Geology of the Ewing Quadrangle Kentucky and Virginia

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ABSTRACT

The Ewing quadrangle includes an area of about 60 square miles in parts of Bell and Harlan Counties in southeastern Kentucky and part of Lee County in southwestern Virginia. The southern third of the quadrangle lies within the Valley and Ridge province and is underlain by Late Cambrian to Mississippian sandstone, shale, limestone, and dolomite. These rocks are divided into 27 mapped units which dip northward beneath Pennsylvanian formations in the dissected Appalachian Plateaus province. Rocks of Pennsylvanian age include both continental and marine beds and are divided into 19 mapped units consisting of alternating beds of sandstone, siltstone, shale, underclay, and coal. Approximately 13,000 feet of sedimentary rocks are exposed in the area.

The Ewing quadrangle is situated near the center of the Cumberland overthrust block and includes parts of the Middlesboro syncline and the Powell Valley anticline. The Pine Mountain overthrust fault underlies the area and comes to the surface in the Hamblin Branch and Dean fensters. Displacement on the fault is approximately 4.2 miles to the northwest.

Coal of high-volatile A bituminous rank occurs principally in the Puckett Creek, Path Fork, Harlan, Kellioka, and Wallins Creek coal beds. The total estimated original reserves contained in these beds are 196,349,000 tons of which approximately one-third is depleted by mining. Assuming 50 percent recovery, the remaining recoverable reserves are 67,241,000 tons. Oil has been produced from several wells on the fringe of the Rose Hill oil field in the southeast corner of the quadrangle.

INTRODUCTION

The Ewing quadrangle comprises an area of about 60 square miles in Bell and Harlan Counties in southeastern Kentucky and Lee County in southwestern Virginia. The town of Ewing, Va., is 17 miles east of Middlesboro, Ky., and about 75 miles north of Knoxville, Tenn. Mapping of the Ewing quadrangle by the U.S. Geological Survey is the first part of a study of several quadrangles in a southeastward-trending belt in the folded Appalachians.

The Ewing quadrange includes part of the Appalachian Plateaus province northwest of Cumberland Mountain, and part of the Valley and Ridge province to the southeast. Physiographically the quadrangle is further divisible from north to south into three areas, each closely related to the weathering characteristics and structure of the underlying rocks. In the northern third of the quadrangle deep V-shaped valleys and sharp sinuous ridges accentuate the rugged, mature topography of the Cumberland Mountains section of the Appalachian Plateaus. The rocks are relatively flat lying and consist of alternating beds of shale, siltstone, sandstone, and coal. The central area of the quadrangle, from the north slope of Brush Mountain southward to Cumberland Mountain, is characterized by hogbacks and ridges carved from massive conglomeratic sandstones. In the southern third of the quadrangle the high slopes of Cumberland Mountain drop abruptly to broad, rolling lowlands underlain by gently folded rocks consisting predominantly of dolomite and limestone.

Previous detailed mapping in the Ewing quadrangle was limited to the belt of Silurian and older rocks which was mapped as part of the Rose Hill district (Miller and Fuller, 1947, 1954). Much of that mapping was recompiled for this study; many of the contacts had to be adjusted to the present topographic base. Intermittent fieldwork for the present investigation was started in 1956 in the coal-bearing rocks by H. L. Smith, and in the Middle and Upper Ordovician rocks by J. G. Stephens and J. J. Musser. Most of the mapping was done from the fall of 1958 to the spring of 1959 by K. J. Englund and H. L. Smith in the Pennsylvanian rocks, and by L. D. Harris and J. G. Stephens in the pre-Pennsylvanian rocks.

The rock types and correlation problems are described in detail by Miller and Brosgé (1954) and Miller and Fuller (1954). Only the most significant features of the lithology and nomenclature are treated in this report. The Wentworth scale (Wentworth, 1922) is used for grain sizes in detrital rocks. Descriptive textural terms used herein for carbonate rocks include. lutite-textured limestone that ranges in particle size from clay to silt, and arenite-textured limestone made up of sand-size particles. Dolomite is described as very finely, finely, medium, coarsely, and very coarsely crystalline. Bed or bedding thicknesses are generalized; the term "thin" is used for measurements of less than a foot, and the term "thick" for measurements of a foot or more.

STRATIGRAPHY

About 13,000 feet of sedimentary rocks, from Late Cambrian to Pennsylvanian age, crop out in the Ewing quadrangle (pl. 1). The pre-Pennsylvanian rocks, which consist of 27 mapped units, are mostly of marine origin. They are exposed in an east- to northeast-trending belt in the southern third of the quadrangle. These units dip steeply northward and underlie Pennsylvanian rocks in the northern two-thirds of the area. Rocks of Pennsylvanian age, including both continental and marine beds, are divided into 19 mapped units. Surficial sand, gravel, and talus are present at many places throughout the quadrangle. The nomenclature of the Ordovician and Silurian units follows the usage of Miller and Brosgé (1954).

CAMBRIAN SYSTEM

MAYNARDVILLE LIMESTONE

The Maynardville limestone of Late Cambrian age is exposed in a small area in the southeast corner of the Ewing quadrangle; its base is marked by the Pine Mountain thrust fault.

Miller and Fuller (1954, p. 34) subdivided the Maynardville into the Low Hollow limestone member and the Chances Branch dolomite member. The Low Hollow is predominantly a ribbon-bedded, medium-gray, very fine grained limestone, and the Chances Branch is in large part a medium-gray or yellowish-gray, very finely crystalline dolomite. In the two sections measured by Miller and Fuller (1954, p. 40), the thickness of the Maynardville ranges from 249 to 302 feet.

CAMBRIAN AND ORDOVICIAN SYSTEMS

KNOX GROUP

The Knox group has been divided in Tennessee into five formations, which, in ascending order, are the Copper Ridge, Chepultepec, Longview, Kingsport, and Mascot dolomites. In measured sections in and near the Ewing quadrangle, Miller and Fuller (1954, p. 167–177) divided the Knox group into these same five formations; however, because of poor exposures and mixing of residual float they did not map the Longview, Kingsport, or Mascot dolomites individually.

