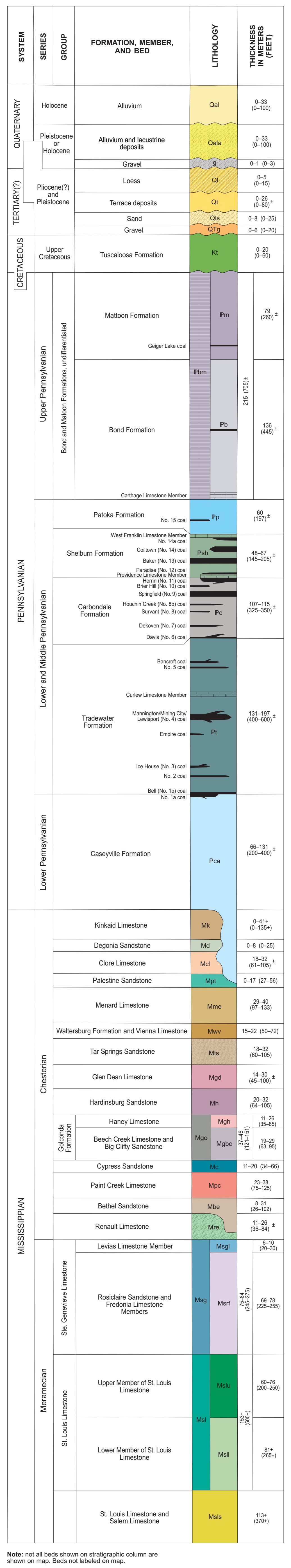
KENTUCKY GEOLOGICAL SURVEY
James C. Cobb, State Geologist and Director
UNIVERSITY OF KENTUCKY, LEXINGTON

GEOLOGIC MAP 12
Series XII, 2006



Note: not all beds shown on stratigraphic column are shown on map. Beds not labeled on map.

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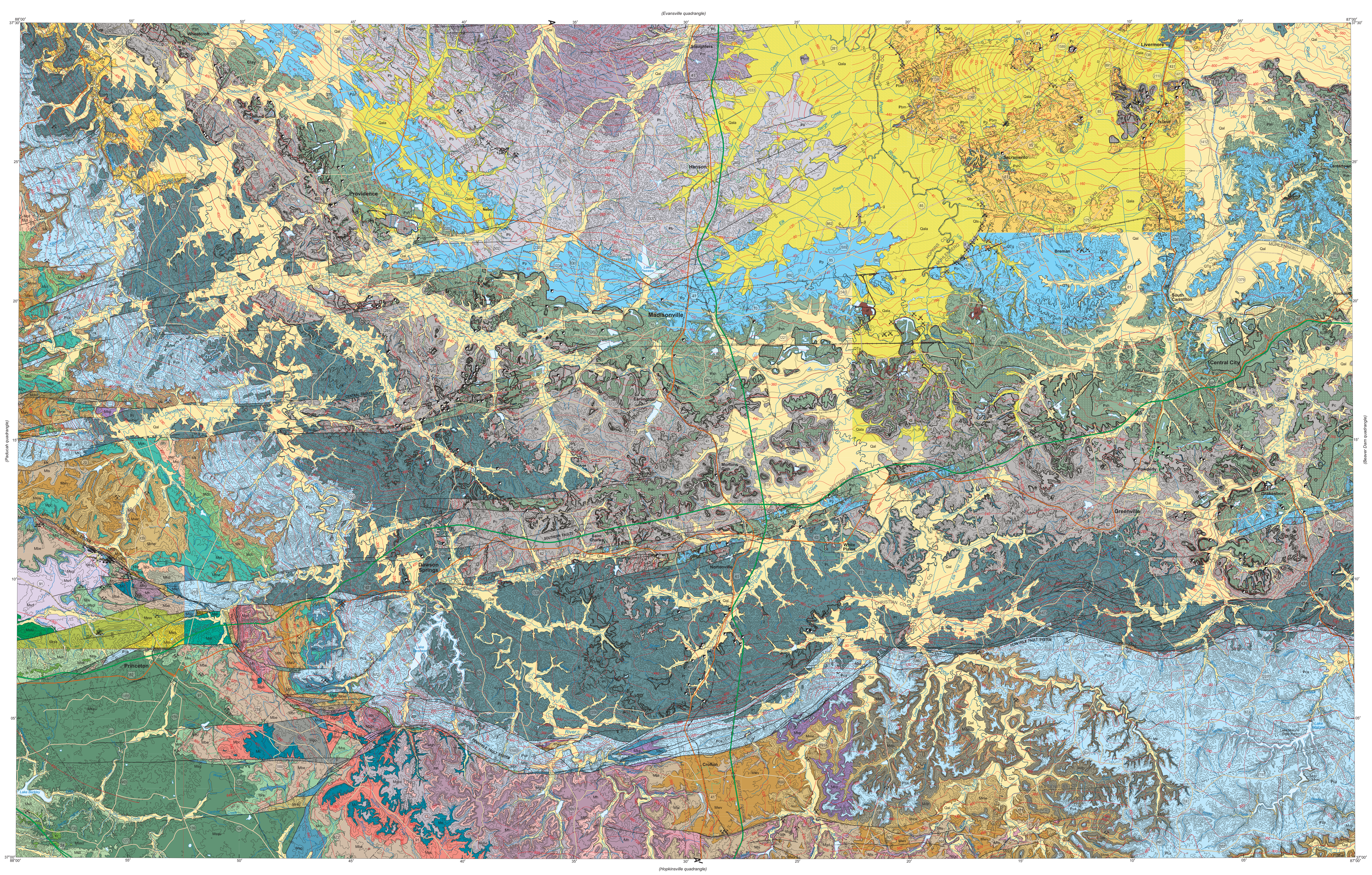
This map was digitally generated from 1:24,000-scale geologic maps under the STATEMAP Program authorized by the National Geologic Mapping Act of 1992, Grant No. 02HQPA0003 and was funded in part by the U.S. Geological Survey National Cooperative Geologic Mapping Program.

The author would like to thank Stephen F. Greb, Warren H. Anderson, Thomas J. Conley, Kieran T. Hosey, Tammi L. Johnson, Jack E. Mullins, Hugh L. Nelson, Patrick C. Smith, and Kristin S. Toth.

