KGS KENTUCKY GEOLOGICAL SURVEY
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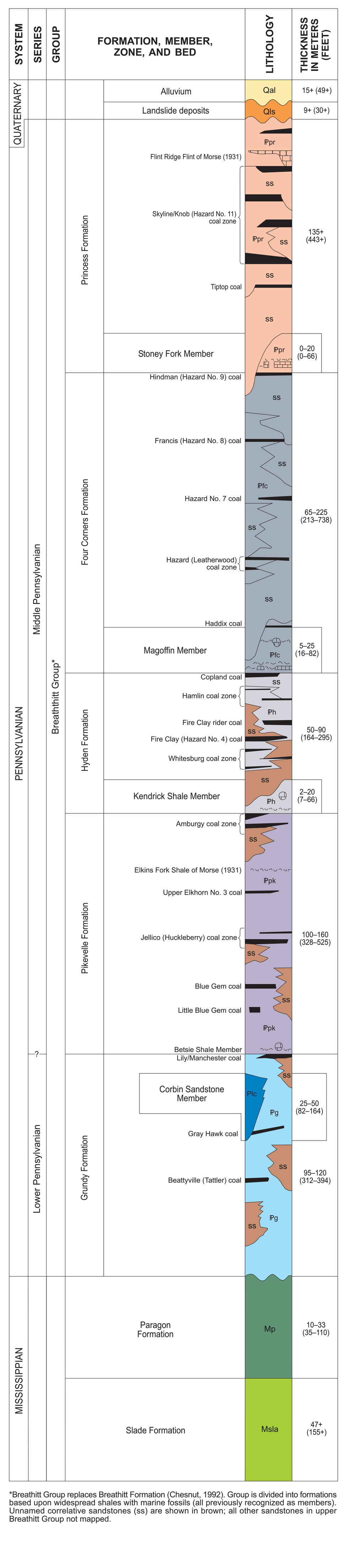


*Breathitt Group replaces Breathitt Formation (Chesnut, 1992). Group is divided into formations based upon widespread shales with marine fossils (all previously recognized as members). Unnamed correlative sandstones (ss) are shown in brown; all other sandstones in upper Breathitt Group not mapped.

DESCRIPTIONS OF MAPPED UNITS

Qal — ALLUVIUM (QUATERNARY)—Sand, silt, clay, and gravel. Clay, silt, and sand dominate rivers and tributaries, but pebbles and cobbles of locally derived sandstone, limestone, and coal also occur, especially in tributaries. Silts locally occur as remnants of alluvium on cutoff meanders and terrace deposits (not mapped) of larger rivers. Unit commonly grades into colluvium (not mapped) and landslide debris. Only larger alluvial deposits are mapped, and contacts are approximately located.

Qls — LANDSLIDE DEPOSITS (QUATERNARY)—Landslide debris commonly consists of locally derived slump deposits and other small rock debris along valley sides, intermixed with soil and disintegrating rock. Contacts approximately located. Mapped only on the Buckhorn 7.5-minute quadrangle (Danilchik and Lewis, 1978).

BREATHITT GROUP (LOWER TO MIDDLE PENNSYLVANIAN)—The Breathitt was mapped as a formation on the thirty-two 7.5-minute geologic quadrangle maps that were used to construct the Hazard 30 x 60 minute quadrangle map, but Chesnut (1992) elevated the Breathitt to group status and divided the group into formations based on regionally widespread shale members with marine fauna. Several of these shale members were mapped on the 7.5-minute maps and are described below. The Breathitt Group contains conglomerates, sandstones, siltstones, shales, coals, and limestones. Two types of sandstones occur: quartzarenites (more than 90 percent quartz), in the Corbin Sandstone Member, which was previously assigned to the Lee Formation, but was reassigned to the Grundy Formation by Chesnut (1992); and an unnamed sandstone beneath the Corbin Sandstone, informally called the Hazel Patch sandstone (Blancher and Brown, 1970). More common in the rest of the Breathitt Group are light- to medium-gray, tan- to brown-weathering sandstones that are fine- to medium-grained, locally coarse-grained, siliceous but locally calcareous, and arkosic to sublitharenitic. They consist of 60 to 80 percent quartz, 2 to 15 percent feldspar, and lesser amounts of mica, opaque minerals, and rock fragments. Conglomerates in the Corbin are composed of quartz pebbles; in other Breathitt sandstones they consist of shale, siderite, and coal clasts.

All the formations in the Breathitt Group are lithologically similar. The shale members (Betsie, Kendrick, Magoffin, Stoney Fork) at the base of each formation generally contain a thin, black to dark-gray clay shale and discontinuous, dark-gray to black limestone or sideritic sandstone with common marine fossils (summarized in Chesnut, 1991b). Basal shales grade upward into laminated, dark-gray silty shale with abundant siderite laminae and nodules, elliptical saucer-shaped carbonate concretions, and scarce fossils. Silty shales coarsen upward into thin-bedded, often bioturbated siltstone interbedded with fine-grained, ripple-bedded sandstone and shale; the siltstone-sandstone-shale unit in turn coarsens upward into massive to crossbedded sandstone, which may truncate the coarsening-upward profile.

