which consists largely of light-olive-gray finely crystalline partly argillaceous dolomite. Chert occurs in nodules in both members, and it commonly contains oolites with sand-grain nuclei. The combined thickness of the lower and upper members of the Chepultepec Dolomite in the Elk Valley area is about 600 feet. The upper contact appears conformable and is placed where the very finely crystalline dolomite of the Chepultepec is succeeded by coarsely crystalline chert-bearing dolomite of the Longview. In the Elk Valley area the Chepultepec Dolomite occurs only in the subsurface.

LONGVIEW DOLOMITE

The name Longview originated in Alabama (Butts, 1926, p. 92) and is applied in eastern Tennessee and southwestern Virginia to the part of the Knox Group that is typically coarsely crystalline and conspicuously cherty. The Longview Dolomite is of Early Ordovician age and consists of medium to coarsely crystalline very light gray to white thin- to thick-bedded dolomite and a few thin beds of very fine grained to fine-grained sandstone. Partly oolitic chert occurs in nodules and in beds as much as 2 feet thick. Within the Elk Valley area the formation is limited to the subsurface, but it crops out just beyond the southeast corner of the Ivydell quadrangle. The top contact is conformable and is placed at the top of the sequence of predominantly coarsely crystalline dolomite. The Longview is about 275 feet thick in the Elk Valley area.

NEWALA DOLOMITE

The Newala Dolomite (Butts, 1926, p. 95) of Early Ordovician age is the oldest strata exposed in the Elk Valley area. Various representative dolomite lithologies of the underlying formations of the Knox Group recur in the Newala; but very finely to finely crystalline dolomite is most common, and chert nodules or beds are locally abundant. Coarsely crystalline dolomite, similar to that of the underlying Longview, occurs in a few beds near the base of the formation, and yellowish-gray argillaceous dolomite is characteristic of the uppermost beds. A regional disconformity delineates the top contact and causes local variations in the thickness of the Newala, which averages about 450 feet. From the outcrop belt in the southeast corner of the Ivydell quadrangle, the Newala dips steeply northwestward to where it is truncated in the subsurface by the Pine Mountain overthrust fault (pl. 4, cross section $A–A'$).

ORDOVICIAN SYSTEM

MIDDLE ORDOVICIAN SERIES

The Middle Ordovician Series in the Elk Valley area is represented by about 1,850 feet of limestone that disconformably overlies the Knox Group. Exposures are limited to a belt of upturned beds that underlie fertile agricultural lowlands at La Follette in the southeast corner of the area. Northeastward along this outcrop belt in Virginia the Middle Ordovician Series has been subdivided into 10 formations (Miller and Brosgé, 1954), names of which have been introduced into parts of Tennessee by Harris, Stephens, and Miller (1962) and Englund (1964a) in place of the term Chickamauga Limestone (Hayes, 1891, p. 142–144). However, except for the Trenton Limestone, which averages about 500 feet thick, the formations of Middle Ordovician age are too thin in the report area to be conveniently shown individually. Therefore, they are referred to collectively on the map (pl. 4) and in the text as lower Middle Ordovician limestone beds. In addition to the outcrop at La Follette, which is in the overthrust sheet, the Middle Ordovician Series underlies the Elk Valley area in the autochthonous plate at a minimum depth of about 3,000 feet below the surface.

LOWER MIDDLE ORDOVICIAN LIMESTONE BEDS

The limestone beds of Middle Ordovician age between the top of the Knox Group and the base of the Trenton Limestone are herein referred to informally as the lower Middle Ordovician limestone beds. Included are the Dot Formation, and Poteet, Rob Camp, Martin Creek, Hurricane Bridge, Woodway, Ben Hur, Hardy Creek, and Eggleston Limestones, which are described in considerable detail by Miller and Brosgé (1954) and are approximately equivalent to the lower and middle parts of the Chickamauga Limestone as described by Rodgers (1953, p. 64).

The basal beds, which are equivalent to the Dot Formation, contain unsorted detritus ranging in size from scattered grains of quartz to locally derived boulders of chert and dolomite just above the regional disconformity at the top of the Knox Group. The matrix is argillaceous dolomite that grades upward to light-gray to yellowish-gray very finely crystalline dolomite that occurs above the basal detritus. Interbedded with the dolomite is light-olive-gray fine-grained limestone that increases in proportion upward. Overlying lower Middle Ordovician limestone beds are thin to massive and range in composition from light-olive-gray to olive-gray relatively pure limestone to yellowish-gray and grayish-red argillaceous limestone. Also included are a few medium-gray and brownish-gray limestone beds. The texture is predominantly fine grained but ranges from aphanitic to coarse grained. Medium-gray to black chert nodules as much as a few inches in diameter are sparse to abundant.

The uppermost strata of the lower Middle Ordovician sequence, the Eggleston Limestone equivalent, characteristically contain two widespread bentonite beds that range in thickness from 2 to 5 feet. The top contact of the unit appears to be conformable and is marked by a change in lithology from olive-gray fine-grained partly argillaceous limestone of the upper part of the lower Middle Ordovician beds to medium-gray medium- to coarse-grained limestone of the overlying Trenton Limestone. The lower Middle Ordovician limestone beds total about 1,350 feet in thickness, of which the upper 120 feet was penetrated by the Meredith 1 oil and gas test below the Pine Mountain overthrust fault in the Pioneer quadrangle.

TRENTON LIMESTONE

The name Trenton Limestone is applied in the Elk Valley area to a predominantly coarse-textured coquinoid limestone at the top of the Middle Ordovician Series. This usage follows that established by Miller and Brosgé (1954, p. 67–70) in Lee County, Va., and refers to rocks included in the upper part of the Chickamauga Limestone by Rodgers (1953, p. 94). Typically, the Trenton is light-olive-gray, medium-gray, and brownish-gray, fine- to coarse-grained limestone in thin beds with intervening shale laminae (fig. 3). It is composed largely of bioclastic detritus consisting of broken brachiopod and gastropod shells and bryozoan fragments. Uppermost beds are rarely exposed, but the top

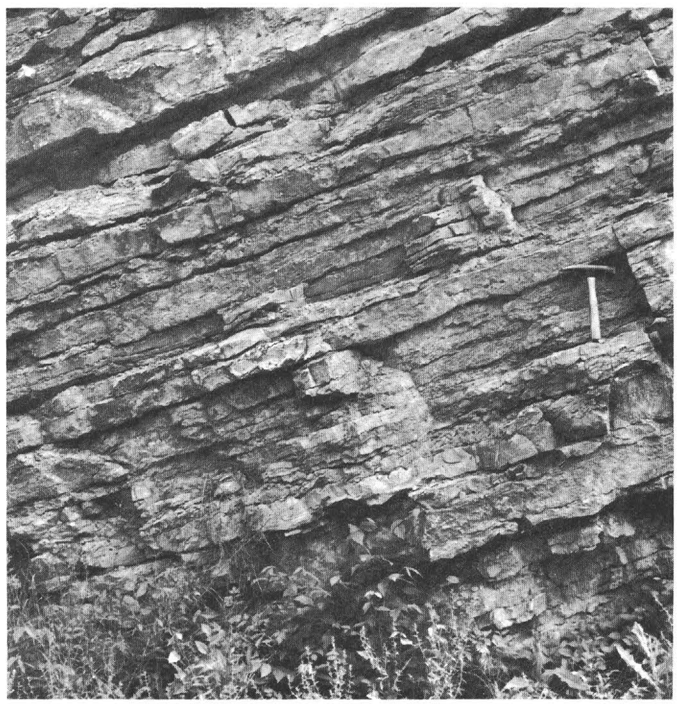


FIGURE 3.—Limestone beds separated by shale laminae in the lower part of the Trenton Limestone in a railroad cut at Harrogate, Tenn., about 30 miles northeast of La Follette, Tenn.

contact appears conformable and is placed where the relatively coarse-textured limestone of the Trenton is succeeded by calcareous shale of the overlying Reedsville Shale. Thicknesses of the Trenton range from about 450 feet in the east-central part of the Pioneer quadrangle, as indicated by drill cuttings from the Meredith 1 test, to about 550 feet in the outcrop belt at La Follette.

A fossil collection made by the writer at La Follette included the coral *Tetradium fibratum* Safford (identified by R. B. Neuman, U.S. Geol. Survey), the brachiopod *Hebertella frankfortensis* Foerste (identified by G. A. Cooper, U.S. Natl. Mus.) and the following conodonts and scolecodonts which were identified by W. H. Hass and J. W. Huddle, both of the U.S. Geological Survey:

Conodonts:
- *Cordylodus* sp.
- *Drepanodus homocurvatus* Lindström
- *Drepanodus subarcuatus* Furnish
- *Oistodus* sp.
- *Ozarkodina concinna* Stauffer

Scolecodonts:
- *Leodicites*
- *Lumbriconereites*

The age of this assemblage is in agreement with the generally accepted Middle Ordovician age for the Trenton Limestone.

REEDSVILLE SHALE

The Reedsville Shale of Late Ordovician age, named from Mifflin County, Pa. (Ulrich, 1911, pl. 27), is widely recognized in southwestern Virginia (Miller and Brosgé, 1954, p. 71) and in eastern Tennessee (Rodgers, 1953, p. 95). In the Elk Valley area it consists predominantly of medium-gray calcareous shale with interbedded medium-gray medium- to coarse-grained coquinoid limestone in beds as much as 5 inches thick. Lesser amounts of calcareous siltstone occur in beds that range mostly from 1 to 2 inches in thickness. The upper 25 feet of the Reedsville is largely medium- to coarse-grained medium-gray limestone which is conformably overlain by contrasting grayish-red calcareous siltstone beds of the Sequatchie Formation. Outcrops are limited to the northwest side of Powell Valley in the southeast corner of the Ivydell quadrangle. Although the Reedsville is poorly exposed, low rounded knobs along the outcrop belt indicate that it is somewhat more resistant to erosion than the underlying limestone beds. From this outcrop area the Reedsville dips northwestward to where it is truncated in the subsurface by the Pine Mountain fault (pl. 4, cross section *A–A′*). Its occurrence below the Pine Mountain fault at depths of 3,000–3,300 feet below the surface has been confirmed by test drilling. A thickness of 250–275 feet is fairly constant throughout the Elk Valley area. Bryozoans, brachiopods, and pelecypods are abundant in the Reedsville Shale; the most common forms collected by the writer near La Follette were identified as the bryozoans *Dekayia* sp. *and Constellaria* sp. by R. S. Boardman, U.S. National Museum.

SEQUATCHIE FORMATION

The Sequatchie Formation of Late Ordovician age was named by Ulrich (1913, p. 614, 648–649) from Sequatchie Valley which is in Tennessee southwest of the Elk Valley area. In gross lithology the Sequatchie is fairly uniform and consists of gritty calcareous siltstone with poor fissility. Variation is most conspicuous in the mottled grayish-red and greenish-gray color of the beds. An unconformity at the top of Sequatchie Formation in southwestern Virginia (Miller and Brosgé 1954, p. 77) was not evident in the few exposures in the Elk Valley area where the formation is overlain conformably by olive-gray and greenish-gray shale or by very fine grained sandstone at the base of the Rockwood Formation. The Sequatchie Formation ranges in thickness from 200 to 250 feet and is exposed principally in the outcrop belt at La Follette. The uppermost beds also occur in a thin short strip just above the fault plane at the southwest end of the Pine Mountain fault zone. This latter occurrence can be attributed to furrowing by the Pine Mountain overthrust fault from its normal position near the top of the Sequatchie Formation at the southwest end of the Cumberland overthrust sheet. The Sequatchie Formation underlies the entire Elk Valley area, and its presence just below the overthrust fault in the subsurface was substantiated by test drilling for oil and gas. Outcrops of the formation did not yield any significant paleontologic data.

SILURIAN SYSTEM

ROCKWOOD FORMATION

The Rockwood Formation of Early and Middle Silurian age was named by Hayes (1891, p. 142–143) from the city of Rockwood in nearby Roane County, Tenn. Equivalent strata in southwestern Virginia were subdivided into the Clinch Sandstone and Clinton Shale (Miller and Brosgé, 1954, p. 76–83), and studies in the Middlesboro, Ky., area, 28 miles northeast of La Follette, show that the Clinch thins to the southwest and grades laterally into Clinton or Rockwood-type lithology (Englund, 1964a). The Rockwood consists predominantly of medium-gray and dark-greenish-gray shale which generally alters to light olive gray or olive gray in weathered exposures. At Elk Valley in the Pioneer quadrangle as much as 13 feet of slightly calcareous very fine grained sandstone and siltstone occur at the base of the formation. Thin beds of sandstone and siltstone, 2–3 inches thick, are also distributed throughout the formation and constitute about 10 percent of the strata. Oolitic hematite occurs at several horizons in beds as much as 3 feet thick. Although unconformably overlain by the Chattanooga shale, the Rockwood shows a constant increase in thickness to the southeast from about 225–275 feet. Outcrops occur along a belt of upturned beds on the southeast limb of the Middlesboro syncline at La Follette and in fault slices in the Pine Mountain fault zone southwest of the community of Elk Valley. A line drawn southeastward from this town marks the approximate position where the Pine Mountain overthrust fault has crosscut upward to the northeast through the Rockwood Formation to the base of the Chattanooga Shale. This line delineates the northeast limit of the Rockood in the overthrust sheet below the Middlesboro syncline.

The basal beds of the Rockwood are moderateely fossiliferous, and the hematite beds generally contain fossil fragments. Brachiopods collected by the writer from the basal beds in Elk Valley were identified by A. J. Boucot as *Leptaena "rhomboidalis," Plectodonta* sp., and an orthoid that resembles *Dolerorthis* and *"Orthis" fissiplica* Roemer; this orthooid probably is of no previously described genus. Boucot also states that these fossils seem to be of Middle or Late Silurian age, most likely Middle Silurian age.

DEVONIAN SYSTEM

CHATTANOOGA SHALE

The Chattanooga Shale, named by Hayes (1891, p. 142–143), is considered to be Late Devonian in age in Tennessee and adjoining States (Hass, 1953). It consists almost entirely of carbonaceous pyritic black shale but locally includes a basal conglomerate, as much as 1 foot thick, of medium- to coarse-grained sandstone with granules and small pebbles of quartz. Also included in the black shale are a few thin beds of medium-gray shale; phosphate nodules are common in the upper 2–3 feet of the formation. The thickness of the Chattanooga increases eastward from about 50–75 feet and is nearly 60 feet in the East Tennessee Iron & Coal Co. 2 test hole in the southern part of the Ivydell quadrangle. Outcrops of the Chattanooga Shale are principally along the Pine Mountain fault zone where it occurs near the base of the Cumberland overthrust sheet and in several associated fault slices. Adjacent to the fault planes the shale has a jointed coaly appearance, and the thickness is generally exaggerated by the intense contortion of the beds (fig. 4). The formation is also exposed at La Follette in a northeast-trending belt of nearly vertical beds. The top contact is conformable and is placed where the black shale is succeeded by greenish-gray shale of the Maury or Grainger Formations. Fossils are sparce in the Chattanooga Shale in the Elk Valley area, and only a few linguloid and orbiculoid brachiopods and conodonts were observed.

FIGURE 4.—Contorted beds in the Chattanooga Shale in a railroad cut half a mile southwest of the community of Elk Valley.

MISSISSIPPIAN SYSTEM

MAURY FORMATION

The name Maury (Safford and Killebrew, 1900, p. 141) is applied in Tennessee to a very thin but widespread greenish-gray shale of Early Mississippian age. However, in the Elk Valley area the Maury appears to be limited to the southwestern and central parts of the Pioneer quadrangle, and its only exposures are at the southwest end of the Pine Mountain fault zone (fig. 5). There, the Maury consists of less than 1 foot of clayey greenish-gray shale which includes abundant phosphate nodules, as much as 2 inches in diameter, at the base and top of the bed. Northeastward along the fault zone the Maury grades laterally into moderately fissile greenish-gray shale of the Grainger Formation. The top contact is conformable and is marked by an abrupt change in lithology to cherty dolomite of the overlying Fort Payne

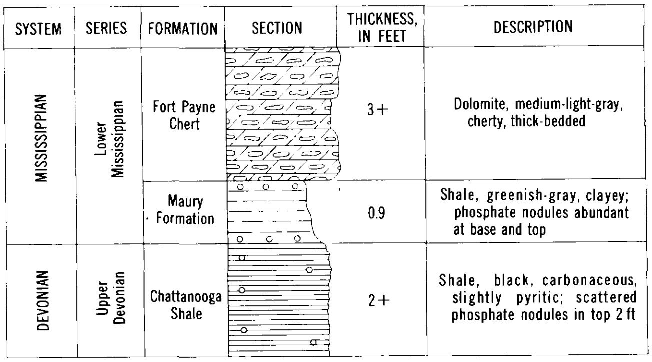


FIGURE 5.—Section of Maury Formation and adjacent strata exposed in a railroad cut near the southwest end of Pine Mountain.

Chert. No significant fossils were obtained from the Maury Formation.

GRAINGER FORMATION

The Grainger Formation (Keith, 1895) of Early Mississippian age includes the basal Mississippian strata in most of the Elk Valley area. It consists of greenish-gray and grayish-red shale that intertongues on a small scale with the overlying Fort Payne Chert (fig. 6). As a result of this intertonguing the Grainger thins southwestward and at its extremity grades laterally into the thin Maury Formation (pl. 3).

In the outcrop belt along Pine Mountain the basal 35 feet of the Grainger contains large elongate siderite nodules as much as 2 inches thick and 8 inches long, and the upper part of the formation contains quartz-lined geodes about 6 inches in diameter. Locally, the shale includes accumulations of bioclastic detritus, consisting mostly of large crinoid stem segments, in lenticular reeflike masses that in cross section are as much as 2 feet thick and 8 feet wide. The top contact is placed where the greenish-gray shale is overlain by the first locally persistent ledge of cherty dolomite. The overlying 5–40 feet of intertonguing greenish-gray shale and cherty dolomite is, for convenience in mapping, included with the Fort Payne Chert (fig. 7). The thickness of the Grainger Formation ranges from less than 1 foot in the south-central part of the Pioneer quadrangle to a maximum of about 225 feet along Pine Mountain near Jellico. In addition to this occurrence of the Grainger at the northwest edge of the Cumberland overthrust sheet, the formation also crops out on the southeast limb of the Middlesboro syncline at La Follette and in several fault slices along Elk Valley.

Fossils are abundant locally in the Grainger, and forms identified by MacKenzie Gordon Jr., H. M. Duncan, and I. G. Sohn, U.S. Geological Survey, from a collection made by the writer in the east-central part of the Pioneer quadrangle are listed below. They reported that this fauna has much in common with that of the New Providence Shale and is most likely of early Osage age.

Corals:
- *Cyathaxonia* sp. indet.
- *Amplexizaphrentis* sp. undet.
- *Trochophyllum verneuili* Milne Edwards and Haime
- "Zaphrentoid" corals
- *Cladochonus amplexus* (Rowley)

Bryozoans:
- *Fenestella* sp. indet.
- *Saffordotaxis* cf. *S. incrassatus* (Ulrich)
- *Cystodictya* sp. undet.

Brachiopods:
- *Schuchertella* sp.
- *Chonetes* aff. *C. glenparkensis* Weller
- *Chonetes* sp.
- Small spinose productoid
- *Strophalosia*? sp.
- *Productina sampsoni* (Weller)?
- *Labriproductus*? sp.
- Rhynchonellid indet.
- *Punctospirifer subellipticus* (McChesney)
- *Strophopleura* sp.
- *Spirifer* aff. *S. shephardi* Weller
- *Spirifer* aff. *S. vernonensis* Weller
- *Spirifer* or *Branchythris* sp. indet.
- *Crurithyris* cf. *C. parva* (Weller)

Pelecypods:
- *Cypricardinia* sp.

Gastropods:
- *Platyceras* sp.

Echinoderms:
- Crinoid stems and plates
- Batocrinoid anal tube
- Echinoid plate

Trilobites:
- *Phillibole* cf. *P. conkini* Hessler
- *Proetides*? sp. indet.

Ostracodes:
- *Bairdia* sp.
- *Graphiadactyllis lineata* (Bassler)
- *Graphiadactyllis*? sp.

FORT PAYNE CHERT

The Fort Payne Chert (Smith, 1890, p. 155–156) of Early Mississippian age is partly equivalent to the Grainger Formation with which it intertongues. Lithologically, the Fort Payne consists of light-olive-gray to medium-light-gray finely crystalline dolomite and light-gray to greenish-gray chert in nodules and beds as much as 1 foot thick. The dolomite is in thick beds that are separated by partings of greenish-gray shale (fig. 8). In outcrops along Elk Valley the upper part of the Fort Payne contains a lenticular bed of light-olive-gray very fine grained to fine-grained dolomite-cemented sandstone as much as 35 feet thick. Because of the leaching of the dolomite cement, the sandstone is moderately

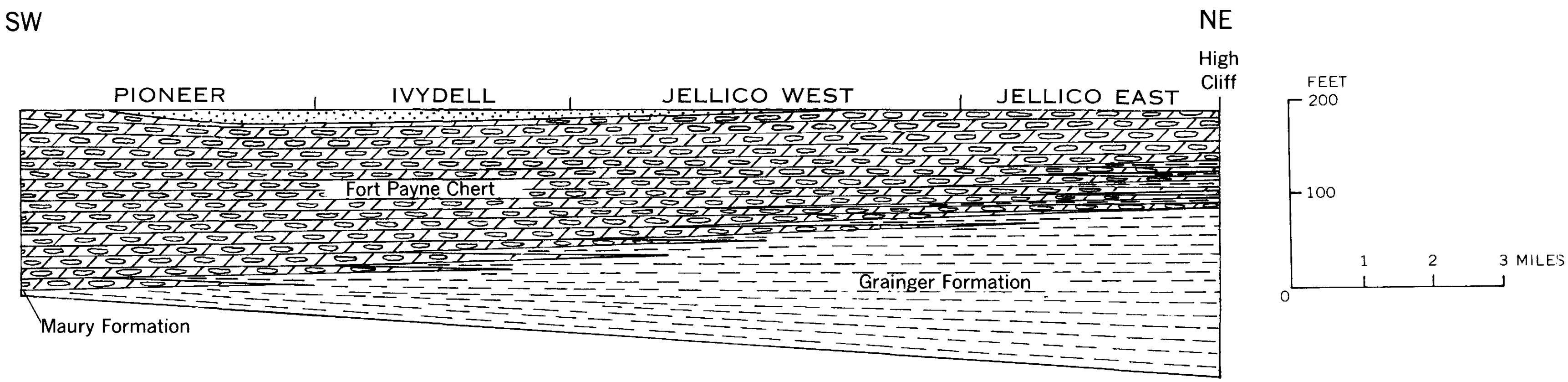


Figure 6.—Stratigraphic section illustrating interrelation of the Grainger Formation and the Fort Payne Chert in the outcrop belt from the central part of the Pioneer quadrangle northeastward along Pine Mountain to High Cliff in the Jellico East quadrangle.

FIGURE 7.—Intertonguing shale and cherty dolomite at the base of the Fort Payne Chert in a railroad cut 1½ miles southwest of the community of Elk Valley. Beds are displaced by a small normal fault at the hammer.

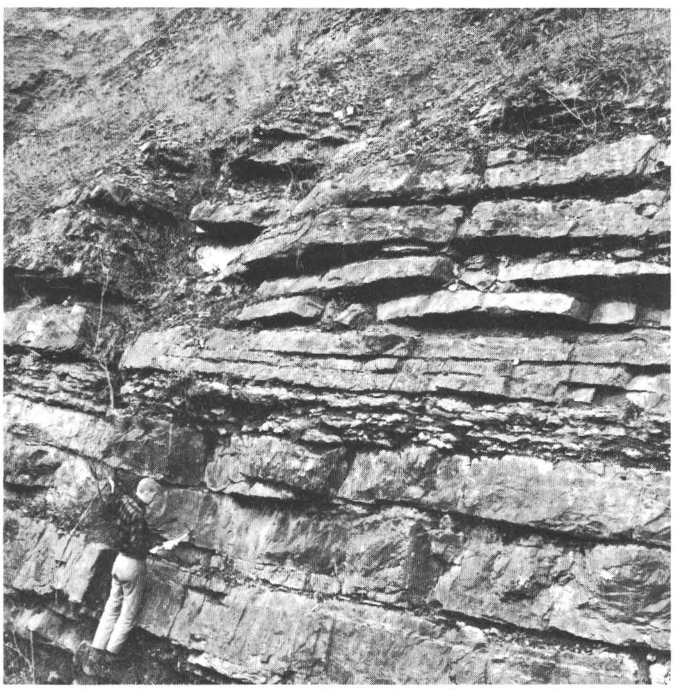


FIGURE 8.—Cherty dolomite beds separated by shale partings in the middle part of the Fort Payne Chert in a railroad cut 1½ miles southwest of the community of Elk Valley.

friable and grayish red to reddish brown in weathered exposures. Sandstone was not observed elsewhere in the report area at this stratigraphic position; however, greenish-gray and reddish-gray shale occurs in the upper 50 feet of the Fort Payne in the section exposed at La Follette. This shale may be a tongue of the Grainger Formation, a relationship which could not be demonstrated because of the remoteness of the outcrop belt at La Follette in relation to other exposures of the formations in the report area. The following section illustrates the interrelation of the formations at La Follette.

Section of the Grainger Formation and Fort Payne Chert measured in roadcuts on the east side of Big Creek Gap at La Follette

	Thickness Feet	Inches
Newman Limestone (in part):		
Limestone, yellowish-gray, argillaceous, very fine grained	3	9
Fort Payne Chert (154 ft 8 in):		
Shale, greenish-gray; few poorly preserved bryozoans	4	4
Dolomite, light-greenish-gray, finely crystalline	0	7
Shale, greenish-gray and grayish-red; interbedded with cherty dolomite beds as much as 1 ft thick; few quartz-lined geodes; poorly exposed	45	0
Dolomite, light-olive-gray, finely crystalline; thick bedded with intervening shale beds as much as 2 in. thick; interbedded chert nodules and beds as much as 1 ft thick; few quartz geodes about 5 in. in diameter	88	0
Chert, olive-gray to greenish-gray, nodular; in beds as much as 5 in. thick	4	5
Dolomite, olive-gray, finely crystalline; few chert nodules	1	7
Shale, greenish-gray	1	0
Dolomite, olive-gray, finely crystalline	1	0
Shale, greenish-gray, calcareous; few dolomite lenses as much as 5 in. thick	5	5
Dolomite, olive-gray, calcitic; few chert nodules	1	0
Shale, greenish-gray, calcareous; few dolomite lenses as much as 1 in. thick	1	6
Dolomite, olive-gray, finely crystalline; few chert nodules	0	10
Grainger Formation (63 ft):		
Shale, greenish-gray; top 3 ft includes chert lenses as much as 2 in. thick; poorly exposed	63	0
Chattanooga Shale (in part):		
Shale, black, carbonaceous, pyritic	1	9

The top contact is placed where cherty dolomite, sandstone, or shale in the upper part of the Fort Payne is succeeded by dolomitic or argillaceous limestone at the base of the Newman Limestone. The thickness of the Fort Payne decreases northeastward from a maximum of 175 feet in the Pioneer quadrangle to about 100 feet in the Jellico West quadrangle as a result of the tonguing out of lower beds. Thinning continues northeastward beyond the report area, and at Cumberland Gap the formation is about 20 feet thick (Englund and Harris, 1961, fig. 10). The Fort Payne Chert crops out on the limbs of the Middlesboro syncline at La Follette and at the foot of the northwest slope of Pine Mountain, but chiefly in fault slices in Elk Valley where it forms or caps hogbacks. Fossils in the Fort Payne consist of brachiopods, crinoid stem segments, corals, and bryozoans. Fucoidal imprints are particularly conspicuous at the base of many dolomite beds, and vertical worm burrows penetrate the sandstone in the upper part of the formation.

NEWMAN LIMESTONE

In the Elk Valley area the Newman Limestone (Campbell, 1893, p. 38) of Late Mississippian age is divisible into two distinct lithologic units which correlate with the lower and upper members as recognized in southwestern Virginia (Englund, Smith, Harris, and Stephens, 1963). The lower member consists almost entirely of limestone, whereas the upper member is largely calcareous shale interbedded with limestone and argillaceous limestone. Locally in eastern Kentucky and Tennessee, the term Newman is restricted to the lower member or "solid" limestone phase of the sequence, and the overlying shale and limestone beds are included in or compose the overlying Pennington Formation. This usage fails to account for nearly 450 feet of interbedded shale and limestone beds in the upper part of the Newman Limestone as originally designated by Campbell (1893, p. 38). Consequently, the writer prefers to adhere to the original usage, especially in consideration of the greater lithologic and genetic affinity of the upper member to the lower member rather than to the overlying Pennington Formation.

