2018

Surficial Geologic Map of the Patriot 7.5-Minute Quadrangle, Kentucky

Maxwell L. Hammond III
Kentucky Geological Survey, max.hammond@uky.edu

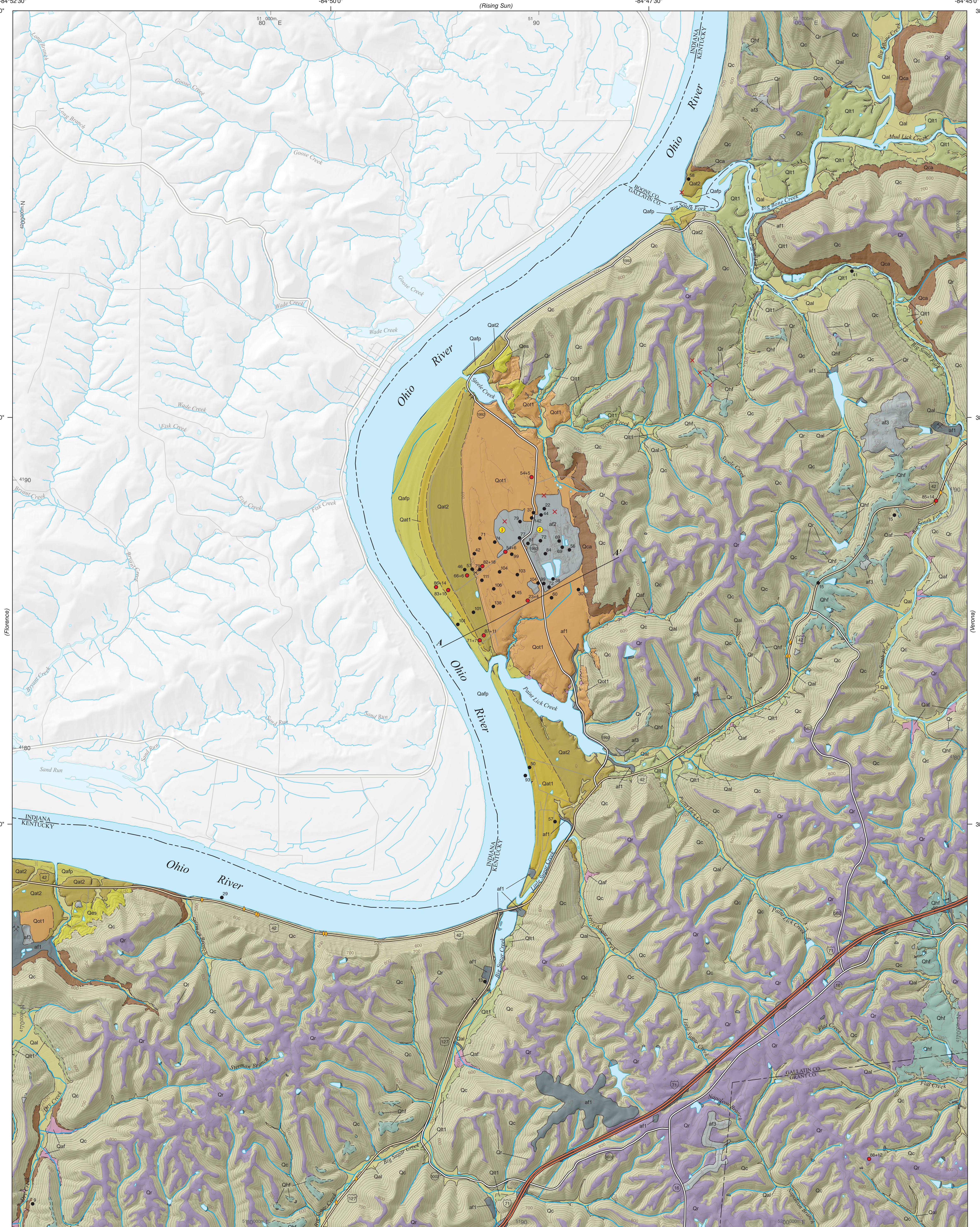
Antonia E. Bottoms
Kentucky Geological Survey, Antonia.Bottoms@uky.edu