Coarsening-upward shale members are overlain by four to five coal zones. Each zone consists of multiple coals that may split laterally or grade into carbonaceous shales and rooted seat rocks, although at least one of the coals is usually extensive and mapped on the 7.5-minute quadrangle maps. Coal zones are separated by shales, siltstones, and sandstones, and generally exhibit considerable lateral variability. Some sandstones are locally extensive and useful as stratigraphic markers.

Ppr — PRINCESS FORMATION (MIDDLE PENNSYLVANIAN)—Named by Chesnut (1992) for strata between the base of the Stoney Fork Member and the base of the Conemaugh Formation, which is not preserved in this quadrangle. The formation is equivalent to a unit mapped as the upper Breathitt Formation by Rice (1985). The base of the Stoney Fork Member (Ping and Rice, 1979) is locally a thin (0 to 4 ft) carbonate, which was mapped on some 7.5-minute quadrangle maps as the Lost Creek Limestone of Morse (1931); the Lost Creek Limestone is not currently recognized as a formal bed. In the northeastern part of the quadrangle, a second carbonate, the Flint Ridge Flint (Morse, 1931), occurs above the Skyline coal zone and is mapped on some 7.5-minute quadrangle maps. The Flint Ridge Flint consists of tan chert and yellowish-gray to dark-gray, sparsely fossiliferous, thin-bedded limestone and sandstone; it is generally less than 3 ft thick, although it may be as much as 30 ft thick in channel deposits (Hinrichs, 1978). Coals in the Princess Formation, in descending order, are the Skyline zone (Hazard No. 11), equivalent to the upper and lower Knob zone (Mixon, 1965a,b; Hinrichs, 1978), and the Tiptop (Hazard No. 10). Because the formation occurs only in the tops of hills in the northeastern part of the quadrangle, it is generally not well exposed, although the Stoney Fork Member is exposed in upper roadcuts along Ky. 80 in the Hazard North 7.5-minute quadrangle (Cobb and others, 1981; Chesnut, 1991b).

Pfc — FOUR CORNERS FORMATION (MIDDLE PENNSYLVANIAN)—Named by Chesnut (1992) for strata between the base of the Magoffin Member and the base of the Stoney Fork Member, which is equivalent to the middle Breathitt Formation of Rice (1985). The Magoffin Member (Outerbridge, 1978), which is equivalent to the Magoffin Beds of Morse (1931) and earlier usage, is the most widely recognized of the marine zones in the Breathitt Group; it varies from 0 to 85 ft in thickness across the quadrangle, thickening to the east. The base of the unit was used as a color break on many of the 7.5-minute quadrangle maps. Coals in the Four Corners Formation, in descending order, are the Hindman (Hazard No. 9), Francis (Hazard No. 8), Hazard No. 7, Hazard zone (which includes the Leatherwood, Hazard No. 5, Hazard No. 5A, and Hazard No. 6 coals), and the Haddix zone. This unit was named for the Four Corners exposure at the intersection of Ky. 15 and Ky. 80 (Cobb and others, 1981), and is also well exposed along the Daniel Boone Parkway (Hal Rogers Parkway) west of Hazard (Horne, 1978) and along Ky. 80 east of Hazard (Chesnut, 1991a).

Ph — HYDEN FORMATION (MIDDLE PENNSYLVANIAN)—Named by Chesnut (1992) for strata between the base of the Kendrick Shale Member and the base of the Magoffin Member. The Kendrick (Jillson, 1919) varies from 0 to 45 ft in thickness and was not mapped on several 7.5-minute quadrangle maps because it had been replaced by sandstone (Rice and Lee, 1978). Where the Hyden Formation is missing, the top of the Amburgy coal is considered the base of the formation. Coals in the Hyden Formation, in descending order, are the Copland, Hamlin zone, Fire Clay rider, Fire Clay (Hazard No. 4), and Whitesburg zone. The Fire Clay coal contains a distinctive 2- to 6-in.-thick, black to brown flint clay with conchoidal fracture that was deposited as a volcanic ash deposit. Sanidines in the flint clay have been radiometrically dated at 312 ±1 Ma by Lyons and others (1992) and 311 ±1 Ma by Rice and others (1994). The Fire Clay coal and flint clay are well exposed along Ky. 15 near Carr Fork Lake (Carr Creek Lake) (Eble and others, 1995). The formation crops out along the Daniel Boone Parkway (Hal Rogers Parkway) west of Buckhorn Reservoir (Cobb and others, 1981), near the dam at Buckhorn State Park (Danilchik and Lewis, 1978), and along the Ky. 15 bypass around Hazard (Eble and others, 1995).