The basal beds of the lower member of the Newman Limestone consist mostly of very finely crystalline light-olive-gray dolomitic or argillaceous limestone, as much as 20 feet thick, that weathers yellowish gray. Lenses of quartz sandstone and conglomerate, as much as 2 feet thick, are common in these beds. The conglomerate is composed of well-rounded pebbles of white quartz and jasper, as much as half an inch in diameter, in a dolomitic or argillaceous limestone matrix. The presence of this conglomerate suggests that an obscure regional unconformity may be present at the base of the Newman Limestone. Overlying beds of the lower member consist of light-olive-gray very fine grained to medium-grained thin-bedded to massive limestone (fig. 9).

FIGURE 9.—Jointed limestone beds in the lower member of the Newman Limestone in a quarry in the Pine Mountain fault zone 1 mile northeast of the community of Elk Valley.

Oolites and bioclastic detritus are abundant in most beds and commonly exhibit faint crossbedding. Also included in the lower member are thin beds of greenish-gray and grayish-red calcareous shale; a few limestone beds contain white, grayish-red, or black chert nodules that range mostly from 1 to 2 inches in diameter. The total thickness of the member is 400–430 feet in outcrops and areas of drilling in the Cumberland overthrust sheet, but it is thinner in the subsurface in the western part of the report area.

Shale in the upper member of the Newman Limestone is partly calcareous and medium to medium dark gray, greenish gray, and grayish red. Interbedded limestone and argillaceous limestone is fine to coarse grained and light olive gray to medium gray. Locally, the upper member includes a few beds of siltstone or very fine grained sandstone as much as 10 feet thick. The top contact appears to be conformable and is placed where shale of the upper member is overlain by a widespread sandstone bed at the base of the Pennington Formation. The thickness of the upper member ranges from 220 to 330 feet in exposures on the limbs of the Middlesboro syncline and in drill holes. The aggregate thickness of the two members of the Newman decreases northwestward across the Middlesboro syncline from 730 feet at La Follette to 690 feet in Pine Mountain and is 400 feet or less in the subsurface west of the overthrust sheet. In addition to the occurrences on the limbs of the Middlesboro syncline, the Newman Limestone is present in several fault slices of the Pine Mountain fault zone.

The Newman Limestone is abundantly fossiliferous, especially the shale and limestone beds of the upper member. A collection made by the writer from these beds on the southeast slope of Hells Point Ridge in the Jellico West quadrangle was identified by J. T. Dutro, Jr., and H. M. Duncan, U.S. Geological Survey, as follows:

U.S.G.S. Upper Paleozoic loc. 17439:
- Echinoderm fragments, indet.
- Fistuliporoid bryozoans, undet.
- Trepostomatous bryozoans, indet.
- *Archimedes* cf. *A. fosteri* Condra and Elias
- *Fenestella tenax* Ulrich
- *Fenestella* sp.
- *Polypora* cf. *P. cestriensis* Ulrich
- *Septopora* sp.
- Rhomboporoid bryozoans, indet.
- *Orthotetes* cf. *O. kaskaskiensis* (McChesney)
- *Diaphragmus*? sp.
- *Spirifer* cf. *S. increbescens* Hall
- *Composita* cf. *C. subquadrata* (Hall)
- Myalinid pelecypod, indet.

The fossils in this collection indicate a Late Mississippian age for the Newman Limestone.

PENNINGTON FORMATION

The Pennington Formation (Campbell, 1893, p. 37) of Late Mississippian age is divided into two mapped members that are analogous to the lower and upper members as mapped along Cumberland Mountain in southwestern Virginia by Englund, Smith, Harris, and Stephens (1963). The lower member is the most persistent part of the formation, and its characteristic lithology, ripple-marked sandstone, is widespread in southeastern Kentucky and adjacent areas of Tennessee. In the Elk Valley area about 20 feet of beds at the base of the member consists of thick-bedded to massive light-gray fine- to medium-grained sandstone that is overlain by ripple-marked beds of light-gray to light-olive-gray very fine grained to fine-grained sandstone with greenish-gray shale laminae common on bedding planes. Quartz ranges from 50 to 70 percent in the ripple-marked beds to as much as 90 percent in the basal beds. The grains are subangular in most of the member but are subrounded to subangular in the basal beds. Although the sandstone is calcareous in fresh exposures, only silica cement is evident in the matrix of weathered samples. Marine fossils are present locally and indicate a marine origin for the member. The total thickness of the lower member ranges from 30 to 80 feet in the Elk Valley area.

In contrast to the regional uniformity of the lower member, the upper member of the Pennington Formation displays much diversity in the lithology and thickness of individual beds. Facies variations, associated with lateral gradation and intertonguing with the overlying Lee Formation, are largely responsible for this irregularity in the member. This intertonguing relationship, originally noted along Cumberland Mountain (Englund and Smith, 1960), involves the northwestward wedging out of sandstone tongues or lobes of the Lee which at their extremities grade from highly quartzose, partly conglomeratic sandstone to less quartzose sandstone similar to that described in the lower member of the Pennington. Intervening tongues of greenish-gray or grayish-red shale with thin limestone beds, assigned to the Pennington Formation, wedge out between the Lee sandstone tongues. These sandstone tongues of the Lee are the principal mountain- or ledge-forming beds and, because of their excellent exposure, can readily be distinguished from the nonresistant beds of the Pennington which generally are concealed by a mantle of detritus from the overlying Lee. The relationship of the Pennington and Lee Formations to one another in the Elk Valley area and to their counterparts in the type area of outcrop in Lee County, Va., is shown diagrammatically in figure 10.

Lithologically, the upper member of the Pennington Formation can be divided in the Elk Valley area into five informal units, three predominantly of shale separated by two predominantly of sandstone. The basal unit, ranging in thickness from 5 feet at Pine Mountain to 120 feet at Cumberland Mountain, is medium-gray, greenish-gray, or reddish-gray shale that contains a bed of medium-gray argillaceous limestone. Marine invertebrate fossils are common in this limestone which is as much as 2 feet thick.

Along Pine Mountain in the Jellico West quadrangle and along Cumberland Mountain, the basal unit of the upper member is overlain by the Pinnacle Overlook Member of the Lee Formation. Southwestward in the Jellico West quadrangle the Pinnacle Overlook Member tongues out and at its extremity grades into sandstone that composes unit 2 of the upper member of the Pennington (fig. 11). The latter is a thin- to thick-bedded very fine grained to fine-grained light-gray sandstone that averages about 25 feet in thickness. Its relatively low quartz content, ripple-marked beds, and nonresistant character are typical of the Pennington.

Unit 3 of the upper member of the Pennington is composed of varicolored shale similar to unit 1, but grayish-red shale predominates where the Pinnacle Overlook Member of the Lee is absent in the Pioneer

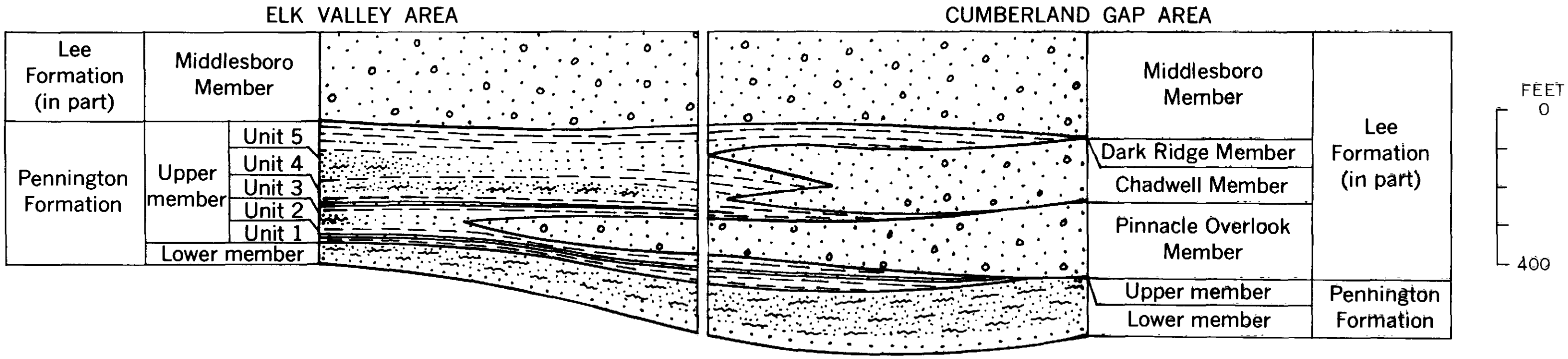


FIGURE 10.—Generalized sections in the Elk Valley and Cumberland Gap areas showing correlations and intertonguing relation of the Pennington and Lee Formations. See plate 5 for explanation.

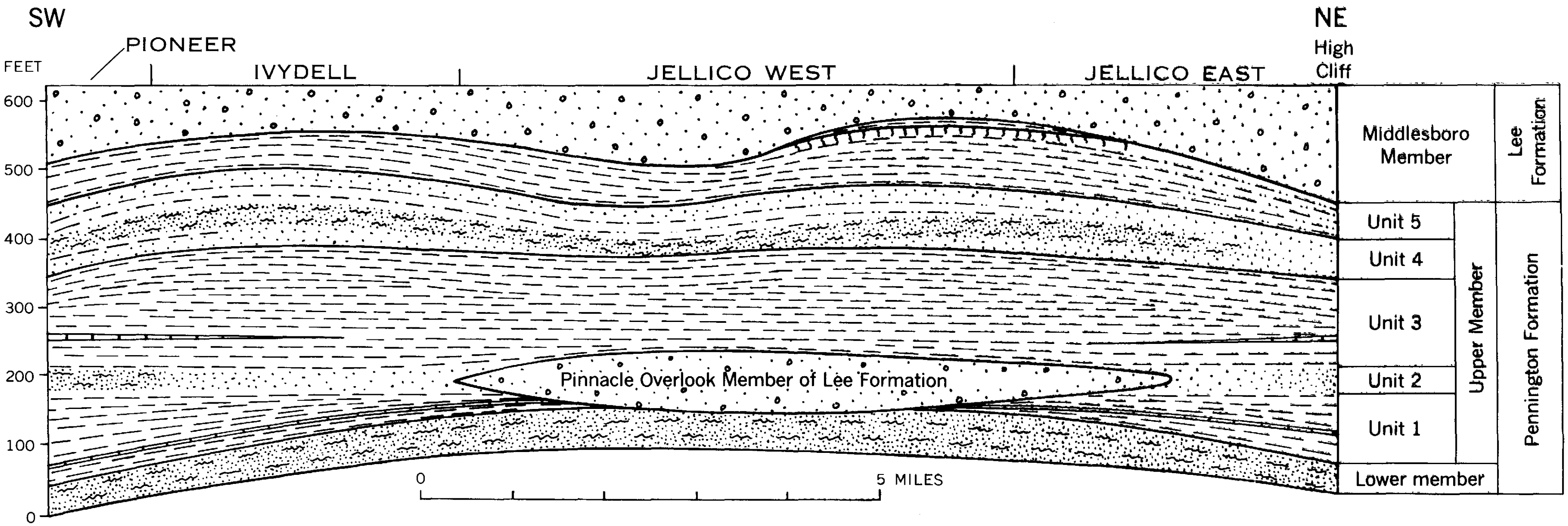


FIGURE 11.—Stratigraphic section showing relation of the Pinnacle Overlook Member of the Lee Formation to adjacent beds from the Pioneer quadrangle northeastward along Pine Mountain to High Cliff in the Jellico East quadrangle. See plate 5 for explanation.

and Ivydell quadrangles. It ranges in thickness from 40 to 100 feet and locally includes as much as 3 feet of medium-gray fossiliferous argillaceous marine limestone.

An interbedded sequence of sandstone that is relatively low in quartz content, siltstone, and shale composes unit 4 of the Pennington. It ranges in thickness from 100 to 250 feet and consists mostly of very fine grained to fine-grained light-gray to light-olive-gray ripple-marked sandstone which is laterally equivalent to the Chadwell Member of the Lee Formation to the northeast (fig. 10). Proximity to the Lee Formation is indicated locally in unit 4 by thick-bedded to massive sandstone in its upper part at Big Creek Gap in the Ivydell quadrangle and by moderately quartzose massive sandstone, as much as 30 feet thick, in its lower part in the Jellico West quadrangle.

Unit 5, from 30 to 100 feet in thickness, is mainly medium-gray and greenish-gray shale or siltstone. The upper part of this unit includes an underclay bed and a thin but persistent coal bed, as much as 1 foot thick, that is here correlated with the Cumberland Gap coal bed of the Cumberland Gap area. Although unit 5 is at the approximate stratigraphic position of the Dark Ridge Member of the Lee Formation (fig. 10), it exhibits greater lithologic similarity, except for the coal bed and associated underclay, to the Pennington than to the medium-dark-gray moderately carbonaceous shale of the Dark Ridge Member. The latter may represent restricted or lagoonal deposition, whereas unit 5 may have been deposited on the seaward or marine side of a restricting bar. Thus, the seaward fluctuation of a continental environment is recorded in the uppermost beds of unit 5 by the Cumberland Gap coal bed.

The total thickness of the upper member of the Pennington Formation decreases from 480 to 320 feet northwestward across the Middlesboro syncline and is probably 300 feet or less in the subsurface west of the overthrust sheet.

The top contact of the Pennington Formation is marked by several feet of relief, the result of scour that preceded the deposition of the overlying conglomeratic sandstone of the Lee Formation. Thicknesses of the Pennington range from 385 to 510 feet where drilled or exposed in the Cumberland overthrust sheet, and northwestward thinning indicates that a thinner sequence is present in the subsurface in the western part of the report area. In addition to outcrops on the limbs of the Middlesboro syncline, the Pennington occurs in several fault slices in the Pine Mountain fault zone.

Marine fossils, consisting of brachiopods, bryozoans, and crinoid stem segments, are fairly abundant in the Pennington Formation, but owing to the deeply weathered condition of the calcareous beds in which they occur in the Elk Valley area, satisfactory material for collecting was not found. Plant fossils were collected by the writer about 50 feet below a limestone bed with marine fossils in the Pennington Formation along Pine Mountain, 11 miles northeast of the report area. The occurrence of plant fossils in a bed of medium-dark-gray moderately carbonaceous shale in the upper member of the Pennington probably represents a seaward fluctuation of the continental environment associated with Lee deposition. The age of these fossils, identified as *Fryopsis* cf. *F. abbensis* (Read) Wolfe by S. H. Mamay, U.S. Geological Survey, is in agreement with the generally accepted Late Mississippian age for the Pennington Formation.

MISSISSIPPIAN AND PENNSYLVANIAN SYSTEMS

LEE FORMATION

The name Lee was assigned by Campbell (1893, p. 36) to a sequence of massive conglomeratic sandstone of Carboniferous age exposed on Cumberland Mountain along the northwest margin of Lee County, Va.; subsequently, it was applied to lithologically similar Carboniferous sandstones in other outcrop belts of Kentucky (Campbell, 1898) and Tennessee (Keith, 1896a). Regionally, the Lee has been generally regarded as the basal formation of the Pennsylvanian System which overlies a widespread unconformity at the top of the Upper Mississippian Pennington Formation. Recent geologic mapping and stratigraphic studies in the type area of the formations (Englund and Smith, 1960) have demonstrated that the Lee and Pennington Formations intertongue. The "unconformity" is actually the result of local scouring that preceded the deposition of the overlying Lee sandstone beds regardless of stratigraphic position with respect to the Pennington. Also, locally, beds near the contact between typical Lee and typical Pennington lithologies exhibit a lithology that is transitional between these two extremes. This relation has caused some discordance in the past, in the placing of the position of the "unconformity" in specific outcrop sections (Wanless, 1946, p. 11). In the Elk Valley area the contact relation between the two formations is similar to that previously recognized (Englund and Smith, 1960) in the type area. Because of this and the lack of conclusive paleontologic age determinations, that part of the Lee that intertongues with the Pennington is arbitrarily considered to be Late Mississippian in age, and the Lee is assigned a Late Mississippian and Early Pennsylvanian age.

About 40 percent of the Lee Formation is fine- to coarse-grained subangular to subrounded white to very light gray thick-bedded to massive conglomeratic sandstone that is commonly more than 90 percent quartz. The conglomerate, consisting largely of well-rounded white quartz pebbles that range mostly from ½ to 1 inch in diameter, is in places concentrated in lenses as much as a few feet thick but more commonly is dispersed sporadically in the sandstone. Fine- to medium-grained thick-bedded to massive nonconglomeratic sandstone constitutes about 30 percent of the Lee. It normally occupies a marginal position to the conglomeratic sandstone in the Lee tongues and is only slightly less quartzose. The remaining 30 percent of the Lee is composed of very fine grained to fine-grained thin-bedded relatively less quartzose sandstone, siltstone, shale, and several beds of coal and associated underclay. In fresh exposures the beds, except coal, display shades of gray that range from dark gray for shale to very light gray or white for quartzose sandstone; upon weathering, these colors are altered to various shades of reddish-brown or brownish-gray by iron-oxide staining. The total thickness of the Lee decreases northwestward from a maximum of 1,180 feet at Big Creek Gap in the Ivydell quadrangle to a minimum of about 700 feet in the subsurface in the northwestern part of the Ketchen quadrangle. Along Pine Mountain the Lee averages about 1,100 feet thick. Thinning is due partly to a decrease in the thickness of individual members but mostly to the tonguing out of lower members toward the northwest. In this direction the top contact rises stratigraphically by the addition of upper members; but the addition at the top is at a much smaller scale than the tonguing out of lower members, so that there is an overall decrease in thickness (pl. 5).

The Lee Formation crops out mostly in Pine, Fork, and Cumberland Mountains around the southwest end of the Middlesboro syncline and less extensively along the Pine Mountain fault zone in fault slices and in klippen thrust over younger Pennsylvanian rocks. Because of the massive and resistant character of the formation, these outcrop belts are marked by precipitous cliffs and hogbacks that pose the most formidable barriers to drainage and routes of travel in the area (fig. 12).

Fossil plant remains indicate that the Lee formation is primarily of continental origin. The environments of deposition varied from swamps that accumulated organic material to beaches where sandstone tongues were deposited between marine tongues of the Pennington Formation.

Lithologically, the Lee Formation in the Elk Valley area is subdivided into four mapped members, including, in ascending order, the Pinnacle Overlook, Middlesboro, Hensley, and Naese Sandstone. The following descriptions of the members are accompanied by a discussion of their regional relations with reference to the section exposed in the type area.

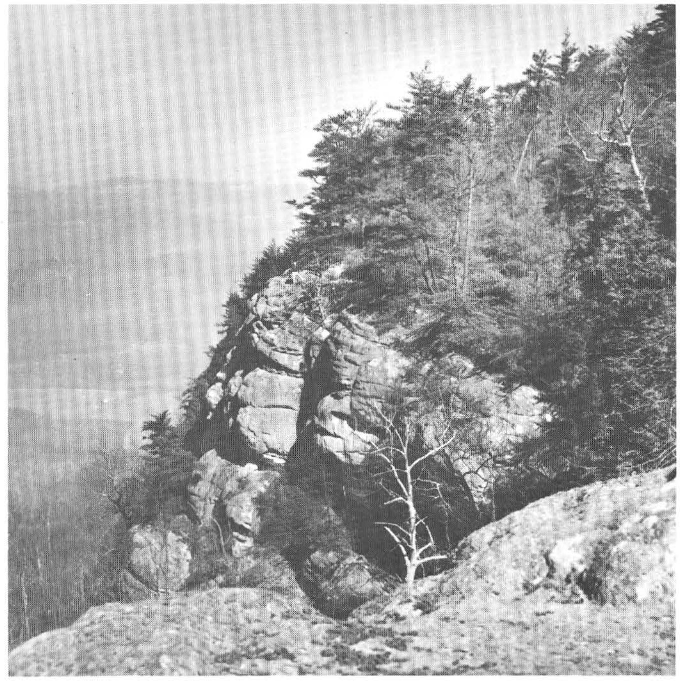


FIGURE 12.—Massive conglomeratic sandstone in the Middlesboro Member of the Lee Formation capping Pine Mountain at Cave Gap.

Pinnacle Overlook Member

The Pinnacle Overlook Member (Englund, 1964b), the lowest tongue of the Lee Formation in the Elk Valley area, is a thick-bedded to massive crossbedded conglomeratic sandstone. Its lithology is typical of the Lee Formation and consists of very light gray subangular to subrounded fine- to coarse-grained quartz sandstone that contains well-rounded quartz pebbles as much as half an inch in diameter. At the top contact the sandstone grades into shale in the overlying upper member of the Pennington Formation.

Outcrops of the Pinnacle Overlook Member are limited to Big Creek Gap in the Ivydell quadrangle where the member is about 40 feet thick and to a cliff, from a few feet to 90 feet high, at or near the crest of Pine Mountain in the Jellico West quadrangle. In the Elk Valley area the member forms the southwestern part of a northwestward-protruding lobe of Lee sandstone that grades at its extremity into unit 2 of the upper member of the Pennington Formation (fig. 10). This gradation occurs near the intersection of Pine Mountain and the south edge of the Jellico West quadrangle where the crestline of Pine Mountain is offset from the wedging-out Pinnacle Overlook Member to the stratigraphically higher Middlesboro Member. Exposures along this outcrop belt display a section across the end of the lobe formed by the member (fig. 11). Although in cross section the member appears to be lenticular, the overlying beds of the Pennington Formation tongue out and grade eastward into the Lee Formation, so that in the vicinity of Cumberland Gap, about 25 miles to the east-northeast, the Pinnacle Overlook Member is in sequence with overlying beds of the Lee Formation.

Fossil remains are scarce in the member and consist mostly of bark impressions in the basal beds which may represent logjam accumulations in a continental environment.

Middlesboro Member

A cliff-forming sequence of massive conglomeratic sandstone constitutes the Middlesboro Member of the Lee Formation in the Elk Valley area. It generally crops out in a series of four parallel cliffs or hogbacks, representing four distinct beds of conglomeratic sandstone, a feature that is also characteristic of the member in the type area along Cumberland Mountain (Englund, 1964b, p. B35). Most of the member is fine- to coarse-grained white to very light gray quartzose sandstone with an abundance of well-rounded white quartz pebbles an inch or more in diameter. Quartz constitutes 90 percent or more of the sandstone, which is largely silica cemented. Relatively nonresistant beds of shale, coal, underclay, and very fine grained to fine-grained micaceous sandstone occupy intervals between the resistant sandstone and accentuate the fourfold subdivision of the Middlesboro Member. Mapping of the nonresistant beds individually is impractical because of their thinness, spotty occurrence, and inadequate exposure. Each set of these weak beds is mapped with the overlying conglomeratic sandstone. A fifth bed of medium-grained nonconglomeratic quartzose sandstone is present locally at the base of the member in the Jellico West quadrangle. It does not appear to have a counterpart at the type locality, but because it is lithologically similar to, and occurs in sequence with, overlying beds, this basal sandstone is included in the Middlesboro Member. Of the beds in the member, the middle and highest sandstones are the most conglomeratic and form the most persistent and highest cliffs which in places are 100 feet or more in height. The top surface of the conglomeratic sandstone beds of the Middlesboro Member commonly exhibits a unique pillow-type weathering feature (fig. 13).

The top contact of the member is conformable and in most places is marked by an abrupt change from

FIGURE 13.—Pillow-type weathering on the top surface of a conglomeratic sandstone bed in the Middlesboro Member of the Lee Formation at Cave Gap in Pine Mountain.

conglomeratic sandstone to shale. Thicknesses of the Middlesboro Member range from 500 to 575 feet in the outcrop belts around the fringe of the Middlesboro syncline, except where the lowest sandstone bed is present in the Jellico West quadrangle; this bed adds as much as 100 feet to the total thickness of the member.

Fossils in the member consist of bark impressions of *Sigillaria* and *Lepidodendron* in sandstone, *Calamites* and other stem and leaf imprints in shale, and *Stigmaria* in underclay. These paleontologic data indicate that the Middlesboro Member was deposited in a continental environment.

Hensley Member

In the type area at Cumberland Mountain in southeastern Kentucky the Hensley Member is a nonresistant sequence of shale and sandstone beds in the upper part of the Lee Formation (Englund, 1964b). About 50 percent of the member is sandstone which occurs in two persistent beds and is, in part, moderately quartzose. In the Elk Valley area the Hensley Member likewise includes two sandstone beds; but in contrast to the sequence in the type area, the sandstone is mostly quartzose and constitutes about 90 percent of the member. It is white to very light gray, well sorted, very fine to medium grained, thick bedded to massive, and in a small area adjacent to the east edge of the Jellico West quadrangle, is sparsely conglomeratic. Commonly, the upper bed is finer grained, less massive, and is calcite cemented in fresh exposures. Medium- to dark-gray shale beds at the base, middle, and top of the member include thin beds of siltstone, coal, and underclay. About 60 feet of dark-gray shale in the upper part of the member at Big Creek Gap is truncated northwestward across the Middlesboro syncline, so that along Pine Mountain the upper sandstone bed of the Hensley Member is in contact with the overlying Naese Sandstone Member. Truncation of the Hensley Member is caused by a regional unconformity (pl. 5), which is at the base of the Naese Sandstone Member in the Cumberland Gap area also.

Each of the sandstone beds in the Hensley Member is as much as 150 feet thick, and the total thickness of the member increases southeastward from 240 feet along Pine Mountain to a maximum of 370 feet in the southeastern part of the Ivydell quadrangle. In outcrops, located mostly on the lower slopes of Pine and Cumberland Mountains, two minor ledges reflect the twofold character of the member.

Palenotologic data, consisting of fossil rootlets in underclay and fragments of stem and leaf imprints in shale, indicate that the member was deposited in a continental environment.

Naese Sandstone Member

The Naese Sandstone Member of the Lee Formation was named by Ashley and Glenn (1906, p. 35) from outcrops on the southeast slope of Pine Mountain in nearby Bell County, Ky. This outcrop belt extends southwestward through the Elk Valley area where the outcrop features and physical characteristics of the member are similar to those displayed at the type locality. In contrast to the underlying sandstone beds that tongue out to the west or northwest, the Naese Sandstone Member tongues out principally to the east, as shown by a decrease in thickness, grain size, and quartz content. Along Pine Mountain it is fine to coarse grained, white to very light gray, sparsely conglomeratic thick bedded to massive, and largely quartzose. Southeastward near Big Creek Gap the upper part of the member grades laterally to very fine grained to fine-grained light-gray sandstone that is relatively low in quartz content and is interbedded with shale and siltstone lenses as much as 7 feet thick (pl. 5). Also at Big Creek Gap the lower half of the member grades laterally to very light gray medium- to coarse-grained sandstone that is low in quartz content and lithologically transitional between sandstone of the Lee Formation and sandstone of the overlying Hance Formation.

Because the top of the Naese Sandstone Member is gradational in the Elk Valley area, the upper contact is placed for convenience in mapping at the base of the overlying Naese coal bed. Therefore, in addition to sandstone, the member includes about 5 feet of silty sandstone and ½–2 feet of medium-gray underclay at the base of the Naese coal bed.

In the outcrop of the Lee Formation along Pine Mountain the Naese is recognized as the uppermost member. However, in the outcrop belt along Cumberland Mountain the Naese Sandstone Member tongues out toward the east, and northeast of Cumberland Gap the uppermost member is the stratigraphically lower Bee Rock Sandstone Member (Englund, 1964b). Regional studies show that the Bee Rock is a westward-protruding lobe of Lee sandstone which is truncated west of Cumberland Gap by the unconformity at the base of the Naese Sandstone Member and which is absent in the Elk Valley area to the southwest, beyond the periphery of the lobe. These studies (Englund, 1964b) also show that upper beds of the Lee Formation, involving the Naese Sandstone Member and other higher members, intertongue with the Hance Formation (pl. 5). Because of this intertonguing relationship, the top contact of the Lee rises about 450 feet stratigraphically northwestward across the Elk Valley area to the outcrop belt on the west edge of the eastern Kentucky coal field. (fig. 1).

Exposures of the Naese Sandstone Member in the report area are limited to the limbs of the Middlesboro syncline where the member ranges in thickness from a maximum of 225 feet at Pine Mountain to about 175 feet at Fork Mountain. In the outcrop of the Lee Formation on the western edge of the eastern Kentucky coal field, the Naese Sandstone Member is herein correlated with the lower part of the Rockcastle Sandstone Member (pl. 5).