Steven L. Martin
University of Kentucky, slmart5@email.uky.edu

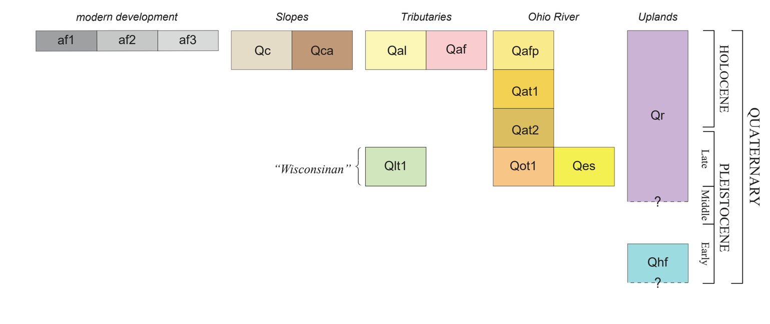
KENTUCKY GEOLOGICAL SURVEY
William C. Haneberg,
State Geologist and Director
University of Kentucky, Lexington

Contract Report 15
Series 13, 2018

Kentucky Geological Survey



Correlation Of Map Units



Description Of Map Units

af1 — **Artificial fill, engineered (modern)**
Engineered fill that includes compacted material used for road embankments, roadway interchanges, dams, major commercial development, and levees. Narrow areas of fill along railroads and most highways are not differentiated.

af2 — **Artificial fill, mine and quarry spoil (modern)**
Disturbed areas associated with the mining of natural resources. Sand and gravel are excavated from glacial outwash along the Ohio River. A limestone quarry is also present in the eastern part of the quadrangle.

af3 — **Artificial fill, other (modern)**
Disturbed sediment associated with the development of densely populated neighborhoods and urban areas, or areas where original topography has been significantly modified.

Qafp — **Alluvium, river floodplain (Holocene)**
Silt, sand, and gravel, brown to dark brown, regionally derived limestone, siltstone, and igneous and metamorphic rocks from glacial deposition (Fig. 1). Modern river floodplain. Unit is up to 20 ft thick.

Qal — **Alluvium, small creek floodplain (Holocene)**
Clay, silt, sand, gravel, and boulders; brown, dark yellowish brown, and dark brown. Imbricated slabs of locally derived limestone and carbonate shale deposited in small tributaries and associated floodplains. Sediment provenance is local, but can include quartz, chert, and igneous and metamorphic rocks that have been reworked from sediments with regional provenance. Crossbeds with downstream paleocurrent directions occur locally. Thickness of alluvium is up to 10 ft, and bedrock is commonly exposed in stream bottoms (Swadley, 1969a). Alluvium underlying floodplain of Big Bone Creek at village of Big Bone consists of dark gray, silty clay and sandy silt as much as 30 ft thick that locally contains fossil remains of Pleistocene mammals including mammoths, mastodons, bison, musk oxen, and horses (Schultz and others, 1963).

Qaf — **Alluvial fan (Holocene)**
Silt, sand, gravel, and boulders. Sediment is locally derived. Poorly sorted. Present in watersheds where smaller stream mouths enter a larger tributary. Alluvial fans are usually associated with lobe-shaped contours. Maximum thickness is up to 20 ft, but unit gradually thins downslope to the fan margin. Fans present in the outwash terraces are very sandy and made up of sediments from the outwash.

Qc — **Colluvium, undifferentiated (Holocene)**
Clay, silt, sand, gravel, and boulders, dark yellowish brown to dark olive brown. Consists of locally derived residuum and bedrock fragments (slabs of limestone and shale), commonly with scattered bedrock exposure. Soil horizons are not distinguishable; contacts inferred from LiDAR-derived slope angles greater than 12° and hummocky contours; deposits on Kope Formation mapped from slope angles greater than 10–12°. Deposits occur along slopes of stream valleys and artificial cuts along roadways. Unit generally less than 4 ft thick. Contact with residuum on hilltops is gradational, and generally sharp with alluvium.