DESCRIPTION OF MAPPED UNITS

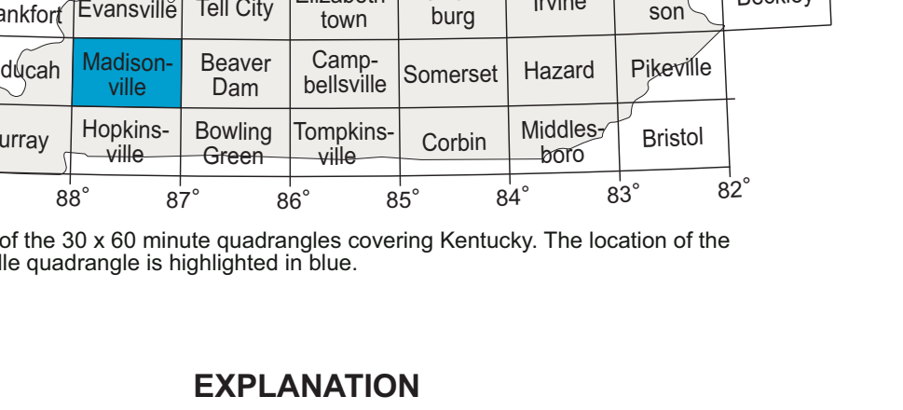
Qal	ALLUVIUM—Silt, sand, clay, and gravel. Silt, micaceous, clayey, locally lignitic; interlaminated with sand and gravel. Sand, poorly sorted, fine- to coarse-grained quartz. Clay, commonly silty, locally well laminated. Gravel, unconsolidated, consists of residual chert rubble, sandstone, siltstone, and ironstone pebbles. Unit is thickest in the Green River area and becomes thin and gravelly in smaller tributaries. Unit may include widespread deposits of lacustrine clay and silt.
Qala	ALLUVIUM AND LACUSTRINE DEPOSITS—Silt, clay, sand, and gravel. Silt and clay, finely laminated; locally limey and fossiliferous. The silt and clay are most likely the lacustrine deposits. Sand, fine- to medium grains; mainly subangular quartz grains. Gravel is sandy and limonitic, few chert pebbles; possibly derived from other nearby gravel deposits. These surface deposits form valley fills in adjacent upland areas.
g	GRAVEL—Gravel and sand. Gravel, subangular to subrounded sandstone pebbles, chert, and quartz sand; generally very sandy. Unit contains small areas where gravel is cemented together by limonite, forming conglomerate. Few pebbles of silicified limestone. Sand, medium- to coarse-grained; consists mainly of quartz grains. Unit is generally present in areas adjacent to silt and clay of lacustrine deposits.
Ql	LOESS—Silt, usually soft and clayey; moderately hard clay may occur in the lower part of the formation; locally contains nodules of limonite and silty calcite. Basal few inches includes bedrock fragments and pebbles.
QTs	SAND—Sand, fine- to coarse-grained, clayey and silty; consists of mostly quartz grains, limonite-stained. Unit is commonly concealed by loess and is only mapped on the Sacramento 7.5-minute quadrangle.
QTg	GRAVEL—Gravel, includes pebbles and cobbles of chert, quartz, ironstone, sandstone, siltstone, and silicified fossiliferous limestone; poorly sorted. Matrix is fine to coarse iron-stained sand, silty to clayey.
Qt	TERRACE DEPOSITS—Unit is mostly clay, silt, and sand within the Tradewater River tributary valleys in the northwest. Terrace deposits of the Green River are mostly gravel.
Kt	TUSCALOOSA FORMATION—Gravel, rounded pebbles and small cobbles of chert, commonly iron-stained; cobbles range from 2 to 4 in. in diameter, weakly cemented by clay, silt, and iron oxide. Formation caps few hills and ridges in the southwestern part of the quadrangle.
Pm	MATTOON FORMATION—Sandstone, shale, coal, limestone, and clay. Sandstone, thin- to thick-bedded; fine- to medium-grained, poorly to well cemented; locally micaceous and friable; locally crossbedded. Basal sandstone, locally underlain by conglomerate, forms a distinct topographic and lithologic break. Shale, carbonaceous, partly limey; contains ironstone concretions and zones of fossiliferous shale, commonly interbedded with sandstone. Formation contains at least five coal beds separated by clay (underclay) or shale and associated with limestone. Limestone, finely crystalline, locally silty; thin- to thick-bedded; contains bryozoans, brachiopods, and gastropods. Base of formation is approximated 200 ft feet beneath the Geiger Lake coal or 1000 ft above the Springfield (W. Ky. No. 9) coal bed based on position of a limestone marker bed in subsurface. In most areas the boundary is not identifiable and the Mattoon and Bond are undifferentiated.
Pb	BOND FORMATION—Sandstone, siltstone, shale, limestone, coal, and clay. Sandstone, fine- to medium-grained, locally micaceous and friable; thin- to medium-bedded, locally crossbedded. Siltstone, interbedded with sandstone; contains ironstone concretions; locally shaley and contains coal stringers. Shale, carbonaceous, partly limy, clayey to silty, contains clay-ironstone concretions; thin- to thick-bedded, generally present below coal and limestone beds. Limestone, fine-grained, well-cemented; commonly grades upward and laterally into sandstone. Numerous thin coal beds occur within the formation, including the Lisman coal bed. Clay, carbonaceous; commonly underlying coal beds. The base of the Carthage Limestone Member is the base of the formation.
Pbm	MATTOON FORMATION AND BOND FORMATION, UNDIFFERENTIATED
Pp	PATOKA FORMATION—Shale, sandstone, siltstone, limestone, coal, and clay. Shale, thin-bedded, locally crossbedded; fissile; carbonaceous, silty, and sandy; micaceous, limonite concretions locally abundant; locally fossiliferous. Sandstone, fine- to medium-grained, micaceous; commonly soft and friable; locally contains thin beds of ironstone pebble conglomerate. Siltstone, fine- to medium-grained, micaceous, limonitic; interbedded with shale and sandstone. Limestone, silty, commonly lenticular or as nodule in shale. Formation contains the W. Ky. No. 15, 16, and 17 coal beds. Clay, silty to sandy; moderately firm. The base of the formation is placed at the top of the West Franklin Limestone Member (formerly Madisonville Limestone) of the underlying Shelburn Formation.
Psh	SHELBURN FORMATION—Sandstone, shale, limestone, coal, clay. Sandstone, fine- to medium-grained, micaceous, friable; locally crossbedded, grades laterally into shale; contains clay-ironstone and limonite concretions. Shale, silty and sandy, micaceous, locally calcareous; interbedded with overlying sandstone. Limestone, thin-bedded, partly nodular. Major coals include the Paradise (W. Ky. No. 12), Baker (W. Ky. No. 13), and Coiltown (W. Ky. No. 14). Coals are variable in thickness, commonly containing rock partings. Clay, soft to hard, silty; present as underclay for coals. The base of the Shelburn Formation is at the base of the Providence Limestone Member.