PENNSYLVANIAN SYSTEM

BREATHITT GROUP

The Breathitt Group of Early and Middle Pennsylvanian age includes all strata lying above the Lee Formation in the Elk Valley area. In eastern Kentucky these rocks were originally named the Breathitt Formation by Campbell (1898, p. 3) and subsequently were divided by Ashley and Glenn (1906) into the Hance, Mingo, Catron, Hignite, and Bryson Formations in the Middlesboro syncline area of Kentucky and Tennessee. After the correlation of the Breathitt Formation of eastern Kentucky with the equivalent formations in the Middlesboro syncline (Wanless, 1946, p. 55), the Breathitt was raised to the rank of group, and the Hance, Mingo, Catron, Hignite, and Bryson Formations were included in the group (Englund, Smith, Harris, and Stephens, 1963, p. B15).

In Tennessee the rocks overlying the Lee Formation were divided into the Briceville Shale, Wartburg Sandstone, Scott Shale, and Anderson Sandstone (Keith, 1896b), a nomenclature that was modified by Glenn (1925) into the Briceville, Jellico, Scott, and Anderson Formations. After extensive usage of the latter group of names in Tennessee (Wanless, 1946; Williams, Gibbs, Crentz, and Miller, 1956; Williams, Gibbs, Crentz, Miller, and Reynolds, 1956; Englund, 1957, 1958), Wilson and others (1956) proposed to abandon these names and replace them with the Slatestone, Indian Bluff, Graves Gap, Red Oak Mountain, Vowell Mountain, and Cross Mountain Groups. An undesirable feature of this proposed nomenclature in the Elk Valley area is that the contacts between the groups are inconsistently drawn (Wilson and others, 1956, pl. 6), with the result that the base of their Indian Bluff Group varies from the Jellico coal bed to the Jordon coal bed. Also, the contact at the base of their Slatestone Group is at the position of the Swamp Angel coal bed in the western part of the report area and at the Murray (Poplar Creek) coal bed, nearly 200 feet lower stratigraphically, in the area of the Middlesboro syncline.

Consideration of each of the four sets of nomenclature that have been applied to Pennsylvanian rocks that overlie the Lee Formation in Tennessee indicates that the contacts are arbitrarily defined in a repetitious sequence of sandstone, siltstone, shale, coal, underclay, and argillaceous limestone, and that, in some places, the contacts between units of these nomenclatures coincide. Also, the characteristics of beds that define these contacts change from place to place, so that a bed that is thick and readily mapped at one locality may be thin and obscure elsewhere. Consequently, the advantages and disadvantages of each set of nomenclature are local and are dependent on the variable character of the bed selected for the contact. To simplify future stratigraphic studies and to prevent preceding reports from becoming out of date because of the abandonment of well-established names, it is preferable in this case to adhere to the rule of priority of the Code of Stratigraphic Nomenclature (Am. Comm. Strat. Nomenclature, 1961) which would require usage of the nomenclature of Ashley and Glenn (1906).

The Breathitt Group attains a total thickness of 2,450 feet in the Elk Valley area; it consists of interbedded sandstone, siltstone, and shale with lesser amounts of coal, underclay, and argillaceous limestone. In contrast to sandstone beds of the underlying Lee Formation, those of the Breathitt Group are generally nonconglomeratic, less quartzose, less massive, and thinner. Of these features, the most diagnostic of Breathitt sandstones appears to be the low quartz content, commonly ranging from 50 to 70 percent, and an abundance of mica flakes. Grain sizes range mostly from very fine to fine but are also fine to medium in a few massive sandstone beds. The roundness of the grains does not differ appreciably from that of the Lee sandstone beds.

Siltstone consists of angular quartz grains in a matrix of clay minerals, carbonaceous material, and mica flakes that are oriented parallel to bedding. It occurs as distinct laminae in other lithologies or as a gradational bed between sandstone and shale or underclay.

Shale, the most abundant lithology in the Breathitt Group, is clayey to silty, well laminated, and commonly contains siderite nodules or beds about half an inch thick. Black carbonaceous shale and canneloid shale occur in thin beds overlying coal. In fresh exposures a few thin beds of shale are calcareous.

Coal in the Elk Valley area occurs principally in the Breathitt Group in beds that range in thickness from a few inches to about 6 feet. It is commonly underlain by 1–3 feet of clayey to silty nonlaminated underclay. Slickensided surfaces in the underclay appear to result from compaction associated with dewatering of the sediment.

Although limestone beds are rare in the Breathitt Group, they mark distinct horizons and therefore are useful for correlation. Most of the limestone is very argillaceous and occurs in beds as much as 1 foot thick or in large ellipsoidal concretions as much as 10 feet in diameter.

The color of beds in the Breathitt Group ranges from very light gray to very dark gray or black. In general, a decrease in grain size is accompanied by an increase in the amount of finely disseminated carbonaceous material and also by an increase in the darkness of the rock. Upon weathering the various shades of gray are altered to grayish red or reddish brown by iron oxide staining.

Continental, marine, and brackish beds compose the Breathitt Group, as indicated by the presence of fossils that are representative of these environments. Of greatest abundance are fossil plant remains in the form of leaf and stem imprints that are generally well preserved in laminated shale beds overlying coal beds. Bark and trunk impressions, locally in logjam accumulations, are present in sandstone beds or in erect position in other sediments overlying the coal beds. Locally, sand- or silt-filled stumps occur at or near the base of a coal bed, and branching *Stigmaria* with abundant fossil rootlets are present in the underclay. Marine invertebrate fossils, consisting mostly of brachiopods, are abundant in a few widespread beds of limestone and calcareous shale. Pelecypods, which probably originated in a brackish environment, occur in dark-gray or black shale and are pyritized in some beds.

The upper part of the Breathitt Group has been eroded in the Elk Valley area, so that only the lower four formations—the Hance, Mingo, Catron, and Hignite—are preserved.

HANCE FORMATION

The Hance Formation (Ashley and Glenn, 1906, p. 31) includes beds between the top of the Lee Formation and the base of the Jellico coal bed. It is a sequence of interbedded medium-dark-gray shale, very fine grained to fine-grained sandstone, siltstone, underclay, and coal. Because of intertonguing with the upper part of the Lee Formation, the base of the Hance Formation rises stratigraphically northwestward across the report area (pl. 5). Beyond the northwest corner of the Ketchen quadrangle on the west edge of the coal field, the massive quartzose conglomeratic sandstone beds of the Lee Formation, including the widespread Corbin Sandstone Member, crop out at a position equivalent to the lower part of the Hance in the Elk Valley area. Southeastward into the basin of deposition, these sandstones of typical Lee lithology wedge out and at their extremities grade gradually into thin and partly ripple-marked sandstone beds of the Hance Formation that are relatively low in quartz content. Conversely, the shale beds of the Hance Formation wedge out to the northwest between the Lee sandstone tongues. Also, the coal beds in the lower part of the Hance Formation thin or wedge out completely to the northwest. The evolution of thought concerning this contact relationship, which, in turn, affects the correlation of overlying coal beds, is shown diagrammatically in figure 14. Before Glenn's work (1925), correlations (fig. 14*A*) show for the most part a layer-cake relationship in which the top of the Lee is a plane and coal beds are correlated according to the interval above it. This practice was extensively used commercially, and in places the Kent coal bed was erroneously correlated with, and is still commonly known as, the Jellico coal bed as a result of both coals having approximately the same interval from the top of the Lee Formation. Inaccuracies in this method of correlation were pointed out by Glenn (1925), who, by relying on the physical characteristics of the coal and associated beds for correlations, demonstrated that the post-Lee section to the east contained stratigraphically lower beds than the section to the west, as indicated by *B* of figure 14. As to the actual contact of the Lee with the immediately overlying rocks, here referred to as the Briceville Formation, Glenn states (1925, p. 417): "The Briceville overlaps the Lee to the west and rapidly thins westward by the wedging out of its lower beds as it nears its western margin. There is some evidence that the surface of the Lee, on which the overlapping Briceville rests, is itself an irregular one." By pointing out the occurrence of the stratigraphically lower beds in the post-Lee section to the east, Glenn made a noteworthy contribution to the concept of intertonguing and lateral gradation between the Lee and overlying formations which was advanced in 1961, as indicated in *C* of figure 14 (Englund, 1962).

In the Elk Valley area, the Hance Formation crops out in the broad trough of the Middlesboro syncline, and the upper part crops out on the lower hill slopes throughout the area west of the overthrust sheet. Thicknesses of the formation increase southeastward from 485 feet in the northwestern part of the Ketchen quadrangle to 1,180 feet in the Middlesboro syncline.

Paleontologic data from the Hance Formation consist almost entirely of the plant fossils that indicate a continental environment during deposition. A few beds of dark-gray shale yield pelecypods of probable fresh- or brackish-water origin. Plant fossils collected by the writer from the roof shale of the Mason coal bed, a correlative of the Murray coal, in Bell County, Ky., support a Middle Pennsylvanian age designation for most of the Hance Formation in this area. These fossils were identified by S. H. Mamay, U.S. Geological Survey, as follows:

Asterophyllites cf. *A. longifolius* Sternberg
Calamites sp.
Sphenophyllum cuneifolium Sternberg
Lycopodites meeki Lesquereux
Lepidodendron sp.
Mariopteris cf. *M. inflata* White
Neuropteris elrodi Lesquereux
Neuropteris cf. *N. tenuifolia* Brongniart
Sphenopteris sp.

Basal beds that intertongue with the Naese Sandstone Member of the Lee Formation are considered to be Early Pennsylvanian in age. For the following detailed lithologic description, the Hance Formation is informally subdivided into five units.

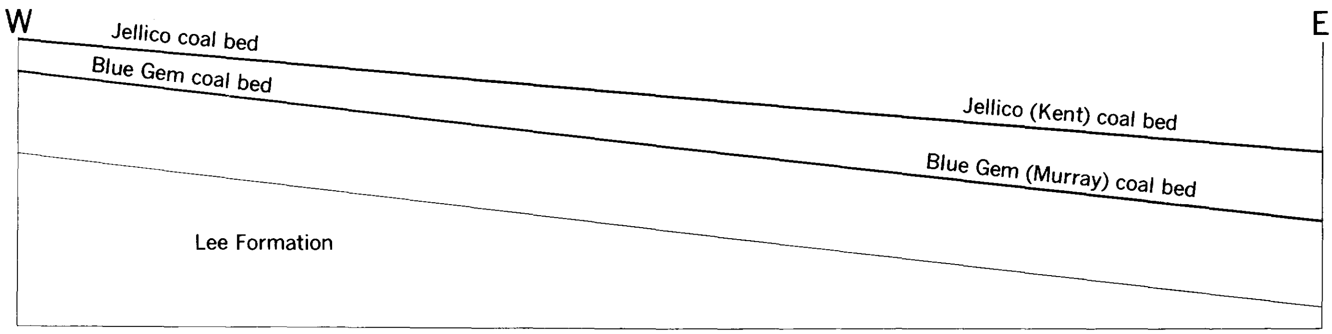
Lower part of the Hance Formation

The Naese coal bed (Englund, Landis, and Smith, 1963), at the base of the Hance Formation, is overlain by 20–50 feet of dark-gray shale which contains abundant siderite nodules and locally includes a lens of very fine grained to fine-grained sandstone as much as 15 feet thick. This shale marks a conspicuous topographic break or depression between the Naese Sandstone Member of the Lee and the overlying Yellow

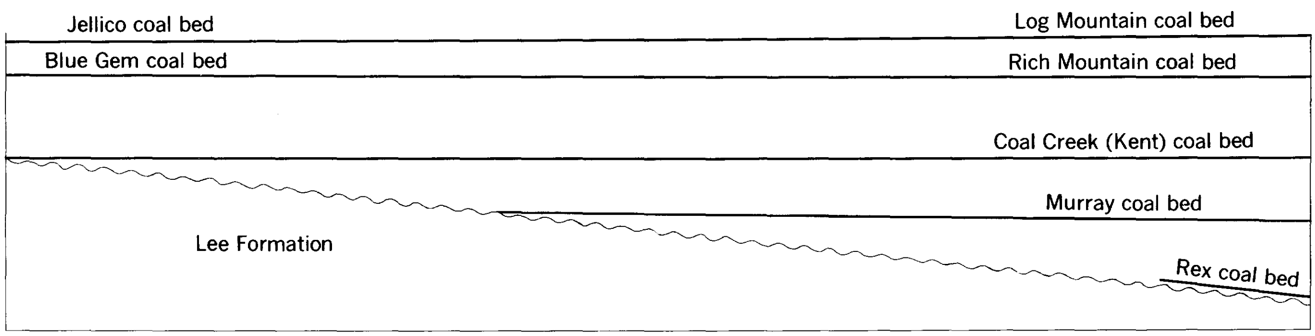
Creek Sandstone Member, but because the bed is thin, it is mapped with the Yellow Creek Sandstone Member.

Yellow Creek Sandstone Member

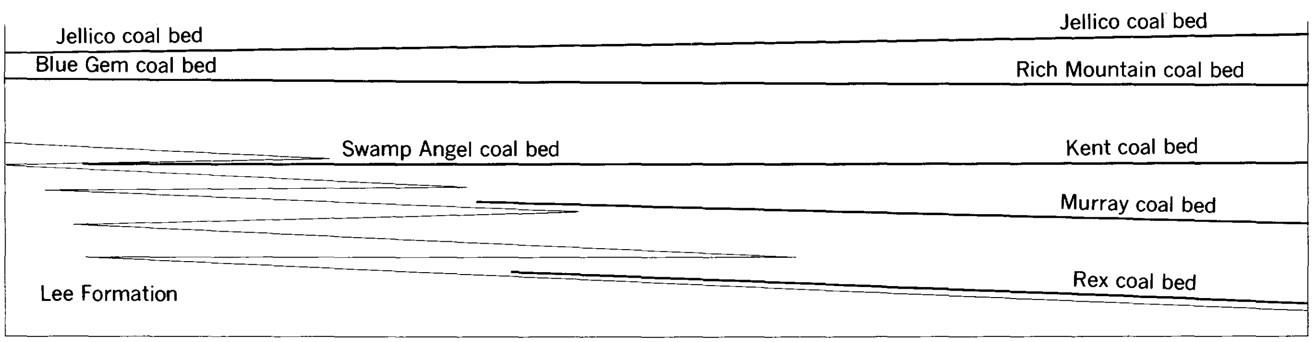
On the basis of its stratigraphic position and distinctive lithology, the Yellow Creek Sandstone Member (Ashley and Glenn, 1906, p. 38) has been traced southwestward into the Elk Valley area from the type locality in Bell County, Ky. In outcrops along Pine Mountain northeast of this report area, the intervening shale wedges out and the Yellow Creek Sandstone Member merges with the underlying Naese Sandstone Member (Englund, Roen, and DeLaney, 1964). Although this relation was not observed in the Elk Valley area, it may prevail locally where the beds involved are concealed. Lithologically, the Yellow Creek Sandstone Member is very fine grained to fine grained, thick bedded, and light gray. Its quartz content averages about 60 percent. The basal contact is sharp and commonly undulates several



A, Early correlation (Glenn, 1925, p. 115, 117)



B, Glenn (1925)



C, Englund (1962)

FIGURE 14.—Diagrammatic sections showing concepts of the relation of the Lee Formation to overlying beds across the northern part of the Tennessee coal field.

inches into the underlying shale. Gradation to siltstone occurs locally in the member but mostly toward the top contact which, because of gradation, is placed in mapping at the base of the overlying Rex coal bed. Therefore, the top of the member contains as much as 5 feet of medium-gray, poorly bedded siltstone and underclay beds that are too thin to be mapped separately. Low rounded hogbacks are formed by the Yellow Creek Sandstone Member on the lower dip slopes of Pine, Fork, and Cumberland Mountains, in a belt around the inside of the southwest end of the Middlesboro syncline. Thicknesses of the member in the syncline range from 80 to 100 feet, and the total thickness of beds between the Naese coal bed and the top of the Yellow Creek Member, which are exposed only in the syncline, range from 100 to 130 feet. On the basis of its stratigraphic position, the Yellow Creek Sandstone Member is here correlated with the upper part of the Rockcastle Sandstone Member of the Lee Formation (pl. 5).

Middle part of the Hance Formation

The middle part of the Hance Formation includes as much as 900 feet of strata between the base of the Rex coal bed and the base of the Ivydell Sandstone Member and consists predominantly of medium-gray shale, silty shale, and siltstone beds (pl. 6). Four coal beds—Rex, Murray, Swamp Angel-Kent, and Blue Gem-Rich Mountain—are widespread in this interval, and the Dixie and Black Wax coal beds are mapped locally. Except for nearly 50 feet of massive sandstone in a channel deposit that truncates the Kent coal bed in the southeast corner of the Pioneer quadrangle, sandstone in this part of the Hance Formation is very fine grained and thin bedded. Within the broad trough of the Middlesboro syncline, beds in the middle part of the Hance Formation crop out on the lower hill slopes which rise abruptly to a broad bench capped by the Ivydell Sandstone Member. West of the overthrust sheet the uppermost of these beds are also widely exposed on the lower hill slopes; however, those beds below the Swamp Angel coal are in the subsurface, except for 150 feet of beds below the Swamp Angel coal bed that crops out in the northwest corner of the Ketchen quadrangle.

Ivydell Sandstone Member

In the Middlesboro syncline the Rich Mountain coal bed is overlain by as much as 70 feet of sandstone that is here named the Ivydell Sandstone Member of the Hance Formation. The type section of the member (pl. 6, section 20) is exposed along a road that extends up the left side of Kent Hollow from the community of Ivydell to a broad upland formed on the sandstone. In the type section the Ivydell Sandstone Member consists of 55 feet of massive light-gray sandstone which is mostly fine to medium grained with a few scattered coarse grains. It is lithologically similar to sandstones of the Breathitt Group, except for a large number of weathered white feldspar grains which were noted in most outcrops. The basal contact of the Ivydell Sandstone Member is sharp and commonly undulates 1 foot or more into the underlying beds. At the type section the underlying Rich Mountain coal bed has been completely truncated, but fragments and discontinuous laminae of coal are abundant in the basal 2 feet of the sandstone. At the top contact, sandstone changes abruptly to shale or siltstone. The Ivydell Sandstone Member occurs in a broad channellike deposit that extends across the Middlesboro syncline. In the western part of the report area a thin unmapped sandstone bed occurs locally above the Blue Gem coal bed at the position of the Ivydell Sandstone Member (pl. 6, section 3).

Upper part of the Hance Formation

The beds between the Ivydell Sandstone Member, or the Blue Gem-Rich Mountain coal bed where this sandstone is absent, and the top of the Hance Formation range in thickness from 100 to 150 feet. They consist mostly of shale, siltstone, thin-bedded very fine grained to fine-grained sandstone, underclay, and one or two thin coal beds. An exception to these lithologies is a massive sandstone, about 80 feet thick, that crops out in a prominent cliff below the Jellico coal bed in the vicinity of Sand Gap in the Pioneer quadrangle where it was named the Sand Gap Sandstone (Wilson, Jewell, and Luther, 1956, p. 6). This sandstone decreases in thickness northeastward to about 20 feet or less in the Jellico West quadrangle. There, it appears to be the sandstone to which Wilson, Jewell, and Luther (1956, p. 6) applied the name Newcomb Sandstone, although an adequately described type section and other criteria for establishing boundaries of their Newcomb Sandstone were not given (fig. 15). One to three feet of medium-light-gray underclay at the base of the Jellico coal bed is the uppermost bed of the Hance Formation. The total thickness of beds in the upper part of the formation ranges from 100 to 150 feet.

MINGO FORMATION

The Mingo Formation of Middle Pennsylvanian age was defined by Ashley and Glenn (1906, p. 39) in the Black Mountain area of the Middlesboro syncline in Kentucky as extending from the base of the Harlan coal to the base of the Wallins Creek coal. These coal beds are widely recognized in Kentucky and have been mapped into Tennessee (Englund, 1964a) where the Jellico and Windrock coal beds, respectively, are cor-

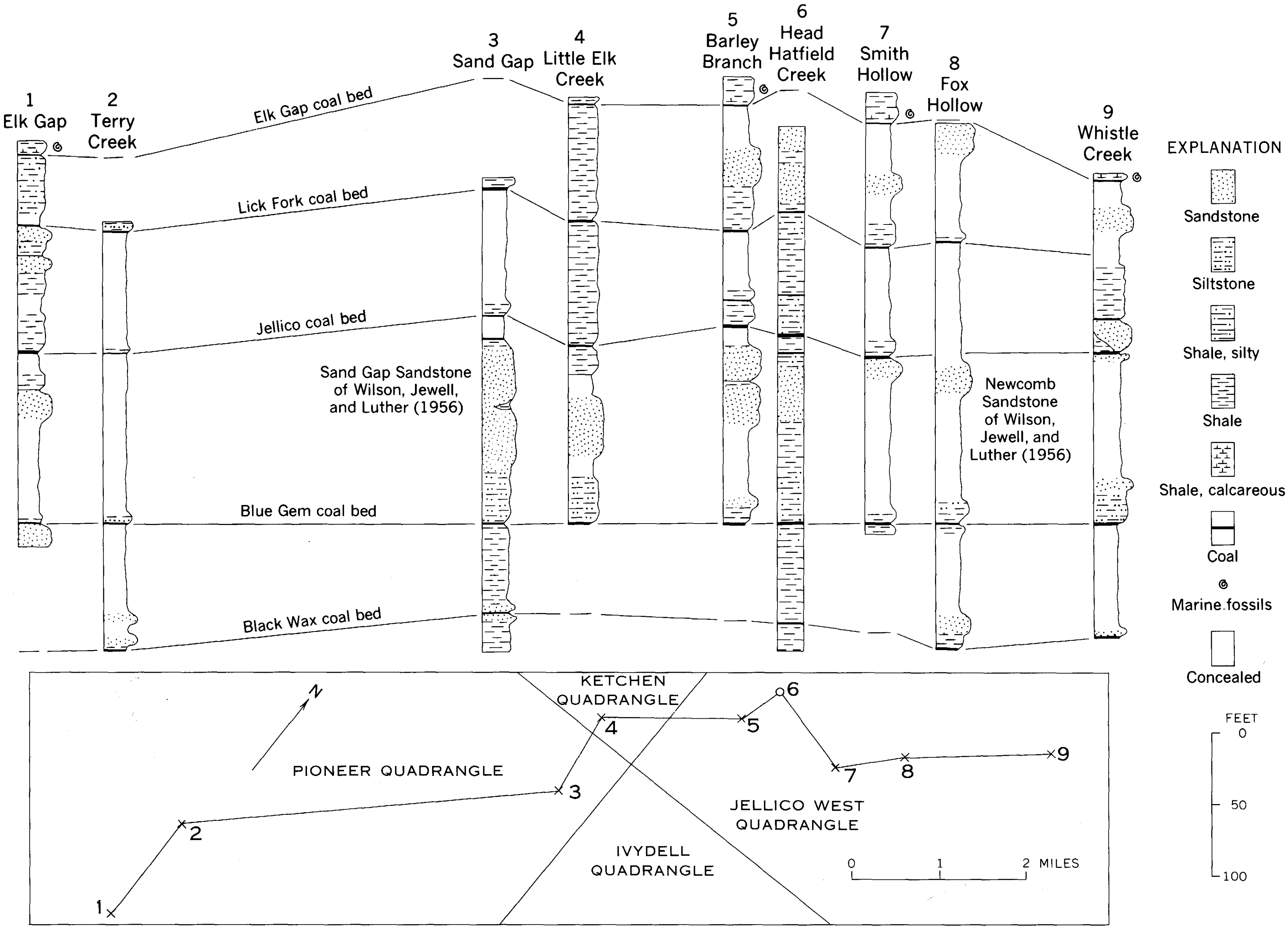


Figure 15.—Correlation of the Jellico and other coal beds in the central part of the Elk Valley area.

relatives. On the basis of this correlation, the Mingo Formation in the Elk Valley area includes 480–545 feet of beds which extend from the base of the Jellico coal bed to the base of the Windrock coal bed. Within this interval the rocks consist of sandstone, siltstone, shale, coal, and underclay which crop out extensively on the middle to upper hill slopes in the area west of the Cumberland overthrust sheet and to a lesser extent on the upper hill slopes in the central part of the Middlesboro syncline.

Leaf and stem imprints are common throughout the Mingo Formation but are generally most abundant and best preserved as coalified films that are impressed in the roof shale of coal beds.

Of particular stratigraphic significance is a thin bed of calcareous shale that contains the brachiopod *Marginifera* in abundance. Although the range of *Marginifera* is extensive, the unique occurrence of one genus in abundance in a single thin bed in the report area proved to be a useful and readily identifiable marker in outcrop sections and cores. Locally in the east-central part of the Jellico West quadrangle, this calcareous shale bed grades laterally into canneloid shale which contains abundant *Lingula*.

For the following lithologic description the Mingo Formation is divided into lower and upper parts by the Pioneer Sandstone Member.

Lower part of the Mingo Formation

The lower part of the Mingo Formation extends from the base of the Jellico coal bed to the base of the Pioneer Sandstone Member and consists mostly of medium- to dark-gray evenly bedded shale, silty shale, and siltstone. In addition to the widespread Jellico coal bed, this interval includes two moderately persistent coal beds, the Lick Fork and Elk Gap, and one or two very thin coal beds between the Jellico and Lick Fork coals. Associated with the coals are beds of clayey medium- to medium-dark-gray underclay that range mostly from 1 to 3 feet in thickness. Sandstone in the lower part of the Mingo Formation is commonly very fine to fine grained, thin bedded, and less than 10 feet thick. Locally in the Ketchen and Jellico West quadrangles, however, sandstones overlying the Jellico and Lick Fork coal beds are fine to medium grained, massive, and cliff forming. These sandstones are as much as 25 feet thick and in places were deposited in channels that truncate the underlying coal bed.

Throughout most of the Elk Valley area the Elk Gap coal bed is overlain by ½–3 feet of poorly bedded very dark gray to black calcareous shale that contains an appreciable amount of randomly oriented mica flakes. This shale is of major stratigraphic significance as a key bed because it contains an abundance of *Marginifera* (pl. 6). A similar occurrence has not been noted elsewhere in the stratigraphic column in the central part of the Appalachian coal field. Brachiopods collected by the writer from the bed were identified by E. L. Yochelson, U.S. Geological Survey, as follows:

USGS 18011–PC, 18012–PC, and 18013–PC:
Marginifera missouriensis Girty of Morningstar

In the vicinity of Indian Mountain in the Jellico West quadrangle, a canneloid shale, probably representing a local brackish environment, overlies the Elk Gap coal bed. Brachiopods from this shale were identified by E. L. Yochelson as follows:

USGS 18010–PC:
Lingula cf. *L. carbonaria* Shumard

Scattered siderite nodules and beds, about half an inch thick, and large argillaceous limestone concretions, as much as 3 feet in diameter, occur in a medium-gray shale that overlies the fossil bed.

Pioneer Sandstone Member

The Pioneer Sandstone Member was originally named by Glenn (1925, p. 18–19) from exposures in a gap at Old Pioneer, presently designated Poteet Gap, in the Pioneer quadrangle (pl. 3). Previously, the term Pioneer had been applied to a formation in the Precambrian Apache Group of central Arizona; however, there appears to be sufficient stratigraphic and geographic separation to avoid ambiguity in the usage of this name. In view of the extensive use of the term in Tennessee, the Pioneer Sandstone is hereby formally considered and adopted as a member of the Mingo Formation.

In the type section at Poteet Gap the Pioneer Sandstone Member consists of 50 feet of light-gray massive fine- to medium-grained sandstone (pl. 6, section 13). It is a prominent cliff former, averaging about 40 feet thick, on the upper hill slopes across the southern part of the Pioneer quadrangle and throughout the central part of the Ivydell quadrangle. Toward the northern edge of the Pioneer quadrangle the member thins to about 25 feet thick, decreases in texture to very fine to fine grained, and becomes interbedded with laminae and lenses of shale. Mapped areas of the Pioneer Sandstone Member, limited to the Pioneer and Ivydell quadrangles, show virtually the entire distribution of the mappable massive phase of the member. In the Ketchen and Jellico West quadrangles where the member is thin and nonresistant, its outcrop position is indicated by the outcrop line of the overlying Jordan coal bed. In contrast to the basal contact which is sharp and undulating, the top contact is gradational, and the upper part of the member is interbedded with finer textured sediments. For convenience in mapping, the top contact is drawn at the base of the overlying Jordan coal bed; therefore, as mapped, the top of the Pioneer Sandstone Member includes a gradational sequence, 2–15 feet thick, of siltstone, shale, and underclay.