The present study shows that the Knox group in the Ewing quadrangle is divisible into four distinct lithologic units, which were recognized throughout the quadrangle by insoluble products derived from the bedrock by weathering. The lower two formations of the Knox as mapped in the Ewing quadrangle closely parallel the Copper Ridge and Chepultepec dolomites as mapped by Miller and Fuller; the third formation corresponds to what Rodgers (1953, p. 58) mapped as the Longview dolomite; and the fourth formation, the Newala as used by Rodgers (1953, p. 55), probably includes equivalents of both the Kingsport and Mascot dolomites that cannot as yet be differentiated in the area.

COPPER RIDGE DOLOMITE

The Copper Ridge dolomite of Late Cambrian age, about 750 feet thick, can be subdivided into two members on the basis of texture. The lower member is dominantly coarsely crystalline, very thick bedded, olive-brown dolomite that emits a petroliferous odor when broken. The upper member is mainly a finely crystalline, slightly argillaceous olive-brown or olive-gray to light olive-gray dolomite, but it does contain some beds of coarsely crystalline dolomite. The most conspicuous feature seen in the residuum derived from the weathering of the formation is an olive-black oolitic chert. The individual coarse-grained ooids are well sorted and show marked concentric color banding. The upper contact of the Copper Ridge dolomite is mapped where the oolitic chert residuum is superseded by abundant sandstone float weathered from the basal sandy member of the overlying Chepultepec dolomite.

CHEPULTEPEC DOLOMITE

The most distinctive feature of the Chepultepec dolomite of Early Ordovician age is the presence of many beds of fine- to medium-grained quartz sandstone in the lower part of the formation. This occurrence of sandstone permits subdivision of the Chepultepec into a lower sandy dolomite member about 300 feet thick, and an upper argillaceous dolomite member about 350 feet thick.

Dolomite in the sandy member is mostly finely crystalline and light olive gray, but the member includes a few thin zones of medium to coarsely crystalline dolomite similar to the dolomite of the lower member of the Copper Ridge. Oolitic chert, which occurs sparingly throughout the member, differs from the oolitic chert of the Copper Ridge dolomite in that quartz sand grains commonly form the nuclei of the ooids.

The upper argillaceous dolomite member is composed principally of platy-bedded, finely crystalline, light olive-gray, argillaceous dolomite. Chert, which weathers white, is locally abundant near the base and middle parts of this member in irregular porous masses, nodules, or porcelaneous blocks.

LONGVIEW DOLOMITE

The Longview dolomite of Early Ordovician age is about 320 feet thick; it is a light-gray or light olive-gray, very thick bedded dolomite with a coarsely crystalline texture. Scattered throughout the unit are grains of subrounded, fine- to medium-grained quartz sand which occur either isolated or in thin lenticular beds. Abundant chert, which weathers white, is present in lenses and beds; most of the beds are at least 1 foot thick and at two localities the beds are about 6 feet thick. The chert mantles the surface in a poorly defined band that facilitates the mapping of the Longview. P. E. Cloud, Jr., of the Geological Survey, identified a few specimens of gastropods from a section along Chances Branch as *Lecanospira* and *Rhombella*.

NEWALA DOLOMITE

The Newala dolomite of Early Ordovician age is composed predominantly of very light gray to light-gray argillaceous dolomite in thin even beds. It contains a few thin zones of coarsely crystalline, thick-bedded, light olive-gray dolomite similar to the dolomite of the underlying Longview. Throughout the Newala are irregular lenticular masses of chert and isolated grains of quartz sand or thin beds of sandstone. The formation along Chances Branch is 450 feet thick. The variation in thickness of the Newala in and near the Ewing quadrangle is about 100 feet. This range in thickness is due to differential erosion at the top of the Newala before deposition of the Middle Ordovician rocks.

ORDOVICIAN SYSTEM

DOT FORMATION

The Dot formation of Middle Ordovician age ranges in thickness from 125 to 215 feet; this range is due to deposition on an uneven erosional surface on top of the Newala dolomite. The Dot contains variable lithologies that change laterally, depending upon their position in relation to the unconformity. In general the formation can be subdivided into two members—a lower dolomite member and an upper limestone member. The lower member contains at its base one of the most distinct lithologic units in the Middle Ordovician sequence, a 3- to 10-foot bed of erosional debris derived from weathered Newala dolomite. The debris includes pebbles and boulders of dolomite, chips and boulders of chert, quartz grains, and locally some grayish-red argillaceous dolomite. Above this basal bed, very finely crystalline argillaceous, yellowish-gray dolomite with some shaly partings grades upward into a shale with some lutite-textured limestone and dolomite.

The upper limestone member of the Dot formation is composed of even-bedded, light olive-gray, lutite-textured limestone in beds generally less than a foot thick. These limestone beds are separated by light-gray shale partings, but the shale becomes less prominent upward in the member. The top of the Dot is marked by a zone of thick-bedded limestone 3 to 11 feet thick.

POTEET LIMESTONE

The Poteet limestone of Middle Ordovician age consists of medium-gray or light-olive-gray, chert-bearing, lutite to arenite-textured limestone interbedded with thin beds of yellowish-gray dolomite similar to that found in the lower member of the Dot formation. A few thin intraformational conglomerates occur in the purer limestones and some beds of argillaceous limestone contain mud cracks. Generally the beds are less than 6 inches thick and are nonresistant to weathering. Although exposures are rare, mapping of the Poteet is aided by the presence of a mantle of cherty soil. The chert is dark gray to olive black and occurs in irregular nodules and lenses about 2 inches thick and as much as 1 foot long. The Poteet ranges from 76 to 100 feet in thickness.

ROB CAMP LIMESTONE

The Rob Camp limestone of Middle Ordovician age is thick bedded, lutite-textured, light olive-gray, and commonly contains abundant irregular patches of clear, anhedral calcite as much as an inch across. Generally the limestone is exposed as rounded, vertically fluted ledges about 4 feet high. The thickness of the Rob Camp in the Ewing area ranges from 47 to 97 feet. This variation in thickness is due to differential erosion at the top of the Rob Camp before deposition of the overlying Martin Creek limestone.