Pc	CARBONDALE FORMATION—Sandstone, siltstone, shale, coal, underclay, limestone. Sandstone, fine- to medium-grained, micaceous, partly friable; thin- to thick-bedded, locally crossbedded; coal partings and limonite stringers common; locally fills channeled erosion surface in underlying shale. Siltstone, thin-bedded, brittle, compact; partly sandy, micaceous, commonly argillaceous. Shale, silty, sandy; carbonaceous; limonite and pyrite nodules common; grades laterally into siltstone. The four mapped coal beds, in ascending order, are the Davis (W. Ky. No. 6), Dekoven (W. Ky. No. 7), Springfield (W. Ky. No. 9), and Herrin (W. Ky. No. 11). These coals are regionally persistent with varying thickness. Other coals are persistent but thin, discontinuous, and missing locally. Underclay, silty, carbonaceous; moderately firm. Limestone, thin- to medium-bedded, finely crystalline; common as concretions associated with coal.
Pt	TRADEWATER FORMATION—Sandstone, shale, siltstone, coal, clay, limestone. Sandstone, fine- to coarse-grained, micaceous; thin- to very thick-bedded, partly friable, locally crossbedded, commonly interbedded with shale; limonitic; locally forms steep cliffs. Shale, clayey to sandy to silty, micaceous; varying amounts of carbonaceous plant debris, contains lenticular claystone fragments and siderite nodules, commonly occurs as parts of coarsening-upward intervals. Siltstone, micaceous, locally sandy; thin-bedded, commonly interbedded with sandstone and shale. Coal beds, in ascending order, are the Bell, Western Kentucky No. 2, Mannington/Mining City (W. Ky. No. 4), and Western Kentucky No. 5 coal. As many as eight coals may occur between the No. 2 and No. 4 coals (Greb and others, 1992). Few coals can be traced across the region; others only have local extent. Clay, underclay associated with coal beds, locally absent. Limestone, finely to coarsely crystalline, cherty; thin- to thick-bedded; fossiliferous, mainly crinoid columnals and brachiopods. The Curlew Limestone Member directly overlies the No. 4 coal.
Pca	CASEYVILLE FORMATION—Sandstone, siltstone, shale, coal. Sandstone, fine- to coarse-grained, poorly sorted, conglomeratic, contains quartz pebbles up to 1 in. in diameter, generally well-cemented; thin- to very thick-bedded; some beds have concretions of iron boxwork and leisegang banding; well-developed crossbedding; commonly contains thin siltstone beds and coal stringers; locally forms cliffs as much as 100 ft high. Caseyville Formation fills channels and paleovalleys cut into Mississippian rocks to depths of 170 ft below the base of the Kinkaid Limestone. Siltstone, thin and even-bedded, commonly interbedded with shale; micaceous. Shale, carbonaceous, sandy, or silty; sometimes associated with thin coals. Coal, thin, lenticular, and discontinuous.
cs	CONGLOMERATE AND SANDSTONE (mapped separately)—Ellipsoidal quartz pebbles up to 2 in. in diameter within a sandy, calcareous, iron-rich matrix. Only mapped on the Shady Grove 7.5-minute quadrangle.
Mk	KINKAID LIMESTONE—Limestone, shale, sandstone. Limestone, finely to moderately crystalline, locally cherty; generally thick-bedded, thin-bedded where interbedded with shale; dolomitic in lower half of formation; commonly fossiliferous containing brachiopods, crinoids, corals, and gastropods. Shale, clayey to silty, calcareous; thin shale partings commonly separate limestone beds. Sandstone, fine-grained, calcareous; medium-bedded. Formation becomes more sandy and shaley toward the middle, with the thick-bedded limestone on the top and base.
Md	DEGONIA SANDSTONE—Shale and sandstone. Shale, silty to sandy. Sandstone, fine-grained, thin-bedded, slightly calcareous. Where thin, generally mapped with overlying and underlying units.
Mkd	KINKAID LIMESTONE AND DEGONIA SANDSTONE, UNDIFFERENTIATED
Mcl	CLORE LIMESTONE—Limestone and shale. Limestone, finely to moderately crystalline, partly fossiliferous. Shale, calcareous, especially where interbedded with limestone.
Mkc	DEGONIA SANDSTONE, KINKAID LIMESTONE, AND CLORE LIMESTONE, UNDIFFERENTIATED
Mdc	DEGONIA SANDSTONE AND CLORE LIMESTONE, UNDIFFERENTIATED
Mpt	PALESTINE SANDSTONE—Shale, sandstone, siltstone. Shale, silty to sandy, interbedded with sandstone in lower part, contains 2- to 6-in.-thick beds and lenses of siltstone. Sandstone, very fine- to fine-grained, thin-bedded, calcareous at top of formation. Where thin, generally mapped with overlying and underlying units.
Mdp	DEGONIA SANDSTONE, CLORE LIMESTONE, AND PALESTINE SANDSTONE, UNDIFFERENTIATED
Mkp	KINKAID LIMESTONE, DEGONIA SANDSTONE, CLORE LIMESTONE, AND PALESTINE SANDSTONE, UNDIFFERENTIATED
Mbw	BUFFALO WALLOW FORMATION
Mme	MENARD LIMESTONE—Limestone and shale. Limestone, finely to moderately crystalline, argillaceous, generally thick-bedded; abundant fossil fragments including brachiopods, gastropods, crinoids, and bryozoans, locally cherty. Shale, clayey to sandy, calcareous where interbedded with limestone.
Mdm	DEGONIA SANDSTONE, CLORE LIMESTONE, PALESTINE SANDSTONE, AND MENARD LIMESTONE, UNDIFFERENTIATED
Mwv	WALTERSBURG FORMATION AND VIENNA LIMESTONE—Shale, siltstone, and limestone. Shale, generally clayey, slightly calcareous in lower part. Siltstone, sandy, partly carbonaceous; occurs as thin partings as much as 2 in. thick. Limestone finely to moderately crystalline, thin- to medium-bedded; chert present as lenses or nodules, locally dolomitic; abundant fossil fragments. Base of Waltersburg Formation is placed at top of cherty layer of the Vienna Limestone.
Mpv	PALESTINE SANDSTONE, MENARD LIMESTONE, WALTERSBURG FORMATION, AND VIENNA LIMESTONE, UNDIFFERENTIATED
Mts	TAR SPRINGS SANDSTONE—Sandstone and shale. Sandstone, fine- to medium-grained; medium- to thick-bedded, locally thin- or flaggy-bedded; limonitic where thin-bedded; locally crossbedded, ripple-marked; shaly and calcareous in lower part. Shale, silty or sandy, siderite nodules common. Upper part of formation is mainly shale and lower part is sandstone (channel fill?); forms cliffs as much as 30 ft high.