Upper part of the Mingo Formation

The upper part of the Mingo Formation includes 230–350 feet of strata from the top of the Pioneer Sandstone Member to the base of the Windrock coal bed and consists of about equal proportions of sandstone, siltstone, and medium- to medium-dark-gray evenly bedded shale. Commercial coal occurs principally in the Upper Pioneer coal bed but is also of minable thickness locally in the underlying Jordan and Lower Pioneer coal beds. Several thin coal beds, 2–18 inches thick, occur at irregular intervals between the Upper Pioneer coal bed and the top of the formation. The coals in the upper part of the Mingo Formation are underlain by 1–4 feet of light- to medium-gray underclay, some of which is sandy, which contains abundant fossil rootlets. In the floor of strip mines in the Upper Pioneer coal bed, branching sand-filled impresions of *Stigmaria* are commonly exposed. The thickest and most persistent sandstone in this sequence of beds occurs below the Upper Pioneer coal bed and ranges from very fine to medium grained, from thin bedded to massive, and from 5 to 80 feet in thickness. The most conspicuous development of the sandstone is on the upper hill slopes in the Ketchen and Jellico West quadrangles where it is a prominent cliff former, about 50 feet thick.

The only occurrence of marine fossils, including brachiopods, in this part of the formation was noted in a siltstone bed about 20 feet above the Upper Pioneer coal bed at one locality (pl. 6, section 12).

CATRON FORMATION

The Catron Formation of Middle Pennsylvanian age was named by Ashley and Glenn (1906, p. 41) from exposures in Harlan County, Ky., where it includes strata from the base of the Wallins Creek coal bed to the top of the Jesse Sandstone Member. The basal contact is widely recognized throughout the coal field as the Wallins Creek coal bed, and its correlatives are readily identified by a thin bed of flint clay that occurs as a parting in the coal or in strata underlying the coal. On the basis of the widespread occurrence of the flint clay at this stratigraphic position, the Wallins Creek coal is correlated with the Windrock coal bed of the Elk Valley area. Placement of the top contract of the Catron Formation in the type area is based on the occurrence of another unique lithology, which is a quartz-pebble conglomerate in the Jesse Sandstone Member. Although a conglomeratic sandstone was not observed at this part of the stratigraphic sequence in the Elk Valley area, the top contact is drawn at the base of the Magoffin Beds of Morse (1931, p. 301–303) which occur at the base of the overlying Hignite Formation. The Magoffin Beds of Morse, a widely recognized fossiliferous marine horizon, overlie the upper split of the Sharp coal bed in the Elk Valley area.

The Catron Formation in most of the Elk Valley area consists of shale, underclay, and coal, but locally as much as 50 percent of the formation is composed of sandstone and siltstone. The shale is medium to dark gray, evenly bedded, and contains sparse to abundant siderite nodules or beds as much as half an inch thick. Coal in the Catron Formation is of significant thickness in the Big Mary coal bed and, locally, in the Windrock, Hatfield, Beech Grove, and Sharp coal beds. The last-mentioned bed commonly occurs in two "splits" that are separated by 5–20 feet of strata of variable lithology. The coals are underlain by beds of clayey to silty medium- to medium-dark-gray underclay that average about 2 feet in thickness. Flint clay associated with the Windrock coal bed ranges in thickness from less than 1 inch to 12 inches but is mostly 3–4 inches thick. The 12-inch thickness, which is the greatest recorded in the general area of this report, was noted in the southeast corner of the Ketchen quadrangle where the bed was prospected along the road in Incline Hollow of Capuchin Creek. Where the bed is typically developed, it is brownish gray, relatively resistant, and breaks with a distinct concoidal fracture. At a few localities the flint clay grades in part to semiflint clay. Sandstone in the Catron Formation is mostly thin bedded, very fine to fine grained, conspicuously micaceous, and less than 10 feet thick. However, sandstones above the Hatfield and Beech Grove coal beds thicken to 50 feet or more in parts of the Ketchen and Jellico West quadrangles and become fine to medium grained, massive, and cliff forming.

The Catron Formation ranges in thickness from 160 to 180 feet and is distributed principally on the upper hill slopes or hilltops in the area lying west of the Cumberland overthrust sheet. Within the overthrust sheet, it is confined to the upper slopes of Walnut Mountain in the central part of the Middlesboro syncline.

Fossil plant remains are abundant in the Catron Formation and consist of *Stigmaria* in underclay, leaf and stem impressions including *Calamites* in shale, and the bark imprints of *Lepidodendron* and *Sigillaria* in sandstone. Locally, the roof shale of the Big Mary coal bed contains a few brachiopods and pelecypods, and where the Windrock coal is cannel, the roof shale contains pyritized pelecypods.

HIGNITE FORMATION

The Hignite Formation of Middle Pennsylvanian age conformably overlies the Catron Formation and includes the youngest Pennsylvanian rocks in the Elk Valley area. As defined by Ashley and Glenn (1906, p. 43), the top contact of the Hignite Formation was placed at the top of the Red Springs coal in nearby Bell County, Ky. The stratigraphic position of this coal may intersect one or two of the highest knobs at the crest of Braden Mountain in the Pioneer quadrangle; but at these hilltop localities the rocks are largely concealed, and the position of the Red Springs coal, if present, is obscured. Therefore, because the localities that may include the overlying Bryson Formation are of negligible size, all strata above the Catron Formation in the Elk Valley area are assigned to the Hignite Formation.

Lithologically, the Hignite Formation is similar to the underlying formations of the Breathitt Group and consists of interbedded sandstone, siltstone, shale, coal, and underclay. Thin but persistent beds of calcareous shale and argillaceous limestone are also present. Sandstone, constituting about 25 percent of the Hignite Formation, is very fine to medium grained, light gray, thin bedded to massive, and micaceous. In comparison with sandstones of the underlying formations, those of the Hignite tend to be coarser textured and more massive as shown by precipitious cliffs, as much as 50 feet high, on the upper slopes of Braden Mountain (figs. 16, 17). About 30 percent of the formation is siltstone, which ranges from light to medium gray and evenly to irregularly bedded, with interlaminations of very fine grained sandstone and shale. Fine mica flakes are commonly concentrated on bedding planes but are also nonoriented in irregularly bedded siltstone. Shale and silty shale, composing nearly 40 percent of the Hignite Formation, is mostly medium gray and evenly bedded. Many of the beds contain siderite nodules; shale overlying the Braden Mountain coal bed locally contains argillaceous limestone concretions as much as 6 inches thick. At the base of the formation a dark-gray calcareous shale with marine fossils makes up the Magoffin Beds of Morse (1931, p. 301–303). The shale ranges in thickness from 1 to 3 feet and includes a bed of medium-dark-gray dense argillaceous limestone, as much as 14 inches thick, in parts of the Ketchen and Jellico West quadrangles. A thin bed of calcareous shale with abundant marine fossils, including brachiopods, was observed in the upper part of the formation (pl. 6, section 12).

FIGURE 16.—Massive cliff-forming sandstone in the Hignite Formation underlying a broad bench near the crest of Braden Mountain.

FIGURE 17.—Unconformity at the base of sandstone (fig. 16) about 10 feet above the Braden Mountain coal bed on Braden Mountain.

Coal in the Hignite Formation occurs principally in the Red Ash, Braden Mountain, and Big Wheel coal beds. The Red Ash is a relatively thin and persistent bed, whereas the Braden Mountain and Big Wheel coals are locally thick but occur in a zone with one or more thin coal beds that exhibit lateral variation, including the splitting and wedging out of the coal and intervening beds. Clayey to silty light- to medium-gray underclay in beds as much as 3 feet thick, underlie the coals in the Hignite Formation. A 2-inch parting of brownish-gray flint clay occurs in a thin coal bed about 35 feet below the Walnut Mountain coal bed at the east end of Walnut Mountain (pl. 6, section 17).

Remnants of the Hignite Formation cap the high points of mountains west of the Cumberland overthrust sheet and the crest of Walnut Mountain in the Middlesboro syncline. Only the lower part of the Hignite Formation is preserved in most of these isolated occurrences, and it is generally less than 250 feet thick. On Braden Mountain, however, where the basal beds of the overlying Bryson Formation may arbitrarily have been included, about 550 feet of beds is present.

Continental plant fossils and marine invertebrate fossils were both observed in the Hignite Formation. A collection from the Magoffin Beds of Morse at a locality 0.1 mile south of Pit Gap in the Jellico West quadrangle were identified by E. L. Yochelson as follows:

USGS 18009–PC:
- *Lingula* sp. indet.
- *Posidonomya* sp.
- "*Pteria*" sp.
- *Astartella*? sp.
- Coiled nautiloid cephalopods, indet.
- *Trepospira* sp. indet.
- *Phymatopleura* sp.

QUATERNARY SYSTEM

Quaternary deposits in the area consist of flood-plain alluvium along nearly all the stream courses and colluvium in sporadic accumulations on hill slopes. Alluvium is most extensive in belts ranging from an eighth of a mile wide along tributary branches to as much as half a mile wide along Elk Creek which flows through the broad strike valley carved into the Pine Mountain fault zone. Strip mines in this valley bottom in the Jellico West quadrangle disclose a complete section of the alluvium from the uneven but abrupt basal contact to the soil development on the flat upper surface. The following descriptions are based largely on these high-wall exposures.

Deposits attain maximum thicknesses of 10–15 feet in the central part of the valley and thin to 6 feet or less toward the outer edges. At the edge of the valley the alluvium grades imperceptibly to soil developed on the weathered bedrock. The composition of the alluvium reflects the various lithologies of formations, ranging in age from Ordovician to Pennsylvanian, that are subject to erosion along the Pine Mountain fault zone. Chert from the Fort Payne is the most resistant of this locally derived debris, and it occurs in the alluvium as angular blocks as much as 1 foot in diameter and as subrounded pebbles. Well-rounded sandstone pebbles and boulders together with white quartz pebbles from the Lee Formation occur with the chert detritus in lenses in the lower and middle parts of the deposits. Poorly sorted sand occurs throughout the alluvium, but the percentage of clay increases upward, and as much as 2 feet of highly weathered clayey soil is at the top. Stream-abraded branches and trunks of trees are sparsely distributed in the lower and middle parts of the deposits. Along other streams of the Elk Valley area the alluvium is thinner and less extensive but has characteristics similar to those described for deposits in the valley bottom along Elk Creek. These characteristics include locally derived material, a decrease in grain size upward, and gradation to soil at the top surface.

Colluvium in the area is composed predominantly of angular to subrounded pebbles and boulders of sandstone and conglomeratic sandstone (fig. 18). The size of the constituents in the deposits varies from clay and sand, which compose less than 25 percent, to large blocks that range in thickness from 1 to 40 feet. The colluvium occurs mostly in narrow, elongate deposits, about 25 feet or less in thickness, which increase in width and thick-

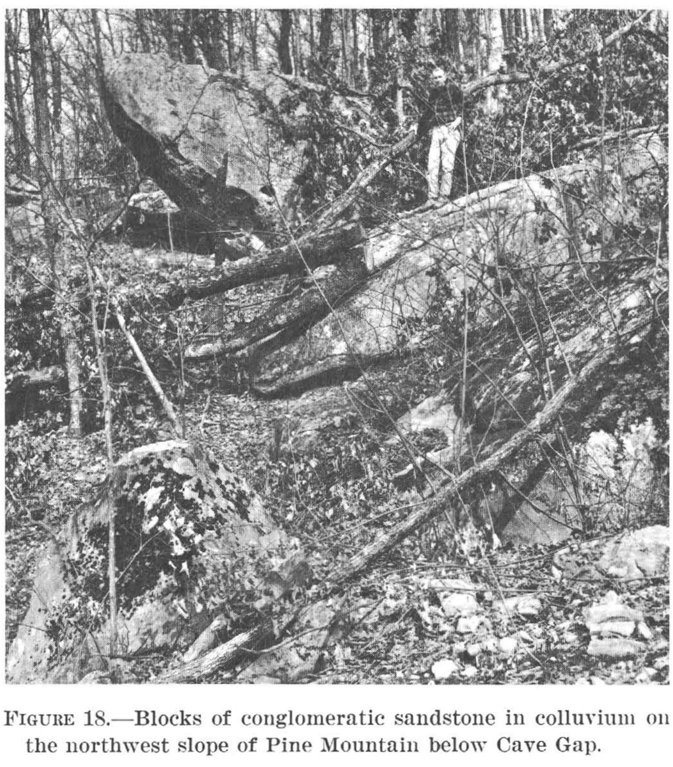


FIGURE 18.—Blocks of conglomeratic sandstone in colluvium on the northwest slope of Pine Mountain below Cave Gap.

ness downslope, and which in places are fan shaped at the foot of a slope. The deposits are best developed where massive cliff-forming standstones, cropping out upslope, are a source of detritus. Largely by means of frost action, talus breaks loose from exposed sandstone beds and slides downslope slowly or bounces and rolls rapidly with sufficient force to uproot or break off trees. Detritus accumulates in the center of V-shaped drains or hollows on the hillsides and causes the streams to bifurcate and flow along the sides of the mounds or ridges of colluvium. Many of these deposits are too narrow to be mapped at the scale used; colluvium is generally mapped where the deposits are indicated by strip-mine excavations (pls. 1, 3).

STRUCTURE

GENERAL FEATURES

The Elk Valley area is on the western flank of the Appalachian geosyncline and occupies an intermediate position between gently dipping rocks on the southeast limb of the Cincinnati arch and intensely faulted and folded rocks of the Appalachian Mountains to the southeast. Within the area the general southeasterly dip of the outcropping rocks is abruptly terminated at the Pine Mountain fault zone. This fault zone and the Jacksboro fault zone bound the southwest corner of the Cumberland overthrust sheet (fig. 2). In addition to moving about 11 miles to the northwest, the overthrust sheet was warped into two broad folds—the Middlesboro syncline and the Powell Valley anticline. Only the southwest end of the Middlesboro syncline, a northeast-trending flexture, extends into the Elk Valley area; parallel to the syncline on the southeast is the Powell Valley anticline (fig. 2). In contrast to the rocks of the overthrust sheet, most of the rocks of the underlying autochthonous plate form part of a conformable sequence dipping gently southeastward off the Cincinnati arch.

Structurally, the Elk Valley area is divided by faults into three distinct segments: (1) the Cumberland overthrust sheet, (2) the area northwest of the Pine Mountain fault zone, and (3) the area southwest of the Jacksboro and Terry Creek faults. A detailed description of the structure in each of these segments is preceded by the following description of the principal faults.

FAULTS

PINE MOUNTAIN FAULT ZONE

The Pine Mountain overthrust fault, at the base of the Cumberland overthrust sheet, is one of the most important structures in eastern Kentucky, northern Tennessee, and southwestern Virginia. It extends from the Jacksboro fault zone in the Pioneer quadrangle northeastward across parts of the three States for about 125 miles. Displacement of the overthrust sheet along the fault ranges from about 11 miles at the southwest end to about 2 miles, estimated by Wentworth (1921), at the northeast end.

The trace of the Pine Mountain fault is conspicuously marked at the northwest edge of the overthrust sheet by a narrow strike valley at the foot of the northwest slope of Pine Mountain in both Kentucky and Tennessee. In the Elk Valley area this strike valley broadens to about 1 mile wide and reflects an increase in the width of the fault zone. Several imbricate faults compose the fault zone; they dip southeastward and converge to a single bedding-plane fault in the subsurface. Below the Middlesboro syncline this bedding-plane fault is at an average depth of about 1,600 feet below sea level and is confined principally to the basal beds of the Rockwood Formation at the southwest end of the overthrust sheet. Locally, as much as 40 feet of the Sequatchie Formation has been faulted and thrust to the surface in the Pine Mountain fault zone. These beds of the Sequatchie are the oldest rocks observed at the surface in the fault zone. Northeastward, below the Middlesboro syncline in the Ivydell quadrangle, the Pine Mountain fault gradually crosscuts upward through the Rockwood Formation and passes into the lower part of the Chattanooga Shale along a line extending southeastward from the community of Elk Valley (pl. 4). This northeastward crosscutting restricts the distribution of the Sequatchie and Rockwood Formations in the overthrust sheet to its southwest end; this, in turn, is reflected in the limited exposure of these formations at the southwest end of the fault zone.

In the subsurface the position of the fault plane is indicated in drill holes by slumping and by slickensided shale fragments, as much as 1 inch long, recovered from oil and gas test holes. In the East Tennessee Iron & Coal Co. 2 test hole, at the southwest end of the Middlesboro syncline, slickensides and slumping were found in beds of the Rockwood Formation at a depth of 1,400 feet below sea level. From there, the Pine Mountain fault continues as a bedding-plane fault southeastward below the Middlesboro syncline to Cumberland Mountain, where, in the subsurface, the fault has crosscut stratigraphically lower beds of the overthrust sheet (pl. 4, cross section *A–A′*) down through the Knox Group. A study of cuttings by J. O. Fuller (written commun., 1964) from the N. A. Shoun 1 test hole, 3 miles south of the Ivydell quadrangle, indicates that dolomite beds possibly of the Maynardville Limestone are in fault contact with the Sequatchie Formation of the autochthonous plate at a depth of about 1,900 feet below sea level.

The Pine Mountain fault in the Elk Valley area rises northwestward from a depth of about 1,750 feet below sea level in the southeast corner of the Ivydell quadrangle to the surface along Elk Creek by (1) crosscutting competent Cambrian and Ordovician formations, (2) passing into a bedding-plane fault in the incompetent Ordovician to Devonian shale sequence, and (3) crosscutting competent Mississippian and Pennsylvanian formations.

Structural effects with regional implications are also evident in rocks exposed along the Pine Mountain fault zone in the Elk Valley area (pl. 7). These include, from southwest to northeast, a decrease in the number of imbricate faults, diminishing width of the fault zone, and an increase in the involvement of younger rocks in the imbricate fault slices. In the Pioneer quadrangle the southwest 4½ miles of the fault zone averages about 1 mile wide at the surface; on the northwest side the fault zone consists mostly of highly contorted and faulted shale of the Sequatchie and Rockwood Formations. The Chattanooga Shale is prevalent in the central part of the fault zone, and rocks of Mississippian age are present on the southeast side. In addition to the seven principal mapped faults (pl. 3), the beds on the northwest side of the fault zone are displaced by numerous small faults that are obscured by the deformation of the beds and by extensive lowland alluviation. Northeastward into the western part of the Ivydell quadrangle the percentage of Chattanooga Shale in the fault zone increases, and locally, the apparent thickness of the shale is greatly increased because of flowage and numerous tight folds and faults within the formation (fig. 4). Mississippian rocks, including the Grainger Formation, Fort Payne Chert, and Newman Limestone, predominate in the fault slices in the Ivydell quadrangle and are succeeded to the northeast by the Lee Formation which crops out in the two principal fault slices in the south-central part of the Jellico West quadrangle (pl. 2). The southeastern of these two slices was compressed into an isoclinal anticline, and the northwestern slice, which was less compactly folded into an anticline, was thrust over younger Pennsylvanian rocks. The crest of the latter anticline has been completely breached by Little Elk Creek, so that part of the northwest limb is a klippe at the edge of the fault zone. The occurrence of these two rootless anticlines indicates that folds may be present to the southeast in the autochthonous plate.

In the Jellico West quadrangle the Grainger Formation, rather than the Chattanooga Shale, crops out locally at the base of the overthrust sheet. The unusual absence of the Chattanooga at the base of the overthrust sheet is most likely due to the fault plane having crosscut upward to the base of the Grainger Formation. If the Chattanooga is present locally, it is covered by slump from the overlying Grainger Formation. Northeastward into the eastern part of the Jellico West quadrangle, the Chattanooga Shale recurs at the base of the overthrust sheet where the fault zone becomes a single fault plane.

The northwest edge of the Pine Mountain fault zone is fringed by a fault slice of the Lee Formation, which, in contrast to the imbricate fault slices which compose the major part of the zone, originated from the autochthonous plate and was dragged upward and westward along the fault plane (pls. 3, 4). The Lee in this fault slice ranges from a few feet to nearly its entire thickness, and the top of the beds is to the northwest rather than to the southeast as in the imbricate fault slices. Lithologically, this northwesternmost fault slice is typical of the Lee and consists mostly of sandstone and conglomeratic sandstone beds which are highly sheared and well cemented with silica, so that in some pieces, fractures extend through sand grains and quartz pebbles. Because of this unusually intense shearing and cementation, these rocks commonly weather into white angular blocks instead of the friable iron oxide-stained sand that is typical of the weathered formation elsewhere. This deformed Lee is also evident to the northeast where the formation occurs sporadically in fault slices along the trace of the Pine Mountain fault in the eastern part of the Jellico West quadrangle (pl. 2).

Imbricate faulting at the southwest end of the Pine Mountain fault zone may explain, at least in part, the differential movement of the overthrust sheet. The greater movement there probably resulted in the distribution of displacement along the imbricate faults. Decreasing movement northeastward along the Pine Mountain fault zone is likewise accompanied by a decrease in the number of imbricate faults. This relation is noteworthy because a similar pattern of faulting occurred in the Cumberland Gap area on the diagonally opposite or northeast corner of a block of the Cumberland overthrust sheet that is bounded by the Jacksboro, Pine Mountain, Rocky Face, and Doublings faults. In the Cumberland Gap area the Rocky Face fault, like the Jacksboro fault, is a strike-slip fault with rocks on the northeast side displaced to the northwest. The Rocky Face fault also intersects a zone of imbricate faults at the trace of the Doublings fault which, like the Pine Mountain fault zone, also converges to a single fault plane. Movement along the Jacksboro, Pine Mountain, Rocky Face, and Doublings faults indicates that the part of the Cumberland overthrust sheet from the Elk

Valley area northeastward to the Rocky Face fault has rotated slightly in relation to the remainder of the overthrust sheet (Englund, 1961).

JACKSBORO FAULT ZONE

The Jacksboro fault zone borders the southwest side of the Cumberland overthrust sheet for about 18 miles and extends from the Pine Mountain fault zone southeastward beyond the southern edge of the Elk Valley area. Movement is largely strike slip and occurs along a high-angle to vertical fault zone, ½–1 mile wide, of intricately faulted and folded rocks. The southwest end of the overthrust sheet was displaced approximately 11 miles northwestward along the Jacksboro fault zone, which is the maximum displacement noted along the entire length of the Pine Mountain overthrust fault.

The trace of the Jacksboro fault zone is strikingly delineated by upwarped conglomeratic Lee sandstone beds in Chestnut Ridge and Fork Mountain at the southwest edge of the overthrust sheet. Cove Creek flows parallel to these ridges in a deep narrow gorge that is incised into the most highly fractured rocks of the fault zone. In the fault zone the upwarped rocks of the overthrust sheet are folded into two narrow anticlines and an intervening syncline which strike approximately at right angles to the Middlesboro syncline. Of these, the principal fold underlies Chestnut Ridge and Fork Mountain and is herein designated the Chestnut anticline. Its southwest limb is displaced as much as 100 feet by a high-angle reverse fault. Southwest of the fault zone the rocks of the autochthonous plate are less intensely deformed, except for a block, about one-fourth mile wide at the mouth of Rector Branch, which has pivoted slightly on an axis at right angles to the fault plane.

The most intensely sheared and slickensided rocks of the fault zone occur adjacent to the principal fault plane of strike-slip movement, located at the southwest edge of the fault zone. Locally, breccia and fault gouge are exposed along the fault, and conglomeratic Lee sandstone at the fault plane is tightly cemented similar to the Lee in the fault slice on the northwest edge of the Pine Mountain fault zone. In addition to the mapped structural features along the Jacksboro fault, the zone includes numerous faults and folds that are too small and closely spaced to be shown conveniently at the map scale.

Although strike-slip movement along the Jacksboro fault involves stratigraphically equivalent rocks, lateral changes in the thickness and other physical features of the formations are sufficient to determine the approximate amount of strike-slip movement. The measurement of movement based on differences in thickness can be demonstrated by referring to an interval between two readily identified beds in the overthrust sheet, namely the top of the Chattanooga Shale and the base of the Kent coal bed. As shown in figure 19, this interval in drill holes and outcrop sections thickens southeastward parallel to the direction of movement. Therefore strike-slip movement to the northwest has placed a section of rocks in the overthrust sheet opposite a thinner counterpart across the Jacksboro fault. This difference in thickness indicates approximately 11 miles of movement. A similar amount of movement is shown by lateral variations in the character of Pennsylvanian rocks that crop out at the surface. In the Middlesboro syncline at the southwest end of the overthrust sheet, the Kent coal bed is commonly more than 3 feet thick, whereas just across the Jacksboro fault zone, core drilling indicated that the Kent coal bed is less than 1 foot thick. However, approximately 11 miles southeastward in the autochthonous plate, this coal bed, known locally as the Coal Creek coal, is similar in thickness and character to the Kent coal bed in the overthrust sheet.

The northwestward movement of a relatively thick section of rocks in the overthrust sheet along a bedding-plane fault caused Pennsylvanian rocks at the surface, excluding those in the locally disturbed fault zones, to be as much as 500 feet higher than their correlatives on the opposite side of the Jacksboro fault zone. This relationship was previously attributed to vertical displacement (Luther, 1959, p. 33), but because the overthrust fault is a bedding-plane fault, there is no significant duplication of beds to account for this postulated uplift. Thus, the accumulated increase in the thickness of all Paleozoic formations above the overthrust fault, as shown in cross section *B–B′*, plate 3, is responsible for beds being higher in the overthrust sheet.

Previous estimates of the total amount of strike-slip movement along the Jacksboro fault zone range from about 9 miles (Miller and Brosgé, 1954, p. 8) to 10 miles (Wentworth, 1921). These amounts are of about the same magnitude as the 11 miles of movement calculated in the present study. However, the reliability of the early estimates of the amount of movement is questionable because it is based on the displacement of upturned beds, such as the Chattanooga Shale, on opposite sides of the Jacksboro fault zone. To be indicative of the amount of strike-slip movement, these steeply dipping beds, which crop out on Cumberland Mountain in the overthrust sheet and on Walden Ridge in the autochthonous plate, must have been originally on the northwest flank of the same fold before movement along the Jacksboro fault zone. Contrary to this assumption,

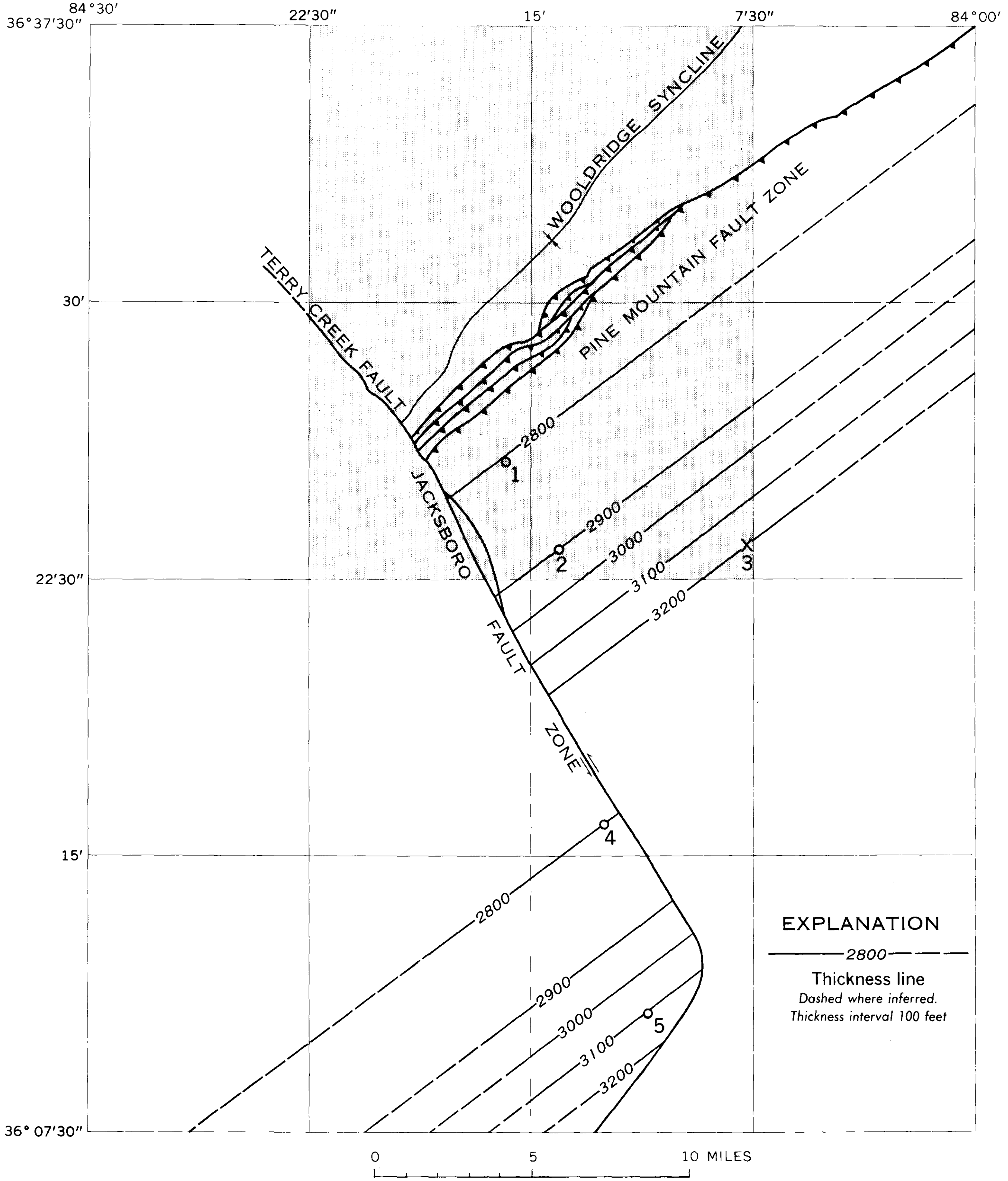


FIGURE 19.—Thickness map of rocks between the top of the Chattanooga Shale and the Kent coal bed showing 11 miles of strike-slip movement along the Jacksboro fault zone. 1, T. E. B. Siler Oil & Gas Co., Meredith 1 test hole; 2, Columbian Carbon Co., East Tennessee Iron & Coal Co. 2 test hole; 3, Outcrop section at Big Creek Gap; 4, W. F. Lacy, Lindsey Land Co. 1 test hole; 5, David Greenup, et al., Coal Creek Mining & Manufacturing Co. 1 test hole. Elk Valley area shaded.

however, is the structural interpretation advanced by Rich (1934, p. 1589) and substantiated by subsequent workers (Miller and Brosgé, 1954, pl. 7) that folds in the overthrust sheet attained their present amplitude after the initial movement of the overthrust sheet. Therefore, the apparent displacement in the offset of the outcrop belt is not only a function of strike-slip movement but also of the amplitude and location of these folds.

