KENTUCKY GEOLOGICAL SURVEY
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MAP AND CHART 26
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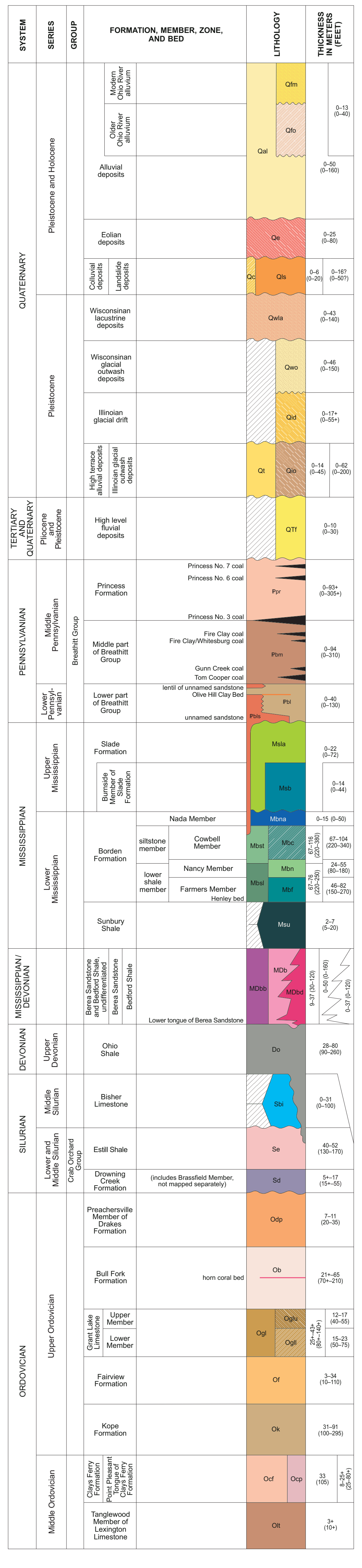

DESCRIPTION OF MAPPED UNITS

Qal ALLUVIUM—Sand, silt, gravel, and clay. Sand, micaceous, noncalcareous, interbedded with clayey silt, silty gravel and sandy silt, lenses of gray organic matter. Stream channel gravel deposits contain coarse limestone, minor chert, quartz, and shale pebbles in a silty matrix. Channel deposits derived from Illinoian glacial drift contain fine- to medium-grained quartz sand in beds 2 to 10 ft thick. Unit occurs as floodplains 10 to 30 ft thick. Near the Ohio River, tributary stream alluvium grades downstream into Ohio River alluvium.

Qfm MODERN OHIO RIVER ALLUVIUM—Silt, sand, and clay. Silt and sand grade from clayey silt downward to sandy silt and fine- to medium-grained sand, interbedded with clayey silt, noncalcareous, micaceous, and obscurely to well-bedded lenses of organic matter, clay, gravel, and detrital coal; forms low ridges that are sandy and poorly drained with clayey swales. Backwater deposits consist of nonstratified silt and clay; intertongues with coarser-grained tributary alluvium. Entire unit rests on glacial outwash. Thickness ranges from 20 to 30 ft beneath the higher terrace and 30 to 40 ft beneath modern floodplains.

Qfo OLDER OHIO RIVER ALLUVIUM—Silt, sand, and clay. Poorly bedded and carbonaceous, noncalcareous, intertongues with tributary stream alluvium. Beneath the Ohio River floodplain, sand, medium- to fine-grained, well-sorted to clayey, interbedded with clayey silt.

Qe EOLIAN DEPOSITS—Silt and sand. Silt, clayey, well-sorted, poorly to nonstratified. In areas where unit thickness is greater than 15 ft, leaching has produced carbonate concretions at the base of each leached zone. Sand, fine- to medium-grained, well-sorted, noncalcareous and crossbedded; forms ridges and mounds.

Qls LANDSLIDE DEPOSITS—Large blocks and boulders intermixed with smaller fragments, derived from local bedrock, in an unconsolidated matrix of sand, silt, and clay. Found at base of steep slopes; only largest and most conspicuous deposits shown.

Qc COLLUVIAL DEPOSITS—Incoherent fragments, angular boulders, and finer detritus; found along base of steeper valley walls in the Greenup and Ironton 7.5-minute quadrangles; includes some landslide debris.

Qwla LACUSTRINE DEPOSITS (Wisconsinan)—Silt, clay, sand, and gravel. Silt, mixed with clay, light olive-gray to bluish gray, commonly calcareous, nonstratified and laminated, poor- to well-sorted; alternating from silty to clayey beds with a leached zone and calcareous concretions at the base of the leached zone; locally fossiliferous. Unit commonly found at mouth of Ohio River tributaries interbedded with sand and gravel glacial-outwash deposits; deposits thin and finer-grained upstream along tributaries.

Qwo GLACIAL OUTWASH (Wisconsinan)—Sand, gravel, silt, and clay. Sand and gravel, well-sorted, locally calcareous, shows cut-and-fill stratification and locally contains lenses of clayey silt. Sand, fine- to medium-grained, subangular, quartzose, with notable amounts (as much as 10 percent) of carbonate and chert and minor amounts of feldspar and coal grains. Gravel, fine- to coarse-grained, granular to pebbly, well-rounded, mostly in upper and lower 20 ft of deposit. Unit forms terrace surfaces with broad, gentle ridges and swales; locally has well-defined sandy ridges. A mantle of silt, 5 to 20 ft thick, that varies from sandy silt on terrace ridges to sandy clayey silt in the swales, covers the gravelly outwash. Unit is interbedded with silt and clay of lacustrine deposits.

Qid GLACIAL DRIFT (Illinoian)—Boulders, sand, silt, clay, and gravel. Till deposits, unsorted and massive. Grain sizes range from clay to boulders, mostly local limestone and shale fragments; other mineral clasts from outside the region are common. Gravel, mostly limestone mixed with sandstone, siltstone, dolomite, chert, igneous and metamorphic rock components cemented by calcite. Unit has low permeability, with well-preserved organic material present. Outwash, associated with and generally overlying till, massive to poorly bedded with well-rounded pebbles and cobbles, minimal silt and clay particles. Unit is only found in one locality, near the mouth of Bracken Creek, east of Augusta, Ky., resting on Illinoian outwash deposits.

Qio GLACIAL OUTWASH (Illinoian)—Sand, gravel, silt, and clay. Thin- to medium-bedded; shows cut-and-fill stratification, crossbedded, and graded bedding. Unit similar to Wisconsinan outwash but contains more gravel and calcite-cemented concretions throughout.

Qt HIGH TERRACE ALLUVIUM—Silt, gravel, chert, and siltstone fragments. Silt, gravelly, noncalcareous, contains abundant nodular iron oxide concretions between 0.1 and 4.0 in. in diameter. Gravels, angular to subrounded, containing white and red chert fragments and rounded siltstone fragments. Deposits are found in one locality within the mapped area about 4 mi southwest of Washington, Ky., above and along the Licking River.

QTf HIGH-LEVEL FLUVIAL DEPOSITS—Sand, silt, and clay. Sand, very fine- to medium-grained, well-sorted. Silt and clay beds, thin and moderately well-sorted. Entire deposit is extremely weathered and oxidized, with a mantle of silt or loess. Deposits are found in one locality within the mapped area, about 5 mi northwest of Maysville, Ky.

BREATHITT GROUP

The Breathitt and Lee were mapped as formations on the 7.5-minute quadrangle maps, but Chesnut (1992) elevated the Breathitt to group status, incorporating the Lee Formation (no longer used), and divided the group into formations based on regionally widespread shale members with marine fauna. The upper part of the Breathitt Group contains shale, siltstone, argillaceous and lithic sandstone, coal, and some thin limestone. The upper four formations (Princess, Four Corners, Hyden, and Pikeville) are lithologically similar and overlie the Grundy Formation. These strata onlap the post-Mississippian unconformity surface and are described below.

Sandstone, fine- to coarse-grained, poorly sorted, sublitharenitic and arkosic (60 to 80 percent quartz, 2 to 15 percent feldspar, and lesser amounts of mica, opaque minerals, and rock fragments), occasionally containing sparse well-rounded quartz pebbles, thin-bedded to massive, crossbedded, and cliff-forming. Quartzarenites (more than 90 percent quartz), often as crossbedded channel fills, occur in the Grundy Formation beneath the Betsie Shale. Some sandstones are locally extensive and useful as stratigraphic markers. Siltstone and shale, micaceous, locally carbonaceous and calcareous, thin-bedded; coaly partings on some bedding planes. The marine shale members (Betsie, Kendrick, Magoffin, Stoney Fork) if present at the base of the four upper formations generally contain a thin, black to dark gray clay shale and discontinuous, dark gray to black limestone or sideritic sandstone with common marine fossils at their base. 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 several coal zones. Each zone consists of multiple coals that may split laterally or grade into carbonaceous shales and rooted seat rocks. Coal zones are separated by shales, siltstones, and sandstones, and generally exhibit considerable lateral variability.