Qca — **Colluvium, accumulation zone (Holocene)**
Clay, silt, sand, gravel, and boulders, poorly sorted. Unit includes local areas of windblown sand and silt deposited on hillslopes, margins of lake deposits; possibly overlaps with outwash and river terraces near the hillslope. Unit mapped based on decreasing slope angle, hummocky topography, and thickening of colluvial deposits near the base of the slope. Approximately 5–30 ft thick.

Qat1 — **Alluvium, fluvial terrace generation 1 (Holocene)**
Silt, sand, and clay, brown, dark yellowish brown, and dark brown. Deposit consists of reworked glacial material, silt, and sediment carried by the river. First benched terrace above the floodplain of the Ohio River (Fig. 1); terrace is benched into the outwash plain. Unit is up to 20 ft thick.

Qat2 — **Alluvium, fluvial terrace generation 2 (Late Pleistocene? – Holocene)**
Silt, sand, and clay, brown, dark yellowish brown, and dark brown. Deposit consists of reworked glacial material, silt, and sediment carried by the river. Second benched terrace above the floodplain of the Ohio River (Fig. 1); terrace is benched into the outwash plain. Unit is up to 20 ft thick.

Qes — **Eolian, sand (Late Pleistocene)**
Sand and silt, grayish orange to dark yellowish orange, moderately well sorted, angular to subrounded, unconsolidated. Largely quartz, but contains some feldspar, rock fragments, mica, and coal. No bedding observed. Sand occurs most commonly on west- and southwest-facing slopes adjacent to large areas of Wisconsinan outwash, indicating deposition by prevailing southwesterly wind. Normally poorly exposed. Unit is up to 15 ft thick.

Qlt1 — **Lacustrine, terrace generation 1 (Late Pleistocene)**
Clay, silt, and sand, yellowish brown to yellowish gray. Yellowish orange, calcareous concretions common. Stringers of pebbles occur locally. Interbedded clay, silt, and sand. Unit contains some glacially derived pebbles and large amounts of glacial sand near mouths of streams. Laminated to thinly bedded. Grades downstream into outwash, and upstream into alluvium. Up to 60 ft thick. Unit well developed along lower part of Gunpowder Creek. Well exposed at mouth of Big Bone Creek, where it consists of light brown, thin-bedded sand interbedded with bluish gray, thin-bedded to laminated plastic clay and silty clay overlain by obscurely bedded silty clay containing calcareous and limonitic nodules. Also well exposed in roadcut 0.5 mi southwest of junction of Craigs Creek and Vera Cruz Branch, where it consists of dark yellowish orange silty clay interbedded with light gray to grayish orange silt in beds 0.5 to 3 in. thick that contain numerous calcareous concretions. Equivalent to unit mapped as older alluvium in Union and Patriot quadrangles (Swadley, 1969a, b).

Qot1 — **Outwash, terrace generation 1 (Late Pleistocene)**
Sand and gravel. Gravel is light brownish gray to light reddish brown, well to poorly sorted, well rounded; includes fragments of limestone, siltstone, dolomite, quartz, chert, quartzite, granite, gneiss, schist, fine-grained igneous and metamorphic rocks, and coal; fragments mostly less than 6 in. across; contains a few well-rounded boulders as much as 3 ft in diameter and locally derived slabs of limestone as much as 1 ft in diameter; locally, gravel is cemented by calcite; commonly overlain by 5–20 ft of sand (Figs. 2, 3). Sand is reddish brown to brownish gray, very fine to coarse, poorly to well sorted; locally silty and clayey; detrital coal is locally common along bedding planes; occurs as matrix in gravel and as beds and lenses; outwash in tributary valleys is composed almost entirely of sand (Swadley, 1969a). Laminated to massive, and commonly crossbedded. Outwash terrace tread surfaces are approximately 525 ft elevation (Fig. 1). One boring near Duke Energy Power Plant (Rising Sun quadrangle) indicates depth to bedrock is 186 ft. Unit previously mapped as Wisconsinan and interpreted to overlie outwash of Illinoian age (Swadley, 1969a). Upstream from the mouth of the Great Miami River, outwash consists of medium and coarse sand containing only scattered pebbles.