TERRY CREEK FAULT

Northwestward from Elk Gap in the Pioneer quadrangle, Glenn (1925, p. 137) recognized a line of slight crushing and faulting which he referred to as a dying-out phase of the Jacksboro fault. Along this trend of deformed strata, recent detailed geologic mapping has delineated the high-angle Terry Creek fault which has as much as 200 feet of vertical displacement (Englund, 1957). The trace of the fault strikes N. 40° W. from the junction of the Pine Mountain and Jacksboro fault zones for a distance of at least 5 miles. Along Terry Creek in the central part of the Pioneer quadrangle, beds on the southwest side of the fault dip steeply into the fault plane, whereas beds on the upthrown side to the northeast are relatively flat lying. From Terry Creek the trace of the fault passes through Marcum Gap and extends across the Marcum Creek drainage where beds on the northeast side of the fault dip as much as 30° to the southwest, and beds on the upthrown side to the southwest are relatively flat lying. Beyond Marcum Creek the fault displaces beds in Chimney Mountain and then crosses Smith Creek in the northwest corner of the quadrangle where the fault plane includes several inches of gouge and is nearly vertical in a stream-cut exposure. Elsewhere along the fault, exposures are scarce, particularly of the fractured nonresistant beds adjacent to the fault plane. The most prominent rocks that manifest displacement by the fault are massive sandstones, such as the Pioneer Sandstone Member of the Mingo Formation, which can be traced nearly to the fault.

The development of the Terry Creek fault appears to be genetically related to the Jacksboro fault. Stresses that produced the initial rupture of the Jacksboro fault may have been transmitted northwestward, and subsequent thrusting may have caused a slight forward shift of rocks in front of the overthrust sheet. However, significant strike-slip movement is not evident northwest of the Cumberland overthrust sheet, so that vertical displacement is the major apparent component of movement along the Terry Creek fault. In contrast, the Jacksboro fault is a cross fault that is associated with 11 miles of strike-slip movement at the southwest edge of the Cumberland overthrust sheet. The northwestward change in the movement along the Terry Creek fault from upthrown on the northeast side to upthrown on the southwest side appears to be the result of differential warping accompanied by local collapse of beds along the fault.

SMALL FAULTS

Numerous small faults in the Elk Valley area are associated with overthrusting. Most of these small faults are in or adjacent to the Pine Mountain and Jacksboro fault zones and trend parallel to the principal fault planes. Locally along the Pine Mountain fault zone, thrust faults were offset by minor transverse faults.

A fault of probable regional significance occurs in the lower part of the Chattanooga Shale in the southeast corner of the Ivydell quadrangle. It is virtually a bedding-plane fault that parallels the southeast slope of Cumberland Mountain and may be an extension of the Doublings thrust fault, which is more evident where it crosscuts younger formations about 24 miles to the northeast (Englund, 1964a). In this outcrop belt the Chattanooga is largely concealed, but the position of the fault plane is indicated by slickensides and by local contortion of the underlying beds.

The Blue Gem and Jellico coal beds in the southwest corner of the Jellico West quadrangle are displaced as much as 50 feet by a small thrust fault. The fault strikes northeastward across Pruitt Hollow and Barley Branch and is parallel to the Pine Mountain fault zone. After crosscutting several hundred feet of strata, the fault passes northwestward into an obscure bedding-plane fault.

Rocks of the autochthonous plate are also displaced by a thrust fault south of Newcomb in the central part of the Jellico West quadrangle. The fault plane dips 30° to the southwest and is exposed in a strip mine where it displaces the Swamp Angel coal bed approximately 9 feet.

CUMBERLAND OVERTHRUST SHEET

The dominant structural feature of the Cumberland overthrust sheet in the Elk Valley area is the broad flat-bottomed Middlesboro syncline. Within the trough, which is about 6 miles wide, structure contour lines show that coal-bearing rocks of the Breathitt Group are warped into gentle northwestward-trending flexures (pls. 2–4). Dips are generally less than 1° but increase to as much as 5° toward the fringes of the trough area. Because of the transverse trend of these minor folds, an axial line is not well delineated in the syncline.

The limbs of the Middlesboro syncline are outlined by Cumberland and Pine Mountains on the southeast and northwest, respectively. Beds on the southeast limb are nearly vertical in the southeast corner of the Ivydell quadrangle, and the most resistant of these beds, conglomeratic sandstone of the Lee Formation, composes the backbone of Cumberland Mountain. As mentioned in the preceding discussion of the Pine Mountain fault zone, the location of the southeast limb of the Middlesboro syncline indicates the position where underlying beds of the overthrust sheet are crosscut.

The northwest limb of the Middlesboro syncline attains a maximum dip of about 40° near the crest of Pine Mountain, but dips of 20° or less are typical and result in a wide belt of hogbacks of resistant Lee sandstones on the southeast or back slope of the mountain (pls. 2–4). The northeasterly trend of this limb, across the central part of the Elk Valley area, is slightly warped around a bulge in the underlying autochthonous plate at the west edge of the Ivydell quadrangle. This warp is also evident in the deflection of structure contour lines at the northwest edge of the syncline. In general, however, beds on the northwest limb dip parallel to the fault at the base of the overthurst sheet (pl. 4, cross section *A–A′*).

AREA NORTHWEST OF THE PINE MOUNTAIN FAULT ZONE

Directly northwest of the Pine Mountain fault zone, most of the beds dip steeply northwestward as a result of drag associated with the movement of the Cumberland overthrust sheet. Exposed strata in strip and underground mines indicate that the deformation of these rocks is variable in character and intensity. The least disturbed rocks are warped into gentle folds that are parallel to the fault and have less than 10 feet of structural relief. Within about 100 feet of the fault plane, the gentle folds are superseded by an abrupt inclination of beds upward to the fault plane, and locally, beds near the fault are overturned. This relatively simple type of drag is prevalent in the eastern part of the Jellico West quadrangle, where movement of the overthrust sheet is virtually on one fault plane that crosscuts the autochthonous plate at an angle of about 30°–40°.

In contrast, in areas where the fault plane is nearly horizontal, the deformation is more intense, and in places the autochthonous plate shows tight overturned folds, small thrust faults that merge upward with the Pine Mountain overthrust fault, and chevron folds on the limbs of larger folds (fig. 20).

Drag on rocks below the Pine Mountain fault is also responsible for local discordance in the interval between coal beds. Near Sand Gap in the northeast corner of

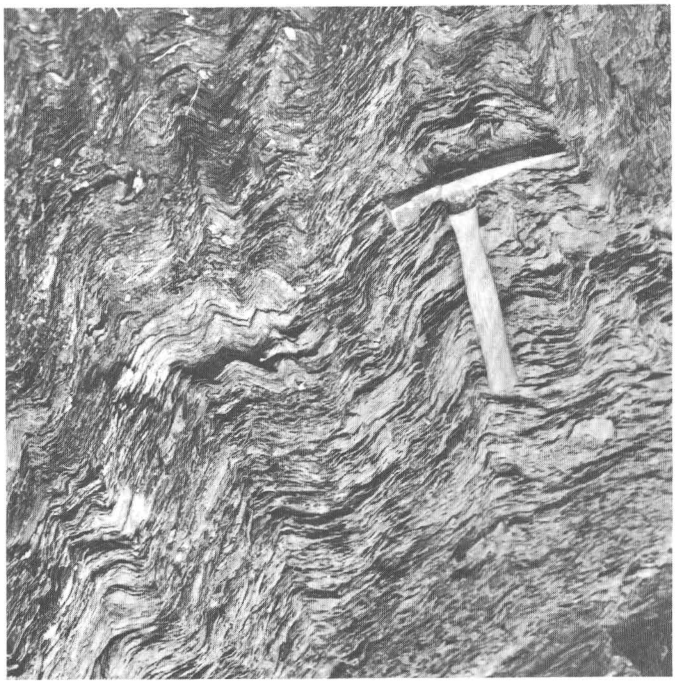


FIGURE 20.—Chevron folds in shale of the Hance Formation below the Pine Mountain overthrust fault in the gap on the northeast end of Hells Point Ridge.

the Pioneer quadrangle, the Blue Gem coal bed is relatively flat lying at about 200 feet below the fault plane which underlies klippen on Hells Point Ridge east of the gap. West of the gap the strata in which the Jellico and Lick Fork coal beds occur dip as much as 40° as a result of drag. As the underlying Blue Gem coal bed is relatively flat lying, the vertical distance up to the Jellico and Lick Fork coal beds is abnormally great locally.

Northwest of the narrow belt of deformed rocks adjacent to the Pine Mountain fault zone, the beds are relatively flat lying but continue to dip northwestward about 1° or less into a shallow flexure, herein named the Wooldridge syncline, that extends northeastward from the Terry Creek fault. The axis of the syncline strikes N. 43° E. and diverges slightly northeastward from the trace of the Pine Mountain fault zone (fig. 19) which conforms with the slight clockwise rotation of the overthrust sheet.

On the northwest, the Wooldridge syncline is bordered by a low anticline that plunges northeastward from a dome in the north-central part of the Pioneer quadrangle (pl. 3). The northwestern limb of the anticline also dips into a shallow syncline; as the intervening anticline plunges to the northeast, the two synclines converge. Northwest of these flexures, which extend across parts of the Pioneer, Ketchen, and Jellico West quadrangles, the beds rise about 40 feet per mile and reflect the regional dip off the southeast side of the Cincinnati arch.

AREA SOUTHWEST OF THE JACKSBORO AND TERRY CREEK FAULTS

In the southwestern part of the Elk Valley area the movement of the Cumberland overthrust sheet has affected the structure of a narrow belt of strata, as much as one-half mile wide, adjacent to the Jacksboro and Terry Creek faults. The beds along the Jacksboro fault are locally crumpled and faulted, but the most prevalent trend is a southwestward dip of as much as 60° away from the fault. As there is no indication of overthrusting along the Jacksboro fault, this inclination of strata is most likely associated with the wedging action of the overthrust sheet against the autochthonous plate. In contrast, northwestward, beyond the wedging effect of the overthrust sheet, the beds dip as much as 30° northeastward into the Terry Creek fault. This wedging action against the autochthonous plate was accentuated by the slight clockwise rotation of the overthrust sheet.

Structure contour lines show that beds are relatively flat lying southwest of the disturbed rocks adjacent to the Jacksboro and Terry Creek faults. A north-trending syncline in the south-central part of the Pioneer quadrangle is the dominant structural feature, and beds on its limbs dip about 40 feet per mile.

STRUCTURAL DEVELOPMENT OF THE ELK VALLEY AREA

At the end of Paleozoic sedimentation, a southeastward-thickening wedge of sediments extended from the Cincinnati arch southeastward through the Elk Valley area and into the trough of the Appalachian geosyncline. During the Appalachian orogeny, mountain-building stresses were projected northwestward into the geosyncline with sufficient intensity to affect rocks in the Elk Valley area on the northwest flank of the geosyncline. Consequently, the attitude of the bedrock in the Elk Valley area reflects both the regional downwarping of the Appalachian geosyncline during deposition and structural deformation associated with post-depositional thrust faulting. Because of the irregular projection of stresses across the geosyncline, beds in the area northeast of the Jacksboro fault were subjected to greater stresses and consequently were warped into low folds. The rocks that were slipping gradually northwestward then ruptured along the Jacksboro fault and left rocks to the southwest relatively undisturbed.

Crustal shortening associated with the folding also caused disengagement at the base of the northwestward-moving sheet. Initially, the thrust sheet probably moved on bedding-plane faults which rose gradually to the surface by crosscutting competent beds at anticlinal flexures. The occurrence of rootless anticlines of Lee sandstone beds in the Pine Mountain fault zone in the Jellico West quadrangle suggests that folding preceded faulting and that the roots of these folds may be present to the southeast in the autochthonous plate (pl. 2, cross section *A–A′*). In response to less resistance upward, the fault crosscut to the surface from an anticlinal flexure. However, sufficient resistance was encountered by the fault, possibly because of steepening of the fault plane, to inhibit movement on a single fault plane, and imbricate faults developed.

Deformation of the overthrust sheet has also occurred at the southwest edge of the overthrust sheet as a result of secondary compressive stresses directed toward the southwest. The overthrust sheet tapers toward the northwest and therefore is shorter along its northwest edge than along its southeast edge. This is shown, in part, by the 7° divergence between the Jacksboro cross fault and the direction of movement of the overthrust sheet (fig. 21). Northwestward movement has wedged the overthrust sheet into an increasingly narrower space between the bounding cross faults. This wedging action, together with the slight clockwise pivotal movement of the overthrust sheet, has resulted in a secondary compressive stress toward the southwest that has folded the adjacent beds into two anticlines parallel to the Jacksboro fault zone. Lateral shortening of the overthrust sheet was also accommodated by several faults parallel to the Jacksboro fault.

The wedging action of the overthrust sheet against rocks southwest of the Jacksboro fault may also be responsible for the tensional stresses that contributed to rupture along the Terry Creek fault. Unlike beds along the Jacksboro fault, which are upwarped as a result of compressive stress, the beds adjacent to the Terry Creek fault are crumpled or folded downward into the fault plane which was probably accommodated by the movement of beds away from the fault plane because of the tensional stresses.

Structural features in the Elk Valley area indicate that deformation progressed from southeast to northwest and included concurrent faulting and folding on the periphery of the Cumberland overthrust sheet. In general, structural features seem to have developed in the following order:

1. Rupturing along the Jacksboro fault in association with slight northwestward movement of rocks on the northeast side of the fault.

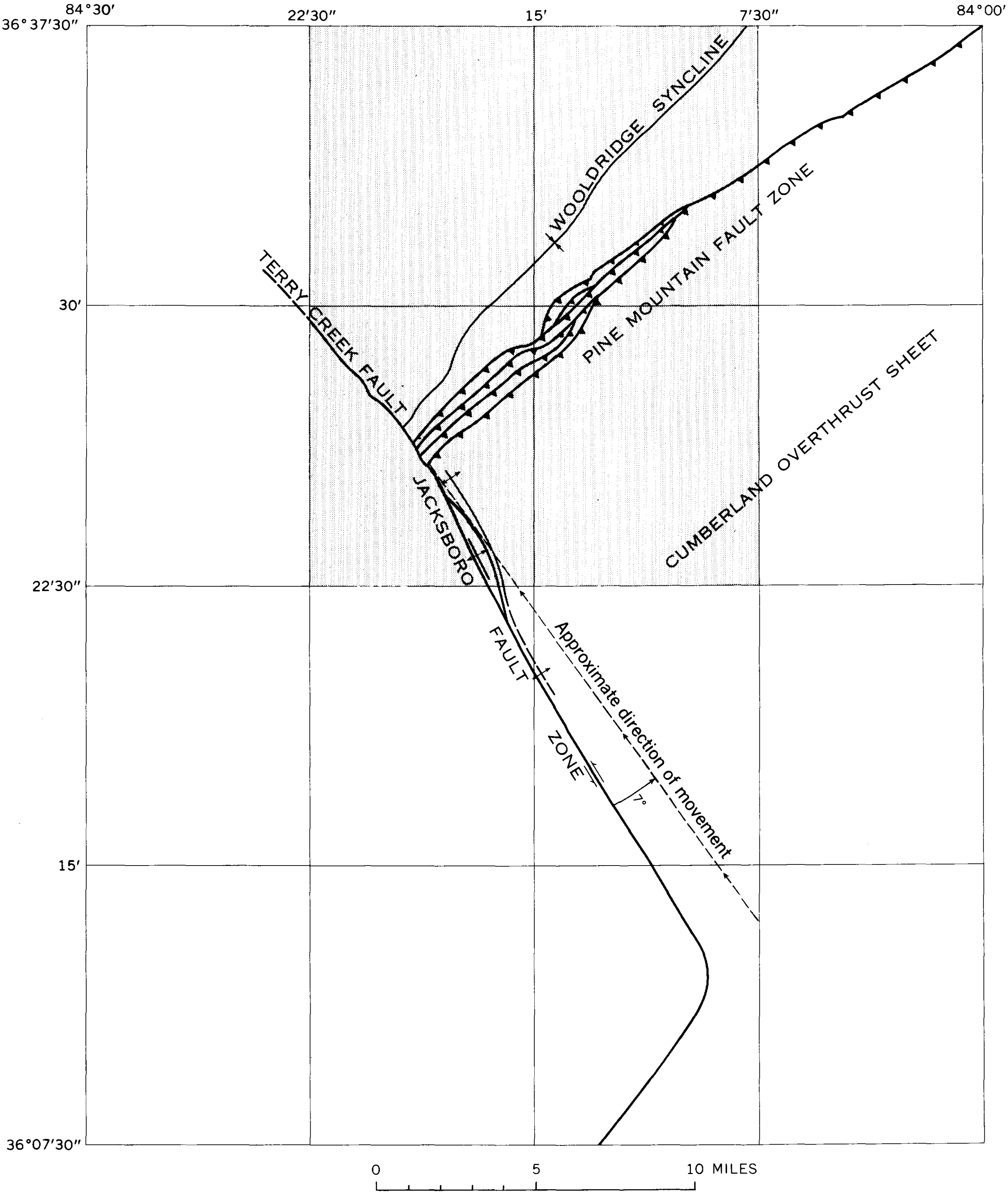


FIGURE 21.—Map showing a slight divergence between the direction of movement of the Cumberland overthrust sheet and the Jacksboro fault. Elk Valley area shaded.

2. Disengagement along the Pine Mountain fault at the base of the Cumberland overthrust sheet, slight warping of the overthrust sheet, and folding near the trace of the Pine Mountain fault zone.
3. Crosscutting of the Pine Mountain fault to the surface along imbricate faults from southeast to northwest across the Pine Mountain fault zone, a relation indicated by the termination of successive imbricate faults at preexisting faults to the southeast.
4. Continuing northwestward movement of the Pine Mountain fault together with slight clockwise rotation of the overthrust sheet, wedging along the Jacksboro fault, and faulting and folding in the Jacksboro fault zone.
5. Rupturing and subsequent displacement of rocks along the Terry Creek fault as a result of the wedging of the overthrust sheet along the Jacksboro fault.

ECONOMIC GEOLOGY

COAL

HISTORY OF MINING

Coal mining flourished in much of eastern Kentucky and Tennessee before utilization of the coal in the Elk Valley area. The first rail facilities were constructed in the early 1880's, and from the main line along Elk Creek, spurs were extended up tributary valleys to serve newly opened mines in the Jellico and Blue Gem coal beds. Early mines in the vicinity of Newcomb and Jellico were opened by the Wooldridge Jellico Coal Co. in 1882, the Standard Co. in 1883, and the Falls Branch Coal Co. in 1891 (Glenn, 1925, p. 95). During this period the Proctor Coal Co. and the Kensee Coal Co. operated mines in the Jellico coal bed northwest of Jellico in Kentucky. In the late 1880's, mining followed an extension of the railroad southward into the Pioneer quadrangle, and the development of the Lower and Upper Pioneer coal beds at Poteet Gap was initiated. In 1904, rail lines were constructed northwest of La Follette, and several mines were opened in the Rex, Kent, Rich Mountain, and Jordan coal beds (Glenn, 1925, p. 95).

The expansion of underground mining in the Elk Valley area continued until the 1920's when the bulk of high-quality readily accessible coal was under development. In the following years the large railroad mines were largely depleted and subsequently abandoned. During this period of declining underground mining, the only railroad mine with significant output was opened at Royal Blue in the southwest corner of the Ivydell quadrangle. It operated from about 1947 to 1953 in the Kent coal bed. In recent years underground mining has been limited to numerous small truck mines.

Large-scale strip mining began in the early 1940's and has operated intermittently in most parts of the Elk Valley area. Extensive areas of the Swamp Angel coal have been depleted in the bottom land along Elk Fork Creek (pl. 2), and several other beds have been contour strip mined on hill slopes. Locally, these operations are accompanied by auger mining.

RANK AND QUALITY OF COAL

Coal in the Elk Valley area consists mostly of common banded varieties of high-volatile A bituminous rank. It ranges from dull to bright attritus and is interlaminated with sparse to moderate amounts of thin to thick vitrain bands. The dull or splint coals are hard and blocky, whereas the bright coals tend to be fragile and crumble into finer fractions. Of exceptional quality are the brightly banded coals of moderately dull and bright attritus which block well in mining. Cannel coal occurs locally as pockets or thin partings in the banded coal and is moderately dull to bright, nonbanded, and blocks with a concoidal fracture.

Partings in the coal, shown graphically together with the thickness of the coal bed (pl. 8), consist of shale, underclay, and impure coal. Discontinuous laminae of powdery fusain are common locally. The impure coal is either hard and blocky or soft and flaky with shale laminae and is known to miners as bone and rash, respectively. Other visible impurities in the coal include pyrite in finely disseminated particles or in nodules as much as several inches in diameter and erratic boulders of metamorphic rock as much as 1 foot in diameter.

The analyses of channel samples collected from the principal coal beds during the fieldwork for this report are given in table 1. These samples were collected by the author and submitted to the U.S. Bureau of Mines for analysis. Also included are analyses of mine samples reported by the U.S. Bureau of Mines. As shown by its composition and physical characteristics, coal in the area is of good quality and is typical of bituminous coal in the south-central part of the Appalachian coal field. On an as-received basis, the heating value ranges from 12,980 to 14,010 Btu; the ash, from 1.9 to 10.3 percent; the sulfur, from 0.6 to 4.5 percent; and the moisture, from 2.3 to 5.2 percent. Some of these samples are from strip mines where weathering may have increased the ash content slightly and decreased the heating value, but all are of essentially fresh coal. Weathering along the coal outcrop is variable, and its extent is dependent on several factors, including steepness of the

TABLE 1.—*Analyses of coal in the Elk Valley area, Tennessee and Kentucky*

[Channel samples by U.S. Geol. Survey except as indicated by footnotes. Analyses by U.S. Bur. Mines. Rank of all samples is high-volatile A bituminous. Condition of sample: A, as received; B, moisture and ash free]

Coal bed	Quadrangle	Map locality	U.S. Bureau of Mines laboratory No.	Condition	Proximate analyses (percent)				Ultimate analyses (percent)					Heat value (Btu)	Free swelling index	Ash softening temperature °F
					Moisture	Volatile matter	Fixed carbon	Ash	Sulfur	Hydrogen	Carbon	Nitrogen	Oxygen			
Big Wheel	Ketchen	2	F-60397	A	5.2	35.8	55.5	3.5	0.7	5.5	76.4	1.5	12.4	13,550	2	2,750
				B	----	39.2	60.8	----	.7	5.4	83.7	1.7	8.5	14,830		
Braden Mountain	do	7	F-60398	A	3.6	38.4	54.5	3.5	.8	5.6	77.4	1.7	11.0	13,790	4	2,480
				B	----	41.4	58.6	----	.9	5.6	83.4	1.8	8.3	14,850		
Do	Jellico West	95	F-29218	A	4.1	37.4	55.2	3.3	.7	5.5	77.2	1.7	11.6	13,790	4	2,470
				B	----	40.4	59.6	----	.8	5.5	83.4	1.8	8.5	14,900		
Do	Pioneer	191	E-45663	A	3.5	38.2	52.0	6.3	1.0	5.4	74.2	1.7	11.4	13,340	3.5	2,780
				B	----	42.3	57.7	----	1.1	5.5	82.2	1.9	9.3	14,780		
Big Mary	Ketchen	13	F-84588	A	3.5	37.0	51.1	8.4	1.0	5.4	72.6	1.8	10.8	13,030	4.5	2,910+
				B	----	42.0	58.0	----	1.2	5.6	82.4	2.0	8.8	14,800		
Do	do	15	F-29219	A	2.3	39.1	48.3	10.3	2.3	5.3	71.9	1.6	8.6	12,980	3.5	2,730
				B	----	44.8	55.2	----	2.7	5.7	82.2	1.8	7.6	14,850		
Upper Pioneer	Jellico West	107	F-29221	A	2.3	37.8	49.8	10.1	3.6	5.3	71.8	1.7	7.5	13,100	4	2,230
				B	----	43.2	56.8	----	4.1	5.7	82.1	1.9	6.2	14,970		
Do	do	Near 104	F-84587	A	2.8	39.0	52.8	5.4	.6	5.5	76.5	1.8	10.2	13,710	3.5	2,910+
				B	----	42.5	57.5	----	.7	5.7	83.4	2.0	8.2	14,940		
Jordan	Ivydell	277	E-45661	A	4.2	36.8	56.7	2.3	.7	5.6	77.2	1.9	12.3	13,820	4	2,910+
				B	----	39.3	60.7	----	.7	5.4	82.6	2.1	9.2	14,780		
Lick Fork	Jellico West	114	F-29220	A	2.5	37.5	52.7	7.3	4.5	5.1	73.7	1.8	7.6	13,320	5	2,220
				B	----	41.5	58.5	----	5.0	5.4	81.7	2.0	5.9	14,760		
Do	Pioneer	228	(1)	----	2.7	38.7	56.2	5.1	2.5	------	----	----	----	14,120	----	-------
Jellico	Jellico West	124	F-44287	A	3.0	39.0	55.9	2.1	.8	5.7	78.9	2.0	10.5	14,010	4.5	2,500
				B	----	41.1	58.9	----	.8	5.7	83.2	2.1	8.2	14,770		
Do	do	126	F-32501	A	4.3	37.7	56.1	1.9	.9	5.7	77.2	1.9	12.4	13,760	2	2,500
				B	----	40.1	59.9	----	1.0	5.5	82.3	2.0	9.2	14,660		

TABLE 1.—*Analyses of coal in the Elk Valley area, Tennessee and Kentucky*—Continued

Coal bed	Quadrangle	Map locality	U.S. Bureau of Mines laboratory No.	Condition	Proximate analyses (percent): Moisture	Volatile matter	Fixed carbon	Ash	Ultimate analyses (percent): Sulfur	Hydrogen	Carbon	Nitrogen	Oxygen	Heat value (Btu)	Free swelling index	Ash softening temperature °F
Rich Mountain	Ivydell	293	E-45662	A	3. 3	39. 2	54. 4	3. 1	0. 8	5. 8	77. 7	1. 9	10. 7	14, 010	4	2, 480
				B	----	41. 9	58. 1	----	. 9	5. 8	83. 0	2. 0	8. 3	14, 960		
Swamp Angel	Jellico West	175	F-26665	A	3. 1	38. 5	51. 1	7. 3	1. 9	5. 5	73. 0	1. 8	10. 5	13, 300	4	2, 130
				B	----	42. 9	57. 1	----	2. 2	5. 7	81. 4	2. 0	8. 7	14, 830		
Do	do	178	F-26663	A	3. 2	38. 4	51. 8	6. 6	2. 6	5. 4	73. 9	1. 7	9. 8	13, 460	4	2, 100
				B	----	42. 6	57. 4	----	2. 9	5. 6	81. 9	1. 9	7. 7	14, 930		
Do	do	176	F-26664	A	2. 8	40. 2	50. 8	6. 2	2. 4	5. 5	73. 9	1. 7	10. 3	13, 450	3. 5	2, 140
				B	----	44. 1	55. 9	----	2. 6	5. 7	81. 1	1. 9	8. 7	14, 780		
Do	Ketchen	83	(2)	----	2. 3	38. 2	54. 0	5. 5	1. 2	------	----	----	----	14, 310	----	-------
Do	Jellico West	Near 177	(1)	----	4. 0	38. 7	54. 1	7. 2	2. 0	------	----	----	----	13, 680	----	-------
Murray	Ivydell	333	(1)	----	2. 4	41. 6	52. 3	6. 1	2. 8	------	----	----	----	13, 940	----	-------
Rex	Pioneer	274	(1)	----	2. 6	40. 3	54. 5	5. 2	1. 1	------	----	----	----	14, 300	----	-------

[1] Williams, Gibbs, Crentz, Miller, and Reynolds, 1956, p. 45. [2] Williams, Gibbs, Crentz, and Miller 1956, p. 25.

slope, composition of the roof rock, character of the coal, and fractures and joints in the coal and overlying rocks. Slight deterioration in the quality of strip coal is also related to the amount of contamination induced by mining.