UPPER PART OF BREATHITT GROUP

₱pr Princess Formation—Previously mapped as upper part of Breathitt Formation on 7.5-minute quadrangle maps. Renamed by Chesnut (1992) for strata above base of the Stoney Fork Member and below Conemaugh Formation, which is not present in this quadrangle. Base of Stoney Fork Member is a thin marine carbonate with argillaceous limestone and calcareous shale containing abundant fossil fragments. Because the Stoney Fork Member was absent or not mapped in this quadrangle, the base of the Princess Formation is placed at the top of the Princess No. 3 coal bed or its inferred position, which is stratigraphically lower than the Stoney Fork Member. Coal beds, in ascending order, are the Princess No. 6 and No. 7.

MIDDLE PART OF BREATHITT GROUP

₱bm FOUR CORNERS, HYDEN, AND UPPER PART OF PIKEVILLE FORMATION, UNDIFFERENTIATED

FOUR CORNERS FORMATION—Mapped as part of Breathitt Formation on earlier maps. Named by Chesnut (1992) for strata between base of Magoffin Member and base of Stony Fork Member. The Magoffin Member was absent or not mapped in this quadrangle.

HYDEN FORMATION—Mapped as middle part of Breathitt Formation on earlier maps. Named by Chesnut (1992) for strata between base of Kendrick Shale Member and base of Magoffin Member. The Kendrick Shale was not mapped or is absent in this quadrangle.

PIKEVILLE FORMATION—Mapped as part of Breathitt Formation on earlier maps. 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 (1987) and was not mapped on earlier 7.5-minute quadrangle maps.

Coals in the middle part of the Breathitt Group, in ascending order are the Tom Cooper, Gun Creek, Fire Clay/Whitesburg, Fire Clay, and Princess No. 3. The Fire Clay coal contains, near its base, a distinctive 1- to 4-in.-thick, light- to dark-brownish-gray flint-clay parting with conchoidal fracture, which was originally deposited as volcanic ash. The flint clay has been radiometrically dated at 312 ±1 Ma by Lyons and others (1992) and 311 ±1 Ma by Rice and others (1994).

₱bl LOWER PART OF BREATHITT GROUP
LOWER PART OF PIKEVILLE FORMATION AND GRUNDY FORMATION

GRUNDY FORMATION— Named by Chestnut (1992) for strata from the top of the Bee Rock Sandstone to the base of the Betsie Shale. Unit in this quadrangle generally corresponds to the material above the post-Mississippian unconformity and below the top of the highest lentils identified as Lee Formation on the 7.5-minute quadrangle maps. Unit therefore includes these lentils and Olive Hill Clay Bed, both described below.

₱bls UNNAMED PENNSYLVANIAN SANDSTONES
Several sandstone units have been renamed in the lower part of the Breathitt Group. These units were previously recognized as members of the Lee Formation, a unit no longer formally recognized in Kentucky (Chesnut, 1992). These sandstones differ from other sandstones in the Breathitt Group in that they are generally quartz-rich, may contain pebbles of quartz, and are light in color. They typically have scoured bases and may contain large-scale crossbeds and locally truncate the St. Louis Limestone Member of the Slade Formation and the Nada Member and siltstone member of the Borden Formation.

OLIVE HILL CLAY BED—Clay, sandy flint clay. Clay, micaceous, plastic, and flinty, semi-indurated, fossiliferous, and commonly oolitic; iron impurities. Flinty clay dark due to carbonaceous impurities; in places, clay grades upward into overlying sandstone; underlain by plastic underclay and silty shales. Unit as much as 11 ft thick and generally less than 30 ft above the base of the Breathitt Group.

Msla SLADE FORMATION—Limestone, minor chert, and minor sandstone. Limestone, finely to microcrystalline, oolitic to bioclastic in some areas; thin- to thick-bedded, some crossbedding, locally dolomitic, slightly cherty with white chalky nodules. Crystalline structure coarsens with depth. Sandstone, quartzose, crossbedded. Locally abundant marine fossil fragments consisting of brachiopods, bryozoans, and corals. Uppermost beds are brecciated. Lower contact, at base of cherty limestone rubble, marked by seeps and springs.

Msb BURNSIDE MEMBER OF SLADE FORMATION—Limestone and dolomitic limestone. Limestone, very finely crystalline, dense, beds as much as 1 ft thick. Abundant marine fossils and nodular chert layers as much as 2 in. thick; more prominent in brecciated upper part of unit and on weathered surfaces. Basal 3 ft of St. Louis Member is dolomitic limestone; dense, silty, may contain calcite fracture fillings, in beds as much as 1 ft thick, generally forming a ledge or cliff; in some areas, unit is too thin to be mapped, and may occur locally as a chert-bearing ironstone bed. Mapped locally on Brushart and Friendship 7.5-minute quadrangle maps. Mapped as St. Louis Limestone Member of the Newman Limestone on earlier maps. Renamed St. Louis Limestone Member of Slade Formation by Ettensohn and others (1984). Revised formally to Burnside Member of Slade Formation by Dever and Moody (2002).

BORDEN FORMATION

The Borden is composed of four members, in ascending order: Farmers, Nancy, Cowbell, and Nada Members. The formation is dominated by terrigenously derived detrital rocks deposited as a prograding deltaic wedge that thins to the southwest. Contacts of members within the Borden are generally gradational and do not show evidence of significant depositional or erosional breaks (Sable and Dever, 1990).

Mbna NADA MEMBER, BORDEN FORMATION—Shale and siltstone. Shale, red and green, calcareous, blocky, plastic, or laminated. Contains thin lenses of glauconitic limestone that weathers yellowish brown. Siltstone, very thin-bedded, calcareous, slightly glauconitic, weathers yellowish brown. Basal contact placed to separate more shaly or clayey beds above from more silty beds below. Unit included with siltstone member of Borden Formation where not thick enough to map.

Mbc COWELL MEMBER, BORDEN FORMATION—Siltstone and shale. Siltstone, sandy to argillaceous, ferruginous and micaceous, slightly calcareous. Bedding varies from irregular thin and medium beds to massive beds; crossbedding, ripple marks, and cut-and-fill structures rare; blocky. Heavy iron staining occurs locally along joints and fractures; ironstone concretions occur throughout unit. Shale, silty, occurs as thin, lenticular interbeds; more abundant in upper and lower parts of unit. Unit generally equivalent to middle and upper parts of siltstone member of Borden Formation. Unit more resistant than overlying and underlying units, forms remnant caps on hilltops and ledgy outcrops of steep slopes. Basal contact gradational, placed to separate more silty beds above from more shaly and clayey beds below.

Mbn NANCY MEMBER, BORDEN FORMATION—Shale, siltstone, and sandstone. Shale, slightly to very silty. Ironstone concretions common throughout. Worm trails and burrows common. Siltstone, sandy, occurs in irregular beds as much as 2 ft thick separated by shale beds as much as 1 ft thick; hackly fracture. Sandstone, fine-grained; occurs in even beds 1 to 4 in. thick, especially in lower part; similar to sandstone in underlying unit. Lower contact gradational; placed at base of lowest continuous shale sequence and above highest continuous sandstone sequence generally more than 1 ft thick. Unit equivalent to approximately the lower 40 ft of the siltstone member and upper 130 ft of the lower shale member of the Borden Formation in the Brushart 7.5-minute quadrangle.

Mbf FARMERS MEMBER, BORDEN FORMATION—Sandstone and shale. Sandstone, very fine- to fine-grained; consists of subangular quartz grains in clayey to silty matrix. Moderately to well indurated, porous and permeable. Pyrite occurs as disseminated specks and crystals. Generally even-bedded with distinct laminae, beds as much as 3 ft thick in lower part; sole marks (groove and load casts) on bottom of beds common; *Zoophycus* markings and other trace fossils common. Weathers to tan to orange-brown. Shale, clayey, silty; as partings and interbeds, thicker and more abundant in upper part. Contact with Henley Bed at base generally sharp but in places slightly interbedded. Unit forms prominent ledges on valley walls, and ridges and steep rims on uplands. Unit equivalent to approximately the lower 130 ft of the lower shale member of the Borden Formation in the Brushart 7.5-minute quadrangle.

HENLEY BED, FARMERS MEMBER, BORDEN FORMATION (not mapped separately)—Shale, greenish gray and reddish brown, clayey, even-bedded; locally contains stringers of silty sandstone as much as 2 ft thick. Plastic when wet; weight of overburden can cause lateral flowage. Together with underlying shale forms topographic recess. Unit 5 to 30 ft thick. Basal contact generally sharp but locally gradational. Contact rarely exposed, at most places located by black shale chips in soil on underlying unit.