MARTIN CREEK LIMESTONE

The Martin Creek limestone of Middle Ordovician age contains arenite-textured olive-gray limestone, lutite-textured olive-gray limestone with abundant olive-black nodular chert, and a lutite-textured medium-light-gray well-bedded limestone which bears nodular chert. The last two types of limestone are most typical of the Martin Creek and have wide distribution. The arenite-textured limestone is more restricted in its distribution and occurs as channellike fillings on top of the Rob Camp limestone. The thickness ranges from 97 feet at the eastern and western ends of the outcrop belt to 145 feet in the central part.

HURRICANE BRIDGE LIMESTONE

In the Ewing area the Hurricane Bridge limestone of Middle Ordovician age is composed of lutite-textured light-olive-gray limestone with subordinate amounts of grayish-red or yellowish-gray argillaceous limestone. The lutite-textured limestone, which commonly contains clear anhedral patches of calcite, generally is in beds from 3 inches to 1 foot thick but locally is in beds as much as 3 feet thick. The Hurricane Bridge limestone ranges in thickness from 345 feet near the east side of the quadrangle to 312 feet near the west side.

WOODWAY LIMESTONE

The Woodway limestone of Middle Ordovician age is composed of about 240 feet of interbedded lutite- to arenite-textured, light-brownish-gray to brownish-gray limestone. Generally the beds are less than a foot thick and many are only a few inches thick. Chert is not common in the Woodway, but a few nodules were found near its top. The sponge *Camarocladia* is abundant in the upper part of the formation and commonly stands in relief on weathered surfaces as branching rodlike markings. The basal contact of the Woodway is the base of a thin zone containing abundant *Stromatocerium rugosum*. The upper contact is the base of a thick bed of argillaceous limestone that weathers yellowish gray.

BEN HUR LIMESTONE

The Ben Hur limestone of Middle Ordovician age is a nonresistant, argillaceous limestone that weathers yellowish gray. It is poorly exposed in contrast to the underlying Woodway limestone and the overlying Hardy Creek limestone. A few thin beds of arenite-textured limestone, rich in bryozoan detritus, occur near the base of the unit, and mudcracks are well developed throughout the argillaceous beds. The thickness increases from 130 to 165 feet westward across the outcrop belt.

HARDY CREEK LIMESTONE

The Hardy Creek limestone of Middle Ordovician age is about 120 feet thick; it is an even bedded light-olive-gray lutite-textured limestone in beds 1 to 6 inches thick. Many of the beds are laminated and locally include intraformational conglomerate. The lower half of the formation contains olive-black chert in nodules that generally have a flattened elliptical outline. The Ben Hur limestone is transitional with the overlying Hardy Creek, and the contact is placed where the purer, lutite-textured limestones predominate over the argillaceous beds of the Ben Hur.

EGGLESTON LIMESTONE

The Eggleston limestone of Middle Ordovician age is about 150 feet thick and contains three unmapped members: two dusky-yellow calcareous mudstone members separated by a lutite- to arenite-textured light-olive-gray limestone. Miller and Fuller (1954, p. 112) indicate that there are two prominent bentonite beds in the Eggleston, one about 100 feet above the base at the top of the middle member and the other about 10 feet below the top of the formation. The stratigraphic position of these bentonites is generally marked by silicified limestones that weather out in cuneiform blocks.

TRENTON LIMESTONE

Exposures of the Trenton limestone of Middle Ordovician age in the Ewing quadrangle are poor and the description of the formation is based on the discussion by Miller and Fuller (1954, p. 117–122) of the exposures at Hagan, Va. They divided the Trenton into three unmapped parts. The lower and upper parts of the formation are predominantly coquinoid limestone containing minor amounts of chert, and they differ in color and thickness; the lower part is 200 feet of mottled gray and white limestone, and the upper part is 75 feet of brownish-gray limestone. The middle part, 275 feet thick, is composed of lutite- to arenite-textured gray limestone with few coquinoid beds.

REEDSVILLE SHALE

The Reedsville shale of Late Ordovician age is about 335 feet thick and is composed of shale interbedded with thin layers of fine- to coarse-arenite-textured coquinoid limestone and calcareous beds of quartz sand and silt. On weathering the thin limestone beds generally dissolve, leaving a concentration of light-olive-gray silty blocks. The upper 30 to 40 feet of the Reedsville is predominantly greenish gray limestone, which is relatively resistant to erosion and forms a prominent bench on the south slope of Poor Valley Ridge.

SEQUATCHIE FORMATION

Grayish-red and greenish-gray calcareous shale and siltstone are predominant in the Sequatchie formation of Late Ordovician age. Some nodular limestone occurs near the sharp basal contact. In the Ewing quadrangle the formation is about 260 feet thick.

SILURIAN SYSTEM

CLINCH SANDSTONE

Miller and Fuller (1954, p. 140) subdivided the Clinch sandstone of Early Silurian age into the Hagan shale member in the lower part and the Poor Valley Ridge member in the upper part. The Hagan is predominantly a pale-olive shale with minor amounts of siltstone or very fine grained sandstone which occur in planar beds from 1 to 2 inches thick. Locally a bed of very fine grained sandstone about a foot thick is at the base of the member. Miller and Fuller (1954, p. 142), give a range in thickness for the Hagan of 70 to 77 feet. The member is too thin to be mapped separately in the Ewing quadrangle.

Most of the Poor Valley Ridge member is composed of interbedded pale-olive shale and thin-bedded sandstone. Crossbedded, fine- to medium-grained, slightly conglomeratic sandstone occurs only in two beds—one near the base and one in the upper part of the member.

These two beds are separated by interbedded pale-olive shale and thin-bedded sandstone. The member is 180 feet thick at Hagan, Va., about 5 miles east of the Ewing quadrangle.

CLINTON SHALE

Exposures of the Clinton shale of Middle Silurian age in the Ewing quadrangle are sparse. The scattered outcrops indicate that the formation is predominantly light-olive-gray shale with some layers of grayish-red shale, and is interbedded with very fine grained, medium-light-gray to light-olive-gray sandstone in platy beds from ½ to 1 inch thick. Beds of oolitic hematite from a few inches to as much as 2 feet thick occur near the base of the Clinton. A few pieces of hematite float about 1 inch thick, which apparently weathered out of the middle and upper parts of the formation, indicate that thin beds of hematite are present. Calculated thicknesses of the Clinton range from 350 to 400 feet.