Preparation and carbonization studies show that several coal beds in the Elk Valley area are suitable for metallurgic use (Williams, Gibbs, Crentz, and Miller, 1956; Williams, Gibbs, Crentz, Miller, and Reynolds. 1956).

DESCRIPTION OF COAL BEDS

Coal in the Elk Valley area is of Carboniferous age and occurs in the Pennington, Lee, Hance, Mingo, Catron, and Hignite Formations in at least 36 beds, of which 17 beds are of commercial importance. Throughout most of the report area, coal-bearing rocks are at the surface, and the distribution of individual beds ranges from those with less than 1 square mile of area to regionally widespread beds that extend into other parts of the Appalachian coal field. The areal distribution, thicknesses, and mined areas of three of the principal beds are shown on plates 9–11. Additional coal-bed thicknesses at mines, prospects, and core holes are shown on plate 8. Coal beds range from less than 1 inch to as much as 6 feet in thickness and compose 1–2 percent of the total thickness of the Breathitt Group, the principal coal-bearing sequence.

COAL BEDS OF THE PENNINGTON FORMATION

Regionally, coal occurs sparingly in the Pennington Formation, and in the Elk Valley area it is limited to two thin beds. At the west side of Big Creek Gap in the Ivydell quadrangle, the uppermost part of the formation contains a highly sheared coal bed about 1 foot thick. At this approximate stratigraphic position a 26-inch coal bed was previously reported in this vicinity (Ashley and Glenn, 1906, p. 36). A thin coal bed in the lower part of the upper member of the Pennington Formation was disclosed by a prospect on the east side of the gap. On the basis of available information, the coal beds of the Pennington Formation are economically unimportant because of their thinness and limited lateral extent.

COAL BEDS OF THE LEE FORMATION

The coal beds of the Lee Formation are entirely in the subsurface in the Elk Valley area, except for a few exposures in the outcrop belts along Pine and Cumberland Mountains. Outcrops of the formation indicate that coal occurs in five beds of the Middlesboro and Hensley Members, but the sheared condition of the coal and the moderate to steep inclination of the beds have discouraged mining. Development of the beds is confined to a few exploratory adits which may have provided a minor amount of coal for local household use. Three coal beds occur, together with underclay and shale, between massive conglomeratic sandstone beds in the middle and upper parts of the Middlesboro Member. At Big Creek Gap these coals range in thickness from 7 to 25 inches, and on the eastern slope of Pine Mountain a 34-inch coal was reported by Glenn (1925, p. 107). The Hensley Member contains two thin coal beds, near the base and top of the member, which are a few inches thick in outcrop exposures.

Only the uppermost beds of the Lee Formation have been penetrated by core drilling, but coal of undeterminable thickness is indicated in the subsurface by drill cuttings from oil and gas test holes. Available data suggest that coal beds of the Lee Formation may be of unpredictable lateral extent and too thin to contain commercially important reserves. However, future core drilling may reveal small areas of minable coal.

COAL BEDS OF THE HANCE FORMATION

The Hance Formation in the Elk Valley area contains 12 coal beds, of which 6 are thick enough to contain reserves. Five of the beds have been mined commercially, and most of the others have been mined on a small scale for local domestic use. As shown on plate 5, the distribution of the lower part of the Hance Formation is limited northwestward by lateral gradation and intertonguing with upper beds of the Lee Formation. Because of this facies change, coal beds below the Swamp Angel coal are of significant distribution and thickness only in the Middlesboro syncline, whereas the Swamp Angel coal and most of the overlying coal beds are widely distributed.

NAESE COAL BED

The Naese coal bed, at the base of the Hance Formation, crops out on the limbs of the Middlesboro syncline in a thin shale interval between the Naese and Yellow Creek Sandstone Members. Because of its negligible thickness, which ranges from a few inches to about 1 foot, the Naese coal bed does not contain any reserves; but it is persistent enough to be useful stratigraphically to mark the base of the Hance Formation in outcrop sections and drill cores. The undulating base of the massive Yellow Creek Sandstone Member may locally truncate the coal, but this relation was not evident along the outcrop.

REX COAL BED

The Rex coal is a persistent bed 100–130 feet above the base of the Hance Formation and within a few feet of the top of the Yellow Creek Sandstone Member. This description of the coal pertains only to the Middlesboro syncline, for in other parts of the Elk Valley area the bed is below drainage, and available data indicate that it is of insignificant thickness.

The Rex coal bed crops out just above drainage along Stinking, Ollis, and Titus Creeks to form a continuous outcrop line around the broad trough of the Middlesboro syncline. Only in and near the southeast corner of the Jellico West quadrangle is the outcrop sufficiently dissected to separate outlying areas of the bed on the limb of the syncline from the trough proper. Along the outcrop the bed dips as much as 12° toward the axis of the syncline, and because of this downdip relation, access by drift entry is generally unfavorable. To avoid pumping water from the working face of the coal as well as updip haulage of loaded coal cars, recent mining of the bed is concentrated in the dissected outcrop area of the Jellico West quadrangle. Development includes both underground and strip mines, which have depleted about 22 percent of the coal in this vicinity. Current operations consist of small truck mines that supply fuel for domestic heating and steam generation.

The only large development in the trough of the Middlesboro syncline was at the Rex mines, along the southeast edge of the Ivydell quadrangle. Nearly 3 square miles of the bed were exploited by these operations which include the Rex No. 2 mine, an inclined shaft at Kent Hollow, and the Rex Nos. 1, 3, 4, and 5 mines whose adits were in the adjacent La Follette quadrangle. Coal from these mines, which were abandoned before geologic mapping of the Ivydell quadrangle, was used for the production of coke. The Rex coal was also mined locally in the Jackboro fault zone.

In mined areas the Rex coal ranges mostly from 30 to 40 inches in thickness, excluding partings; beyond the mine workings, core drilling indicates from 28 to 33 inches of coal in the trough of the syncline. At a few localities along the outcrop, the coal decreases to 12 inches or less in thickness.

The Rex coal is brightly banded and locally includes one or two thin partings (pl. 8). In the southeast corner of the Jellico West quadrangle the bed generally includes at its base as much as 8 inches of flaky impure coal interbedded with medium-gray shale laminae. Analyses, on an as-received basis, of five samples from the Rex No. 1 mine show that the coal contains 2.7–3.7 percent ash and has a heating value of 13,830–14,100 Btu (Glenn, 1925, p. 201). The 5.2 percent ash reported for the bed in table 1 may reflect weathering or contamination at the outcrop. The roof rock of the Rex coal bed is mostly shale which is commonly black and carbonaceous in the basal 16 inches and medium gray in the upper part.

The total estimated original reserves for the Rex coal bed—122,010,000 tons—are located in the Middlesboro syncline. Of this total, about 8 percent has been mined or lost in mining.

SPLITSEAM COAL BED

The name Splitseam is used in this report for a thin persistent coal bed 75–120 feet above the Rex coal bed. On the basis of its stratigraphic position, it is correlated with the Splitseam coal bed of nearby Bell County, Ky. The bed is confined to the Middlesboro syncline where it ranges in thickness from about 6 to 16 inches. The Splitseam coal is sparsely prospected, and available measurements indicate that it is too thin to warrant the calculation of reserves. A coal of similar thickness occurs locally about 25 feet above the Splitseam coal bed.

MURRAY COAL BED

The Murray coal bed is commercially important locally in the Middlesboro syncline of the Elk Valley area. West of the Cumberland overthrust sheet the bed is in the subsurface, and information from a few core holes indicates that it is relatively thin. In the Middlesboro syncline the Murray coal bed crops out around the trough area and roughly parallels the outcrop of the Rex coal bed which is 240–270 feet lower stratigraphically. The Murray coal bed also crops out on the lower parts of Louse and Hickory Creeks where the Rex coal is beneath drainage. The principal occurrence of the Murray coal is in the northern part of the Ivydell quadrangle where it ranges in thickness from 25 to 52 inches along Stinking Creek and from 19 to 27 inches along Louse and Hickory Creeks. Mining is most intense along Stinking Creek from about 1 mile northeast of Jordan Hollow to Charlie Hollow. In this area, truck mines have extracted most of the coal within 500–1,000 feet of the outcrop, and a small amount of coal adjacent to the outcrop has also been strip mined. Development of the bed on Louse and Hickory Creeks is limited to a few small truck mines.

In the mined areas the Murray coal is generally unparted and consists predominantly of bright attritus with sparse thin to thick vitrain bands. Southwestward in the Middlesboro syncline the bed splits and thins to less than 1 foot thick in both drill core and exposed sections. Locally on Titus Creek in the southeast corner of the Pioneer quadrangle, the coal increases to as much as 30 inches in thickness and has been worked on a small scale for local use.

An analysis of a sample from one of several active truck mines along Stinking Creek indicates that the coal is moderate in ash and high in heating value (table 1). The coal is used for domestic fuel and steam generation.

Of noteworthy occurrence in the coal are smooth well-rounded boulders of quartzite and other metamorphosed sedimentary and igneous rocks which were seen in mine workings along Stinking Creek. Similar material was rarely found in other coal beds of the report area. The presence of these erratics in the Murray coal bed does not deter mining operations, but it is of geologic interest because of the lack of a local source area as well as the general absence of similar rocks in the stratigraphic column. Environmental conditions may have been temporarily conducive to the rafting of material to the locale of deposition during the inundation of the ancient coal swamp. Subsequently, the boulders settled into the partially compacted peat.

The Murray coal bed is consistently overlain by medium-gray to black carbonaceous shale which ranges in thickness from 3 to 30 feet.

About 90 percent of the total estimated reserves—38,361,000 tons—in the Murray coal bed is in the northern part of the Ivydell quadrangle. Mining has depleted about 6 percent of the total reserves.

MURRAY RIDER COAL BED

A thin coal bed, 40–75 feet above the Murray coal, is herein referred to as the Murray rider coal bed. Because the bed is generally less than 1 foot thick, it does not contain any significant reserves.

SWAMP ANGEL-KENT COAL BED

The Swamp Angel coal bed and its correlative in the Middlesboro syncline, the Kent coal bed, form the most widespread coal of minable thickness in the Elk Valley area (pl. 9). Outcrops of the Swamp Angel coal bed are confined to the northwestern parts of the Ketchen and Jellico West quadrangles where the coal is exposed just above drainage along Jellico Creek, Gum Fork, and the head of Hayes Creek. At these outcrops the thickness of the bed ranges mostly from 22 to 30 inches, excluding a discontinuous parting of impure coal, shale, or underclay. Southeastward from the outcrop area, the bed dips into the subsurface and underlies the remainder of the Elk Valley area that lies west of the Cumberland overthrust sheet. The bed is at depths of 20–40 feet below the broad valley bottom of Elk Creek in the east-central part of the Jellico West quadrangle and ranges in thickness from 28 to 34 inches in extensive strip-mine developments. Below the valley bottoms of the Pioneer quadrangle the coal is at depths of 100–200 feet, and available core data indicate that its thickness is as much as 28 inches.

Development of the Swamp Angel coal bed in the outcrop area consists of several truck mines, mostly along Gum Fork, in pockets of coal that average about 30 inches in thickness. Strip mines have also operated in this area in coal that averages about 22 inches in thickness, and much of the coal in a belt 75–150 feet wide adjacent to the outcrop line is depleted. Along Jellico Creek many shallow adits have provided fuel for local domestic use. In addition to the strip mining of the Swamp Angel coal bed along Elk Creek, coal was also slope mined on the northwest side of the valley at Newcomb.

In the Middlesboro syncline the Swamp Angel coal bed is known as the Kent coal and erroneously as the Jellico coal at a few mines. It crops out 170–220 feet above the Murray coal bed around the margin of the trough and extends along several reentrants into the central part of the syncline (pl. 9). The principal occurrence of the Kent coal is in the southwest corner of the Ivydell quadrangle where it averages about 40 inches in thickness in the vicinity of the abandoned Royal Blue mine. Northwestward along Titus Creek is the Pioneer quadrangle a pocket of coal about 36 inches thick was mined. From Kent Hollow in the Ivydell quadrangle, where the coal averages about 36 inches in thickness at several abandoned railroad mines, relatively thick coal extends northward into the Hickory Creek area where it is more than 50 inches thick, excluding one or two partings of shale or underclay. On the lower part of Hickory and Louse Creeks the coal is as much as 40 inches thick and has been truck and strip mined on a small scale. In the outcrop bordering Stinking Creek on the northwest side of the trough, the coal ranges in thickness from 15 to 25 inches.

The physical characteristics of the Swamp Angel–Kent coal bed are persistent throughout the Elk Valley area. The coal consists of dull to bright attritus with few vitrain bands. Moderately dull attritus predominates in much of the bed, so that mined coal tends to be hard and blocky. Discontinuous fusain laminae and visible pyrite are fairly common. Other partings are variable in composition, thickness, and extent, but are most prevalent in the Middlesboro syncline. In comparison with other commercially important coal beds in the Elk Valley area, the Swamp Angel–Kent coal is slightly higher in ash and sulfur and is somewhat lower in heating value. Samples of the bed from under alluvium (loc. 175), normal shale roof (loc. 176), and contorted shale roof below the eroded overthrust sheet (loc. 178) do not indicate any significant differences in analyses (table 1).

The Swamp Angel–Kent coal bed contains about 40 percent of the estimated coal reserves of the Elk Valley area. Of the total estimated original reserves of 400,317,000 tons, only about 1½ percent has been mined or lost in mining.

SWAMP ANGEL RIDER COAL BED

A thin widespread coal bed, 10–25 feet above the Swamp Angel coal and 10–60 feet above the Kent coal bed in the Middlesboro syncline, is herein referred to as the Swamp Angel rider coal bed. It increases in thickness southeastward, as indicated by maximum thicknesses of 12 inches in the Ketchen quadrangle, 15 inches in strip mines along Elk Creek, and 18 inches in the Middlesboro syncline. The coal commonly lacks partings and is of good quality; but because of its thinness, the bed is generally disregarded in the stripping of the underlying Swamp Angel coal bed. Because the Swamp Angel rider is of little economic importance, reserves are not included in this report.

DIXIE COAL BED

The Dixie coal bed occurs locally in the central part of the Jellico West quadrangle where it lies 110 feet above the Swamp Angel coal. The bed averages about 24 inches in thickness, excluding a thin shale or underclay parting, in a narrow belt that extends for about 2 miles northeastward across Old Standard Hollow and Crooked Creek. Away from this pocket of coal, the thickness abruptly decreases to less than 1 inch, and in other parts of the Elk Valley area an underclay with rootlets locally marks the stratigraphic position of the Dixie coal bed.

The coal consists predominantly of bright attritus that includes one or two discontinuous fusain laminae and a parting of underclay or shale as much as 4 inches thick. Several abandoned adits along Crooked Creek indicate small-scale mining of the coal for local household use. The estimated original reserves, 1,456,000 tons, are confined to the Jellico West quadrangle, and only a very small percentage has been depleted by mining.

BLACK WAX COAL BED

The Black Wax coal bed is unimportant commercially, but it marks a widespread coal horizon about 170–185 feet above the Swamp Angel coal bed and, in the Middlesboro syncline, 140–185 feet above the Kent coal bed. The thickness of the Black Wax coal is less than 14 inches at most outcrops, and reserves are limited to small areas in the Ketchen and Pioneer quadrangles where the coal is also thick enough to be worked for local use. In the Ketchen quadrangle the bed averages about 15 inches in thickness at the head of Rock Creek, and in the Pioneer quadrangle it is as much as 19 inches thick in the ridge between Ned and Douglas Branches. In the Middlesboro syncline the bed rarely exceeds 14 inches in thickness. The most common roof rock of the bed is medium- or dark-gray shale.

Although thin, the Black Wax coal is unparted, consists largely of bright attritus, and generally appears to be of good quality. The total estimated reserves for the Black Wax coal bed—6,418,000 tons—are in the 14- to 28-inch category.

BLACK WAX RIDER COAL BED

The Black Wax rider coal is a thin discontinuous bed 35–70 feet above the Black Wax coal bed. It is generally less than 1 foot thick, but is as much as 30 inches thick at a few abandoned adits along Smith Creek near the northwest edge of the Pioneer quadrangle. Medium- to dark-gray shale commonly overlies the coal. Reserve tonnages were not determined for this report, as areas of reserve thickness are of limited lateral extent.

BLUE GEM-RICH MOUNTAIN COAL BED

The Blue Gem coal bed is the thinnest of the commercially mined coals in the Elk Valley area. The bed is economically important because of its high quality and ease of access in the lower hill slopes.

West of the Cumberland overthrust sheet the name Blue Gem is applied to this bed which lies 240–300 feet above the Swamp Angel coal and 90–140 feet below the base of the Jellico coal, or top of the Hance Formation. The thickness of the Blue Gem coal is fairly uniform and ranges mostly from 18 to 24 inches. Extensive areas of the bed were developed in the vicinity of Jellico and Newcomb during the early period of underground mining (pl. 10). The adits of these operations, which have been largely abandoned for at least 30 years, were on railroad spurs in tributaries of Elk Creek. The mine sites were apparent during the field investigations only from their unusually large dump piles of shale and underclay that were extracted for the enlargement of haulageways. This initial development was followed by truck mine operations at widely scattered localities, and, in recent years, short sections of the outcrop have been strip mined. Current production is from several intermittently operated truck mines and from a few shallow adits that provide coal for local household use. The Blue Gem coal is commonly overlain by medium-gray shale which may include a basal bed 2–8 inches thick, of dark-gray to black carbonaceous shale. Locally, the roof rock consists of siltstone or sandstone.

In the Middlesboro syncline the Rich Mountain coal bed, a correlative of the Blue Gem, is 240–310 feet above the Kent coal and 110–155 feet below the Jellico coal. It crops out around the fringe of the trough area and to a lesser extent along reentrants in the central part of the syncline. Because of truncation at the base of an overlying sandstone, the coal is generally thin or absent. The thickest occurrence is between Kent Hollow and Barley Creek in the Ivydell quadrangle where the coal ranges in thickness from 25 to 34 inches (pl. 8, sections 291–294). This pocket of relatively thick coal has been truck mined intermittently. Other developments include several abandoned adits on the upper part of Meadow Branch in the southwest corner of the quadrangle. About 18 inches of coal at that locality was mined for local use. In addition to sandstone, medium-gray shale locally overlies the coal bed.

The Blue Gem-Rich Mountain coal bed is characteristically a high-quality brightly banded coal. Partings are uncommon except for 1–4 inches of impure coal or shale that occurs in the Rich Mountain coal. Analyses, on an as-received basis, of 23 samples (Glenn, 1925, p. 204–206) of the Blue Gem coal bed show the following range (in percent) in composition: moisture 3.5–5.7; volatile matter 36.7–39.8; fixed carbon 53.0–56.5; ash 1.6–3.9; sulfur .77–1.3. The calorific value (in Btu) ranges from 13,370 to 14,180. A recent analysis of the Rich Mountain coal (table 1) is approximately within this range.

The total estimated original reserves, 152,063,000 tons, in the Blue Gem-Rich Mountain coal bed are mostly in the 14- to 28-inch category. Of this total, about 6 percent is mined or lost in mining.

RICH MOUNTAIN RIDER COAL BED

A relatively thin discontinuous coal bed 25–65 feet above the Rich Mountain coal is herein referred to as the Rich Mountain rider. In the Middlesboro syncline the bed is generally less than 14 inches thick, but locally it is as much as 3 feet thick and characteristically includes several persistent partings of shale and underclay. West of the Cumberland overthrust sheet the bed is thinner and more sporadic in distribution. It lies 10–35 feet above the Blue Gem coal bed and attains a maximum thickness of 18 inches including a 2-inch shale parting. Reserves are not calculated for the Rich Mountain rider coal bed, as areas where the coal is more than 14 inches thick are of limited lateral extent.

COAL BEDS OF THE MINGO FORMATION

In comparison with the persistent and uniform character of coal beds in the middle and upper parts of the Hance Formation, those of the Mingo Formation exhibit similar lateral continuity but tend to be much more variable in thickness. Of the eight coal beds in the Mingo Formation, five beds contain significant reserves and have been mined. Most of the reserves are in the western part of the Elk Valley area, for only one coal bed of the Mingo Formation is commercially important in the Middlesboro syncline.

JELLICO COAL BED

The Jellico coal bed, at the base of the Mingo Formation, is the most intensely mined bed in the Elk Valley area. It is a high-quality coal that is readily accessible on the lower hill slopes throughout the area west of the Cumberland overthrust sheet. The principal occurrence of the bed as well as the bulk of mining is in the hills around the towns of Jellico and Newcomb (pl. 11), where the bed is mostly 36–40 inches thick, but locally is as much as 52 inches thick. Westward and southwestward from the area of thick coal in the Jellico West quadrangle, the Jellico coal thins gradually to 14 inches or less in the western part of the Ketchen quadrangle and the northern part of the Pioneer quadrangle. Beyond the area of thin coal, the bed increases in thickness and averages about 24 inches in a northwest-trending belt in the central part of the Pioneer quadrangle. The Jellico coal is also widespread in the Middlesboro syncline, but it rarely exceeds 14 inches in thickness.

Large railroad mines, which operated during the early period of underground mining, depleted extensive areas of the Jellico coal in the Jellico West quadrangle. Later, numerous truck mines operated in coal which had been disregarded around the fringes of the early mined area. In the Ketchen and Pioneer quadrangles the Jellico coal was also truck mined at several localities, but more commonly it has been worked at shallow adits for local household fuel. The roof rock of the Jellico coal is variable within small areas and commonly ranges from medium-gray shale to thick-bedded or massive sandstone.

The Jellico coal bed is composed of brightly banded coal which blocks well in mining. Partings, consisting of as much as 9 inches of underclay or shale, are fairly uncommon. The high quality of the coal is apparent from analyses, which show an unusually low ash content of about 2 percent, less than 1 percent sulfur, and a heating value of about 14,000 Btu (table 1).

Mining has depleted about 20 percent of the total original estimated reserves of 119,190,000 tons in the Jellico coal bed. As most mining was in areas of thick coal, remaining tonnages are largely in the 14- to 28-inch category.

JELLICO RIDER COAL BED

The Jellico rider is a thin commercially unimportant coal bed about 25 feet above the Jellico coal in the Jellico West quadrangle. It is as much as 13 inches thick and is generally thinner and less persistent in other parts of the Elk Valley area. Available data indicate that the Jellico rider is of insufficient thickness to contain estimated reserves.

LICK FORK COAL BED

The name Lick Fork is applied to a coal bed that lies at an average distance of 90 feet above the Jellico coal on Lick Fork and at the head of Little Elk Creek in adjoining parts of the Ketchen and Pioneer quadrangles (Englund, 1957). Previously, the Lick Fork coal in this immediate area was recognized as the Jellico coal (Glenn, 1925, p. 155; Wanless, 1946, pl. 33, sec. 8; Williams, Gibbs, Crentz, Miller, and Reynolds, 1956, p. 58). This erroneous correlation of the Lick Fork coal probably resulted from the fact that the normally thick and commercially important Jellico coal bed is very thin in the area where the Lick Fork is relatively thick and extensively mined (fig. 15). In addition to a difference in strategraphic position, the Lick Fork coal bed can be differentiated from the Jellico coal on the basis of its significantly higher ash and sulfur content (table 1). The effect of the early miscorrelation of the two coal beds can best be demonstrated by pointing out that the high-quality Jellico coal bed was erroneously reported to be unsuitable for metallurgic use on the basis of a sample with a relatively high ash and sulfur content which was actually taken from the Lick Fork coal bed (Williams, Gibbs, Crentz, Miller, and Reynolds, 1956, p. 58).

The Lick Fork coal bed crops out on the middle to upper hill slopes throughout the Elk Valley area at a distance of about 50–100 feet above the Jellico coal bed. In the principal outcrop area, which extends from the head of Little Elk Creek westward along Lick Fork, the coal ranges in thickness from 24 to 42 inches and averages about 30 inches in mined areas. Northward and northeastward the coal thins to 14 inches or less in the central parts of the Ketchen and Jellico West quadrangles. The coal also thins southward and is more than 14 inches thick at only a few localities in the central part of the Pioneer quadrangle; it is generally less than 14 inches thick in the Middlesboro syncline.

Development of the Lick Fork coal bed consists mostly of underground mining from several adits at the head of Little Elk Creek and from one adit on Lick Fork opposite the mouth of Granny Barnes Branch. These operations, currently abandoned, extend in from the outcrop for a maximum distance of about 1,000 feet. Coal adjacent to the outcrop on the upper part of Lick Fork has also been strip mined in a belt as much as 75 feet wide. Underground mining of the bed includes several small adits where the coal was worked for local household use. The coal is overlain by medium-gray or dark-gray to black carbonaceous shale.

The Lick Fork coal bed is composed of abundant thin vitrain bands in a moderately bright attrital matrix. In contrast to other brightly banded coals of the Hance and Mingo Formations, the Lick Fork contains a substantially higher ash and sulfur content and is slightly lower in heating value. Partings of shale or impure coal are rare in the bed, but pyrite in thin lenses as much as a quarter of an inch thick is apparent at many localities.

Of the total estimated original reserves of 60,251,000 tons, less than 1 percent has been mined or lost in mining.

ELK GAP COAL BED

The Elk Gap coal, a relatively thin and commercially unimportant coal bed, is a useful marker bed in the Mingo Formation. In most parts of the Elk Valley area, the coal is readily recognized by an abundance of *Marginifera* in the roof rock which consists of thin-bedded black shale or poorly bedded very dark gray calcareous shale. The stratigraphic position of the bed, slightly below the Pioneer Sandstone Member and about 50–90 feet above the Lick Fork coal, also aids in its indentification. The Elk Gap coal (Englund, 1966) was named from Elk Gap in the central part of the Pioneer quadrangle where the bed is exposed about midway between the gap level and a cliff formed by the Pioneer Sandstone Member (pl. 6, section 11).

Except for a few scattered localities in the Ketchen and Jellico West quadrangles, the coal is generally less than 14 inches thick. It attains a maximum thickness of about 3 feet, excluding partings, in an abandoned mine at the head of Little Elk Creek (pl. 8, section 30). Elsewhere in the area, developments consist of a few shallow adits which were opened primarily to prospect the bed.

The Elk Gap coal consists mostly of moderately dull attritus with sparse thin vitrain bands. Impurities in the bed include shale and impure coal partings and pyrite nodules.

A negligible amount of the total estimated original reserves of 2,775,000 tons has been depleted by mining.

JORDAN COAL BED

The Jordan coal occurs widely on the upper hill slopes of the Elk Valley area, and its outcrop position is generally within 10 feet of the underlying cliff-forming Pioneer Sandstone Member. Commercially important coal in the bed is limited to the Middlesboro syncline in the Ivydell quadrangle and to the south-central part of the Pioneer quadrangle. In the remainder of the area the coal is about 14 inches or less thick.

Mining of the Jordan coal is concentrated in the ridge between Stinking and Louse Creeks in the Ivydell quadrangle where the coal bed ranges in thickness from 30 to 60 inches. Southward it thins to an average of about 22 inches in Walnut Mountain. In the Pioneer quadrangle the coal is as much as 29 inches thick and includes a few small abandoned mines. Interbedded medium-gray shale and fine-grained sandstone compose the roof rock in mined areas.

An analysis of a sample from one of several active truck mines in the Ivydell quadrangle (table 1, loc. 277) indicates that the coal is of good quality. In most of the area it consists of thin to medium vitrain bands in a dull to bright attrital matrix; locally, it includes as much as 13 inches of cannel coal.

Estimated original reserves in the Jordan coal bed are 16,932,000 tons; of this total, less than 1 percent is mined or lost in mining.