Mbst SILTSTONE MEMBER, BORDEN FORMATION—Siltstone and shale. Siltstone, quartzose, with thin to massive uneven beds, slightly undulating in places. Crossbedding, ripple marks, and cut-and-fill structures are present but not common. Thin beds have hackly fracture; massive beds have an apparent jointing or fracture at acute angle to bedding and parallel to slope. *Zoophycus* markings and worm trails occur sporadically throughout but most common in upper part. Brachiopod and crinoid fossils occur throughout but most common in calcareous lenses. Richly fossiliferous zone overlain by green glauconitic siltstone or impure glauconitic limestone. Interbedded with minor thin beds of shale, common near top. Shale, micaceous, interbeds. Lower part thin-bedded, shaly siltstone; contact with underlying member transitional. Unit mapped in eastern part of quadrangle, equivalent to upper members of Borden Formation.

Mbsl LOWER SHALE MEMBER, BORDEN FORMATION—Shale and siltstone. Shale, bluish gray to medium gray, blocky; much iron oxide film on fractures, joints, and bedding planes. Contains ellipsoidal and disk-shaped siderite concretions as much as 6 in. in diameter. Upper part transitions into overlying member. Consists of interbedded shale or silty shale and thin siltstone; proportion of siltstone to shale increases upward. Siltstone, micaceous, even-bedded; individual beds range from less than 3 in. to 30 in. thick; contain abundant *Zoophycus* markings. Beds have locally been quarried for building stone. Lenses as much as 6 ft thick occur locally in the upper part. Locally contains a little very fine-grained sand. Beds generally 6 in. to 7 ft thick separated by thin shale partings. Basal contact is sharp. Unit mapped in the eastern part of quadrangle, equivalent to lower members of Borden Formation.

Msu SUNBURY SHALE—Shale, black, thin-bedded and fissile; highly carbonaceous with crystals of pyrite and marcasite. High trace-metal content. Abundant conodonts. Unit forms low slopes with a thin soil mantle; basal contact sharp.

MDbb BEREA SANDSTONE AND BEDFORD SHALE, UNDIFFERENTIATED—See formation descriptions below.

MDb BEREA SANDSTONE—Sandstone, siltstone, shale. Sandstone, fine- to very fine-grained, well-sorted, angular to subangular quartz with minor pyrite and mica. In part silty, locally calcareous. Poorly to well indurated. Porous and permeable. Varies from thick-bedded, massive channel sandstone to thinner-bedded sandstone with interbeds of ripple-marked, sandy siltstone and silty shale. Flow rolls, ball-and-pillow structures, load casts, and ripple marks common. Thins to southwest. Forms resistant ledges. Basal contact sharp with underlying Ohio Shale, intertongues laterally with Bedford Shale.

MDbd BEDFORD SHALE—Shale, siltstone, and sandstone. Shale, silty, fissile to chunky; locally contains pyrite concretions and nodules as much as 3 in. in diameter, sparse brachiopods; commonly in bedding sets a few inches to as much as 3 ft thick separated by siltstone. Siltstone, in very thin lenses and beds; commonly ripple marked. Worm trails common; contains pyrite disseminated as specks and crystal aggregates. Sandstone, very fine-grained, locally calcareous, occurs near base in a zone from a few inches to as much as 4 ft thick. Unit thins to southwest. Lower contact sharp.

Do OHIO SHALE—Shale, dark gray to black, and siltstone. Shale, thin-bedded, fissile, highly carbonaceous with pyrite crystals present, fossiliferous with sparse conodonts. Siltstone, calcareous in lenses as much as 3 ft thick; concretions as much as 1 ft diameter and lenses of clayey shale as much as 5 ft thick near base. Mineral springs common in the southeastern part of quadrangle. Fresh breaks in rock emit a petroleum odor. A ferruginous zone as much as 5 ft thick at base is interpreted as an unconformity.

Sbi BISHER LIMESTONE—Limestone, dolomitic limestone, and dolomite. Finely crystalline to coarse-grained, silty, locally sandy, porous, thin- to very thick-bedded, even- to irregularly bedded, lenticular bedded, in part crossbedded; thin beds and partings of shale common. Contain sparse pyrite and barite concretions and nodules. Locally fossiliferous, with brachiopods, gastropods, crinoids, bryozoans, and corals common. Petroleum residue common in vugs in more porous beds. Unconformity at top of unit marked by undulatory surface of low relief and commonly by a 1- to 2-ft-thick layer of red clay locally containing fragments of white to red chert. Unit forms karst topography. Lower part of the unit is thick-bedded, forms cliffs with numerous springs at base. Lower contact sharp; locally slightly undulatory.

CRAB ORCHARD GROUP

Includes units previously identified as the Brassfield Dolomite and Crab Orchard Formation and mapped as the upper part of Crab Orchard Formation, lower part of Crab Orchard Formation, and Brassfield Formation. Revised by McDowell (1983) as the Crab Orchard Group to include all Silurian rocks below the Bisher Dolomite in Kentucky east of the Cincinnati Arch. In this quadrangle the Crab Orchard Group consists of the basal Drowning Creek Formation with its Brassfield Member (rank reduced) and an upper Estill Shale (rank raised).

Se ESTILL SHALE—Shale and clay shale, thin-bedded, obscurely laminated, fissile to blocky; expands and becomes plastic when wet. Contains scattered very thin beds and lenses of fine-grained, silty dolomite. Glauconite locally abundant near base. Forms steep to low slopes with deep gullies and irregular hummocky surfaces. Subject to slumping and landslides. Unit originally mapped as upper part of Crab Orchard Shale.

Sd DROWNING CREEK FORMATION—Dolomite and dolomitic limestone with interbedded clay shale. Dolomite and dolomitic limestone, finely to moderately crystalline, some coarse grains, bioclastic, fossil fragmental; locally glauconitic, especially in basal beds. Thin- to medium-bedded, irregular to even-bedded, locally crossbedded and ripple-marked. Contains very light gray chert as nodules and in thin irregular beds in a persistent zone a few feet above base. Locally vuggy with some secondary mineralization. Petroleum residue occurs locally. Fossils are generally poorly preserved. Crinoid columnals described as "cogwheel" present in zone (top of Brassfield Member; not mapped separately) described both as 5 to 15 ft below top and 30 to 40 ft above base of unit. Clay shale, thin-bedded, fissile, plastic when wet; occurs as thin partings and as sets from 1 to 4 ft thick; more abundant in upper part. Cherty beds form prominent ledge on hillsides. Contacts sharp. Unit originally mapped as lower part of Crab Orchard Shale and Brassfield Formation.

Odp PREACHERSVILLE MEMBER, DRAKES FORMATION—Shale, siltstone, mudstone, and dolomite. Shale, calcareous, dolomitic, moderately indurated with hackly fracture, fissile to chunky, silty, and thin-bedded with lenses of argillaceous dolomite and dolomitic limestone. Siltstone, dolomitic, in beds and lenses as much as 6 in. thick; rare megafossils. Mudstone, thin-bedded, fissile to blocky, plastic when wet, calcareous to dolomitic, silty with thin beds and lenses of argillaceous dolomite and dolomitic limestone; brachiopods and bryozoans present in carbonate deposits. Unit forms gullied slumps in roadcuts and stream beds; exhibits hummocky topography.

Ob BULL FORK FORMATION—Shale and limestone, interbedded. Shale, 20 percent at the bottom to 80 percent at the top of the unit, fissile to lumpy, calcareous, thin- to medium-bedded, tabular to irregular; shale partings and bedding as much as 3 ft thick. Plastic when wet. Limestone, thin- to medium-bedded and even- to irregularly bedded with ripple casts; forms lens in shale. Contains argillaceous inclusions. Coarse-grained to well-sorted calcarenite to fine-grained, even-textured, silty limestone; minor beds of limy siltstone and lenses in upper part of limestone unit. Abundantly fossiliferous. Dominant limestone composed of closely packed, medium to coarse fossil fragments in a very fine- to fine-grained limestone matrix; whole fossils common on bedding planes. Less common types are coarse- to very coarse-grained, well-sorted, fossiliferous calcarenite, and fine-grained, well-sorted, silty limestone with few fossils. In middle of unit is a distinctive 15- to 30-ft zone of abundant horn corals, including *Grewingkia rustica*. The large brachiopods *Platystrophia* and *Hebertella* prominent near base; *Leptaena* and *Strophomena* occur about 20 to 30 ft above base. Unit forms moderate to steep slopes.

Ogl GRANT LAKE FORMATION, UNDIFFERENTIATED— See member descriptions below.

Oglu UPPER MEMBER, GRANT LAKE LIMESTONE—Limestone, interbedded limestone and shale. Limestone (upper part of member), rubbly weathering, mottled, thin-bedded, irregularly bedded to nodular; consists of whole fossils and fossil fragments on a micrograined to fine-grained argillaceous limestone matrix. Contains irregular partings and seams of gray shale. Minor fine- to coarse-grained, fairly well- to well-sorted calcarenite present locally. Very fossiliferous. Dominant fossils are large brachiopods of genera *Platystrophia* and *Hebertella*. Interbedded limestone and shale (lower part of member). Limestone (65 to 90 percent) fine- to coarse-grained, medium to well sorted, evenly bedded, thin to medium bedded. Minor thin, irregular-bedded argillaceous limestone. Shale, thin-bedded, fissile, calcareous. Fossils sparse to abundant. Unit gradational with lower member.