HANCOCK DOLOMITE

The Hancock dolomite of Late Silurian age crops out intermittently in the west half of Poor Valley, but it is covered by colluvium and alluvium in the east half of this valley. The base of the formation is marked by a poorly sorted, conglomeratic sandstone a few inches to 5 feet thick. This sandstone is in places calcareous and light gray or grayish orange; its grains range in size from silt to pebbles. The rest of the formation is dark-gray very finely crystalline dolomite. A suitable place to measure the thickness of this formation was not found in the Ewing quadrangle, but Miller and Fuller (1954, p. 159) state that in the Ewing area this formation, which they called the Cayuga, ranges in thickness from 90 to 188 feet.

DEVONIAN SYSTEM

CHATTANOOGA SHALE

The Chattanooga shale of Devonian age is not continuously exposed in the Ewing quadrangle, but scattered outcrops suggest that the formation is mainly a carbonaceous black shale with some thin zones of greenish-gray shale. The calculated thickness of the formation is 375 feet. Studies in the Duffield quadrangle in nearby Scott County, Va., show that black shale and siltstone, which are probably equivalent to the Chattanooga of the Ewing quadrangle, contain beds of Devonian and Mississippian age (Harris and Miller, 1958). Because the age span of the Chattanooga shale in the Ewing quadrangle has not been determined, the age of the formation is referred to as Devonian.

MISSISSIPPIAN SYSTEM

GRAINGER FORMATION

Many isolated outcrops of the Grainger formation of Mississippian age occur above the Chattanooga shale, but a continuous section was not seen. At the only place where the base and top of the formation were sufficiently well exposed for measurement, the formation was calculated to be 325 feet thick. The Grainger consists principally of shale with moderate amounts of siltstone. The color is generally greenish gray or pale olive, but in a few places grayish-red beds occur in the lower part and at the top of the formation.

NEWMAN LIMESTONE

In the Ewing quadrangle the Newman limestone of Mississippian age is divided into a lower member composed of limestone and an upper member composed of interbedded argillaceous limestone and calcareous shale. The combined thickness of these members is about 600 feet.

The lower member of the Newman limestone, which is about 245 feet thick, crops out along Cumberland Mountain in the western half of the quadrangle but is poorly exposed in the eastern half. In measured sections this member can be divided into five units. The basal unit, about 28 feet thick, consists of interbedded, lutite-textured, olive-gray, slightly argillaceous to argillaceous limestone. Unlike the other units of the Newman, this unit contains abundant nodules of medium- to dark-gray chert. Overlying the basal unit is 18 feet of sparsely oolitic, arenite-textured olive-gray limestone. The next unit, 19 feet thick, is an argillaceous, lutite-textured olive-gray limestone, which is overlain by about 90 feet of thick-bedded, light olive-gray oolitic limestone. The top unit, also 90 feet thick, is composed of interbedded olive-gray, lutite-textured limestone and light olive-gray oolitic limestone.

Because the upper member of the Newman limestone is poorly exposed in the quadrangle, stratigraphic data were obtained from a section measured in Lewis Hollow, about 8 miles west of the Ewing quadrangle. In this section the member is 350 feet thick and consists of interbedded olive-gray, argillaceous, lutite-textured limestone and dark-greenish-gray calcareous shale, and a few beds of oolitic and arenite-textured limestone. The rocks in the few isolated outcrops of this member in the Ewing area are similar to those in the Lewis Hollow section.

PENNINGTON FORMATION

In the Ewing quadrangle the Pennington formation of Mississippian age is divided into two members. The lower member, ranging from 195 to 245 feet in thickness, is the thickest and most consistent part of the formation. It is composed of very fine- to fine-grained sandstone, which occurs in both platy and cross-laminated beds, and includes minor amounts of interbedded pale-olive shale and siltstone. To the northeast where the Pennington is considerably thicker, Wilpolt and Marden (1959) used "Pennington group" divided into three formations; however, for practical mapping purposes the thin Pennington of this area is considered a formation.

The upper member of the formation is composed of 5 units of alternating shale and sandstone, which show lateral facies variations. The basal unit, ranging in thickness from 68 to 147 feet, is mostly a pale-olive shale that locally contains some grayish-red siltstone and shale in its lower part. It is overlain in the western part of the area by a conglomeratic fine- to medium-grained sandstone which grades eastward to fine- to medium-grained slightly conglomeratic sandstone that contains some greenish-gray siltstone and shale. This unit ranges in thickness from 65 to about 100 feet. Unit 3 of the upper member is a 60- to 125-foot sequence of interbedded pale-olive shale, siltstone, and platy-bedded very fine grained sandstone. Unit 4, a platy-bedded sandstone that ranges from fine grained in the lower part to very fine grained in the upper part, occurs only in the eastern half of the outcrop belt. This unit grades westward into massive conglomerate sandstone of the Lee formation. Unit 5, from 0 to 80 feet thick, is mainly pale-olive shale containing some thin beds of platy, very fine grained sandstone. Unit 5 wedges out westward. A coal bed about 3 inches thick occurs locally at the top of the unit.

PENNSYLVANIAN SYSTEM

LEE FORMATION

The name Lee was originally applied by Campbell (1893, p. 36) to rocks characterized by massive conglomeratic sandstone exposed along Cumberland Mountain on the northwest boundary of Lee County, Va. This outcrop belt lies across the center of the Ewing quadrangle. Ashley and Glenn (1906) also used the term Lee in the area of the Ewing quadrangle in describing the geology of the Middlesboro syncline. Their usage differed from Campbell's in that they included younger rocks in the Lee. This upward placement of the top contact of the Lee formation by Ashley and Glenn was pointed out by Wentworth (1927, p. 180) and was recognized by Wanless (1946, p. 42). In this report the Lee refers to beds consisting predominantly of massive conglomeratic sandstone, as originally proposed by Campbell.