LOWER PIONEER COAL BED

The Lower Pioneer coal bed is of notable thickness only in Limestone Ridge in the south-central part of the Pioneer quadrangle. There, the bed attains a maximum thickness of at least 4 feet but thins abruptly in all directions. Data from outcrop sections and core holes indicate that the bed thins to less than 1 foot elsewhere in the Elk Valley area. Early underground mining has depleted much of the bed, and some coal remaining near the outcrop was recently strip mined near Poteet Gap. In Limestone Ridge the Lower Pioneer coal lies at a maximum distance of about 100 feet above the Jordan coal; elsewhere in the Elk Valley area, this distance averages about 50 feet. Locally, the coal is absent, and a few inches of black carbonaceous shale and underclay occur at its stratigraphic position.

Reserves are not calculated for the Lower Pioneer coal bed, as available information indicates that coal of reserve thickness is virtually mined out.

UPPER PIONEER COAL BED

The Upper Pioneer coal bed, the uppermost coal of minable thickness in the Mingo Formation, is 75–125 feet below the Windrock coal bed at the top of the formation. Reserves are widely distributed on the upper slopes of hills west of the Cumberland overthrust sheet. In the Middlesboro syncline the coal bed underlies a small area on the upper slopes of Walnut Mountain where a few prospects indicate that the bed is relatively thin.

The thickness of the Upper Pioneer coal bed is greatest in the south-central part of the Pioneer quadrangle where the coal is as much as 48 inches thick and averages about 33 inches. Northward across the Pioneer quadrangle and into the southern edges of the Ketchen and Jellico West quadrangles, the bed is generally more than 28 inches thick; locally, it is as much as 37 inches thick. In the northern parts of these quadrangles the coal thins to 20 inches or less.

Mining of the Upper Pioneer coal is most extensive in the south-central part of the Pioneer quadrangle where much of the coal in Limestone Ridge was depleted by railroad mines during the early period of underground mining. The only other concentration of underground development is along the outcrop that fringes the upper part of Little Elk Creek near the common corners of the Pioneer, Ketchen, and Jellico West quadrangles; this development includes both abandoned and active truck mines. Underground mines in other parts of these quadrangles consist of widely scattered truck mines and a few shallow adits where the coal is worked for domestic fuel. Contour strip mining of the Upper Pioneer coal was also active at the time of the fieldwork for this report in the northern part of the Pioneer quadrangle and in adjoining parts of the Ketchen and Jellico West quadrangles. At these localities the coal bed is particularly suitable for stripping and can be extracted in a belt as much as 150 feet wide, because it lies on a broad bench that is held up by a thick cliff-forming sandstone. The roof rock is mostly medium-gray shale, and at a few localities it includes thick-bedded to massive sandstone.

A distinct physical feature of the Upper Pioneer coal bed is a predominance of dull attritus which gives the coal a dull hard blocky character. Because of the abundance of dull attritus, the Upper Pioneer coal is locally known as the Splint coal bed in the Ketchen and Jellico West quadrangles. The bed also includes minor amounts of bright attritus and thin bands of vitrain which increase substantially southward in the Pioneer quadrangle.

Analyses of the Upper Pioneer coal bed show that the coal is fairly high in ash and sulfur and is lower in heating value than most of the coals of the Breathitt Group. However, the coal is satisfactory for domestic heating and steam generation. Pyrite nodules and shale or underclay partings are common locally in the bed.

Coal that has been mined and lost in mining represents about 2 percent of the total estimated original reserves of 76,337,000 tons in the Upper Pioneer coal bed.

UPPER PIONEER RIDER COAL ZONE

Several thin coal beds, between the Upper Pioneer coal bed and the top of the Mingo Formation, compose the Upper Pioneer rider coal zone. Strip-mine exposures indicate that some of these beds are splits that diverge laterally from the underlying Upper Pioneer coal bed. This divergence is accompanied by thinning of the rider beds to 1 foot or less. Locally, the uppermost of the two to six coal beds in the zone is as much as 15 inches thick. Reserves are not calculated for any of the coals in the Upper Pioneer rider coal zone, as areas of coal more than 14 inches thick appear to be of limited lateral extent.

COAL BEDS OF THE CATRON FORMATION

The Catron Formation in the Elk Valley area includes six coal beds, of which three beds are of sufficient thickness to warrant the calculation of reserves. Although laterally persistent, the coal beds of the Catron Formation are of secondary commercial importance because of their general thinness or because of the presence of persistent partings where the coal is of minable thickness. The distribution of reserves is confined to the upper hill slopes in the area west of the Cumberland overthrust sheet.

WINDROCK COAL BED

The Windrock coal bed, at the base of the Catron Formation, is relatively thin and of little economic importance in the Elk Valley area. However, it is a useful key bed because of a persistent readily recognizable flint-clay parting, which is the basis for correlating the Windrock coal with the Fire Clay, Hazard No. 4, and Wallins Creek coal beds in other parts of the eastern Kentucky coal field.

Although widely distributed, the Windrock coal is more than 14 inches thick at only a few localities. These include as much as 27 inches of coal in the southwest corner of the Ketchen quadrangle (pl. 8, section 19), as much as 37 inches of cannel coal at the head of Whistle Creek in the Jellico West quadrangle, and about 24 inches of coal at a few exposures on Braden and Gunsight Mountains in the Pioneer quadrangle.

Commercial development of the Windrock coal is confined to the vicinity of Whistle Creek where a pocket of cannel coal is nearly depleted. At other localities of reserve thickness, the bed includes a few small adits that were a source of fuel for local residents. The roof rock is mostly medium-gray shale, and where cannel coal is present a thin bed of canneloid shale intervenes. A rider coal, generally less than 14 inches thick, occurs fairly persistently 5–20 feet above the Windrock coal bed.

The cannel coal, which is moderately bright, has an ash content of about 19 percent and a heating value of 12,340 Btu (Glenn, 1925, p. 211). Partings, other than the flint-clay marker bed, include as much as 2 inches of clay ironstone where the bed is largely cannel coal and as much as several inches of shale, underclay, and impure coal where the bed consists of banded coal.

About one-fourth of the total estimated original reserves of 3,952,000 tons has been depleted by mining in the vicinity of Whistle Creek.

BIG MARY COAL BED

The Big Mary coal bed is thick and widely distributed in the area lying west of the Cumberland overthrust sheet, but is of minor commercial importance because of one to three persistent partings. It occurs 20–40 feet above the Windrock coal bed and crops out on the main ridges in the Pioneer and Jellico West quadrangles. The regional rise of strata to the northwest places the bed at the level of hilltops in the Ketchen quadrangle. The Big Mary coal attains a maximum thickness of nearly 4 feet, excluding partings of underclay and shale as much as 10 inches thick, in the south-central part of the Pioneer quadrangle. Northward in the quadrangle the bed thins to an average of about 34 inches. In the Ketchen and Jellico West quadrangles the coal averages about 30 inches in thickness and is locally as much as 38 inches thick.

Commercial development of the Big Mary coal consists of both early underground mining and recent contour strip mining. Underground exploitation of the coal is confined principally to the pocket of thick coal in the south-central part of the Pioneer quadrangle. At these workings, coal was extracted from adits on the east side and south end of Limestone Ridge. Localities of contour strip mining include Gunsight Mountain in the southwest corner of the Pioneer quadrangle, Anderson Mountain in the north-central part of the Ketchen quadrangle, and Barley Branch at the east end of the latter quadrangle. Coal from these mines, which became inactive during the fieldwork for this report, was used mostly for steam generation. The coal has also been mined at widely scattered localities for household use by local residents. Overlying the Big Mary coal is a medium-gray shale, and locally a massive fine-grained sandstone lies within 20 feet of the top of the coal.

The Big Mary coal bed is characteristically dull and blocky owning to a predominance of dull attritus in the coal. Bright attritus and thin vitrain bands are minor constituents. In addition to shale and underclay partings, impurities in the coal include pyrite nodules and rashy impure coal. The ash and sulfur content of the coal is fairly high, and the heating value is about 13,000 Btu or less (table 1).

Nearly all the total estimated original reserves of 51,280,000 tons are in the 28- to 42-inch category. Less than 2 percent of the coal has been mined or lost in mining.

HATFIELD COAL BED

A relatively thin coal, that lies 15–35 feet above the Big Mary coal bed locally in the Ketchen and Jellico West quadrangles, is herein named the Hatfield coal bed (pl. 8, section 98). It occurs principally at the head of Hatfield Creek in the southwestern part of the Jellico West quadrangle where the maximum thickness is about 2 feet. Coal has only been mined at a few shallow adits by local residents. Medium-gray shale overlies the coal at most places.

The Hatfield coal bed is brightly banded and locally includes an underclay parting as much as 7 inches in thickness. The total estimated original reserves, 1,620,000 tons, are in the 14- to 28-inch category.

BEECH GROVE COAL BED

The Beech Grove coal bed is widely distributed on high ridges of the Elk Valley area, but it is too thin to be of commercial importance. It lies 50–90 feet below the top of the Catron Formation and is generally less than 12 inches thick. Locally, the bed is split into two equally thin benches by shale and underclay as much as 30 inches thick. Reserves are not calculated for the Beech Grove coal bed, because areas of coal in excess of 14 inches thick are of limited lateral extent.

SHARP COAL ZONE

Two to three thin coal beds at the top of the Catron Formation form the Sharp coal zone in the Elk Valley area. This zone is commonly represented by a single coal bed in other parts of Tennessee and is widely recognized by the presence of marine fossils in the overlying shale. The individual coal bed is generally less than 12 inches thick and occurs in a sequence of shale and underclay with a total thickness of about 20 feet. Locally, the coal splits converge, so that the intervening shale and underclay thin to less than 1 foot. A thickness of about 20 inches of coal was recorded in the south-central part of the Jellico West quadrangle, and an isolated prospect on the northeast slope of Walnut Mountain disclosed about 43 inches of weathered coal.

Coal in the Sharp coal zone is largely dull attritus which grades into cannel coal, canneloid shale, or black carbonaceous shale. The occurrence of cannel coal and canneloid shale and the presence of marine fossils in the roof shale are extensive enough to aid in establishing the identity of the coal zone. As commercial development of the coal is lacking and the distribution of coal of reserve thickness is spotty, reserves are not included in this report.

COAL BEDS OF THE HIGNITE FORMATION

The Hignite Formation contains four named coal beds: the Red Ash, Braden Mountain, Walnut Mountain, and Big Wheel. The last three beds were actively strip mined at the time of the fieldwork for this report. Coal in the formation is of good quality, but it is variable in thickness and commonly exhibits extensive splitting. However, the hilltop position of the beds is highly favorable for strip mining. The Red Ash, Braden Mountain, and Big Wheel coal beds are widely distributed west of the Cumberland overthrust sheet; only the Walnut Mountain coal bed, a probable correlative of the Braden Mountain coal, is of significant thickness in the Middlesboro syncline. The Hignite Formation also includes thin coal beds or splits which are most commonly associated with the Braden Mountain and Big Wheel coal beds.

RED ASH COAL BED

The Red Ash coal is a thin persistent bed 40–75 feet above the base of the Hignite Formation. It occurs principally in the central part of the Pioneer quadrangle, where it is as much as 24 inches thick (pl. 8, section 197). Elsewhere in the Elk Valley area, the coal is generally less than 14 inches thick.

Development of the Red Ash coal consists of a few shallow adits which provided fuel for local household use. Core-hole and outcrop data show that the roof rock is variable and may be shale, siltstone, or sandstone. The coal is mostly dull to bright attritus and is rarely parted. The total estimated original reserves, 4,414,000 tons, are in the 14- to 28-inch category.

BRADEN MOUNTAIN COAL BED

The Braden Mountain coal bed, previously correlated with the Red Ash coal (Luther, 1959, p. 286), lies 40–80 feet above the Red Ash coal in the Elk Valley area. It is in a zone with several thin coal beds and occurs principally in Braden Mountain in the central part of the Pioneer quadrangle and to a lesser extent in other hilltops west of the Cumberland overthrust sheet. In the northern and central parts of the Pioneer quadrangle the coal ranges mostly from 3 to 4 feet in thickness, excluding one to three persistent shale partings as much as 13 inches thick. Southward in the Pioneer quadrangle the amount of coal in the bed remains at about the same thickness, but it is split by 5 feet or more of shale, underclay, and sandstone. In the Ketchen and Jellico West quadrangles, the coal averages about 26 inches in thickness and is distributed mainly in the ridge along the Scott and Campbell County line.

Large areas of the Braden Mountain coal bed were mined out in Braden Mountain during the early period of underground mining. From entries near Braden Gap, workings extended from about one-half mile north to about 1 mile south of the gap. The coal was also being strip mined at the time of the fieldwork for this report, and at several localities a strip of coal, ranging in width from 50 to 150 feet, adjacent to the outcrop was extracted primarily for steam generation. The roof rock is shale that includes thin beds of sandstone, coal, and underclay.

The Braden Mountain coal is composed of thin to medium vitrain bands in a dull to bright attrital matrix. Except for the presence of partings, which also include impure coal and fusain laminae, the coal is of good quality, and analyses indicate that it is fairly low in ash and sulfur and moderately high in heating value (table 1). Of the total estimated original reserves of 9,964,000 tons, about 16 percent is mined or lost in mining.

WALNUT MOUNTAIN COAL BED

The Walnut Mountain coal bed underlies minute areas along the crest of Walnut Mountain in the central part of the Ivydell quadrangle. This bed is a likely correlative of the Braden Mountain coal, but because of the geographic and structural isolation of the bed in the trough of the Middlesboro syncline, the local coal-bed name is used. The Walnut Mountain coal lies about 100 feet above the base of the formation and, excluding two thin shale partings, is 4–5 feet thick. Development of the bed was on a small scale and consisted of both truck and contour strip mining. At these operations shale and sandstone overlie the coal. The total estimated original reserves, 155,000 tons, is assigned to the more than 42-inch category.

BIG WHEEL COAL BED

The Big Wheel coal bed lies 50–65 feet above the Braden Mountain coal and crops out only on the highest hilltops of the Elk Valley area. Its principal occurrence is along the county line in the southeastern part of the Ketchen quadrangle where the bed is as much as 32 inches thick, excluding one or two thin shale partings. Elsewhere in the report area, the bed is sparsely prospected, but available data indicate as much as 2 feet of coal along the outcrop of the bed.

At several localities in the Ketchen quadrangle the Big Wheel coal bed has been strip mined in conjunction with the underlying Braden Mountain coal bed. Overlying the coal in these operations is a medium-gray shale which includes thin beds of sandstone, underclay, and locally, a rider coal bed as much as 20 inches thick. The analysis of a channel sample from a strip-mine exposure shows that the Big Wheel coal compares favorably with other coal beds that are mined in the report area (table 1). Original estimated reserves total 1,194,000 tons, of which an insignificant amount has been mined or lost in mining.

COAL-BED CORRELATIONS WITH OTHER AREAS

The coal-bed names used in this report have originated in or near the Elk Valley area, and most of these names have been applied to coal beds in adjoining parts of the Tennessee coal field. Northward into Kentucky, only the Blue Gem and Jellico coal-bed names are widely used. Therefore, correlations with other parts of the eastern Kentucky coal field are given in figure 22. These correlations are based on several factors, including stratigraphic position, relation to widespread key or marker beds, and regional trends in the physical characteristics of the individual coal bed. Because of its central location, the Elk Valley area provides a north-south link between the coal beds of Kentucky and Tennessee and also an east-west link between the coal beds of the Cumberland overthrust sheet and the coal field proper. Some factors that are pertinent in the correlation of the principal coal beds of the Breathitt Group are, in ascending order, as follows:

The lower coal beds of the Hance Formation, including beds from the Naese to the Murray rider, occur in the easternmost parts of the Tennessee and eastern Kentucky coal fields; westward distribution is restricted by the previously described intertonguing at the base of the formation. From the Middlesboro syncline of the Elk Valley area, outcrops of these coal beds extend northeastward in the trough of the syncline into Kentucky. There, the stratigraphic section that includes coal beds in the lower part of the Hance Formation is nearly identical because it is situated along the sedimentary strike of the beds.

The Swamp Angel coal bed is stratigraphically the lowest widespread coal in the Hance Formation. West of the Cumberland overthrust sheet it crops out continuously northward into Kentucky where it is known as the Williamsburg, Lily, or Manchester coal bed. The Kent coal bed, the correlative of the Swamp Angel coal in the Middlesboro syncline, is equally widespread, and it extends northeastward in the trough of the syncline into southeastern Kentucky where it is known as the Hance coal bed. The physical characteristics of the coal and the association with a rider bed are similar throughout these areas.

KENTUCKY		ELK VALLEY AREA		KENTUCKY
Area northwest of Pine Mountain fault			Middlesboro syncline	
Bruin and Isonville quadrangles (Englund and DeLaney, 1966a, 1966b)	Hazard district (Englund, 1963)	This report		Middlesboro area (Englund, Smith, Harris, and Stephens, 1963; Englund, Landis and Smith, 1963)
Mudseam	Hazard No. 6	Braden Mountain		
	Haddix	Red Ash	Walnut Mountain	
Copland	Copland	Sharp		
	Upper Hamlin	Beech Grove		
	Lower Hamlin	Hatfield		
Fire Clay rider	Fire Clay rider	Big Mary		Fire Clay rider
Fire Clay	Fire Clay	Windrock	Windrock	Wallins Creek
	Upper Whitesburg	Upper Pioneer		
Whitesburg		Lower Pioneer		
	Lower Whitesburg	Jordan	Jordan	
	Amburgy rider	Elk Gap		
Cannel City	Amburgy	Lick Fork		Kellioka
Little Caney	Upper Elkhorn No. 3	Jellico	Jellico	Harlan
			Rich Mountain rider	
Grassy	Upper Elkhorn No. 2	Blue Gem	Rich Mountain	Path Fork
Bruin	Upper Elkhorn No. 1	Black Wax	Black Wax	
		Dixie		
		Swamp Angel rider		
	Lower Elkhorn	Swamp Angel	Kent	Hance
			Murray rider	Mason rider
			Murray	Mason
			Splitseam	Splitseam
			Rex	Clear Fork
			Naese	Naese

FIGURE 22.—Correlation of coal beds in the Elk Valley area with principal coal beds of eastern Kentucky.

The Dixie coal bed is of local occurrence, and coal has not been found at its stratigraphic position in neighboring areas of Kentucky.

The Black Wax, Blue Gem, and Jellico coal beds and associated rider coals occur in the widely recognized upper Elkhorn coal zone of eastern Kentucky. Regionally, this zone is recognized by the high quality of the coal, which has the lowest ash content of coals in the Breathitt Group.

The Lick Fork and Elk Gap coal beds, which are correlated with the Amburgy and Amburgy rider coal beds, respectively, are generally thin and are only of economic importance locally. The Lick Fork contains a higher-than-average sulfur content for coals of the Breathitt Group, and the Elk Gap is widely recognized by the occurrence of marine fossils and limestone concretions in the overlying shale which may be the Kendrick Shale of Jillson (1919) in Kentucky.

On the basis of their stratigraphic position between the Kendrick Shale of Jillson (1919) and the Windrock or Fire Clay coal bed, the Jordan, Lower Pioneer, and Upper Pioneer coal beds are correlated with the Whitesburg coal beds. This zone is characterized by several thin discontinuous coal beds, but generally two of the beds, the Lower and Upper Whitesburg, are fairly extensive and most likely correspond to the Jordan and Upper Pioneer.

The most widely recognized coal bed in the southern Appalachian coal field is the Windrock and its correlatives the Fire Clay, Hazard No. 4, and Wallins Creek. This coal is readily identified by a bed of flint clay, about 4 inches thick, that occurs in the coal or slightly below.

The Big Mary coal bed is at the stratigraphic position of the Fire Clay rider coal bed and exhibits similar physical characteristics. The roof rock of both coal beds locally contains marine fossils.

The Hatfield and Beech Grove coal beds occur in an interval of one to five thin coal beds that are known as the Hamlin coals in Kentucky.

The Sharp coal bed is identified with the Copland coal of Kentucky on the basis of its occurrence just below the Magoffin Beds of Morse (1931).

Coal beds above the Magoffin Beds of Morse (1931) are less firmly correlated with the coal beds of Kentucky because of their isolated hilltop distribution. However, the Braden Mountain is at the approximate stratigraphic position of the Mudseam, Index, or Hazard No. 6 coal beds of eastern Kentucky.

MINING METHODS

Coal in the Elk Valley area has been extracted from both underground and strip mines. Most of the early underground operations consisted of drift mines, which extended into relatively flat-lying coal beds from adits situated along the outcrop of the bed. The coal was mined by the room-and-pillar method, and pillars were generally recovered in the advance stage of development. The size of these underground operations ranged from small adits driven less than 100 yards into the coal bed, to large railroad mines which have exploited several square miles of a coal bed. The small mines, known as "coal banks" or wagon mines, were operated seasonally with a minimum of mechanical equipment to supply coal for local household use. Mechanization, including the use of cutting and loading machines, was widespread in the larger mines, which also had preparation facilities for the cleaning and sorting of the mined coal. Locally in the Jellico West and Ivydell quadrangles, coal just below drainage was reached by inclined shafts or slopes.

The current underground production of coal is entirely from truck mines that are intermediate in size to the earlier operations. The room-and-pillar method of mining continues to be used, but preparation for shipment involves only the handpicking of impurities and the sorting of size grades by gravity screening.

Strip mining, which accounted for most of the coal mined in the Elk Valley area in 1962, included the areal stripping of broad alluviated valley bottoms and the contour strip mining of hillsides or mountainsides. In these operations the coal ranges mostly from 20 to 36 inches in thickness; about 1 foot of overburden, generally consisting of shale, is removed for each inch of coal. Localities where the coal is overlain by thick massive sandstone are generally avoided or bypassed by strip-mining operations because of the high cost of removal of sandstone in the high wall.

As shown diagrammatically in figure 23, the area most favorable topographically for strip mining is the valley bottom where large acreages can be stripped without a significant increase in the depth of the overburden. Parallel cuts are made in the high wall by a power shovel or dragline, and the exposed coal is loaded before each succeeding cut. These mines are readily accessible to truck haulage because of all-weather roads along the valley floor. However, the valley-bottom strip miners do encounter problems involving water disposal or diversion during wet seasons and occasionally the threat of flooding during periods of heavy runoff.

Of secondary importance to strip mining are the hilltop areas as shown in figure 23. The thickness of the overburden above a coal bed increases substantially toward the hilltops, but generally the slope is gradual enough to permit several cuts by the strip-mining equipment. Hilltop areas are less desirable than the valley bottoms because of their limited size and also because of the necessity to construct and maintain winding hillside roads which may be inaccessible during adverse weather.

Topographically, the hillsides, as shown in figure 23, are the least ideal for strip mining. Because of the dissection of the region, lengthy outcrop areas are available, but the steepness of the hillsides generally permits only a single narrow cut to be made. The continuity of these strippable belts is interrupted by hillside accumulations of colluvium which are unstable in a high wall. Consequently, these surficial deposits have been bypassed by stripping operations, as in the northern part of the Pioneer quadrangle (pl. 3) and the western part of the Ketchen quadrangle (pl. 1). Contour strip mines along the hillsides are also hampered by abandoned adits and the necessity to maintain lengthy haulage roads along or upon unconsolidated spoil piles. Locally, sections of the coal bed along the high wall are augered in conjunction with the contour strip mining.

An acceleration in strip-mining activity in recent years is indicated by the production figures for Campbell County, Tenn., which includes most of the Elk Valley area (fig. 24). Between 1952 and 1962, for example, the percentage of coal that was strip mined increased from about 3 percent to nearly 63 percent (U.S. Bur. Mines, 1954–55, 1963).

PRODUCTION

Coal has been mined commercially in the Elk Valley area for more than 80 years. Annual production figures, available on a countywide basis in the U.S. Bureau of Mines Mineral Yearbooks, have averaged about 1.3 million tons for Campbell County during the past 60 years (fig. 24). Underground mining, which accounted

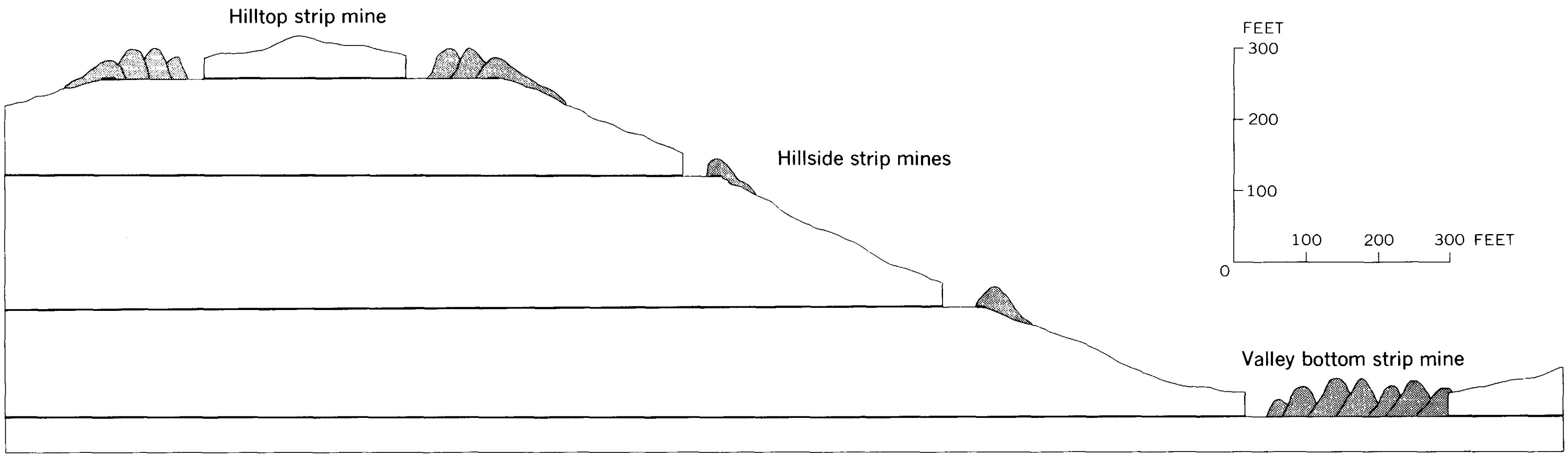


Figure 23.—Diagrammatic section showing relation of topography to the recovery of coal by strip mining.

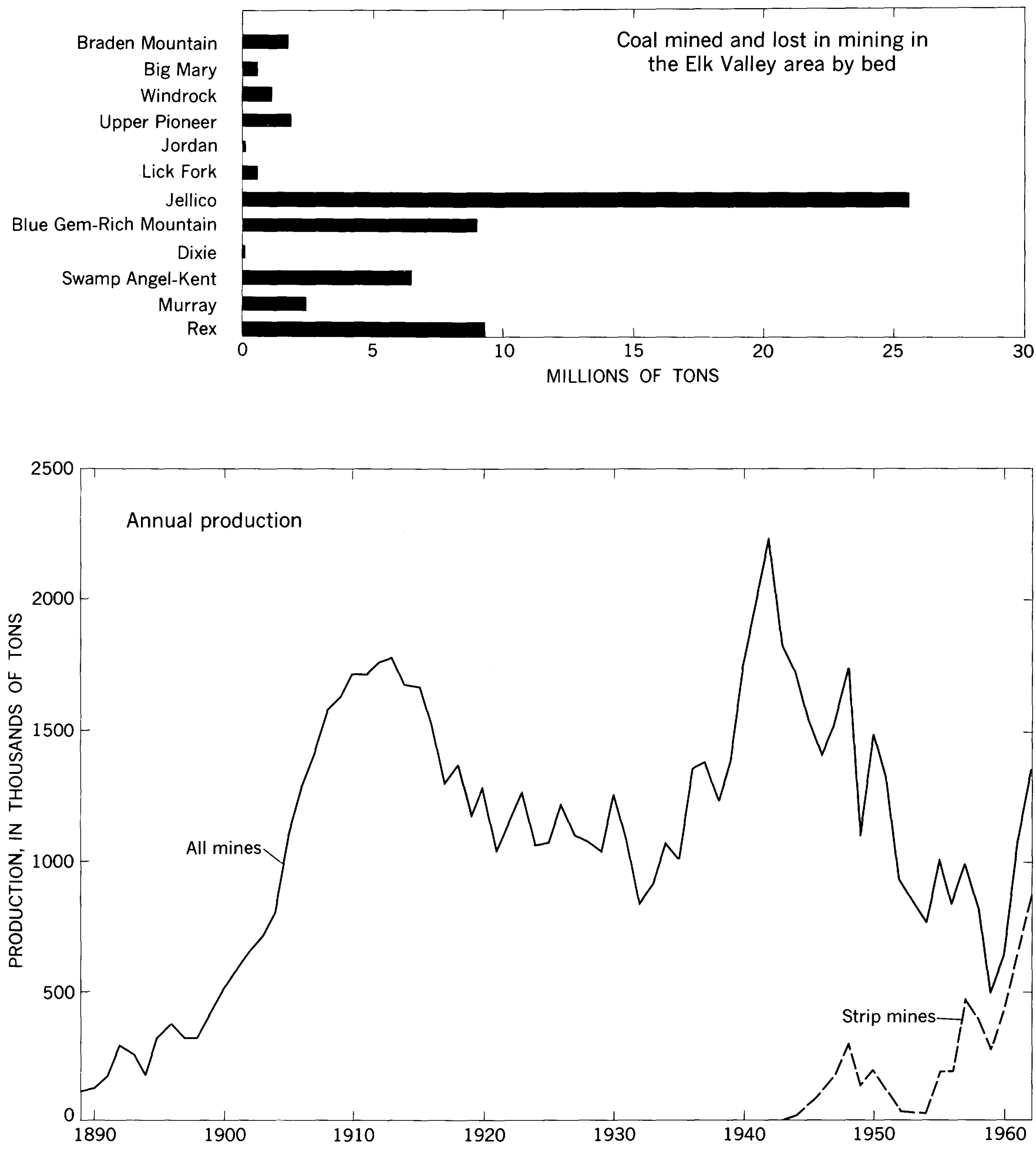


FIGURE 24.—Coal mined and lost in mining in the Elk Valley area by bed, annual production of coal in Campbell County, Tenn. (1889–1962).

for all early production, reached a peak of about 1.8 million tons in 1913 and, following an irregular decline, dropped to 0.8 million ton in the depression year of 1932. This declined coincided with the closing of many large underground railroad mines. In the late 1930's, underground mining was accelerated by the opening of numerous truck mines, and annual production reached an all-time high of 2.2 million tons in 1942.