Ogll LOWER MEMBER, GRANT LAKE LIMESTONE—Limestone, interbedded limestone and shale. Limestone, rubbly weathering, mottled, thin-bedded, irregularly bedded to nodular; consists of whole fossils and fossil fragments on a very fine- to medium-grained argillaceous limestone matrix. Shale occurs as thin irregular partings and beds. Minor fine- to coarse-grained, well- to medium-sorted limestone in thin, even beds, mostly in upper part. Fossils include abundant large brachiopods of genera *Platystrophia* and *Hebertella*. Member gradational with underlying unit.

Of FAIRVIEW FORMATION—Limestone, shale, and siltstone, interbedded. Limestone present in three distinct types: (1) Fine- to coarse-grained in a sparry calcite matrix, equigranular calcarenite; ripple casts and *Rafinesquina*, *Platystrophia*, and *Herbertella* brachiopods common. (2) Fine- to medium-grained, argillaceous, silty limestone in coarsely crystalline calcite cement; interbedded with calcareous fissile shale in partings as much as 6 in. thick; fossiliferous. Flow rolls as much as 1 ft thick may be present. (3) Argillaceous, micrograined, very silty calcilutite with tabular bedding, some laminations; interbedded with shale. Shale, calcareous, fissile, and occurs as partings and sets into the overlying limestone as much as 1 ft thick. Siltstone, calcareous, thin- to medium-bedded in convoluted beds as much as 5 ft thick in the southeastern part of the quadrangle, containing some thin argillaceous limestone beds; fossils throughout. Formation thickens to the west.

Ok KOPE FORMATION—Shale and limestone, interbedded. Shale, gray, fissile, calcareous, locally fossiliferous, laminated, even-bedded; in partings and sets as much as 10 ft thick, makes up 60 to 80 percent of unit. Thicker sections of shale contains lenses 1 in. thick and as much as 3 ft wide of argillaceous limestone. Limestone in even beds as much as 1 ft thick but generally 2 to 6 in. thick, smooth to ripple-marked; dominantly micrograined, silty, commonly showing graded bedding of fossil fragments. Subordinately fine- to coarse-grained, crossbedded in part, composed of whole and broken fossils in a fine-grained argillaceous matrix. Abundant brachiopods include *Strophomena*, *Dalmanella*, and *Rafinesquina*. Unit consists of sets of shale beds 3 to 10 ft thick, alternating with sets 5 to 10 ft thick of closely interbedded shale and limestone, in about equal abundance.

Ocf CLAYS FERRY FORMATION—Limestone and shale interbedded. Limestone, about 50 percent of unit, mostly thin- and even-bedded, commonly pararippled. Dominantly coarse-grained and very fossiliferous, including beds composed almost entirely of crinoid columns. Subordinate amounts of fine-grained limestone, commonly silty and laminated; fossils sparse or absent. Fossils include locally very abundant brachiopods, gastropods, cephelapods, and crinoid columns. Notable brachiopods include *Dalmanella* and *Sowerbyella*. Shale, fissile, calcareous, with bed sets less than 6 in. thick. Shale sets appear to be as thick as in the overlying Kope Formation and may be thin intertongues of that unit. Unit forms moderate to steep slopes. Exposed only along major drainages in the Sardis 7.5-minute quadrangle. Because of poor exposure, uppermost 10 to 15 ft of unit included in Kope Formation on adjacent Mays Lick geologic quadrangle map.

Ocp POINT PLEASANT TONGUE, CLAYS FERRY FORMATION—Limestone, shale, mudstone, and siltstone. Limestone (60 to 70 percent of unit) dominantly medium- to coarse-grained, 1 to 12 in. thick, locally crossbedded, commonly ripple-marked, composed of whole and broken fossils in a fine-grained matrix. Subordinate amounts in 1-in.- to 3-ft-thick, even to very irregular beds; locally contains large flow rolls, fine-grained to micrograined, silty, unfossiliferous, or with sparse whole fossils, commonly gastropods. Shale, fissile, calcareous, laminated, even-bedded, in partings as much as 2 ft thick; contains thin layers of mudstone and siltstone interbedded, fossiliferous throughout. Fossils include bellerophontid gastropods, the trilobite *Cryptolithus*, bryozoans, and crinoid columnals. Unit forms steep slopes and cliffs. Exposed only along several tributaries of the Ohio River in the Germantown, Higginsport, and Maysville West 7.5-minute quadrangles. Base not exposed in these quadrangles.

Olt TANGLEWOOD LIMESTONE MEMBER, LEXINGTON LIMESTONE—Limestone, very coarse- to fine-grained, mostly medium-grained, well sorted, composed mainly of fossil fragments, phosphatic, cemented with sparry calcite, in even to uneven, thin to thick, irregular bedding as much as 6 in. thick, commonly crossbedded; interbedded with fine- to medium-grained, thin, evenly to unevenly bedded limestone with minor shale. Small exposures in cut banks of North Fork of Licking River in the Sardis 7.5-minute quadrangle; outcrops composed mostly of slumped ledges and slabs.

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

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INTRODUCTION

The geology of the Kentucky portions of the Maysville and Ironton 30 x 60 minute quadrangles 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 conversion into digital format has been another USGS-KGS cooperative program funded through the National Cooperative Geologic Mapping Program (STATEMAP). Several regional geologic studies on mapping and stratigraphy (Cressman, 1973; Cressman and Noger, 1976; Chesnut, 1992; Amaral, 1994; Dever, 1999; Dever and Moody, 2002) have resulted in changes in stratigraphic nomenclature and correlation. 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 7.5-minute quadrangles that make up the Maysville and Ironton 30 x 60 minute quadrangles 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 (DVGQ's) by 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 (kgs.uky.edu/kgsmap/KGSGeology) (Weisenfluh and others, 2005).

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 30 x 60 minute maps required the resolution of significant problems, such as (1) correlating geologic formations across quadrangle boundaries, (2) resolving nonuniform structure-contour datums or intervals, and (3) resolving discrepancies in Quaternary alluvium boundaries and inferred contacts. The metadata portion of the digital file provides detailed information about the 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. Formations and formation boundaries were not mapped the same way on each of the 7.5-minute quadrangle maps, since they were compiled by various authors between 1960 and 1978. In addition, numerous small members mapped on individual 7.5-minute quadrangle maps are too small to be mapped at a scale of 1:100,000 on a 30 x 60 minute quadrangle map. Resolution of the differences between quadrangles was necessary for efficient topological analysis in a GIS environment. 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 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 surficial geology of the Kentucky portion of the Maysville and Ironton 30 x 60 minute quadrangles consists of flat-lying sedimentary rocks of Middle and Late Ordovician, Early and Middle Silurian, Late Devonian, Early and Late Mississippian, and Early and Middle Pennsylvanian age, and unconsolidated sediments of Quaternary age. Regional eastward dip from Upper Ordovician through Middle Pennsylvanian sediments is illustrated in the structure-contour index map (Fig. 2) and in the cross section.

These quadrangles are located east of the north-trending Cincinnati Arch. This feature was described by Dever (1999) as a broad anticlinal structure that extends northeast from central Tennessee through central Kentucky toward Cincinnati, Ohio. It was a positive structural feature as early as Silurian time. The arch increasingly influenced sedimentation during Middle and Late Silurian time, gradually limiting westward movement of terrigenous-detrital sediment and forming a barrier to open marine circulation (Freeman, 1951; Currie, 1981). Progressive onlap of the arch by units of the Devonian black shale sequences, and their thinning toward the axis, indicate that the arch was a positive, but submerged, feature during the Late Devonian (Dillman, 1980; Ettensohn and others, 1988). During Mississippian time, the arch was alternately submergent and emergent (Sable and Dever, 1990). Influence of the arch during Pennsylvanian time is indicated by the westward thinning of Pennsylvanian strata in the Appalachian Basin of eastern Kentucky (Chesnut, 1991). Principal features on the arch are the Jessamine Dome (or Lexington Dome) of central Kentucky, the Cumberland Saddle of southern Kentucky, and the Nashville Dome of central Tennessee.

The Maysville Flexure is a sharp monocline that extends north-south for at least 80 mi along the eastern side of the Cincinnati Arch. Its axis passes very close to Maysville in Mason County. Structural contours on the top of the High Bridge Group (Potter and others, 1991) show that the dip from the Cincinnati Arch into the Appalachian Basin is generally about 10 to 15 ft/mi west of the flexure and 40 to 50 ft/mi east of the flexure. A series of intersecting small faults trend north-south on the flexure and indicates some transverse bending of the flexure as it plunges to the north (Potter and others, 1991).