Ppk — PIKEVILLE FORMATION (MIDDLE PENNSYLVANIAN)—Named by Chesnut (1992) for strata between the base of the Betsie Shale Member and the base of the Kendrick Shale Member. The Betsie Shale was defined by Rice and others in 1987 and was not shown on 7.5-minute quadrangle maps, although it normally occurs just above the Manchester-Lily coal, which was extensively mapped in 7.5-minute quadrangles in the western part of the quadrangle. Coals in the Pikeville Formation that were mapped on 7.5-minute quadrangle maps are, in descending order, the Amburgy zone, Upper Elkhorn No. 3 zone, Jellico-Huckleberry zone, Blue Gem/Pond Creek zone, and Little Blue Gem. The Upper Elkhorn No. 3 coal is overlain by a carbonaceous shale containing marine fossils, called the Elkins Fork Shale, which was described on several 7.5-minute quadrangle maps. The Kendrick and Elkins Fork Shales are well exposed along the Daniel Boone Parkway (Hal Rogers Parkway) in Clay County (Cobb and others, 1981).

Pg — GRUNDY FORMATION (LOWER PENNSYLVANIAN)—Named by Chesnut (1992) for strata from the top of the Bee Rock Sandstone to the base of the Betsie Shale. The upper part of the formation is locally dominated by thick, crossbedded sandstones. The Corbin Sandstone Member (described below) interfingers laterally at the top of the unit. The upper part of the Grundy contains the Manchester-Lily coal, which is underlain by the Gray Hawk and Beattyville-Tattler coal. The lower part of the Grundy does not crop out in the mapped area, but it does contain similar coal-bearing rocks.

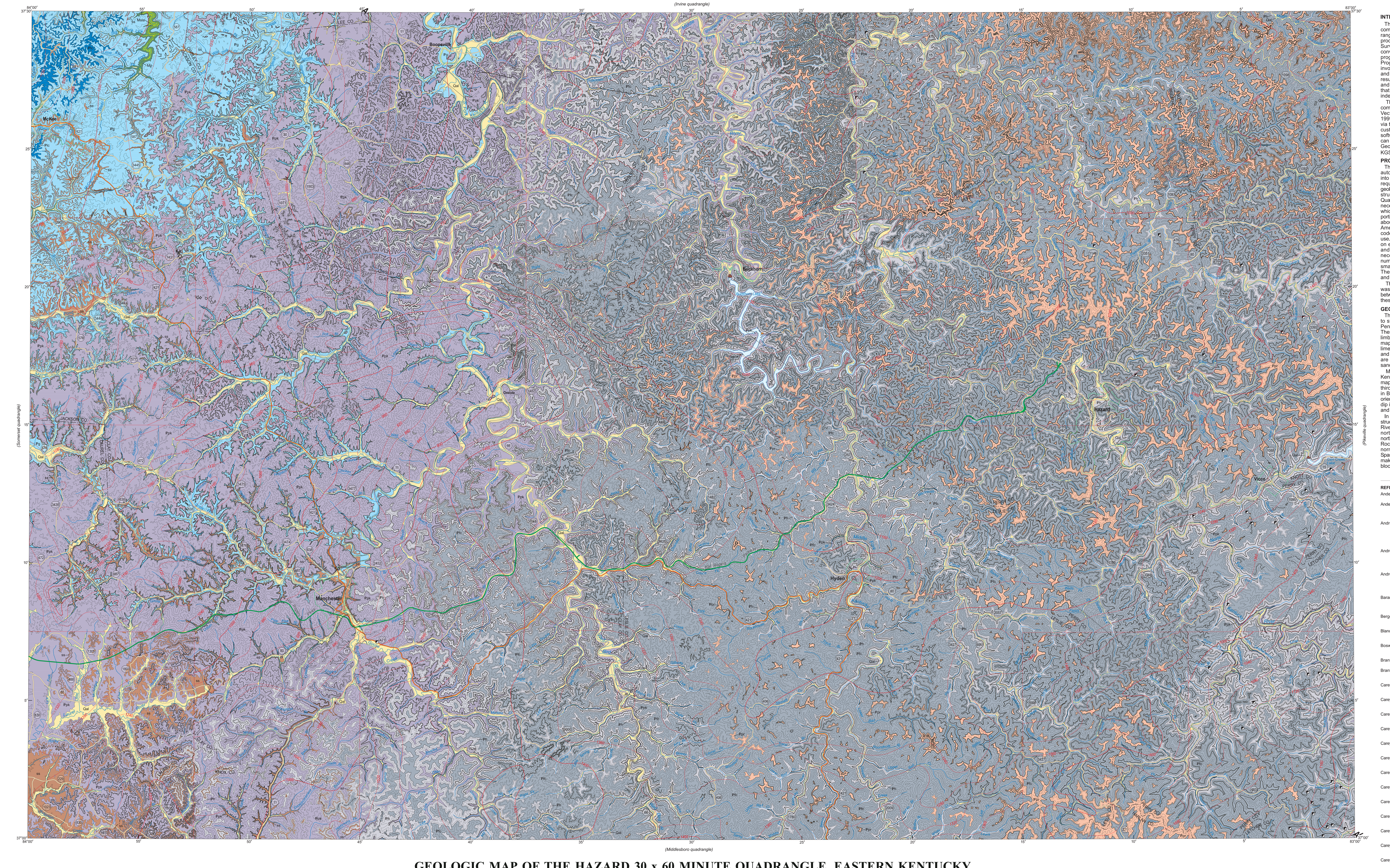
Plc — CORBIN SANDSTONE MEMBER OF GRUNDY FORMATION (LOWER PENNSYLVANIAN)—Sandstone and conglomeratic sandstone. Sandstone, generally medium-grained to very coarse-grained, quartzose, crossbedded; white quartz and gray chert pebbles as conglomeratic layers are common near base. Fairly resistant, forms steep cliffs and ledges. Unit is southwest-trending body present only in northwestern part of quadrangle. Occurs as lateral facies at the top of the Grundy Formation. Previously mapped as member of the Lee Formation (Weir and Mumma, 1973), reassigned to the Grundy Formation (Chesnut, 1992).