Qhf — **High-level fluvial deposits (Pliocene? – Early Pleistocene)**
Silt, sand, clay, and gravel, yellowish brown to dark yellowish brown. Gravel consists of well-rounded quartz pebbles, rounded to subangular chert pebbles and cobbles, and abundant geodes (Swadley, 1972). Thickness is approximately 30 ft. Preglacial fluvial deposits are commonly very weathered, but the contact with the underlying bedrock is sharp. Exposed only along steep banks of creeks and streams.

Qr — **Residual soil (Pleistocene? – Holocene)**
Silt and clay, dark brown to yellowish brown. In-situ weathering of bedrock, locally integrated with loess. Unconsolidated. Found overlying bedrock in uplands throughout the quadrangle. Typically less than 12 ft thick. Contact with adjacent colluvium is gradational.

Geologic Summary

The Patriot 7.5-minute quadrangle is located in Boone, Gallatin, and Grant Counties of northern Kentucky in the Outer Bluegrass physiographic province (McFarlan, 1943). Broad to narrow ridges, steep hillsides, and the Ohio River Valley characterize the topography of the quadrangle. The Ohio River has been made navigable by a series of high-level dams, and the Markland Locks and Dam controls the river level in this area (Ray, 1974). The bedrock geology, originally mapped by Swadley (1969), consists, from oldest to youngest, of the Point Pleasant Formation, the Kope Formation, the Fairview Formation, the Bellevue Tongue of the Grant Lake Limestone, and the Bullfork Formation. The Point Pleasant Formation is approximately 50 to 90 percent limestone and the remainder is shale; it is more than 55 ft thick and occurs along the lower hillsides near the Ohio River and tributary streams. The Kope Formation consists of approximately 80 percent shale and 20 percent limestone, is 190 to 235 ft thick, and is exposed along stream valleys and hillsides. The Fairview Formation is interbedded limestone (50 percent) and shale (50 percent), 105 to 115 ft thick, and occurs as a resistant unit on ridgetops. The Bellevue Tongue of the Grant Lake Limestone consists of rubbly-weathering limestone 3 to 5 ft thick on ridgetops. The Bullfork Formation is interbedded limestone (approximately 50 percent) and shale (50 percent), more than 45 ft thick, and occurs as thin caps on higher ridges in the quadrangle (Swadley 1969a). All formations are fossiliferous.

Multiple advances and retreats of the Laurentide ice sheet throughout the Pleistocene continuously adjusted the landscape of the central United States, including the Covington quadrangle. Pre-Illinoian glaciation in the Early Pleistocene impounded the Teays River system, causing widespread avulsion of the Teays and its tributaries (Teller, 1973; Ray, 1974; Andrews, 2004). Deep incision of bedrock valleys, headward erosion of tributaries, and development of a prominent weathering horizon throughout the region characterized the Yarmouth interglacial stage that followed the pre-Illinoian glaciations (e.g., Durrell, 1961; Ray, 1974). The present day course of the Ohio River was broadly in place before Illinoian glaciation in the Middle Pleistocene, which then served as the approximate limit of Illinoian ice and a drainage for outwash (Ray, 1974; Andrews, 2004; Potter, 2007). The Sangamon interglacial marked another period of Ohio River degradation, incising and removing much of the Illinoian deposits (Ray, 1974; Andrews, 2004; Potter, 2007). Late Pleistocene Wisconsinan ice did not reach Kentucky, but the Ohio River was used to transport high volumes of outwash (Ray, 1974; Andrews, 2004; Potter, 2007). The Holocene has been marked by relatively continuous period of erosion, river degradation, and soil development.