The Waverly Arch is east of the Maysville Flexure. Woodward (1961) named this feature from evidence of depositional and erosional thinning of early Paleozoic formations. This thinning indicated the presence of a low, broad arch extending from northern Ohio southward into eastern Kentucky. The arch was an axis of low and persistent relief or an axis of resistance to subsidence from Middle Cambrian through Early Ordovician time. The arch was emergent in the Late Mississippian, throughout the deposition of all lower units in the Slade Formation above the St. Louis Member. Uplift resumed in the Late Mississippian and continued intermittently into the Pennsylvanian. The depositional environments and sedimentary structures associated with the re-emergences of this arch are presented in Dever and others (1977).

The eastern part of the Maysville-Ironton quadrangles lies in the western part of the central Appalachian Basin, one of the major coal-producing regions of the United States. The northwestern edge of the outcrop of Pennsylvanian rocks serves as a boundary to this basin.

By late Tertiary time the region had been beveled to a plain of low relief traversed by meandering rivers. Gradual, widespread uplift of this gently rolling plain during Pliocene-Pleistocene time (1 to 5 million years ago) resulted in drainage entrenchment 50 to 100 ft below the regional surface (Amaral, 1994). Preserved remnants of this old, entrenched drainage system are found today as high-level fluvial deposits scattered across the uplands in many parts of Kentucky (Amaral, 1994).

Eight deep wells (Cambrian and deeper) have been drilled in these quadrangles. Seven are in the vicinity of the Lewis-Greenup County line, and one is in the vicinity of the Mason-Lewis County line. These wells, all nonproducing, ranged in depth from 3,314 to 5,193 ft; bottom-hole elevations range from 2,416 to 4,150 ft below sea level. Three of the wells are believed to penetrate into the Precambrian crystalline basement. Top-of-basement elevations ranged from –3,633 to –4,135 ft (Nuttall, 1999).

GLACIAL GEOLOGY AND GEOMORPHOLOGY

Prior to glaciation, the Kentucky and Licking Rivers were north-trending and connected to the transcontinental Teays River system in what is now Ohio (Swadley, 1971; Amaral, 1994). The earliest continental glacier (pre-Illinoian, about 500,000 years ago) approached and may have entered northern Kentucky. It radically modified the existing drainage by burying or damming parts of the pre-glacial Teays River and its tributaries (Teller, 1973; Ray, 1974; Swadley, 1979). Along the fluctuating margin of this early ice sheet, the upper Ohio River Valley gradually cut its channel headward across the Cincinnati Arch and captured the preglacial Kentucky and Licking River systems (Amaral, 1994). A second pre-Illinoian glacier advanced into northern Kentucky during middle Pleistocene time, depositing drift across the uplands and in the abandoned channels of the preglacial Kentucky and Licking River drainage system (Amaral, 1994). The Illinoian glacier advanced to its maximum position during late to middle Pleistocene time, encroaching less than 3 mi into northern Kentucky in several places. The evolution of the upper Ohio River Valley was completed at this time (Amaral, 1994).

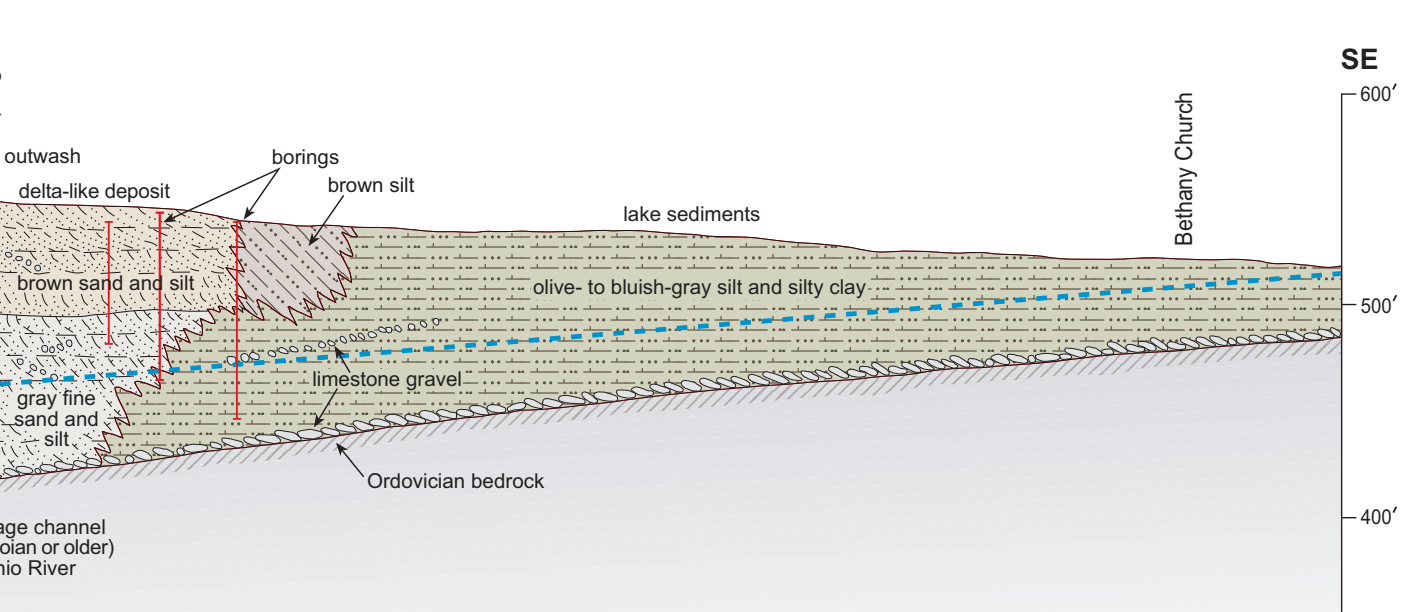

Figure 3. Diagramatic cross section of Wisconsin sediments in a lacustrine-filled valley showing facies relations at the time of maximum valley fill (after Schilling and Peck, 1967). Dashed blue line indicates the approximate profile of a modern Ohio River tributary stream. Cross section shows facies change from gravelly sand to clayey silt and silty clay along the valley from the Ohio River about 2.5 miles up the tributary. During Wisconsin time the tributary was ponded as the Ohio River valley was filled with as much as 130 feet of glacial outwash. As Ohio River glacial floods of debris-laden waters spilled into the ponded waters of the tributary, a delta-like deposit of sand and gravel accumulated near the Ohio River while silt and clay of lake sediments were deposited in the calmer water further up the valley. The silt and clay are derived probably from glacial outwash and nearby bedrock. Calcium carbonate in the clay and silt was derived from silt-laden glacial melt water and unleached loess. Interruption of ponded conditions is indicated by locally derived limestone gravel (Schilling and Peck, 1967).

The region's last continental glacier made its southernmost advance, to within 15 mi of northern Kentucky near Cincinnati, about 21,000 years ago during late Wisconsinan time. The now-completed Ohio River Valley received outwash-laden meltwaters via several major sluiceways. The northern boundary of the Maysville-Ironton quadrangles received outwash sediments from the Sciota River at Portsmouth, Ohio (Amaral, 1994).

ECONOMIC GEOLOGY

Limestone, sand and gravel, and refractory clay deposits are the principal mineral resources in these combined quadrangles. Coal is of secondary importance because the beds are thin and occurrence is spotty (limited primarily to the Pennsylvanian strata). Ferruginous concretions and ferruginous sandstone that were once mined and supported a small iron industry during the 19th century are no longer of economic importance.

The High Bridge Group (Middle Ordovician) is a thick, widespread body of limestone and dolomite that is present at a mineable depth beneath a large area of central and northeastern Kentucky. It consists of three formations, which are, in descending order, the Tyrone Limestone, Oregon Formation, and Camp Nelson Limestone. The depositional environments of the Tyrone, Oregon, and upper Camp Nelson have been interpreted by Cressman and Noger (1976), Horrell (1981), and Kuhnhenn and others (1981). Total thickness of the High Bridge, measured from a core in Mason County, is 510.5 ft. There are zones of high-purity micritic limestone in the Tyrone and Camp Nelson formations. In 2001 the High Bridge was being mined in central and north-central Kentucky for construction and agricultural stone, for the production of lime for flux, and for flue-gas desulfurization. Lime is also used to neutralize acid mine drainage from coal mines and in the chemical industry. The Carmeuse Mine, (previously Cabin Creek Mine), is located along the Ohio River at Springdale in Mason County (Anderson and Barron; 1995, Broyles and Malone, 2010).

Argillaceous limestone suitable for the manufacture of Portland cement occurs in the upper 25 ft of the Grant Lake Limestone. A now inactive quarry south of Springdale was opened in the upper part of the Grant Lake Limestone, and is part of a 1,300-acre tract purchased in 1963 by a cement company to supplement its reserves of limestone (Riley and McGrain, 1964; Schilling and Peck, 1967).