ss — Sandstone—Unnamed correlative sandstones mapped in seven of the eight westernmost 7.5-minute quadrangles of the Hazard mapped area. Mapped units are the lithic ("dirty") sandstones as described above in the Breathitt Group discussion as "light- to medium-gray, tan- to brown-weathering sandstones that are fine- to medium-grained, locally coarse-grained, siliceous but locally calcareous, and arkosic to sublitharenitic." These informal sandstones range from ridgetop, cliff-forming outcrops of the Hyden Formation to the valley-side and valley-floor sandstones of the Pikeville and Grundy Formations in the lower Breathitt Group. The sandstone outcropping along McCammon Branch on the border of the McKee and Tyner 7.5-minute quadrangles is informally designated the Hazel Patch Sandstone.

Mp — PARAGON FORMATION (MISSISSIPPIAN)—Unit consists of rocks assigned to Pennington Formation during U.S. Geological Survey–Kentucky Geological Survey cooperative mapping project, from 1960 to 1978 (Ettensohn and others, 1984). Shale, sandstone, siltstone, and dolomite. Shale, partly silty, locally calceous; partly grades into siltstone. Sandstone, very fine-grained, silty; locally grades into siltstone; irregularly interlayered with shale. Sandstone at top of formation, fine-grained, quartzose, partly to commonly micaceous; up to 33 ft thick; pinches out locally. Siltstone, argillaceous, sandy; irregularly interlayered with shale. Dolomite, in lenses up to 3 ft thick, scattered through upper part of formation. Contact with overlying Breathitt Formation is unconformable, but surface along contact apparently has low relief. Mapped only in northwestern part of quadrangle.

Msla — SLADE FORMATION (MISSISSIPPIAN)—Unit includes rocks assigned to Newman Limestone and Renfro Member of Borden Formation during U.S. Geological Survey–Kentucky Geological Survey cooperative mapping project, from 1960 to 1978 (Ettensohn and others, 1984). Limestone, dolomite, and shale. Limestone, micrograined to coarse-grained, bioclastic, oolitic, peloidal, partly dolomitic, fossiliferous, cherty, conglomeratic, and sandy. Dolomite, very finely crystalline, silty, argillaceous; dominant lithology in basal part of formation; up to 20 ft exposed in quadrangle. Shale, mainly in partings and interbeds; forms distinct unit, as much as 3 ft thick, in upper part of formation. Mapped only in northwestern part of quadrangle.

af — ARTIFICIAL FILL—Compacted rock debris from highway or railroad construction.



GEOLOGIC MAP OF THE HAZARD 30 x 60 MINUTE QUADRANGLE, EASTERN KENTUCKY

Thomas N. Sparks, Warren H. Anderson, and Lance G. Morris

Cartography by Terry D. Hounshell

SCALE 1:100 000

1 0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 KILOMETERS
1 0 1 2 3 4 5 6 7 8 9 10 MILES
1000 0 5000 10 000 15 000 METERS
5000 0 10 000 20 000 30 000 40 000 50 000 FEET

universal transverse Mercator projection, zone 17: 1927 North American datum

TOPOGRAPHIC CONTOUR INTERVAL 50 METERS

EXPLANATION

- Interstate highway or parkway
- U.S. highway
- State highway
- County boundary
- City boundary
- Railroad
- Normal fault (U, upthrown side; D, downthrown side)
- Reverse fault (R, upthrown side)
- Concealed fault
- Contact
- Concealed contact
- Inferred contact
- 960 Structure contour, feet
- Datum horizon boundary
- Coal bed
- Concealed coal bed
- Inferred coal bed
- Strip mine
- Coal mine, status 1978
- Inclined mine shaft
- Abandoned stone quarry, status 1978

Not all coals digitized under the STATEMAP Program are included on this map. Coals on map are Gray Hawk, Lily/Manchester, Blue Gem (Hima area), Jellico zone (including Huckleberry), Amburgy zone, Fire Clay, Fire Clay rider (Haddix area), Copland, Hazard/Leatherwood, Hindman, and Skyline zone (including Upper and Lower Knob).