Mgd	GLEN DEAN LIMESTONE—Limestone, shale, and sandstone. Limestone, finely to coarsely crystalline; thin- to thick-bedded, generally planar beds 1 to 2 ft thick, locally crossbedded and ripple-marked; partly oolitic and fossiliferous, including the bryozoan *Archimedes*, brachiopods, blastoids, and crinoid fragments. Shale, clayey and silty; calcareous; interbedded with limestone. Sandstone, very fine- to fine-grained, generally silty, very thin beds, interbedded with shale.
Mh	HARDINSBURG SANDSTONE—Sandstone and shale. Sandstone, fine- to medium-grained, friable; locally crossbedded, locally forms cliffs as much as 30 ft high. Shale, silty or sandy, fissile; thin-bedded; abundant fossil plant fragments.
Mgdh	GLEN DEAN LIMESTONE AND HARDINSBURG SANDSTONE, UNDIFFERENTIATED
Mgo	GOLCONDA FORMATION—Limestone, shale, sandstone. Limestone, finely to coarsely crystalline; locally oolitic or dolomitic, crinoid and other fossil fragments common. Limestone is equivalent to the Haney Limestone Member of the Golconda Formation. The limestone at the base of the Golconda is equivalent to the Beech Creek Member of the Golconda Formation. Shale, calcareous; fissile, contains small siderite nodules. Sandstone, very fine- to fine-grained, thin-bedded, partly calcareous. The sandstone is the Big Clifty Member of the Golconda Formation.
Mhg	HARDINSBURG SANDSTONE AND GOLCONDA FORMATION, UNDIFFERENTIATED
Mgg	GLEN DEAN LIMESTONE, HARDINSBURG SANDSTONE, AND GOLCONDA FORMATION, UNDIFFERENTIATED
Mtg	TAR SPRINGS SANDSTONE AND GOLCONDA FORMATION, UNDIFFERENTIATED
Mth	TAR SPRINGS SANDSTONE, HARDINSBURG SANDSTONE, AND GOLCONDA FORMATION, UNDIFFERENTIATED
Mgh	HANEY LIMESTONE—Limestone and shale. Limestone, finely to coarsely crystalline, abundant fossil fragments; thin-bedded. Shale, silty, partly calcareous; few siderite nodules. Mapped as part of the Golconda Formation in some areas.
Mgbc	BIG CLIFTY SANDSTONE AND BEECH CREEK LIMESTONE—Shale, sandstone, and limestone. Shale, silty, calcareous; interbedded with limestone. Sandstone, very fine- to fine-grained; commonly in lenticular beds, locally ripple-marked. Limestone, finely to coarsely crystalline, some fossil fragments; locally grades into argillaceous limestone. Mapped as part of the Golconda Formation in some areas.
Mc	CYPRESS SANDSTONE—Sandstone and shale. Sandstone, generally fine-grained; thin- to thick-bedded, some shale partings, commonly ripple-marked; calcareous at base; forms slabby, weathered ledges. Shale, sandy or silty, occurs locally at top and base of formation.
Mhc	HARDINSBURG SANDSTONE, GOLCONDA FORMATION, AND CYPRESS SANDSTONE, UNDIFFERENTIATED
Mpc	PAINT CREEK LIMESTONE—Limestone, shale, finely to coarsely crystalline, abundant fossil fragments, oolitic beds common, locally dolomitic; commonly interbedded with shale. Shale, calcareous, fossiliferous, common in upper 15 ft of formation; mostly argillaceous limestone.
Mbe	BETHEL SANDSTONE—Sandstone, siltstone, and shale. Sandstone, fine- to medium-grained; thin- to thick-bedded with shale partings, locally crossbedded; channel-fill part of formation contains some pyrite and carbonaceous material. Siltstone and shale, thin-bedded, sandy and silty; occurs locally at the top and base of the unit. Where thin, generally mapped with overlying and underlying units.
Mcb	CYPRESS SANDSTONE, PAINT CREEK LIMESTONE, AND BETHEL SANDSTONE, UNDIFFERENTIATED
Mpb	PAINT CREEK LIMESTONE AND BETHEL SANDSTONE, UNDIFFERENTIATED
Mre	RENAULT LIMESTONE—Limestone and shale. Limestone, finely to moderately crystalline, partly oolitic at base; varying bedding thickness; contains beds of weathered chert, abundant fossil fragments, including corals and crinoid fragments, few pyrite cubes. Shale, silty, fissile; occurs mainly at top of formation. Sometimes mapped with overlying or underlying units, especially in small fault blocks.
Mpbr	PAINT CREEK LIMESTONE, BETHEL SANDSTONE, AND RENAULT LIMESTONE, UNDIFFERENTIATED
Mbr	BETHEL SANDSTONE AND RENAULT LIMESTONE, UNDIFFERENTIATED
Msg	STE. GENEVIEVE LIMESTONE—Limestone, oolitic, finely to moderately crystalline; thin- to massive-bedded, locally crossbedded; interbedded dolomitic limestone, oolitic limestone concentrated in beds 1 to 5 ft thick; few chert nodules in lower part of formation. Fossiliferous; including brachiopods, bryozoans, horn corals, and columnals of crinoid *Platycrinites*. Formation forms low rolling hills and flats with numerous sinkholes and caves.
Msgl	LEVIAS LIMESTONE MEMBER—Limestone, finely to coarsely crystalline; beds range from 0.5 to 2 ft thick, few shale partings; partly oolitic, few fossils; limestone breccia common in upppermost foot of formation.
Msrf	ROSICLAIRE SANDSTONE AND FREDONIA LIMESTONE MEMBERS—Sandstone and limestone. Sandstone, fine-grained; calcareous, thin- to medium-bedded; friable. Limestone, oolitic; thick-bedded.
Mrsg	RENAULT LIMESTONE AND STE. GENEVIEVE LIMESTONE, UNDIFFERENTIATED
Msl	ST. LOUIS LIMESTONE
Mslu	UPPER MEMBER OF ST. LOUIS LIMESTONE—Limestone, finely crystalline, few moderately crystalline calcarenite beds, partly oolitic; few fossils, abundant chert nodules in upper 20 ft, contains lenses and thin layers of dolomitic limestone. Gypsum common in thin seams or vugs. Contact with overlying Ste. Genevieve Limestone is poorly defined.
Msll	LOWER MEMBER OF ST. LOUIS LIMESTONE—Limestone, finely to coarsely crystalline, commonly fossil-fragmental; locally dolomitic or clayey, few chert nodules and gypsum fillings; abundant colonial corals originally identified as *Lithostrotionella* and later reclassified as *Acrocyathus*.
Mrss	RENAULT LIMESTONE, STE. GENEVIEVE LIMESTONE, AND ST. LOUIS LIMESTONE, UNDIFFERENTIATED
Mssu	STE. GENEVIEVE LIMESTONE AND UPPER MEMBER OF ST. LOUIS LIMESTONE, UNDIFFERENTIATED
Msls	ST. LOUIS LIMESTONE AND SALEM LIMESTONE—Limestone, finely to coarsely crystalline; locally clayey or dolomitic, few chert nodules; upper and lower parts are coarsely crystalline calcarenites. Few thin oolitic and fossil-fragmental beds. Mapped as a combined unit with the St. Louis Limestone.
af	ARTIFICIAL FILL—Compacted rock debris from highway or railroad construction.