Limestone has been mined from small quarries and from streambeds. Quarries are generally in the Grant Lake Limestone and in the lower part of the Fairview Formation. They furnished construction materials for local use, including fill and unfinished limestone blocks for riprap and rough masonry. All quarries were inactive at the time of mapping.

Dolomite and dolomitic limestone from the lower part of the Crab Orchard Group and the Brassfield Member have been quarried for local use. Dolomite and dolomitic limestone from the lower part of the Brassfield are reported to be difficult to crush and contain a significant amount of chert, which adversely affect their use in concrete or road aggregate.

The Bisher Dolomite in Lewis County contains sphalerite as sparsely distributed nodules, fractures, and cavity fills (Fohs, 1912). Deposits disclosed to date appear to have little, if any, commercial potential (McDowell, 1986).

obtained from evenly bedded sandstone in the lower part of the Borden Formation. It is a hard, gray, even-bedded siltstone and very fine-grained sandstone. Locally, as many as 20 siltstone beds with thicknesses up to 30 in. are found. The sandstone works easily and has two nearly vertical sets of widely spaced perpendicular joints, which facilitate quarrying. No quarries were active at the time of mapping. The depositional environment of the Borden Formation is described in Chaplin (1980).

Valleys and floodplains along the northern border of these two quadrangles received copious quantities of glacial outwash during the Pleistocene (Fig. 3). A large supply of fine to coarse sand occurs in outwash underlying the higher Ohio River terraces. The sand occurs beneath an overburden of 5 to 15 ft of fine-grained alluvium. The valley-fill material along the Ohio River is very heterogeneous, consisting of interbedded and interlensing clays, silt, sand, and gravel. Outwash gravel is poorly to well sorted, containing pebbles, cobbles, and boulders, generally less than 6 in. in diameter. It is composed of glacially transported igneous, metamorphic, and sedimentary rocks, quartz, chert, and locally derived limestone, sandstone, siltstone, and shale (McGrain, 1982).

The largest tonnages of these gravels are used for asphalt and concrete aggregates, fill, concrete products, and road base. Coal, an undesirable material in concrete, is a common impurity throughout the valley, particularly upstream from Cincinnati. McGrain (1982) characterized gravels from the Ohio River Valley in the western part of this two-quadrangle area as carbonate rocks, 10 percent; chert, 35 percent; crystalline rocks, 13 percent; quartz, 7 percent; sandstone and siltstone, 25 percent; shale, 5 percent; and coal, 5 percent. McGrain (1982) noted that outwash samples from east of Maysville (near Manchester, Ohio) were evaluated by the U.S. Army Corps of Engineers for use as concrete aggregate. The sand was judged "fairly good" and the gravel "poor"; both were downgraded because of chert, coal, and weathered rock.

Eolian sand on the Kentucky shore of the Ohio River about 3 mi northwest of Maysville is locally more than 70 ft thick and is a potential source of very fine to medium, well-sorted sand. Eolian sand near Trinity (near the Ohio River, close to the western border of Lewis County) is locally more than 50 ft thick and is a potential source of quartzose fine to medium sand. Current sand and gravel operations are active at the River Sand and Gravel located 5 mi east of Vanceburg (Broyles and Malone, 2010).

Prior to about 1955, clayey silt was dug for the manufacture of bricks from the upper 20 ft of the low terrace upstream from Maysville. Silt and sand from the same low terrace were used in the construction of an impervious artificial levee at Maysville (Weiss and others, 1972).

Clays and clay shales, with potential economic value, are associated with the Pennsylvanian strata in the Ironton quadrangle and in the western part of the Maysville 30 x 60 minute quadrangle. They are present beneath most coal beds in the upper Breathitt Group (approximately correlative with the Princess Formation) and the middle Breathitt Group (approximately correlative with the Pikeville, Hyden, and Four Corners Formations) and hence are referred to as underclays. The thickest of these beds underlies the Princess No. 6 coal bed.

According to Peck (1967), clay from the Crab Orchard Group and the lower 10 to 15 ft of the Borden Formation may be suitable for the manufacture of common brick and tile. This clay may also be useful as a lining material for farm ponds in which leakage through porous soils or slow seepage through bedrock is a problem. Its low structural strength, however, would preclude its use where solution cavities or enlarged fractures in bedrock cause excessive leakage.

The stratigraphic position, distribution, lithology, and economic significance of the Olive Hill Clay Bed of Crider (1913) is presented in Patterson and Hosterman (1960, 1962). According to those references, the clay bed crops out intermittently from Portsmouth, Ohio, south-southwestward for a distance of more than 60 mi. It is mineable within a belt from 5 to 10 mi wide; at several places inliers to the east widen this belt to about 15 mi. This clay was a principal raw material used in the refractory industry of northeastern Kentucky. The average yearly production was 411,385 tons from 1947 to 1956. The clay occurs as a discontinuous bed consisting of irregularly shaped lenses. Its stratigraphic position is from 1 to 20 ft above the base of the Lee Formation, which rests on the prominent unconformity that separates Mississippian and Pennsylvanian strata. The clay consists of approximately one-third flint clay, two-thirds semiflint clay, and minor amounts of plastic clay. The flint clay is a hard, resistant, nonplastic refractory clay consisting of more than 90 percent kaolinite. It possesses the flint-like characteristic of having a conchoidal fracture. The semiflint clays consist mainly of kaolinite, illite, and mixed-layer minerals; the amount of kaolinite generally ranges from 60 to more than 80 percent. The semiflint clays possess little plasticity. The plastic clays develop considerable plasticity when wet, and have a higher illite and mixed-layer mineral content than the semiflint clays; consequently, they have lower refractory properties. The most abundant allogenic nonclay mineral in the clay bed is quartz, which ranges from trace amounts to approximately 50 percent. The most abundant authigenic mineral is siderite ($FeCO_3$) which can approach 10 percent. These nonclay minerals reduce the clay's refractory properties. There are currently no active clay mining operations in this quadrangle (Anderson and Dever, 2001).

Although many coal beds occur in the upper and middle Breathitt Groups, only the Fire Clay, Princess No. 3, Princess No. 6, and Princess No. 7 coal beds are locally as thick as 28 in., which is the minimum thickness mineable with current technology. The Princess No. 3 was extensively mined by underground methods in the southeastern part of the Ironton quadrangle. It is locally called the "Clod seam" because it contains a clay-shale parting 1 to 12 in. thick. The Princess No. 6 has a maximum thickness of about 48 in. in the central part of the Ironton quadrangle, but its thickness includes one to three shale partings. Elsewhere this coal bed is much thinner or absent.

The Fire Clay coal was mined along the north side of the East Fork of the Little Sandy River, where it attains a maximum thickness of about 28 in. Mining was abandoned, apparently because the coal contains a thick shale parting, decreases in thickness, or is cut out by sandstone channels. The Fire Clay coal bed, generally less than 1 ft thick, is absent in many places. The Princess No. 7 occurs in the eastern part of the Ironton quadrangle; shale partings account for much of its total thickness of 48 in.

Coal production data has historically been reported on a county basis. The only county in these combined quadrangles with any coal reserves is Greenup, which extends beyond the borders of the combined quadrangles. Coal production has never been high in this county. Between 1980 and 1999 total yearly coal production peaked in 1987 at 1,065,217 short tons. During 1994 production ceased; production for that year was reported to be only 9,881 short tons, according to the Kentucky Geological Survey coal production database.

Iron ore was mined during the 1800's from four ironstone beds in the Load 7.5-minute quadrangle. Near Hoods Run it was taken from a bed at the top of the Mississippian rocks. South of Raccoon Creek, ore was mined from two beds about 25 and 60 ft, respectively, above the Princess No. 3 coal bed. In the hills at the head of Howe Hollow, iron ore was mined from the Magoffin(?) Beds of Morse (1931). Ironstone beds in the quadrangle are no longer of economic significance, however.

The carbon-rich Ohio Shale of Devonian age constitutes a present and potential economic resource. This geologic unit is classified as a low-grade oil shale. Assays by the modified Fischer retort method indicated yields from 0 to more than 20 gallons of oil per ton of shale (McDowell, 1986). To date, there are no commercial oil shale operations in Kentucky. These black shales are also known to be radioactive, typically containing 15 to 30 parts per million of uranium (Swanson, 1960; Provo and others, 1977) and traces of gold and silver (Theissen and others, 1925). Under present technological and market conditions the low concentration of these elements renders their extraction noneconomical. The depositional environment of these black shales has been interpreted by Ettensohn and Barron (1981).

Sixty-three exploratory wells have been drilled in these quadrangles, 54 of which were drilled for oil and gas. Of these wells, only five produced a show of gas: one in the Ordovician Knox Group, one identified only as being within the Paleozoic, and three in the Mississippian Berea Sandstone (Nuttall and Carey, 1995).