Although the Lee formation is generally regarded as being everywhere of Early Pennsylvanian age, studies in the Ewing and nearby quadrangles show that basal beds of the Lee formation intertongue with upper beds of the Pennington formation and as a result basal beds of the Lee formation are not everywhere contemporaneous. The Lee-Pennington contact in the Ewing quadrangle is drawn to include in the Lee formation rocks consisting predominantly of massive, quartzose, conglomeratic sandstone, and to include in the Pennington formation rocks composed mostly of light-olive-gray to grayish-green shale and thin, platy- to ripple-bedded sandstone. Intertonguing of the formations was demonstrated in the Ewing quadrangle by tracing massive conglomeratic sandstone typical of the Lee formation eastward into thin-bedded, ripple-marked sandstone typical of the Pennington formation. The complementary westward wedging out of light-olive-gray shale near the top of the Pennington formation between massive sandstones of the Lee formation is also evident. Because of intertonguing, the basal contact of the sandstone facies of the Lee rises stratigraphically eastward across the mapped area. The position of the Mississippian-Pennsylvanian boundary in this intertonguing sequence is unknown in the Ewing quadrangle.

The Lee formation is exposed in a broad belt of northward-dipping hogbacks and ridges that extend across the Ewing quadrangle from near the crest of Cumberland Mountain to the north side of Brush Mountain. It has a total thickness of about 1,500 feet. In addition to the typical conglomeratic sandstone, the Lee formation includes lesser amounts of massive fine- to medium-grained sandstone, wavy-bedded fine-grained sandstone, siltstone, shale, and a few thin beds of coal and underclay. Sandstones are commonly quartzose and are very light to light gray when fresh, but they weather to various shades of brown or reddish brown. Finer textured rocks are usually darker as a result of an increase in carbonaceous matter. The shales are clayey to silty and evenly bedded and range from medium gray to black.

Lithologically, the Lee is divided into six members including, in ascending order: sandstone member *A*, the White Rocks sandstone member, sandstone and shale member *B*, sandstone member *C*, sandstone and shale member *D*, and the Bee Rock sandstone member. Members *B* and *D* are relatively nonresistant, nonconglomeratic beds which separate the massive cliff-forming conglomeratic members.

Sandstone member A.—The basal member of the Lee formation, sandstone member *A*, is exposed at or slightly below the crest of Cumberland Mountain. In the western half of the quadrangle the member is shown as a separate unit. It is fine grained to medium grained very light gray quartzose sandstone. Where mapped separately, sandstone member *A* is approximately 180 feet thick and includes as much as 35 feet of conglomeratic, fine- to coarse-grained standstone in the lower part at the west edge of the quadrangle. To the east the lower part of the member thins and grades laterally into massive fine-grained nonconglomeratic sandstone which then grades into thin wavy-bedded very fine grained sandstone of the Pennington formation near White Rocks in the center of the quadrangle. In this vicinity the lower part of sandstone *A* is separated from the upper part by a tongue of light-olive-gray shale, approximately 70 feet thick, of the Pennington formation. This shale thins westward and wedges out about 1 mile west of the lookout tower. The upper part of sandstone member *A* thins eastward and from White Rocks to the edge of the quadrangle it ranges from 35 to 50 feet in thickness. Because of the relative thinness of sandstone member *A* in this area, it is not differentiated on the map from the overlying member.

White Rocks sandstone member.—The name White Rocks sandstone member is here proposed for the massive conglomeratic member of the Lee formation which forms the White Rocks, a prominent south-facing cliff at the crest of Cumberland Mountain. At the type exposure overlooking the town of Ewing, the member is 300 feet thick. The thickness increases from 125 feet on the west edge of the quadrangle to 340 feet on the east edge. The member caps Cumberland Mountain east of White Rocks and forms sheer-sided hogbacks on the north slope west of White Rocks. The White Rocks sandstone member is fine to coarse grained, very light gray, and quartzose. In the Ewing quadrangle it is the most conglomeratic member of the Lee formation. Locally parts of the member contain 75 percent or more of well-rounded quartz pebbles, most of which range from ½ to 1 inch in diameter. The pebbles are generally most abundant and largest near the base of the member, which has a sharp, undulatory, scour-type contact with the underlying sandstone. The upper contact is gradational. At the east edge of the area the member includes at its center a lentil of light olive-gray, thin, wavy-bedded, very fine grained sandstone about 50 feet thick. The lentil wedges out abruptly westward.

Sandstone and shale member B.—A sequence of nonresistant shale and sandstone beds overlying the White Rocks sandstone member comprises member *B*. The lower part of the member is composed of 70 to 130 feet of thin, even-bedded, medium-gray shale. It locally includes a coal bed. The shale grades upward to a thin wavy-bedded very fine grained to fine-grained light-gray and light-olive-gray sandstone, which thins eastward along the outcrop from about 120 feet to 30 feet. Thinning of the sandstone probably results both from scour on the undulatory upper contact and from lateral gradation into the underlying beds of shale in member *B*. The total thickness of the member decreases eastward from about 240 feet to 100 feet.

Sandstone member C.—Sandstone member *C* is essentially a group of massive conglomeratic sandstone beds 300 to 400 feet thick near the middle of the Lee formation. The member is well exposed in a broad belt of linear ridges and hogbacks on the north slope of Cumberland Mountain and in a narrow belt along the west end of Brush Mountain. The sandstone beds are massive in outcrop and cross-bedding is usually very conspicuous. The sandstone is very light gray, fine to coarse grained, and quartzose. It is less conglomeratic than the White Rocks member but locally includes lenses of quartz pebbles as much as 5 feet thick. The pebbles are well rounded; they are commonly ½ to 1 inch in diameter and as much as 2 inches in length. Four individual conglomeratic sandstone beds can be differentiated locally where they are separated by thin lenses of platy sandstone, shale, coal, or underclay. A coal bed as much as 3 feet thick occurs near the center of the member.