Surficial Geology

This map shows the surficial geology above bedrock mapped at 1:24,000 scale or larger. The units described here reflect natural processes that are collectively operating as a dynamic geomorphic system (Newell, 1978). The primary mechanisms of sediment transport and deposition in the area are flowing water (alluvial and glaciofluvial deposits), gravity/mass movement (colluvium), and glacial advances in the Pleistocene, which are sometimes complexly interrelated. Mapping was based on field observation, interpretation of LiDAR elevation data, soil surveys (Weisenberger and others, 1989; Froedge and Weisenberger, 1980), and previous studie from the area (Price, 1964; Swadley, 1969a). Digital elevation model, slope map, contours of various intervals, and a relative elevation model (relative to the water elevation of the Ohio River) were derived from 1 m resolution LiDAR point cloud and used as basemaps and interpretation in the map area. Delineation and identification of all map units are restricted by the scale of this map.

Sediment associated with the modern floodplain of the Ohio River (Qafp) has been derived from a regional source(s) and deposited along the main course of the Ohio River (Fig. 1); Qafp is relatively narrow, given the relatively wide width of the Ohio River Valley, but is controlled by a series of dams, locks, and levees. In contrast, alluvium in valley bottoms of smaller creeks, streams, and tributary valleys is characterized with sediment of a local provenance (Qal). Alluvial fans (Qaf) occur where steep creeks and drainages enter low-relief valleys and terraces, which lowers stream velocity and causes abandonment of the sediment load.

Three generations of regional terraces have developed along the Ohio River in the Patriot quadrangle (Fig. 1), each generation with terrace treads that progressively decrease in elevation downstream. Qat1 (lowest) and Qat2 are alluvial terraces predominantly composed of reworked outwash (Qot1). Qot1 is the highest terrace recognized in the quadrangle, and represents glacial outwash deposition during the Late Pleistocene Wisconsinan glaciation. High sediment volumes and aggradation are implied by the relatively high elevation of Qot1 (Figs. 1, 2, 3), local deposition of outwash and impoundment at mouths of tributaries (Big Bone and Paint Lick Creeks), and lacustrine deposition within the tributary valleys (Qlt1). Eolian sands (Qes) are also interpreted as Late Pleistocene deposits and have been mapped on west- and southwest-facing slopes; loess has not been differentiated, but commonly overlies glacial outwash and residual soils (Qr) on ridgetops.

Upland deposits mostly consist of colluvial slopes and residual soils. Residuum (Qr) has developed on low-relief ridgetops from in-situ weathering and erosion of the underlying limestones and shales. High-level fluvial deposits (Qhf) of the Old Kentucky River have been mapped in the southern and eastern parts of the quadrangle and occupy paleochannels entrenched in bedrock. The Old Kentucky flowed north and was tributary to the Teays River, the major drainage system of the Midwest in the Pliocene-Early Pleistocene (Durrell,1961; Ray, 1974; Andrews, 2004; Potter, 2007). Qr and Qhf are largely mantled by steep slopes of colluvium (Qc). Most slopes of Qc are coincident with the underlying shale-dominated Kope Formation. Accumulations of colluvium (Qca) are common at the base of colluvial slopes, and may also include and/or overlie eolian deposits (sand and loess) and lacustrine sediments.

Geologic Hazards

Landslides pose a potential threat in northern Kentucky. Very few landslides have been mapped in the Patriot quadrangle, but typically occur on steep, colluvial slopes. Shaley colluvium associated with the Kope Formation slumps easily and is susceptible to movement when not properly drained or when the slope is steepened. Landslide movement in colluvium is most common during the spring and winter, when precipitation is greater than in other seasons (Agnello, 2009). Many landslides are associated with some type of human disturbance, such as improper drainage or steepening of slopes during construction of roads, homes, or other structures (Crawford, 2014). Other surficial deposits in the area are prone to landslides as well. Artificial fill, particularly above and below roadways, is susceptible to landslides (Crawford, 2014).

Flooding is a common occurrence along the Ohio River Valley with regular deposition on Qafp and Qat1. Several catastrophic floods have occurred, in 1937, 1945, and 1997. Most recently, the river crested at 60 ft at Cincinnati on Feb. 2, 2018, and flooded parts of Cincinnati, Covington, Aurora, and multiple other localities along the river; for comparison, the historic flood of 1937 crested at 80 ft.