ENGINEERING GEOLOGY

The physical properties of the rocks exposed at the surface in these combined quadrangles present problems in design, construction, and maintenance of structures such as roads, underground utilities, and buildings. Slumping, slides, and foundation failures occur, and are generally associated with the shale content of the bedrock. Some of the physical properties of these rocks and problems caused by them are similar to those discussed below (Dobrovolny and others, 1963).

Shales and sandy shales will not form steep cliffs unless capped by more resistant beds. In most cuts they will remain stable if the inclination of the slope does not exceed 2:1 (ratio of horizontal to vertical distance). They are relatively impermeable and will support moderate to heavy loads if the foundations are kept dry. Underclays, plastic to semiplastic shales, and associated coal beds are the least competent and weakest rocks exposed in the mapped area. Even slopes as low as 3:1 are unstable. The Kope Formation, which consists largely of soft clay shale and the clayey soil above it, are susceptible to slumping and slides, especially when wet and where the surface has been steepened by stream erosion or cuts made for roads or buildings. Lacustrine deposits, floodplains, low-terrace alluvium, and some colluvium also tend to slump when wet. To a lesser degree, the more shale-rich upper part of the Fairview Formation is also subject to slumping. Most landslides in the area occur along the underclays of the middle Breathitt Group, but a few occur in the shales and shaly siltstones of the Conemaugh Formation, where hillsides are steep. Landslides and roadbed failures are prevalent in and near the outcrops of the Princess No. 6 and 7 coal beds.

Groundwater is a significant factor in causing landslides. When clay near the ground surface becomes saturated, it may flow down the slopes as an incompetent mass. This is followed by displacement or falls of the more-resistant overlying beds. Numerous road failures have occurred in areas underlain by the slump-prone materials. Special attention should be given in construction planning to provide adequate drainage and shallow slopes. Fills derived from these formations may fail unless adequate provision for drainage is made. Many small slumps in hillside excavations for roadcuts and houses occur because the slopes have been oversteepened.

HYDROLOGY

Groundwater availability was summarized by (Carey and Stickney, 2005a–c).

The alluvial and glacial deposits in the Ohio River Valley yield moderate to large quantities of water to drilled wells depending upon the thickness and texture of the material encountered. They commonly yield 200 gal/min and as much as 800 gal/min from gravel-packed wells. The water is hard or very hard but otherwise of good quality. The alluvium in tributary valleys, however, is too thin and fine-grained to yield significant quantities of water.

Most drilled wells in the major creek valleys will produce enough water for domestic supply, except during dry weather. An exception is in the western part of Greenup County, where less than half of the wells drilled in valley bottoms produce enough water for a domestic supply. In most upland areas in these combined quadrangles, drilled wells will not produce enough water for domestic supply. Groundwater is typically hard or very hard, and may contain salt or hydrogen sulfide, especially at depths greater than 100 ft.

Bedrock wells in the Conemaugh Formation and the middle Breathitt Group yield more than 500 gal/day to most wells drilled in valley bottoms and a large percentage of the wells on hillsides. Smaller quantities of water are yielded to wells on hilltops. The most common aquifers are sandstone and shale, but coal supplies water to a few wells. Near-vertical joints and openings along bedding plains yield most of the water to wells.

The Grant Lake Limestone, as well as the Crab Orchard, Drakes, Bullfork, Kope, and Fairview Formations, yield 100 to 500 gal/day to drilled wells in broad valleys and along upland streams, but almost no water to drilled wells on hillsides or ridgetops. The water is hard in valley bottoms, and may contain salt or hydrogen sulfide. Locally, the Crab Orchard contains magnesium and calcium sulfate dissolved from epsom salt and selenite (gypsum) in the shale.

The Clays Ferry Formation yields more than 300 gal/day to drilled wells in valley bottoms and small amounts of water on hillsides and ridgetops. Beneath broad interstream areas, much solution enlargement of fractures and bedding-plane openings has taken place. Consequently, many drilled wells in this terrain will produce 100 to 500 gal/day.

The Brassfield Member yields almost no water to wells in the western part of the combined quadrangles (Mason County), but can yield 100 to 500 gal/day to drilled wells in broad valleys in the central part of the combined quadrangles (Lewis County).

The Borden Formation yields 100 to 500 gal/day to wells in valley bottoms and may yield more than 500 gal/day to drilled wells in broad valley bottoms from fractured sandy beds that underlie streams. These soft sandy rocks are well suited to dug wells, many of which yield more than 500 gal/day. Water of poor quality is found at shallow depth in many places in this formation, however.

The Sunbury Shale yields 100 to 500 gal/day to drilled wells in valley bottoms or on low hillsides. It yields some water to almost any dug well, but its quality, ranges from good to poor. The Berea Sandstone may yield 100 to 500 gal/day where it occurs at or below stream level, but unlike most formations, its water is soft. The Bedford Shale and the Bisher Limestone yield little water to wells.

A few springs supply sufficient water for domestic use; however, almost all springs yield less than 5 gal/min.

Waters in drilled wells are highly variable in chemical character. They are typically hard, to extremely hard except for water in wells drilled in the alluvium, which produces moderately hard water, and the Berea Sandstone, which can yield soft water. The naturally occurring contaminants that may be present in objectionable amounts are sulfate, salt (sodium chloride), iron, and manganese. Saline water is commonly encountered in wells drilled less than 100 ft below the level of the principal valley bottoms.

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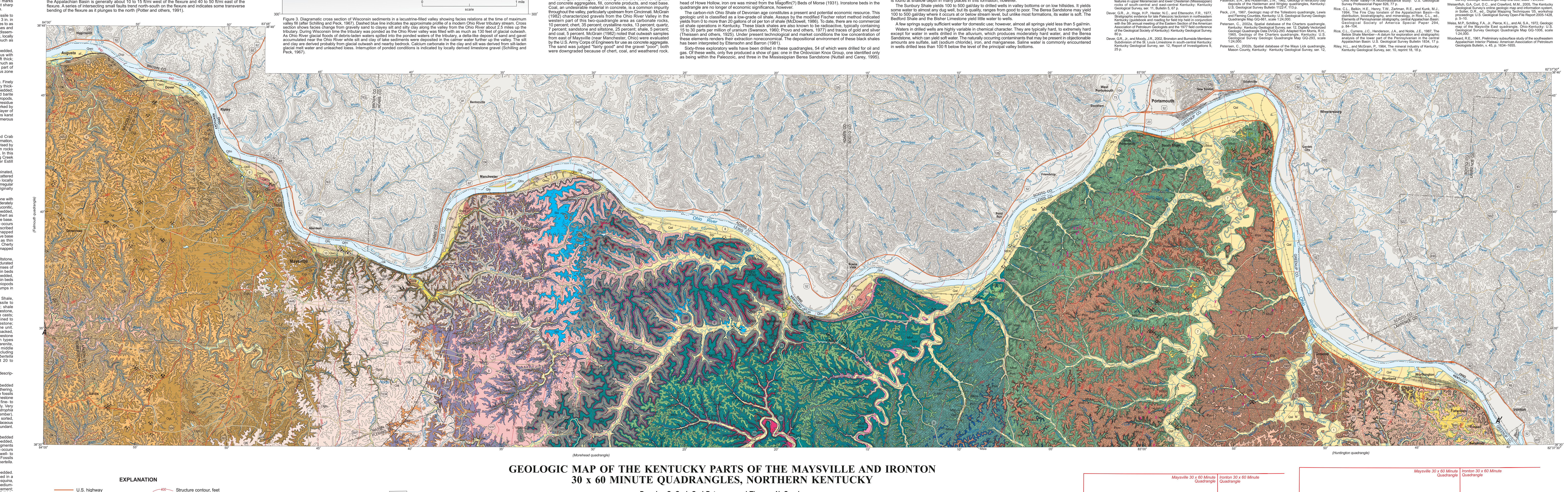
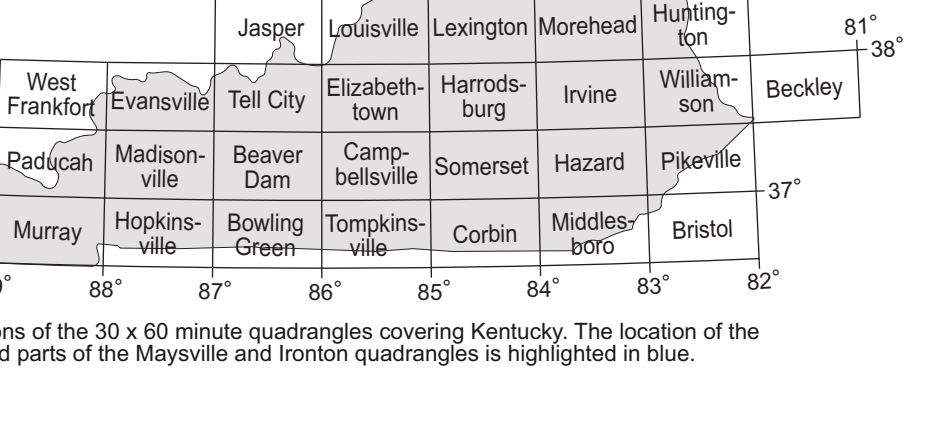