Sandstone and shale member D.—Sandstone and shale member *D* is composed of about 400 feet of alternating beds of sandstone and shale with a few thin beds of coal and underclay. In contrast to the underlying and overlying cliff-forming conglomeratic members, the beds of member *D* are relatively nonresistant and poorly exposed. Although individual beds show considerable lateral variation in thickness and lithology, three units are recognizable in member *D*. The basal unit is about 100 feet thick and consists mostly of medium-gray shale. Very fine-grained to fine-grained sandstone with thin wavy to platy bedding ranging from 5 feet to 25 feet in thickness is present in the upper half of the unit. The sandstone is overlain by a thin coal bed and associated underclay. The middle unit of member *D* is a thick-bedded to massive sandstone. It is approximately 110 feet thick, light gray, and very fine grained to fine grained. The top unit of member *D* is about 190 feet thick. It includes mostly thin wavy- to platy-bedded sandstone in the lower half and medium-gray to black shale in the upper half. The sandstone is very fine grained to fine grained and light gray. A thin coal bed occurs locally near the base of the top unit of member *D* and a coal bed as much as 3 feet thick occurs about 25 feet below the top of the unit.

Bee Rock sandstone member.—The Bee Rock sandstone, as used by Campbell (1893, p. 17), is hereby formally considered the top member of the Lee formation. It was recognized as the top member of the Lee formation at Pennington Gap in Lee County, Va. (Giles 1925, p. 21). In the Ewing quadrangle, the Bee Rock sandstone member caps Brush Mountain and forms steeply dipping hogbacks on the north slope of the mountain. The thickness ranges from about 250 to 300 feet. It is 255 feet thick in cliffs overlooking Martins Fork at the gap in Brush Mountain. The Bee Rock member in the Ewing quadrangle may be two coalescing sandstone units, for it commonly crops out in two ledges which are locally separated by as much as 5 feet of shale. Conglomerate consisting of well-rounded quartz pebbles, most of which are less than one-half inch in diameter, is sparse; like other conglomeratic sandstone members of the Lee formation, the Bee Rock is quartzose, very light gray, fine to coarse grained, and conspicuously crossbedded. The basal contact is sharp and undulating on the underlying shale of member *D*; the relief on the surface of member *D* is several feet.

BREATHITT GROUP

Rocks overlaying the Lee formation in Kentucky were named Breathitt from exposures in Breathitt County (Campbell, 1898, p. 3). Lithologically similar rocks overlying the Lee formation in the Middlesboro syncline, which includes the northern part of the Ewing quadrangle, were named, in ascending order, the Hance, Mingo, Catron, Hignite, and Bryson formations (Ashley and Glenn, 1906, p. 37–44). Because the term Breathitt is extensively used for the post-Lee Pennsylvanian rocks in Kentucky, it is here proposed to raise the Breathitt to the rank of group and to include the Hance, Mingo, Catron, Hignite, and Bryson formations, in the group. Studies in the vicinity of the Ewing quadrangle and in Tennessee (Englund, 1957, 1958) indicate that the contact of the Breathitt group with the underlying Lee formation rises stratigraphically westward, owing to both intertonguing and lateral gradation of basal beds of the Breathitt into beds of the Lee formation.

In the Ewing quadrangle the Breathitt group is about 3,250 feet thick and consists of alternating beds of shale, siltstone, sandstone, and lesser amounts of coal, underclay, and limestone. In contrast with the Lee formation, the Breathitt group contains a greater percentage of fine-grained rocks—shale, siltstone, and very fine grained to fine-grained sandstone. The beds of sandstone rarely contain quartz-pebble conglomerate, and they are generally thinner, less massive, and less quartzose than those of the Lee formation. The shale ranges from clayey to silty and is commonly thin and evenly bedded, and some beds contain ironstone bands and nodules. The underclays, generally associated with coal bed, contain fossil rootlets and range from clayey to silty. Ellipsoidal concretions of argillaceous limestone occur in beds of shale and siltstone. Unweathered exposures range from light gray for sandstone to medium gray or black for shale. Weathering alters these colors to various shades of brown or reddish brown.

HANCE FORMATION

In the Ewing quadrangle the Hance formation includes approximately 1,400 feet of strata from the top of the Bee Rock sandstone member to the base of the Harlan coal bed. The Hance crops out in the lower slopes of valleys in the northern third of the quadrangle, where it consists mainly of medium-gray shale with interbedded very fine grained to fine-grained sandstone, siltstone, coal, and underclay. Sandstone beds as much as 50 feet thick in the lower part of the formation probably are lenses of the Naese sandstone (Ashley and Glenn, 1906, p. 35), a member of the Lee formation in areas west of the Ewing quadrangle. As these sandstones are lithologically similar to sandstone of the Breathitt group and occur in a predominantly shale section in the Ewing quadrangle, the lower contact of the Hance formation is placed at the top of the Bee Rock sandstone member. The Hance formation contains three persistent coal beds: an unnamed coal about 1,050 feet below the top, the Puckett Creek coal 600 to 650 feet below the top, and the Path Fork coal 180 to 220 feet below the top of the formation. At most localities the Path Fork coal is overlain successively by about 15 feet of fine- to medium-grained sandstone and 100 feet or more of medium-gray shale containing ellipsoidal limestone concretions as much as 5 feet in diameter. The shale is overlain by a prominent bench-forming sandstone member which underlies the Harlan coal at most places. This sandstone member is thick bedded, very fine grained to fine grained, and light gray. The thickness of the member decreases northeastward from 90 to less than 40 feet. Approximately 5 to 20 feet of shale, siltstone, and underclay are at the top of the member below the Harlan coal bed. The top contact of the Hance formation was placed by Ashley and Glenn (1906 p. 31, 195) at the base of the Harlan coal bed in the area of the Ewing quadrangle and at the base of the Hance coal bed in nearby areas to the west. The uncertainty of the Hance and Harlan coal bed correlation was recognized by Ashley and Glenn (1906, p. 134), and the present study indicates that the Harlan coal bed is stratigraphically above the Hance coal bed. As the Hance coal bed probably correlates with the Puckett Creek coal bed in the Ewing quadrangle, the top of the Hance formation is placed at the base of the widely mined Harlan coal.