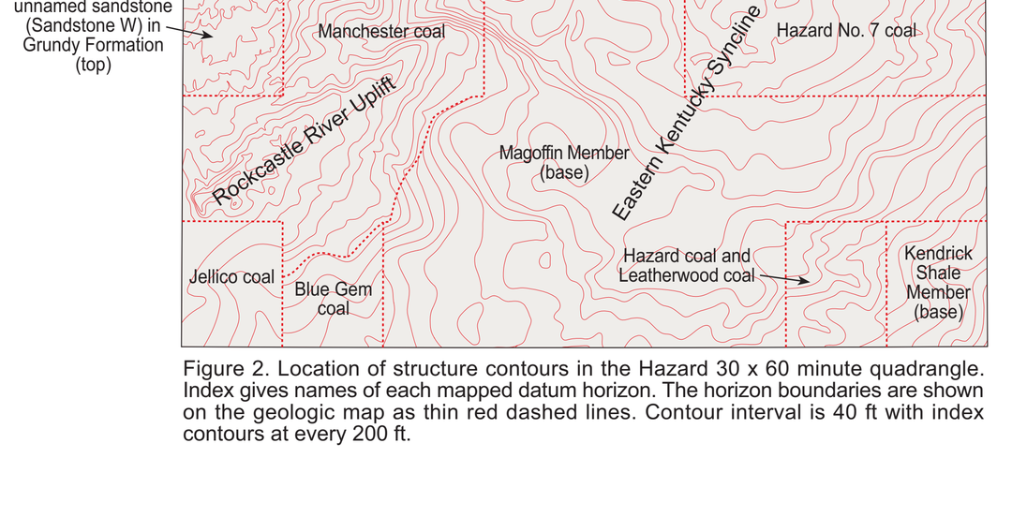
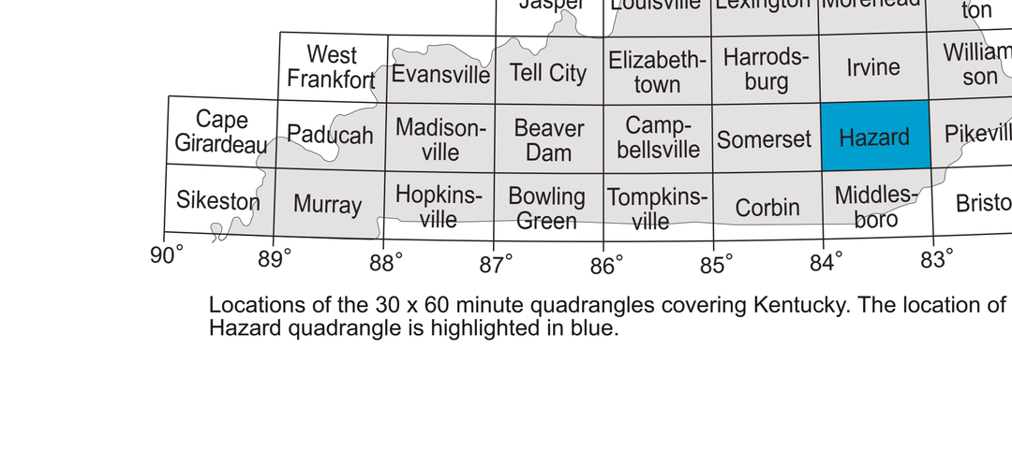


Figure 2. Location of structure contours in the Hazard 30 x 60 minute quadrangle. Index gives names of each mapped datum horizon. The horizon boundaries are shown on the geologic map as thin red dashed lines. Contour interval is 40 ft with index contours at every 200 ft.



Locations of the 30 x 60 minute quadrangles covering Kentucky. The location of the Hazard quadrangle is highlighted in blue.

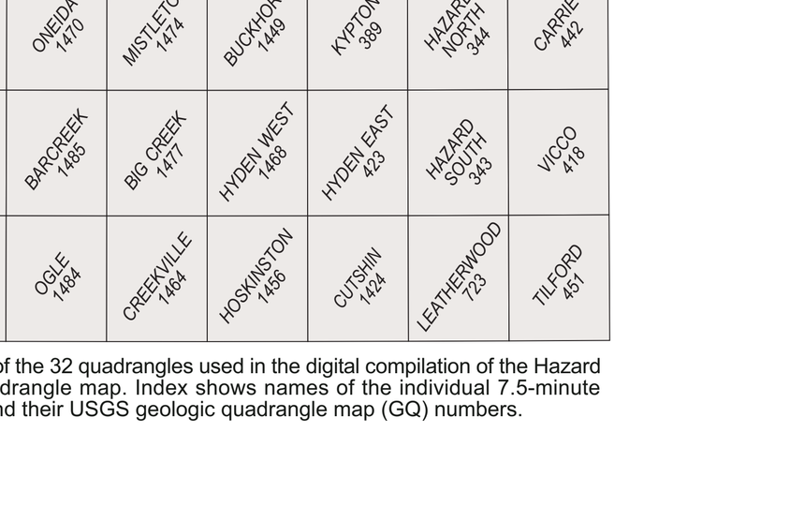
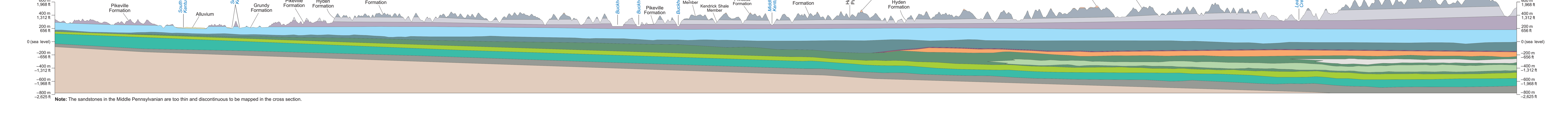