EXPLANATION

- U.S. highway
- State highway
- State boundary
- County boundary
- City boundary
- Railroad
- Normal fault (U, upthrown side; D, downthrown side)
- Concealed fault
- Contact
- Concealed contact
- Inferred contact
- 400 Structure contour, feet
- Datum horizon boundary
- Coal bed
- Concealed coal bed
- ⚒ Active stone quarry
- ⚒ Abandoned stone quarry or mine
- ⚔ Active pit; sand, gravel
- ⚔ Abandoned pit; gravel, clay, sand, or silt
- x Prospect (clay)
- x Fossil point

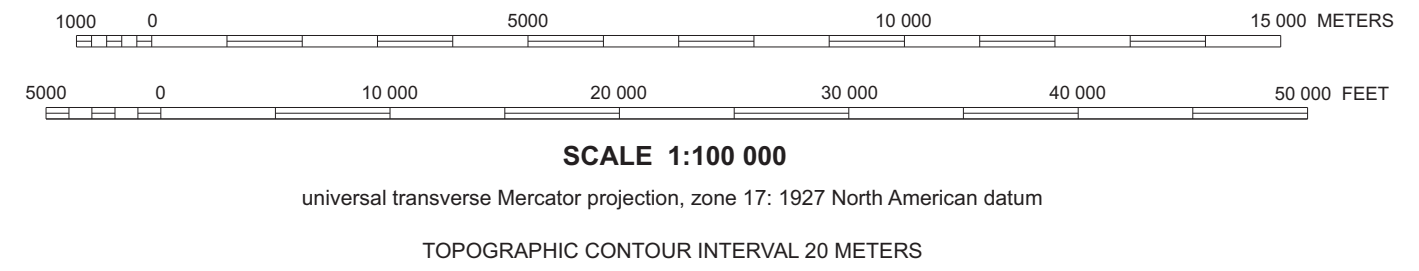


Locations of the 30 x 60 minute quadrangles covering Kentucky. The location of the mapped parts of the Maysville and Ironton quadrangles is highlighted in blue.

GEOLOGIC MAP OF THE KENTUCKY PARTS OF THE MAYSVILLE AND IRONTON 30 x 60 MINUTE QUADRANGLES, NORTHERN KENTUCKY

Douglas C. Curl, Carl Petersen, and Thomas N. Sparks

Cartography by Terry D. Hounshell


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

SCALE 1:100 000

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

TOPOGRAPHIC CONTOUR INTERVAL 20 METERS

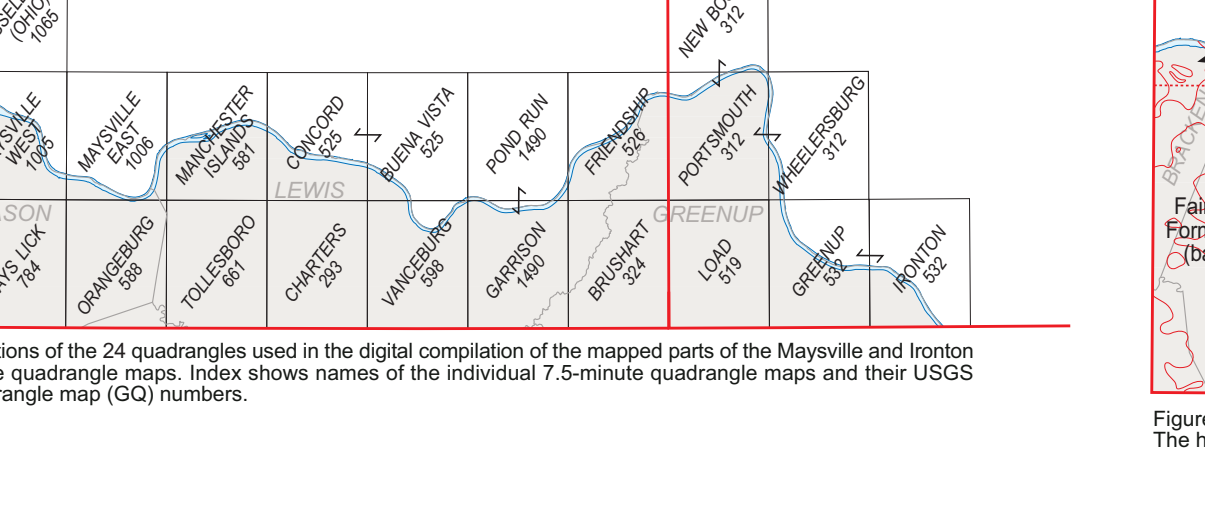
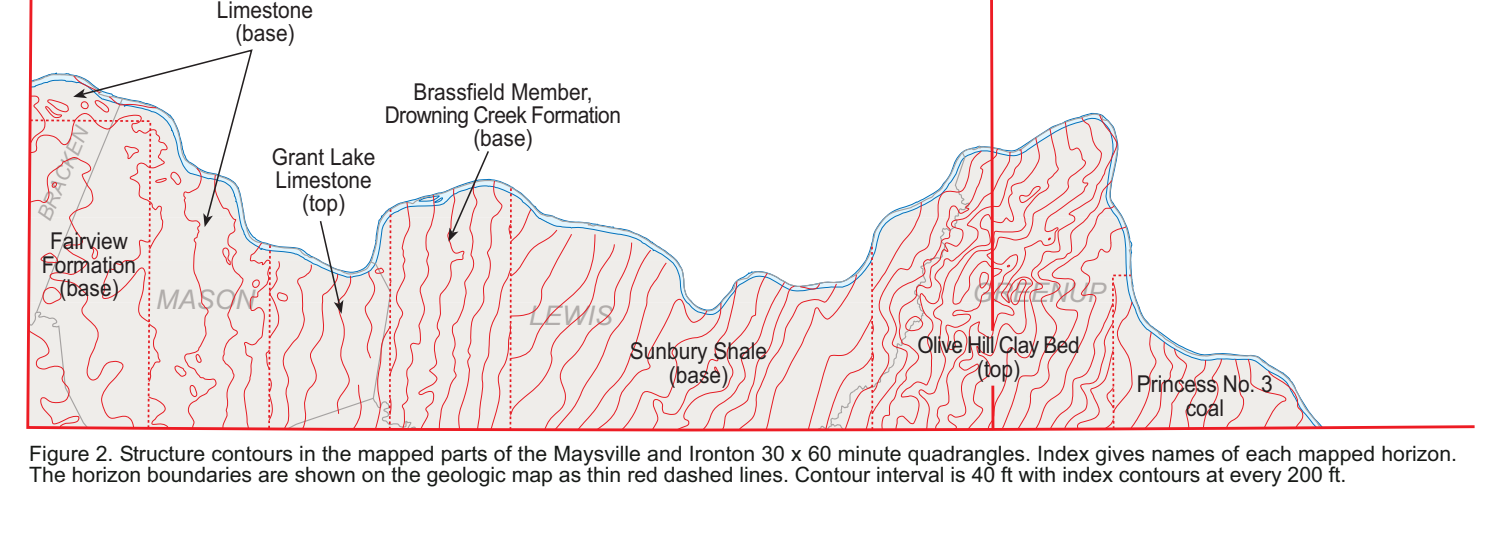
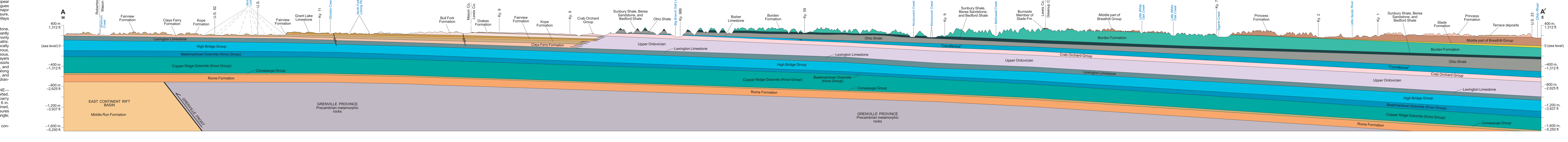


Figure 1. Locations of the 24 quadrangles used in the digital compilation of the mapped parts of the Maysville and Ironton 30 x 60 minute quadrangle maps. Index shows names of the individual 7.5-minute quadrangle maps and their USGS geologic quadrangle map (GQ) numbers.


Maysville 30 x 60 Minute Quadrangle
Ironton 30 x 60 Minute Quadrangle
Grant Lake Limestone (base)
Grant Lake Limestone (top)
Brassfield Member, Drowning Creek Formation (base)
Fairview Formation (base)
Sunbury Shale (base)
Olive Hill Clay Bed (top)
Princess No. 3 coal
MASON
LEWIS
GREENUP

Figure 2. Structure contours in the mapped parts of the Maysville and Ironton 30 x 60 minute quadrangles. Index gives names of each mapped 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.