GEOLOGIC MAP OF THE MADISONVILLE 30 x 60 MINUTE QUADRANGLE, WESTERN KENTUCKY

Matthew M. Crawford

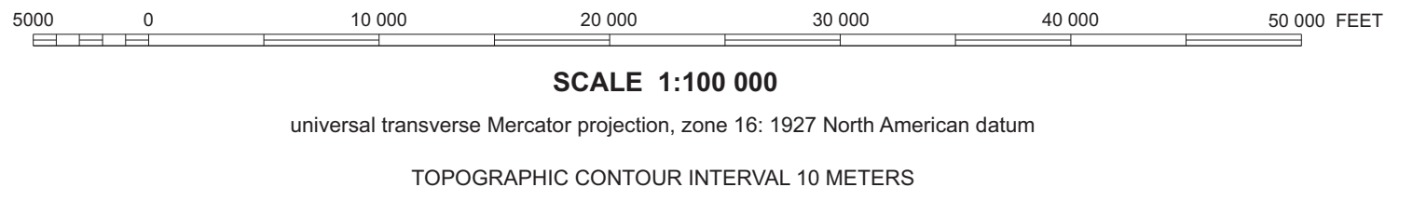
Cartography by Terry D. Hounshell



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

EXPLANATION

- Interstate highway or parkway
- U.S. highway
- State highway
- County boundary
- City boundary
- Railroad
- Normal fault (U, upthrown side; D, downthrown side)
- Concealed fault
- Projected fault
- Contact
- Concealed contact
- Structure contour, feet
- Datum horizon boundary
- Coal bed
- Concealed coal bed
- Active stone quarry or mine
- Abandoned stone quarry or mine
- Active pit; gravel
- Abandoned pit; mineral or gravel
- Fossil point
- Vertical mine shaft
- Inclined mine shaft
- Strip mine; contoured coal with highwall of mine in bold



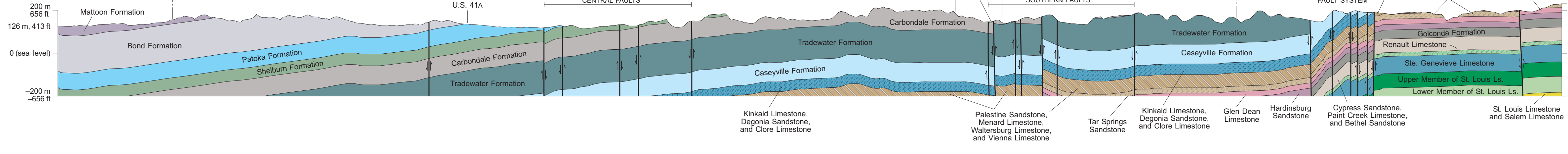
SCALE 1:100 000

universal transverse Mercator projection, zone 16: 1927 North American datum

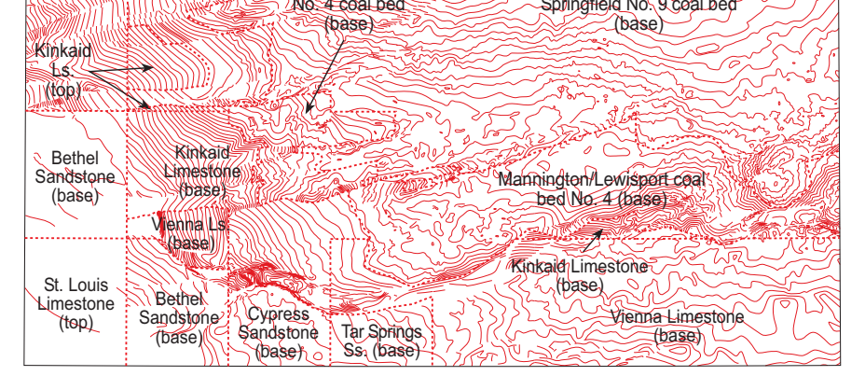
TOPOGRAPHIC CONTOUR INTERVAL 10 METERS

vertical exaggeration 8x

NOTE: Some undifferentiated units are used in cross section
Cross section is diagrammatic



Locations of the 32 quadrangles used in the digital compilation of the Madisonville 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.



Location of structure contours in the Madisonville 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 or faults. Contour interval is 40 ft. Where dip is relatively steep, contour interval is 100 ft.