Figure 1. Locations of the 32 quadrangles used in the digital compilation of the Hazard 30 x 60 minute quadrangle map. Index shows names of the individual 7.5-minute quadrangle maps and their USGS geologic quadrangle map (GQ) numbers.



Note: The sandstones in the Middle Pennsylvanian are too thin and discontinuous to be mapped in the cross section.

This map was digitally generated from 1:24,000-scale geologic maps under the STATEMAP Program authorized by the National Geologic Mapping Act of 1992, grant no. 1434-HQ-96-AG-01489, and was funded in part by the U.S. Geological Survey National Cooperative Geologic Mapping Program.

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Special recognition is given to former State Geologist and Director Donald C. Haney for his effort in securing a project in conjunction with the USGS National Cooperative Geologic Mapping Program's STATEMAP component to convert all published geologic quadrangle maps into digital format. This map, the Hazard 30 x 60 minute geologic quadrangle, was the first deliverable to the USGS upon completion of the first year's conversion process.

For information on obtaining copies of this map and other Kentucky Geological Survey maps and publications call:

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(859) 257-3896 ext. 126
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INTRODUCTION

The geology of the Hazard 30 x 60 minute quadrangle was digitally compiled mostly from U.S. Geological Survey 7.5-minute geologic quadrangle maps (GQ's), as cited in the references. The original GQ's are products of a cooperative mapping project between the U.S. Geological Survey and the Kentucky Geological Survey from 1960 to 1978. The conversion into digital format has been another USGS-KGS cooperative program funded through the National Cooperative Geologic Mapping Program (STATEMAP). Several recent regional geologic investigations, involving map compilations (Rice, 1985), stratigraphy (Chesnut, 1992), and coal resource estimates (Brant, 1983; Brant and others, 1983) have resulted in changes in the stratigraphic nomenclature and correlation, and provided additional coal information. The 7.5-minute quadrangles that make up the Hazard 30 x 60 minute quadrangle are shown in the index map (Fig. 1).

The data files resulting from the digitization of the GQ's are part of a comprehensive relational and spatial data set, being released as Digitally Vectorized Geologic Quadrangles by the KGS (Anderson and others, 1999). These DVGQ's are available on CD-ROM, and will be released via the Internet in the near future. Users of the DVGQ data can prepare custom geologic maps by overlaying data using their own GIS or CAD software. KGS has also developed an Internet map server where users can prepare similar maps without purchasing DVGQ's via an interactive Geologic Map Information Service (kgsmap.uky.edu/website/KGSGeology) (Weisenfluh and others, 2005).

PROCEDURE

The 7.5-minute quadrangle maps were digitally compiled using a semi-automated data-capture technique to convert hard-copy geologic maps into digital format. Compiling 7.5-minute maps into a 30 x 60 minute map required the resolution of significant problems, such as (1) correlating geologic and cartographic quadrangle boundaries, (2) resolving nonuniform structure-contour datums or intervals, (3) resolving discrepancies in Quaternary alluvium boundaries and inferred contacts, and (4) determining necessary formation data for topological analysis in a GIS environment, which was omitted during 7.5-minute quadrangle mapping. The metadata portion of the DVGQ file provides detailed sources of data and information about the conversion process. Formation codes were assigned using the American Association of Petroleum Geologists' standard stratigraphic code (Cohee, 1967), which was modified by the KGS for state-specific use. Formations and formation boundaries were not mapped consistently on each of the 7.5-minute maps as they were compiled between 1960 and 1978. Resolution of the differences between quadrangles was necessary for topological analysis in a GIS environment. In addition, numerous small members mapped on individual 7.5-minute maps are too small to be mapped at a scale of 1:100,000 on a 30 x 60 minute map. These problems were resolved by adhering to geologic, cartographic, and GIS standards appropriate for the scale of the map.

This map is a compilation of existing maps, and no additional field work was attempted. When there were problems in stratigraphic correlation between quadrangles, the best current data available were used to resolve these differences.

GEOLOGIC SETTING AND STRUCTURAL GEOLOGY

The geology of the Hazard 30 x 60 minute quadrangle consists of gently to steeply dipping sedimentary rocks of Mississippian through Middle Pennsylvanian age and unconsolidated sediments of Quaternary age. These rocks occur in the Eastern Kentucky Coal Field along the western limb of the central Appalachian Basin. The dominant rock types for the mapped area are interbedded sandstone, siltstone, shale, coal, and limestone for the Mississippian and Pennsylvanian strata; and terrace and alluvial deposits for the Quaternary strata. The Quaternary sediments are mainly unconsolidated or semiconsolidated, and contain clay, silt, sand, and gravel deposits, some of which may be locally cemented.