MINGO FORMATION

The Mingo formation, as defined by Ashley and Glenn (1906, p. 39) in the Black Mountain area and as used here, extends from the base of the Harlan coal to the base of the Wallins Creek coal. In the Ewing quadrangle the Mingo formation is approximately 950 feet thick and consists mostly of medium-gray shale with interbedded very fine grained to fine-grained light-gray sandstone, siltstone, coal, and underclay. It crops out on the upper slopes of valleys and on hilltops in the northern third of the quadrangle.

The Mingo formation contains three mapped units: the Harlan coal at the base of the formation, the Kellioka coal at approximately 300 feet above the base, and the Puckett sandstone member 180 to 220 feet below the top of the formation. The Puckett sandstone member consists of about 40 feet of light-gray fine-grained sandstone. It crops out in massive cliffs that are conspicuous in tributary valleys on the north side of Puckett Creek and on the south slope of Little Black Mountain.

Marine fossils are abundant in three beds in the Mingo formation. The lowest bed, which is about 80 feet above the Kellioka coal, consists of approximately 2 feet of calcareous siltstone. The upper two beds occur in medium-gray shale at intervals of 45 and 130 feet below the Puckett sandstone member. The shale contains ellipsodial limestone concretions as much as 3 feet in diameter and is calcareous in the fossiliferous beds.

CATRON FORMATION

The Catron formation includes approximately 400 feet of strata between the base of the Wallins Creek coal and the top of the Jesse sandstone member. The intervening rocks usually consist of three massive fine- to medium-grained sandstone beds, and interbedded medium-gray shale, siltstone, coal, and underclay. The Catron crops out on the upper valley slopes and on isolated hilltops in the northeast part of the quadrangle.

In addition to the Wallins Creek coal at its base, the formation includes the Fire Clay Rider and Smith coal beds, which lie approximately 50 and 180 feet, respectively, above the basal coal bed. The Jesse sandstone member in the upper part of the Catron formation is about 60 feet thick, ranges from fine grained to coarse grained, and, in contrast with other sandstone units of the Breathitt group, contains lenses of quartz pebbles. The pebbles are well rounded, range from ¼ to ½ inch in diameter, and usually occur in the lower part of the member.

HIGNITE FORMATION

The Hignite formation overlies the Jesse sandstone member and includes the youngest Pennsylvanian rocks in the mapped area. Outcrops are limited to the northeast corner of the quadrangle where approximately 400 feet of beds in the lower part of the formation cap the highest ridge. The rocks are predominantly massive fine- to medium-grained sandstone and medium-gray shale. Marine fossils are abundant in a calcareous shale about 8 feet thick that lies 80 feet above the base of the formation. In the mapped area a coal bed about 3 feet thick occurs approximately 180 feet above the base of the formation. The Reynolds sandstone member, a prominent cliff-forming sandstone, occurs about 250 feet above the base of the Hignite formation. This sandstone is fine grained, light gray, thick bedded to massive and ranges from 60 to 80 feet in thickness.

QUATERNARY SYSTEM

The bedrock in the Ewing quadrangle is covered locally by surficial deposits including alluvium in flood plains of the main streams, older terrace alluvium bordering present flood plains, and colluvium on steep mountain slopes and adjacent valley bottoms. The alluvium and terrace deposits are generally less than 10 feet thick and consist of unconsolidated clay, silt, sand, and gravel. The colluvium is composed of unconsolidated angular to subrounded cobbles and boulders embedded in clay, sand, and gravel. Deposits of colluvium are mapped locally where their extent and thickness obscure the underlying bedrock. Talus blocks, from several feet to as much as 50 feet thick, commonly occur along or below the outcrops of massive conglomeratic sandstone.

STRUCTURE

The Ewing quadrangle is near the center of the Cumberland overthrust block and includes parts of the two major structural features of the area—the Middlesboro syncline and the Powell Valley anticline. Most of the quadrangle is underlain by the Pine Mountain thrust fault, which is exposed in the Hamblin Branch and Dean fensters in the southeast corner of the quadrangle. Rocks of the overthrust block have been displaced northwestward approximately 4.2 miles as measured between the truncated ends of the Clinton shale (section *A–A′*, pl. 1), which crops out in the Dean fenster about half a mile south of the quadrangle. The displacement shown in section *A–A′* is based on the assumption that the widths of the truncated edges of formations in the overthrust block approximately match their counterparts exposed below the fault in the Dean fenster.

The trough and southeast limb of the Middlesboro syncline extend across the northern third of the quadrangle. Rocks in the trough of the syncline are relatively flat lying as shown by structure-contour lines on the top of the Harlan coal bed. The most conspicuous features shown are gentle northeastward-plunging flexures. Toward the south the dip of the southeast limb of the Middlesboro syncline increases abruptly and is nearly vertical on the north limb of the Brush Mountain anticline, an asymmetric fold with the steepest limb to the north. On the west side of the quadrangle part of the north flank of the Brush Mountain anticline is overturned and dips as much as 59° S. The Brush Mountain anticline plunges to the east edge of the quadrangle where it merges with the steeply dipping beds along the northwest flank of the Powell Valley anticline. On the south limb of the Brush Mountain anticline the rocks dip from 2° to 10° toward the shallow Martins Fork syncline. The dip increases gradually from the trough of this syncline to Cumberland Mountain and is as much as 50° N. near the east edge of the quadrangle. Westward along Cumberland Mountain the dip averages about 20° N. The general southwesterly strike of beds on the northwest limb of the Powell Valley anticline swings to the west in the southwest part of the Ewing quadrangle because of a northward warping of the anticline. Beds on the northwest limb of the Powell Valley anticline dip from 5° to 70° and include gentle monoclinal flexures. The crest of the anticline intersects the southeast corner of the quadrangle. In this area the plane of the Pine Mountain overthrust fault is exposed in the Hamblin Branch and Dean fensters. As mapped by Miller and Fuller (1947) the Maynardville limestone and Copper Ridge dolomite of Cambrian age in the overthrust block have overridden the Clinton shale and Hancock dolomite of Silurian age in the fensters.