INTRODUCTION

This version of the geology of the Madisonville 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 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 7.5-minute quadrangles that make up the Madisonville 30 x 60 minute quadrangle are shown in the index map. The new digital data files resulting from the digitization of the GQ's are part of a comprehensive relational and spatial data set being developed by the Kentucky Geological Survey. Some of the data files are available on the KGS Web site (Anderson and others, 1999). Users will have at their disposal a spatial database from which to select any map or particular map themes to create custom maps and add supplemental oil, mineral, coal, or water information. This powerful database of information can be used in a geographic information system (GIS) for analysis or manipulation of the data.

Several regional studies on the geology and stratigraphy of western Kentucky, summarized in Greb and others (1992), have resulted in changes in the stratigraphic nomenclature and correlation of coal-bearing formations in the Western Kentucky Coal Field since the original GQ's were mapped. These changes are shown on this map, and were necessary for compilation of regional maps and for stratigraphic continuity between 7.5-minute quadrangles.

The Kentucky Geological Survey's new 30 x 60 minute, 1:100,000-scale geologic map series has potential for new analysis of structural features. The Madisonville 30 x 60 minute map provides regional geologic information regarding erosional and depositional features, faulting, and geologic framework that may lead to new discoveries concerning mineral and energy resources.

PROCEDURE

The 7.5-minute geologic 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 formations and contacts across quadrangle boundaries, (2) resolving non-uniform structure-contour datums or intervals, and (3) resolving discrepancies in Quaternary alluvium boundaries and nomenclature. The metadata portion of the digital file provides detailed 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 Kentucky Geological Survey for state-specific use. Since various authors compiled the 7.5-minute GQ's between 1960 and 1978, geologic formations and formation boundaries were not mapped the same way. Resolution of the differences between quadrangles was necessary for efficient topological analysis in a GIS environment. In addition, numerous thin, less extensive formations and associated members mapped on individual 7.5-minute quadrangle maps are too small to be mapped on a 30 x 60 minute quadrangle 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 geologic field work took place. 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 Madisonville 30 x 60 minute quadrangle mainly consists of sedimentary rocks of Mississippian and Pennsylvanian age, Cretaceous sand and gravel, and Quaternary alluvial deposits. Most of the map area is within the Western Kentucky Coal Field; the adjacent Mississippian Plateau is to the west and south. The Western Kentucky Coal Field, part of the Illinois Basin, is a gently rolling to hilly upland underlain by Pennsylvanian coal-bearing strata (Sable and Dever, 1990; Greb and others, 1992). Sandstones and siltstones comprise 50 to 80 percent of the coal-bearing rock sequence. Shales make up 20 to 40 percent of the rocks, and limestones and coal account for 5 percent or less of the rocks in the coal field (Greb and others, 1992).

Mississippian rocks crop out south-southwest of and within the Pennyrile Fault System, all part of the broad Mississippian Plateau that wraps around the Western Kentucky Coal Field in the southeastern and southwestern parts of the quadrangle. Mississippian rocks are subdivided into two series: Chesterian sandstones that cap hills, and underlying, thick, Meramecian limestones that form a broad, low-relief karst terrain.

Cretaceous and Tertiary sediments in the southwestern part of the Madisonville quadrangle thicken westward into the Jackson Purchase Region (Paducah and Murray 30 x 60 minute quadrangles). These deposits consist of marine and terrigenous gravels, sands, silts, and clays. Cretaceous and Tertiary deposits may or may not include high-level fluvial deposits, loess, and terrace deposits. Quaternary deposits are typically thicker than the Cretaceous and Tertiary sediments and cover much of the northeastern parts of the quadrangle. Quaternary deposits occur within stream and river valleys and consist of alluvium, lacustrine deposits, fluvial sands, and gravels. Correlation of rock units across a large region requires understanding the environments of deposition and how they have interacted with one another through time.

Four major structurally distinct areas are present on the Madisonville quadrangle. (1) The Moorman Syncline occupies an area from northwestern Hopkins County eastward across the coal field into Muhlenberg County. The syncline is bounded on the north by the Rough Creek Fault System (north of the quadrangle) and on the south by the Pennyrile Fault System. The syncline narrows and deepens toward the west in the area overlain by the Mattoon Formation. The Moorman Syncline is steepest toward the north and gently dipping toward the south; dips on the southern limb are approximately 50 ft/mi (Mullins, 1968). The cross section on this map shows the gentle dip of strata on the southern limb of the syncline. (2) The Pennyrile Fault System occurs on the southern margin of the coal field and forms the southern margin of the Moorman Syncline. These faults trend mainly east-northeast and commonly parallel one another in short segmented grabens. Most faults in the system are normal and down to the north, with the greatest displacement occurring toward the west, although there are also reverse and small thrust faults (Greb and others, 1992). (3) The Central Faults (Mullins, 1968) are extensions of faults in the Western Kentucky Fluorspar District and trend northeast from Caldwell County across part of the Moorman Syncline, then terminate approaching the Rough Creek Fault System north of the quadrangle. The Central Faults are mainly high-angle normal faults, generally with less displacement than the Pennyrile faults, forming a series of horsts and grabens that cut across the quadrangle along northeast-southwest trends. (4) The Southern Faults (Mullins, 1968) are also extensions of the fluorspar district faults, more specifically the Tabb Fault System. These faults are also mainly northeast-striking normal faults forming a series of horsts and grabens. Many coal beds are exposed because of the faulting, and extensive surface mining has occurred in these areas.

ECONOMIC GEOLOGY

Coal, oil, gas, limestone, vein minerals, sand, gravel, and clay are the principal mineral resources in the Madisonville quadrangle. Although coal beds occur throughout the Pennsylvanian rocks, the most economically significant coals occur in the Carbondale Formation and Shelburn Formations—an interval of strata 90 to 125 m thick (Weisenfluh and others, 2001) that crops out in a belt 6 to 12 mi wide across the central part of the quadrangle. Mined coal beds include the Mannington (W. Ky. No. 4), Springfield (W. Ky. No. 9), Herrin (W. Ky. No. 11), Baker (W. Ky. No. 13), and Coiltown (W. Ky. No. 14). Each of these coals have distinct geologic characteristics, especially faulting, and varying mining conditions (Greb and Williams, 2000). Because of the shallow dip of the Carbondale and Shelburn Formations on the southern limb of the Moorman Syncline, the economic coal beds across the central part of the quadrangle have been extensively surface mined (Weisenfluh and others, 2001). Most of the coals were mined by surface techniques along their cropline, then by underground slope and shaft mines down structural dip where they are in the subsurface (Stephen F. Greb, Kentucky Geological Survey, 2003, personal communication).