Major structural features identified on the Hazard map are the Eastern Kentucky Syncline and the Rockcastle River Uplift (see structure contour map, Fig. 2). The Eastern Kentucky Syncline comprises the eastern two-thirds of the map and is evident by the widely spaced synclinal contours in Breathitt, Perry, and Leslie Counties. The synclinal axis is generally oriented northeast-southwest and is bordered with strong regional eastern dip in Jackson and Owsley Counties and with southeastern dip in Knott and southern Perry Counties.

In the western side of the Hazard quadrangle is a prominent anticlinal structure centered on the northwestern part of Clay County, the Rockcastle River Uplift. Like the Eastern Kentucky Syncline, the uplift is also oriented northeast-southwest, but is a narrow structure with steep dips on its northern and eastern sides. The anticline is associated with the basement Rockcastle River Fault and is the near-surface expression of the deeper normal fault (Chesnut, 1992; Drahovzal and Noger, 1995; Harris and Sparks, 2000). Near the Clay-Owsley County border the structure contours make a sharp deflection, indicating further evidence of deep right-angle block faulting (Harris and Sparks, 2005).

ECONOMIC GEOLOGY

Coal, oil, and natural gas are the principal mineral resources of the Hazard 30 x 60 minute quadrangle. Limestone, sand, gravel, clay, and shale are also available as mineral resources for general construction purposes and for use in the coal industry. The locations of industrial mineral resources, including limestone and sand operations, were mapped and described by Anderson and Dever (2001) and Glass and Malone (2007).

Coal production and reserves

Coal has been mined here for more than 100 years by a variety of surface and underground mining techniques (Currens and Smith, 1977; Cecil and others, 1992). Most of the coal production for the quadrangle has come from the Hyden, Four Corners, and Princess Formations. All of the mined coals are Pennsylvanian in age. Coal beds of the Skyline coal zone in the Princess Formation are the thickest in the quadrangle—one is locally as much as 15 ft thick (Hinrichs, 1978)—but most of the mined coals in the quadrangle are less than 48 in. thick. Mined coals are bituminous and of high-volatile A rank (Williams, 1984); they have mean ash yields of 5.7 to 12.2 percent, mean sulfur contents of 2.8 to 3.6 percent, and mean Btu values of 12,500 to 13,800 (Cobb and others, 1985). Between 1982 and 1992, the top five producing coals in the Hazard quadrangle were the Hazard No. 7, with 54 million short tons (MT) mined, the Hazard No. 4 (Fire Clay), with 42 MT mined, the Hazard No. 8 (Francis), with 39.5 MT mined, the Hazard, with 35 MT mined, and the Hazard No. 9 (Hindman), with 20.5 MT mined. The only significant production in the western part of the quadrangle was from the Manchester-Lily coal, with 4.4 MT mined. Analyses of these coals are provided in Bergeron and others (1983) and Currens and others (1987a, b). Most of the coal mined in the Hazard quadrangle is produced to meet compliance coal needs of the Ohio Valley and other electric-utility markets, but some of it has been of metallurgical grade and used for coking.

The Hazard quadrangle covers parts of the Hazard and Southwestern Coal Reserve Districts. The quadrangle encompasses most or all of Clay, Leslie, Owsley, and Perry Counties, with lesser parts of Breathitt, Jackson, and Knott Counties. Total coal production from the four major counties is summarized in Table 1.

Table 1. Cumulative coal production (million tons) by county and mining method (1829–2004).

County	Undifferentiated	Underground	Surface	Total
Clay	0.386	36.141	26.372	62.898
Leslie	0.001	193.868	64.490	258.359
Owsley	0.002	0.298	9.722	10.022
Perry	21.270	335.769	236.011	593.050
Total	**21.659**	**566.075**	**336.596**	**924.330**

Source: Kentucky Geological Survey coal production database, kgsweb.uky.edu/DataSearching/Coal/Production/prodsearch.asp [accessed 10/14/07].

Resource studies by Brant (1983) and Brant and others (1983) calculated total remaining resources of 12.4 billion short tons (BT) for the quadrangle. Coal availability studies, which take into account technological and land-use limitations to mining, for three of the 7.5-minute quadrangles in the Hazard quadrangle indicate that 42 to 52 percent of the remaining resource may be available for mining with present technology (Sergeant and others, 1988; Davidson and others, 1990; Weisenfluh and others, 1992). Coal-resource and -thickness maps from the availability studies for the Lower Elkhorn coal by Thacker and others (1998, 2000a), for the Fire Clay coal by Thacker and others (2000b, c), and for the Upper Elkhorn No. 3 coal by Esterle and others (2000a–c) have been published. Because mining has historically targeted the thickest and most easily accessible coal resources, future mining will increasingly have to target thinner and less accessible resources, including below-drainage coals (Greb and others, 1999). Remaining coal reserves for the four largest counties in the Hazard quadrangle have been tabulated (see Table 2).