ECONOMIC GEOLOGY

COAL

Coal has been mined in the Ewing quadrangle for more than 50 years, mostly from a few large underground mines which are served by railroad. In recent years this production has been supplemented by the operation of strip, auger, and truck mines. The coal is of high volatile A bituminous rank and occurs principally in five beds; the Puckett Creek and Path Fork coal beds in the Hance formation, the Harlan and Kellioka coal beds in the Mingo formation, and the Wallins Creek coal bed in the Catron formation. The total estimated original reserves in these beds, as shown in table 1, are 196,349,000 tons, of which approximately one-third is estimated as mined and lost in mining. Assuming 50 percent recovery, the remaining recoverable reserves are 67,241,000 tons. Reserves are reported by thickness categories of 14 to 28 inches, 28 to 42 inches, and more than 42 inches, and by measured, indicated, and inferred reliability categories. In general, coal is classified as measured in areas within one-fourth of a mile of an observation point, as indicated in areas extending one-half of a mile beyond measured coal, and as inferred in areas beyond the indicated reserves or where observation points are more than 1½ miles apart.

Puckett Creek coal bed.—The Puckett Creek coal bed is exposed along the southeast limb of the Middlesboro syncline from the upper part of Brownies Creek eastward to the edge of the quadrangle. From this area the bed dips northward and underlies the northern third of the quadrangle. The Puckett Creek coal also crops out on the northwest limb of the syncline beyond the mapped area. A reentrant of this outcrop line extends into the quadrangle along Mill Creek. The coal ranges from 1 to 3 feet in thickness and averages about 2 feet thick in most areas. Mining of the bed consists mostly of shallow adits along Brownies and Mill Creeks where the coal has been worked for local use.

Path Fork coal bed.—The Path Fork coal bed dips gently northward from the south side of the Middlesboro syncline and crops out on the lower valley slopes of the main streams. It averages about 30 inches in thickness in most areas and locally is as much as 40 inches thick. As development of the bed is limited to shallow workings for local use, the amount of coal mined is insignificant.

Harlan coal bed.—The Harlan coal bed, at the base of the Mingo formation, is extensively mined in the Ewing quadrangle. Most of the coal has been extracted from drift entries, but locally some coal is augered or strip mined. The Harlan coal ranges in thickness from 31 to 53 inches, averages about 40 inches thick, and is the most persistent coal bed in the Ewing quadrangle. It is usually a single bed but in several places a shale and clay parting a few inches thick is present in the center of the bed. Approximately 66 percent of the Harlan coal is estimated to have been mined or lost in mining and much of the remaining coal is in thin sections of the bed or in outcrop areas.

Kellioka coal bed.—The Kellioka coal bed crops out on the upper hill slopes but underlies a large area in the northeast corner of the quadrangle. In this area the coal averages about 45 inches in thickness and commonly includes one or two partings of impure coal, clay, and shale from 2 to 5 inches thick. The bed thins westward and probably splits into two benches. There are few prospects in the central and western parts of the outcrop area where the bed probably averages about 18 inches in thickness. Mining is confined to the area of thick coal in the northeastern part of the quadrangle where about 36 percent of the bed has been depleted.

TABLE 1.—*Estimated original and remaining coal reserves of the Ewing quadrangle*

[As of Jan. 1, 1959. Thousands of short tons. Covered by less than 2,000 ft of overburden]

Formation	Coal bed	Original reserves															Mined and lost in mining (estimated to Jan. 1, 1959)	Total remaining reserves
		Measured				Indicated				Inferred			Total					
		14–28 inches	28–42 inches	More than 42 inches	Total	14–28 inches	28–42 inches	More than 42 inches	Total	14–28 inches	28–42 inches	Total	14–28 inches	28–42 inches	More than 42 inches	Total		
Catron	Wallins Creek	12	637	11,978	12,627	--------	210	--------	210	--------	97	97	12	944	11,978	12,934	11,577	1,357
Mingo	Kellioka	1,384	1,912	15,090	18,386	5,249	1,297	3,358	9,904	1,889	1,327	3,216	8,522	4,536	18,448	31,506	11,778	19,728
	Harlan	--------	23,669	34,249	57,918	--------	--------	--------	--------	--------	--------	--------	--------	23,669	34,249	57,918	38,512	19,406
Hance	Path Fork	1,456	3,667	--------	5,123	6,688	11,421	--------	18,109	2,595	23,307	25,902	10,739	38,395	--------	49,134	--------	49,134
	Puckett Creek	2,458	2,129	--------	4,587	11,099	886	--------	11,985	28,285	--------	28,285	41,842	3,015	--------	44,857	--------	44,857
Total	----------------	5,310	32,014	61,317	98,641	23,036	13,814	3,358	40,208	32,769	24,731	57,500	61,115	70,559	64,675	196,349	61,867	134,482

Wallins Creek coal bed.—The Wallins Creek coal at the base of the Catron formation underlies only the highest ridges in the northeast corner of the quadrangle. It is the correlative of the Fire Clay or Hazard No. 4 coal in other parts of the Eastern Kentucky coal field. The typical flint-clay bed, commonly used to identify this coal bed, lies from a few inches to as much as 16 feet below the Wallins Creek coal. The coal ranges from 30 to 90 inches in thickness and averages at least 4 feet in thickness in most areas. Underground, strip, and auger mining has depleted approximately 90 percent of the coal in this bed.

OIL AND GAS

Drilling for oil and gas in the Ewing quadrangle began in 1928 at a well located on the south side of Poor Valley Ridge near the west edge of the quadrangle. Records for this well were not kept, and it was abandoned as a dry hole. From 1947 to 1950 six wells were drilled in part of the Rose Hill oil field in the southeast corner of the quadrangle. Of these 6 wells 2 were dry holes, 3 produced oil from the Trenton limestone, and 1 produced oil from the Reedsville shale. The oil is described by Miller and Fuller (1954, p. 313) as "a clear, greenish-amber, high volatile oil with a paraffin wax-bearing base, and a gravity of 44.4° A.P.I." Production records were not kept for these wells which are now abandoned.

Miller and Fuller (1954, p. 301) point out that most of the oil production has come from the Trenton limestone and that the limits of the field have not been established. Because the Trenton abuts the Pine Mountain fault in the subsurface in the fenster area they believe that extension of the field to the south is impossible, but that favorable structural conditions occur to the east and probably just north of the fenster area (Miller and Fuller, 1954, p. 317–318).

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