The Mannington (W. Ky. No. 4) coal bed, in the Tradewater Formation, mainly crops out or lies within the southern and western boundaries of the Western Kentucky Coal Field. According to Smith and Brant (1980), the original resource of the Mannington coal bed exceeded 6 billion short tons, fourth largest in the entire Western Kentucky Coal Field. Surface and underground methods have extensively mined the Mannington coal bed, with primary production coming from the Dawson Springs, Nortonville, Drakesboro, and Saint Charles 7.5-minute quadrangles. For the Mannington coal bed in the Dawson Springs and Saint Charles 7.5-minute quadrangles, the average available resource is 71 percent of the original resource, but an average of 23 percent has been mined out (Weisenfluh and others, 2001). The Mannington bed has variable thickness throughout the coal field, but averages 42 in. where mined (Weisenfluh and others, 2001). It is commonly a clean coal with variable sulfur and ash content.

The Springfield (W. Ky. No. 9) is the most extensive and heavily mined coal in the Madisonville quadrangle. The coal was extensively surface mined (stripped), but most significant recent production has come from underground mines. The Springfield has been almost completely mined across its surface exposure in this quadrangle (Stephen F. Greb, Kentucky Geological Survey, 2003, personal communication). Table 1 summarizes the availability of the Springfield coal in seven 7.5-minute quadrangles in the Madisonville quadrangle.

Table 1. Availability of the Springfield coal bed (W. Ky. No. 9) in seven 7.5-minute quadrangles in the Madisonville 30 x 60 minute quadrangle.

QUADRANGLE	ORIGINAL RESOURCES (million tons)	MINED OUT (percent)	ECONOMICALLY AVAILABLE (percent)
Blackford	8	89	0
Dawson Springs	6	59	40
Millport	294	38	47
Nebo	341	31	59
Providence	152	65	5
Sacramento	254	2	86
St. Charles	70	20	76

The Springfield coal bed is commonly 4.8 ft thick and especially uniform (Eble, 2000). It averages 3.9 percent total sulfur content and 11.0 percent ash yield. Except in the outcrop belt in which it is surface mined, the Springfield coal bed is at great depths and more difficult to extract.

The Herrin (W. Ky. No. 11) coal varies more in thickness and mineable extent than the Springfield coal bed does (Weisenfluh and others, 2001). In the Madisonville quadrangle, the thickest mineable Herrin coal occurs just north of the Pennyrile Fault System in a northwest–southeast-trending belt. The Herrin coal is overlain by the Providence Limestone Member, which may provide a good roof during excavation (Greb and Williams, 2000). The coal has a distinctive blue band composed of light gray clay about 2 ft above its base. The most economically significant mining occurs in large surface mines where the coal seams are at a shallow depth. In many surface mines, the Paradise (W. Ky. No.12) coal bed occurs within a few feet of the top of the Herrin coal, so the two coals have been mined together. Mining both coals can make estimates of production difficult for either bed, but in the Western Kentucky Coal Field overall, the estimated original resource of Herrin coal greater than 42 in. thick is 3.16 billion tons (Weisenfluh and others, 2001). An estimated 1.03 BT, or 26 percent of the original resource, has been mined or lost in mining (Weisenfluh and others, 2001).

The Baker (W. Ky. No. 13) coal bed lies 40 to 60 ft above the Herrin coal. Rather than being a uniformly thick bed, the Baker coal is a complex zone of multiple beds separated by thin rock partings (Weisenfluh and others, 2001). Although the Baker can be thin and discontinuous, it is relatively close to the top of the Paradise coal and has been surface mined in combination with the Herrin and Paradise coals. The Baker coal zone is thickest in the northwestern part of the Madisonville quadrangle. Large surface and underground mining occurs in the Providence 7.5-minute quadrangle, where the Baker coal averages more than 42 in. thick. The Baker coal zone is usually less than 28 in. thick in the southern and southwestern parts of the Madisonville 30 x 60 minute quadrangle. It averages 3.9 percent sulfur content (dry weight). In the northwestern part of the Madisonville quadrangle, an average of 24 percent of the original Baker coal resources have been mined out (Weisenfluh and others, 2001).

The Coiltown coal bed (W. Ky. No. 14) lies 100 to 150 ft above the base of the Shelburn Formation. In the Madisonville area, the Coiltown reaches as much as 7 ft in thickness, but often contains shale partings and may be truncated by sandstones (Greb and others, 1992). Where the coal is thick it often contains shale partings and may be truncated by sandstones (Greb and others, 1992). Where the Coiltown coal is thin it is often miscorrelated with several other thin coals that occur in the upper part of the Shelburn Formation. In the early 1990's, the Coiltown coal, on average, produced 2.5 million tons annually (Greb and others, 1992). Today there is no significant production of the Coiltown coal in the Madisonville quadrangle, however.

Oil and gas have been produced from several fields in the Madisonville quadrangle. Most of the significant economic discoveries were made in the early to mid 1900's; more than 5,000 oil and gas wells have been drilled in the area. One of the most significant fields in the Madisonville quadrangle is the Midland Gas Field, which is part of the Bethel Channel Reservoir, one of the largest in the Illinois Basin (Brandon C. Nuttall, Kentucky Geological Survey, 2003, personal communication). Total production from approximately 60 wells in the Midland Field was 70 billion cubic feet up until 1969. No later gas production data for the field are available. Midland was converted to a gas storage field in 1970 and is one of the largest in the nation (Brandon C. Nuttall, Kentucky Geological Survey, 2003, personal communication).

Since 1999, approximately 50,000 to 200,000 barrels of oil have been produced in the Madisonville quadrangle and less than 300 cubic feet of gas (Kentucky Geological Survey, 2003b). Average depth for oil and gas wells range from 1,000 to 2,000 ft and penetrate rock units from the Ordovician through the Pennsylvanian. The most common reservoirs are Chesterian and Meramecian sandstones and limestones. Some wells that penetrate the New Albany Shale of Devonian age are also economically productive. Approximately 5 trillion Btu of oil and gas was produced in 2001 in the Madisonville quadrangle. (Kentucky Geological Survey, 2003b).