Table 2. Coal production and remaining resource reserves for major counties in the Hazard quadrangle (million tons). (1) Hazard District, (2) Southwestern District.

County	Original	Mined & Lost	Remaining Reserves
Clay (2)	1,536	124	1,412
Leslie (1)	3,555	443	3,112
Owsley (2)	574	19	555
Perry (1)	3,597	1,034	2,563

Estimated remaining coal resources in major counties: 7,642

Source: Keystone Coal Industry Manual (2003)

Natural gas and petroleum

Gas and oil are both produced in commercial quantities from the Hazard quadrangle. Eastern Kentucky accounts for 98 percent of the statewide gas production, natural gas being produced from the organic-rich Devonian black shale and the Mississippian Big Lime carbonates. During 2005, total oil production from eastern Kentucky was 1.056 million barrels and total gas production was 91 billion cubic feet (bcf) (KGS, 2007a). Approximately 17.4 bcf of gas was produced in the quadrangle for 2005; Perry County's portion accounted for 48 percent of the total gas production (8.37 bcf) from the mapped area.

Structure, stratigraphy, and porosity play important roles in the accumulation of hydrocarbons in the Hazard quadrangle. Major oil production comes from several fields along the Rockcastle River Uplift, a large anticline along the western part of the quadrangle (Fig. 2) and from stratigraphic traps in the southeast (Leslie County and along the Perry-Letcher County line). Most significant gas production comes from the southwestern extension of the Big Sandy Gas Field into the eastern part of the quadrangle from the fractured Devonian black shale (Ohio Shale) (Boswell, 1996). Oil and gas production on the Rockcastle River Uplift comes from Trenton (Lexington Limestone) to Knox fractured carbonates (Lower to Middle Ordovician) (Baranoski and others, 1996; Wickstrom, 1996). The Mississippian carbonates, the Big Lime (Newman Limestone/Slade Formation), are predominantly stratigraphic hydrocarbon traps, with thicker limestone sections being deposited in erosional channels of the underlying Borden Formation (Smosna, 1996; Harris and Sparks, 2005). The Maxon sandstone (Upper Mississippian) and Salina, Lockport, and Keefer Big Six sandy carbonates (Corniferous Devonian/Silurian unconformity play) are also locally productive (Rice, 1985; Meglen and Noger, 1996; Nuttall, 1998).

Industrial minerals

Selected clays and shales from the Breathitt Group may have potential for industrial clay uses. Analysis of shale samples from above and below the Manchester coal and other underclays indicate potential for industrial uses in the brick and tile industry and for use as lightweight aggregate (McGrain and others, 1960). Siltstone and sandstone also have use as flagstone, dimension stone, and aggregate. Limestone, for use as road metal and agricultural lime, is produced by underground mining near McKee (Anderson and Dever, 2001; Glass and Malone, 2007).

ENGINEERING GEOLOGY

The highly dissected topography in the Hazard area has a history of landslides and presents a future potential for engineering and maintenance problems. The slope instability in the thick sequences of interbedded sandstone, siltstone, and shale in the Breathitt Group contribute to failure by landslide and creep, adversely affecting construction projects. The presence of prominent landslide scars and slumped bedrock indicate that future landslides may occur where these relatively unstable beds are undercut by rivers and their tributaries or by construction work for roads and mines. Logging, clearcutting, and removal of vegetation for construction can destabilize slopes. Coal-mining activities can also precipitate landslides, removing vegetation, oversteepening slopes, and cutting the toes of old slides. Landslides of colluvium from hillsides pose engineering hazards and have damaged roads and railroads. Landslides or slumps could occur when slopes are saturated with water.

HYDROGEOLOGY

The availability of groundwater in the Hazard quadrangle is discussed by Price and others (1962), Minns (1993), Wunsch (1993), and Carey and Stickney (2004, 2005a–l). Most fresh groundwater is obtained from shallow bedrock wells that are generally less than 100 ft deep and from shallow, dug wells in alluvium and regolith. Water in bedrock aquifers of the Breathitt Group is derived from sandstone, siltstone, and coal seams (which have enhanced permeability because of fractures). Vertical permeability is restricted by underclays and shales that act as aquitards. Salty water is typically encountered in wells deeper than 100 ft below the valley bottoms of third-order or higher streams (Wunsch, 1993); these wells may also have high, naturally occurring, barium content (Wunsch, 1991). Wells in alluvium near major streams may provide adequate water for farms or commercial operations.

The water resource in large, reclaimed surface mines is discussed in Wunsch and others (1996). Municipal water-supply resources have also been generated from abandoned underground coal mines. Detailed analyses at sites in Letcher, Perry, Clay, and Harlan Counties have been completed (KGS, 2007b), indicating recharge rates ranging from 120,000 to 700,000 gallons per day and storage volumes ranging from 260 to 480 million gallons. Even though water from abandoned underground mines tends to have higher concentrations of sulfate and dissolved metals (iron, magnesium, and manganese), municipal water systems successfully use this source of water after conventional treatment methods.

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