In the period after World War II the extraction of coal from underground mines decreased steadily until 1959. This downward trend was reversed by a rapidly expanding strip-mining industry which produced nearly 63 percent of the coal mined in Campbell County in 1962. The increase resulted from a greater demand by coal-consuming electric generating plants in eastern Tennessee.

USES

Coal currently mined in the Elk Valley area is used for the production of electric power and, to a lesser extent, for household fuel. About two-thirds or more of the coal is consumed by electric powerplants which supplement the hydroelectric facilities of the Tennessee Valley Authority. This production is largely from strip mines and is shipped by rail or truck. Preparation includes only the handpicking of impurities and crushing into fine fractions before shipment.

Underground mines supply most of the coal for household fuel which is trucked to consumers in nearby communities. In addition to the handpicking of impurities, preparation consists of the screening out of the finer fractions that are generally satisfactory for use in the electric powerplants.

COAL RESERVES

METHOD OF PREPARING ESTIMATES OF RESERVES

The estimated coal reserves of the Elk Valley area were calculated according to standard procedures and definitions of the Geological Survey as follows:

Thickness of beds.—Coal reserves are reported in thickness categories of 14–28 inches, 28–42 inches, and more than 42 inches. Coal beds less than 14 inches thick are omitted from the reserve estimate, and in determining the total thickness of a coal bed, partings thicker than three-eighths of an inch are excluded.

Weight of coal.—To compensate for variations in the weight of bituminous coal, an average gravity factor of 1,800 tons per acre-foot or 150 tons per acre-inch is used in the calculation of reserve tonnages. This intermediate figure is widely used in eastern Kentucky and Tennessee.

Thickness of overburden.—Almost all the calculated coal reserves in the Elk Valley area lie under less than 1,000 feet of overburden. Only about 4 percent of the coal reserves, as indicated in footnotes of table 2, lie beneath mountain ridges that form slightly more than 1,000 feet of overburden.

CLASSIFICATION OF MEASURED, INDICATED, AND INFERRED RESERVES

In addition to thickness categories, coal reserves are also classified as "measured," "indicated," and "inferred reserves" according to the density and reliability of data on which the estimates are based.

Measured reserves.—Measured reserves are computed for areas where the thickness and areal extent of the coal bed are well defined by observation points in mine workings, prospects, drill holes, or natural outcrops. The density of data needed to establish the continuity of measured coal varies from bed to bed, but all observation points for measured coal are one-half mile or less apart. Except where local structural deformation interrupts the continuity of a coal bed, measured coal occurs in a belt, one-fourth of a mile wide, adjacent to an outcrop line with closely spaced observation points.

Indicated reserves.—Coal beds of known geologic continuity contain indicated reserves where the observation points are ½–1½ miles apart. Indicated coal extends as much as three-quarters of a mile from an observation point and generally occurs in a belt, about half a mile wide, beyond the measured coal.

Inferred reserves.—Coal is classified as inferred reserves in areas where observation points are more than 1½ miles apart, and the assumed continuity of the coal bed is supported by geologic evidence. In general, inferred reserves occur in broad areas where the coal is below drainage, as in the trough of the Middlesboro syncline. Observations are available on the limbs of the syncline to establish measured and indicated reserves in belts adjacent to the outcrops of the coal beds; however, only scattered core holes penetrate the coal beds in the trough where inferred reserves are considered to occur.

SUMMARY OF RESERVE ESTIMATES

Coal beds in the Elk Valley area contain a total estimated original reserve of 1,068,689,000 tons (table 2). Approximately 3 percent of this total tonnage is in beds more than 42 inches thick, 35 percent is in beds 28–42 inches thick, and 62 percent is in beds 14–28 inches thick. In the categories of reliability, 19 percent of the total estimated reserves is classified as measured, 38 percent as indicated, and 43 percent as inferred.

About 58,500,000 tons or 5½ percent of the total tonnage has been mined or lost in mining, mostly from the Jellico, Blue Gem-Rich Mountain, Swamp Angel-Kent, and Rex coal beds (fig. 24).

TABLE 2.—*Estimated original and remaining coal reserves of the Elk Valley area, Tennessee and Kentucky*

[In thousands of short tons. Covered by less than 1,000 ft of overburden, except as indicated by footnotes]

Formation	Coal bed	State	Original reserves																Mined and lost in mining	Total remaining reserves
			Measured				Indicated				Inferred			Total					
			Thickness of beds, in inches			Total	Thickness of beds, in inches			Total	Thickness of beds, in inches		Total	Thickness of beds, in inches			Total		
			14–28	28–42	>42		14–28	28–42	>42		14–28	28–42		14–28	28–42	>42			
										Ivydell quadrangle [As of July 1, 1954]									
Hignite	Walnut Mountain	Tennessee	------	------	115	115	------	------	40	40	------	------	------	------	------	155	155	------	155
Mingo	Jordan	do	439	1,429	398	2,266	6,478	1,250	------	7,728	294	------	294	7,211	2,679	398	10,288	141	10,147
Hance	Blue Gem-Rich Mountain.	do	1,891	------	------	1,891	8,398	148	------	8,546	454	------	454	10,743	148	------	10,891	527	10,364
	Kent	do	4,992	13,478	7,282	25,752	[1] 18,170	18,080	12,463	48,713	[2] 18,608	[3] 11,331	29,939	41,770	42,889	19,745	104,404	3,317	101,087
	Murray	do	3,764	4,178	------	7,942	18,238	1,956	------	20,194	4,007	------	4,007	26,009	6,134	------	32,143	2,481	29,662
	Rex	do	4,215	7,405	4,325	15,945	[4] 21,404	5,056	------	26,460	[5] 61,222	2,023	63,245	86,841	14,484	4,325	105,650	7,840	97,810
Total Ivydell			15,301	26,490	12,120	53,911	72,688	26,490	12,503	111,681	84,585	13,354	97,939	172,574	66,334	24,623	263,531	14,306	249,225
										Jellico West quadrangle [As of Jan. 1, 1959]									
Hignite	Braden Mountain	Tennessee	283	53	------	336	389	------	------	389	------	------	------	672	53	------	725	------	725
Catron	Hatfield	do	------	------	------	------	840	------	------	840	------	------	------	840	------	------	840	------	840
	Big Mary	Kentucky	------	------	------	------	------	------	------	------	------	4,794	4,794	------	4,794	------	4,794	------	4,794
		Tennessee	------	------	------	------	1,163	3,369	------	4,532	2,677	724	3,401	3,840	4,093	------	7,933	------	7,933
	Windrock	Tennessee	113	1,092	------	1,205	------	------	------	------	------	------	------	113	1,092	------	1,205	1,092	113
Mingo	Upper Pioneer	Kentucky	------	301	------	301	1,353	2,142	------	3,495	2,270	------	2,270	3,623	2,443	------	6,066	18	6,048
		Tennessee	1,316	550	------	1,866	4,000	135	------	4,135	6,530	------	6,530	11,846	685	------	12,531	------	12,531
	Elk Gap	do	------	------	------	------	------	------	------	------	1,417	------	1,417	1,417	------	------	1,417	------	1,417
	Lick Fork	do	1,240	------	------	1,240	8,388	------	------	8,388	2,808	------	2,808	12,436	------	------	12,436	------	12,436
	Jellico	Kentucky	2,160	13,659	------	15,819	5,801	678	1,541	8,020	267	------	267	8,228	14,337	1,541	24,106	13,174	10,932
		Tennessee	2,990	9,803	2,119	14,912	9,217	2,910	1,049	13,176	4,950	718	5,668	17,157	13,431	3,168	33,756	12,338	21,418
Hance	Blue Gem	Kentucky	7,081	------	------	7,081	10,829	------	------	10,829	1,371	------	1,371	19,281	------	------	19,281	1,799	17,482
		Tennessee	14,619	------	------	14,619	12,450	------	------	12,450	4,616	------	4,616	31,685	------	------	31,685	5,995	25,690
	Dixie	do	815	------	------	815	641	------	------	641	------	------	------	1,456	------	------	1,456	11	1,445
	Swamp Angel	Kentucky	1,001	2,727	------	3,728	1,112	8,825	------	9,937	------	27,149	27,149	2,113	38,701	------	40,814	247	40,567
		Tennessee	354	9,170	------	9,524	93	19,522	------	19,615	------	[6] 48,716	48,716	447	77,408	------	77,855	2,242	75,613
	Murray	do	------	------	------	------	489	------	------	489	62	------	62	551	------	------	551	------	551
	Rex	do	4,066	632	------	4,698	1,446	------	------	1,446	------	------	------	5,512	632	------	6,144	1,384	4,760
Total Kentucky			10,242	16,687	------	26,929	19,095	11,645	1,541	32,281	3,908	31,943	35,851	33,245	60,275	1,541	95,061	15,238	79,823
Total Tennessee			25,796	21,300	2,119	49,215	39,116	25,936	1,049	66,101	23,060	50,158	73,218	87,972	97,394	3,168	188,534	23,062	165,472
Total Jellico West			36,038	37,987	2,119	76,144	58,211	37,581	2,590	98,382	26,968	82,101	109,069	121,217	157,669	4,709	283,595	38,300	245,295

Ketchen quadrangle

[As of Jan. 1, 1959]

Hignite	Big Wheel	Tennessee	123	235	------	358	617	------	------	617	219	------	219	959	235	------	1,194	------	1,194
	Braden Mountain	do	1,896	126	------	2,022	1,057	------	------	1,057	177	------	177	3,130	126	------	3,256	------	3,256
Catron	Hatfield	do	------	------	------	------	780	------	------	780	------	------	------	780	------	------	780	------	780
	Big Mary	Kentucky	------	140	------	140	------	148	------	148	------	1,483	1,483	------	1,771	------	1,771	------	1,771
		Tennessee	------	615	------	615	------	7,304	------	7,304	397	13,271	13,668	397	21,190	------	21,587	------	21,587
	Windrock	do	------	------	------	------	------	------	------	------	307	------	307	307	------	------	307	------	307
Mingo	Upper Pioneer	Kentucky	------	------	------	------	332	------	------	332	1,394	------	1,394	1,726	------	------	1,726	------	1,726
		Tennessee	634	3,030	------	3,664	7,033	7,606	------	14,639	10,006	------	10,006	17,673	10,636	------	28,309	87	28,222
	Elk Gap	do	------	------	------	------	438	90	------	528	830	------	830	1,268	90	------	1,358	------	1,358
	Lick Fork	do	947	400	------	1,347	19,312	------	------	19,312	15,202	------	15,202	35,461	400	------	35,861	150	35,711
	Jellico	Kentucky	353	------	------	353	4,860	------	1,458	6,318	7,291	2,629	9,920	12,504	2,629	1,458	16,591	------	16,591
		Tennessee	1,254	------	------	1,254	8,514	1,509	------	10,023	15,264	------	15,264	25,032	1,509	------	26,541	------	26,541
Hance	Blue Gem	Kentucky	1,427	------	------	1,427	9,134	------	------	9,134	15,883	------	15,883	26,444	------	------	26,444	------	26,444
		Tennessee	[7] 3,656	------	------	3,656	20,769	------	------	20,769	[8] 24,794	------	24,794	49,219	------	------	49,219	------	49,219
	Black Wax	Kentucky	------	------	------	------	3,532	------	------	3,532	1,061	------	1,061	4,593	------	------	4,593	------	4,593
	Swamp Angel	do	3,218	713	------	3,931	11,933	109	------	12,042	13,416	39	13,455	28,567	861	------	29,428	------	29,428
		Tennessee	18,906	1,544	------	20,450	[9] 20,466	61	------	20,527	[10] 31,533	[11] 23,741	55,274	70,905	25,346	------	96,251	349	95,902
Total Kentucky			4,998	853	------	5,851	29,791	257	1,458	31,506	39,045	4,151	43,196	73,834	5,261	1,458	80,553	------	80,553
Total Tennessee			27,416	5,950	------	33,366	78,986	16,570	------	95,556	98,729	37,012	135,741	205,131	59,532	------	264,663	586	264,077
Total Ketchen			32,414	6,803	------	39,217	108,777	16,827	1,458	127,062	137,774	41,163	178,937	278,965	64,793	1,458	345,216	586	344,630

Pioneer quadrangle

[As of July 1, 1962]

Hignite	Braden Mountain	Tennessee	------	2,250	1,008	3,258	------	1,395	137	1,532	------	1,193	1,193	------	4,838	1,145	5,983	1,656	4,327
	Red Ash	do	692	------	------	692	2,596	------	------	2,596	1,126	------	1,126	4,414	------	------	4,414	------	4,414
Catron	Big Mary	do	------	1,528	58	1,586	1,643	7,877	------	9,520	387	3,702	4,089	2,030	13,107	58	15,195	594	14,601
	Windrock	do	569	------	------	569	1,871	------	------	1,871	------	------	------	2,440	------	------	2,440	------	2,440
Mingo	Upper Pioneer	do	2,295	9,838	135	12,268	7,359	5,960	------	13,319	2,118	------	2,118	11,772	15,798	135	27,705	1,695	26,010
	Jordan	do	------	------	------	------	2,389	283	------	2,672	3,972	------	3,972	6,361	283	------	6,644	------	6,644
	Lick Fork	do	855	469	------	1,324	8,361	1,157	------	9,518	1,112	------	1,112	10,328	1,626	------	11,954	375	11,579
	Jellico	do	3,393	------	------	3,393	11,348	684	------	12,032	2,771	------	2,771	17,512	684	------	18,196	------	18,196
Hance	Blue Gem	do	3,491	------	------	3,491	10,036	------	------	10,036	1,016	------	1,016	14,543	------	------	14,543	675	13,868
	Black Wax	do	371	------	------	371	1,454	------	------	1,454	------	------	------	1,825	------	------	1,825	------	1,825
	Swamp Angel-Kent	do	648	572	------	1,220	1,643	161	------	1,804	[12] 7,688	[13] 40,853	48,541	9,979	41,586	------	51,565	313	51,252
	Murray	do	350	222	------	572	669	1,544	------	2,213	2,517	365	2,882	3,536	2,131	------	5,667	------	5,667
	Rex	do	------	------	------	------	2,314	1,422	------	3,736	6,480	------	6,480	8,794	1,422	------	10,216	------	10,216
Total Pioneer			12,664	14,879	1,201	28,744	51,683	20,483	137	72,303	29,187	46,113	75,300	93,534	81,475	1,338	176,347	5,308	171,039
Grand total			96,417	86,159	15,440	198,016	291,359	101,381	16,688	409,428	278,514	182,731	461,245	666,290	370,271	32,128	1,068,689	58,500	1,010,189

Tons of coal covered by 1,000–2,000 feet of overburden:

[1] 221.
[2] 684.
[3] 904.
[4] 1,298.
[5] 14,587.
[6] 5,393.
[7] 203.
[8] 1,563.
[9] 468.
[10] 3,640.
[11] 8,576.
[12] 1,256.
[13] 5,284.

The estimated remaining reserves (fig. 25), excluding the amount of coal mined and lost in mining, totaled 1,010,189,000 tons as of July 1, 1962. Assuming 50-percent recovery, the remaining recoverable reserves are 505,094,000 tons. Some of this coal is too thin to be mined at the date of this estimate, but this factor is partly offset by a higher recovery rate for the thicker beds. In highly mechanized mines as much as 80–90 percent of the coal may be recovered. Future adjustment of the rate of recovery will depend on continuing advances in mining technology which tend to increase the rate of recovery and to facilitate the exploitation of thinner coal beds. The actual coal reserves of the area may also be increased in the future by the subsurface prospecting of beds that contain undisclosed reserves at depth.

OIL AND GAS POSSIBILITIES

Exploration for oil and gas in the Elk Valley area has resulted in the drilling of three test holes. Little information is available concerning the results of the earliest test, which was drilled about 1920 near Jellico in the Jellico West quadrangle. A precise location and detailed log could not be obtained, but this hole probably extended deep enough to test the Chattanooga Shale for oil before it was abandoned. In 1928 the T. E. B. Siler Oil & Gas Co., Meredith 1 test hole was drilled near the head of Stinking Creek at the east edge of the Pioneer quadrangle. Drill records indicate that this test penetrated a normal sequence of strata and bottomed in the Reedsville Shale at a depth of 3,000 feet. Middle Ordovician limestone beds were later found when the hole was deepened to 3,825 feet. This test was abandoned as a dry hole after only a show of oil was found. The most recent test, the Columbian Carbon Co., East Tennessee Iron & Coal Co. 2, was drilled in 1956 in the southwest corner of the Ivydell quadrangle. A study of the drill cuttings indicates that this test ended in the Rockwood Formation at a depth of 3,450 feet. The Pine

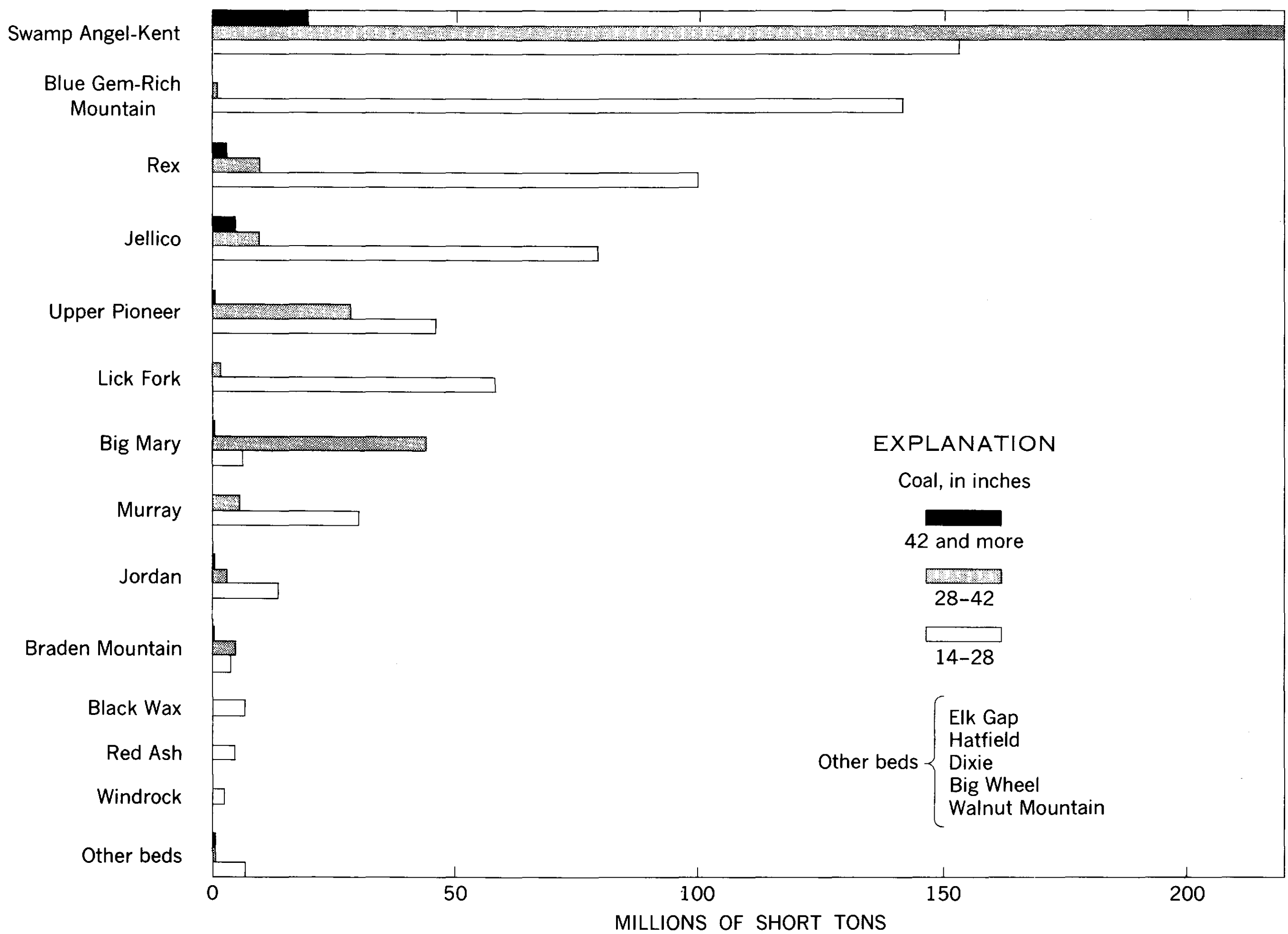


FIGURE 25.—Thickness categories of remaining reserves by bed.

Mountain fault was penetrated by the drill in the Rockwood Formation at a depth of 3,360 feet. This test was abandoned as a dry hole; however, a good show of gas was reported in the Chattanooga Shale.

Drilling has been more extensive in nearby areas of Kentucky, Virginia, and Tennessee and has resulted in the completion of numerous productive wells. As shown by this drilling, the beds most likely to contain oil and gas in the Elk Valley area include the Trenton Limestone, from which oil is produced in the Rose Hill oil field of southwestern Virginia; the Chattanooga Shale, a widespread gas producer in the central Appalachians; the Newman Limestone, which contains gas in Whitley and Bell Counties, Ky.; and the sandstone beds of the Pennington and Lee Formations, which are productive of oil and gas at widely scattered localities in eastern Kentucky. The tonguing out of sandstone beds in the latter formations, previously discussed in the stratigraphic description, is noteworthy in the exploration for stratigraphic traps.

Structure contour lines (pls. 1–4) show several low anticlinal folds that may reflect favorable subsurface structures in the report area. The most prominent of these folds strikes southwestward across the central part of the Jellico West quadrangle, passes through the southeast corner of the Ketchen quadrangle, and terminates in the northwest corner of the Pioneer quadrangle. This flexure is of particular interest because it parallels the regional strike and would form a barrier to the updip migration of oil and gas. Structure contour lines in the Middlesboro syncline show two low anticlinal folds that strike northward across the trough area. Structural entrapment of oil and gas is also possible along the Pine Mountain and Jacksboro fault zone. Flexures in these zones, described in the discussion of the structural geology, include warps and folds along the Jacksboro and Terry Creek faults, a broad warp that extends into the Middlesboro syncline in adjoining parts of the Jellico West and Ivydell quadrangles, and folds postulated in the subsurface below the Pine Mountain fault zone.

CRUSHED STONE

High-calcium limestone in the lower member of the Newman Limestone crops out locally in the Elk Valley area. This rock is widely quarried in the south-central Appalachian region, and in the report area two active quarries supply rock for crushed stone for surfacing roads and for concrete aggregate. These operations are in Elk Valley where the limestone occurs in fault slices of the Pine Mountain fault zone. The beds in the fault slices are well jointed and dip about 15°–40° SE. (fig. 9). One of the active quarries is near the mouth of Lawson Branch in the northwest corner of the Ivydell quadrangle and has been in operation intermittently for a number of years. A second quarry was opened in 1961 at the head of Elk Valley in the central part of the Pioneer quadrangle. Limestone is also available from the Newman Limestone at many other localities in Elk Valley in quantities that are sufficient for commercial development.

The lower member of the Newman Limestone is more extensive but less accessible on the northwest slope of Pine Mountain where it forms a continuous outcrop belt on the northwest limb of the Middlesboro syncline. This limestone is being quarried about 2½ miles east of the Jellico West quadrangle at the gap where Clear Fork flows through Pine Mountain. On the opposite limb of the Middlesboro syncline the Newman Limestone crops out in the vicinity of La Follette and has been quarried at Big Creek Gap, just east of the Ivydell quadrangle.

A potential but unexploited source of crushed stone is the sandstone of the Lee Formation in the fault slice along the northwest side of Elk Valley. The sandstone is tightly cemented in this slice and is sufficiently sheared and jointed, so that upon crushing it breaks into angular fragments which would provide a gritty aggregate for the surfacing of roads.

SAND

The Lee Formation contains large quantities of relatively clean quartzose sandstone that is friable enough in ridgetop exposures to be excavated. Most of this sandstone is in the Middlesboro Member and commonly contains quartz pebbles concentrated in lenses or sparsely distributed throughout the bed. Within the report area, small-scale workings along Pine Mountain have provided a limited amount of sand for local construction purposes. About 3 miles south of the Ivydell quadrangle, sand in the Lee Formation is mined in an opencut at the crest of Fork Mountain.

CLAY AND SHALE

The Elk Valley area contains large quantities of clay and shale in the coal-bearing rocks of the Breathitt Group. Clay occurs principally beneath the coal beds as underclay and is best exposed in mining operations after the coal has been removed. The underclays commonly range in thickness from 1 to 4 feet. Shale, the most abundant rock in the Breathitt Group, occurs in beds ranging in thickness from a few inches to about 100 feet.

Clay and shale beds of the Breathitt Group in the area of this report are suitable for the manufacture of high-grade brick and tile products, but similar material occurs elsewhere appreciably closer to the potential markets and is presently being utilized. Exploitation of clay and shale in the Elk Valley area has been limited to beds in the Hance Formation, between the Swamp Angel and Blue Gem coal beds, for use locally in the manufacture of bricks. This operation and the kiln, at Italian Hollow in the Jellico West quadrangle, have been abandoned.

Shale beds of the Breathitt Group are also a potential source of raw material for the manufacture of lightweight aggregate. In nearby areas of Kentucky, McGrain (1957) collected several samples of Breathitt shale which, upon testing, showed good to excellent bloating characteristics.

Flint clay of refractory quality occurs in a thin widespread bed in or slightly below the Windrock coal. It attains a maximum thickness of about 1 foot in the southeast corner of the Ketchen quadrangle but is too thin for current commercial use.

IRON ORE

Thin beds of hematitic or red iron ore in the Rockwood Formation crop out along the foot of Cumberland Mountain at La Follette and along the northwest edge of Elk Valley southwest of the community of Elk Valley. In the Cumberland Mountain outcrop belt the ore was mined during the early 1900's for use in furnaces at La Follette. The bed ranges in thickness from about 3 to 5 feet and is nearly vertical. Its location is presently indicated by a linear depression which resulted from the caving of underground mine workings. Burchard (1914, p. 303) gave analyses of five samples from mines near La Follette. The range (in percent) of the analyses, which are fairly representative of this ore in the area, is as follows: Fe 26.30 to 44.65; SiO_2 4.54 to 12.48; Al_2O_3 2.57 to 8.30; CaO 3.10 to 15.89; P 0.48 to 0.68.

From the outcrop belt at La Follette the iron ore beds of the Rockwood Formation dip northwestward and at a depth of about 3,000 feet below the surface are truncated by the Pine Mountain overthrust fault. At Elk Valley the ore beds rise to the surface at the base of the Cumberland overthrust sheet and crop out along the southwest end of the Pine Mountain fault zone. The ore beds have been subjected to intense deformation and consequently have been faulted and tightly folded. In general, the beds dip steeply southeastward and are as much as 4 feet thick. Because the ore beds are discontinuous and contorted, mining has not been undertaken in this outcrop belt.

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