Limestone suitable for construction aggregate and agricultural uses is quarried from numerous rock units in the Madisonville quadrangle. Limestone has been quarried from the Kinkaid, Vienna, Renault, and Ste. Genevieve Limestones. The Kinkaid and Vienna Limestones are primarily used for asphaltic aggregate and riprap. The Ste. Genevieve Limestone is used for concrete aggregate, roadstone, riprap, and agricultural limestone. High-calcium limestone, also quarried from the Ste. Genevieve Limestone, is used for flue-gas desulfurization processes in many coal-fired power plants (Dever, 1980). At one time, there were approximately 30 quarries or underground mines in the area, but now only two are active.

Vein minerals have accounted for small amounts of economic production in the Madisonville quadrangle. The quadrangle lies on the southeastern edge of the Western Kentucky Fluorspar District, where fluorite and calcite veins occur largely along faults and fractures. Small amounts of sphalerite, galena, iron ore, and barite were historically extracted from mines and pits in the part of the fluorspar district within the quadrangle.

Sand, gravel, and clay deposits account for a small amount of economic resources in the Madisonville quadrangle. Quaternary sand deposits occur along major streams and their tributaries. The Mississippian Bethel Sandstone was locally quarried for building stone and flagstone; however, there is no current production. Gravel from the Tuscaloosa Formation has been used locally for road beds and railroad ballast. Clay from shallow pits and underclays below Pennsylvanian coals occur in beds as much as 10 ft thick. Uses include lightweight aggregate, brick clay, and ceramics.

HYDROGEOLOGY

The Madisonville 30 x 60 minute quadrangle is part of the Green River and Tradewater River Basins. Streams in these basins dissect the topography and flow north toward the Ohio River. A karst terrain occupies an arcuate belt southeast to northwest across the quadrangle, in the part that occurs within the Mississippian Plateau Region.

Groundwater is an important resource in the region. A large percentage of the population relies on it for domestic use. Unfortunately, in a karst terrain, groundwater is vulnerable to pollution. In the Madisonville quadrangle approximately 11,000 water wells, springs, and other water sources are used by approximately 7,000 people as their private domestic water supply. Most of the wells in areas underlain by Pennsylvanian strata penetrate sandstone units and are less than 300 ft deep. Recovery from wells that penetrate faults is also significant, but highly unpredictable. Much of the water supply for the Madisonville quadrangle comes from the Green River floodplain as well. The quality of the groundwater in the area ranges from soft to very hard; iron and salt are present in significant amounts. Water may become salty or have a high sodium bicarbonate content at depths (Carey and Stickney, 2005).

Groundwater availability is variable. Quaternary alluvium can yield as much as 100 gal/min along the Green River and its tributaries. In the karst regions, however, alluvium yields almost no water to wells. The Cretaceous gravels, sands, and silts of the Tuscaloosa Formation provide water supplies adequate for a bailer at approximately 100 gal/day (Carey and Stickney, 2005). The sandstone of the Carbondale Formation commonly contains iron sulfate water, up to 30 gal/min, where the Springfield coal bed has been mined. Wells in the Pennsylvanian Tradewater Formation yield only small quantities of groundwater, whereas yields of 100 gal/min have been recovered from wells of the Pennsylvanian Caseyville Formation. In Mississippian rocks, groundwater yields vary, but most flowing wells are in Chesterian sandstones. Wells penetrating faulted zones yield as much as 100 gal/min and wells penetrating fractures yield as much as 20 gal/min. The Mississippian Ste. Genevieve and St. Louis Limestones can yield more than 50 gal/min to wells from large solution openings in karst areas. Springs near escarpments and minor streams flow in the range of 10 to 3,000 gal/min in the area (Carey and Stickney, 2005).

ENGINEERING GEOLOGY AND GEOLOGIC HAZARDS

The Madisonville quadrangle is near the New Madrid Seismic Zone. If a major seismic event occurred in the zone, it would significantly affect the Madisonville area. Approximately 13 major earthquakes were recorded in the Madisonville quadrangle from 1974 to 2000. Earthquake prediction is not a defined part of seismology, but geologists and engineers know that earthquakes will cause damage, depending on magnitude, distance from the epicenter, and local geology. Areas of thick alluvium, lacustrine deposits, and other unconsolidated sediments are prone to the most damage because of ground-motion amplification and liquefaction. Liquefaction happens when rock material becomes saturated or loses shear strength, and is temporarily transformed into a fluid mass, resulting in structural damage. Determining the peak ground acceleration (PGA) of an area assists in mitigating the possible damage caused from ground-motion amplification and liquefaction (Kentucky Geological Survey, 2003a). The peak ground acceleration for most of the Madisonville area is about 0.15 g.

Potential engineering problems can be associated with some clay shales beneath coals and in lacustrine deposits with high clay content. Small landslides and slumps occur locally on steep slopes where these deposits are prevalent. Where clay-shale deposits are overlain by massive sandstone, slumping is most common where joints in the sandstone parallel the slope. Excavations in shale, for roads or building foundations, may oversteepen the slope and undercut the overlying sandstone, causing slides to occur, especially when the material is saturated with water. Outwash and lacustrine deposits with high clay content present engineering problems because roads built on them tend to yield and push out under heavy traffic. Lacustrine deposits have good to poor compaction and moderate to high susceptibility to frost action. When the water table reaches the surface, the shrink-swell potential of lacustrine deposits is high.

Surface subsidence above abandoned coal mines has caused structural damage in parts of the Madisonville quadrangle. When strata above mined-out coal beds collapse, resulting property loss can be substantial. If the overlying strata are not of sufficient thickness and strength, or the underclay is too soft, the result will be surface movement, causing structural damage (Sergeant and others, 1988). Structural damage and property damage can include cracks in foundations, cracks and depressions in roads, curvature of walls, collapse of buildings, and damage to utility lines.

The karst terrain in the southwestern part of the Madisonville quadrangle also poses potential geologic and engineering hazards. Numerous sinkholes and caves lie within the Ste. Genevieve and St. Louis Limestones. Sinkhole collapse and sinkhole flooding causes damage to building foundations, roads, farm ponds, and farm equipment. The collapse or slow depression of soil overlying bedrock is caused by weathering and erosion of the soil, which is carried away through cave conduits that drain the sinkhole (Currens, 2002). Sinkhole flooding occurs when cave passages and associated sinkholes become choked with more rainfall than they can handle. Correction and prevention of engineering problems and karst subsidence is possible by analyzing the topography, consulting geologic maps, looking for signs of previous damage, and consulting professional engineers and geologists.

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