Disclaimer

Acknowledgments

This map was generated using new field mapping along with compilation of unreleased and previously published data, and was funded in part by the U.S. Geological Survey's National Cooperative Mapping Program under the STATEMAP program authorized by the National Geologic Mapping Act of 1992, Grant No. G17AC00255, and by the Kentucky Geological Survey. Field mapping was completed by Max Hammond, Antonia Bottoms, and Steve Martin from July 2017 to June 2018. The authors thank Meg Smath and William Andrews for reviews. Cartography is by Emily Morris.

References Cited

Agnello, T., 2009, Overview and field reconnaissance of landsliding in the Tri-State region of Kentucky, Ohio, and Indiana (Kentucky Society of Professional Geologists annual field conference, Highland Heights, Ky., Nov. 14, 2009): Kentucky Society of Professional Geologists, 22 p.

Andrews, W.M., 2004, Geologic controls on Plio-Pleistocene drainage evolution of the Kentucky River in central Kentucky: Lexington, University of Kentucky, 216 pp.

Crawford, M.M., 2014, Kentucky Geological Survey landslide inventory: From design to application: Kentucky Geological Survey, ser. 12, Information Circular 31, ser. 12, 18 p.

Durrell, R.H., 1961, The Pleistocene geology of the Cincinnati area, in, Guidbeook for Field Trips, Cincinnati Meeting, Geological Society of America, p. 45-74.

Froedge, R.B., and Weisenberger, B.C., 1980, Soil survey of Grant and Pendleton Counties, Kentucky: U.S. Department of Agriculture–Soil Conservation Service, 97 p.

McFarlan, A.C., 1943, Geology of Kentucky: Lexington, University of Kentucky, 531 p.

Nelson, H.L., Jr., 2002, Spatial database of the Lawrenceburg, Aurora, and Hooven quadrangles, Boone County, Kentucky: Kentucky Geological Survey, ser. 12, Digitally Vectorized Geologic Quadrangle Data DVGQ-989. Adapted from Swadley, W C, 1972, Geologic map of the Lawrenceburg, Aurora, and Hooven quadrangles, Boone County, Kentucky: U.S. Geological Survey Geologic Quadrangle Map GQ-989, scale 1:24,000.

Newell, W.L., 1978, Understanding natural systems—A perspective for land-use planning in Appalachian Kentucky: U.S. Geological Survey Bulletin 1438, 50 p.

Potter, P.E., 2007, Exploring the geology of the Cincinnati/northern Kentucky region: Kentucky Geological Survey, Special Publication, 8-12, 128 p.

Price, W.E., Jr., 1964, Geology and hydrogeology of alluvial deposits along the Ohio River between Newport and Warsaw, Kentucky: U.S. Geological Survey Hydrogeologic Inventory Atlas HA-98.

Ray, L.L., 1974, Geomorphology and Quaternary geology of the glaciated Ohio River Valley—A reconnaissance study: U.S. Geological Survey Professional Paper 826, 77 p.

Schultz, C.B., Tanner, L.G., Whitmore, F.C., Jr., Ray, L.L., and Crawford, E.C, 1963, Paleontologic investigation at Big Bone Lick State Park, Kentucky: A preliminary report: Science, v. 142, no. 3596, p. 1167–1169.

Swadley, W C, 1969a, Geologic map of parts of the Patriot and Florence quadrangles, north–central Kentucky: U.S. Geological Survey Geologic Quadrangle Map GQ-846, scale 1:24,000.

Swadley, W C, 1969b, Geologic map of the Union quadrangle, Boone County, Kentucky: U.S. Geological Survey Geologic Quadrangle Map GQ-779, scale 1:24,000.

Swadley, W C, 1971, Geologic map of the Rising Sun quadrangle, Boone County, Kentucky: U.S. Geological Survey Geologic Quadrangle Map GQ-929, scale 1:24,000.

Swadley, W C, 1972, Geologic map of the Lawrenceburg, Aurora, and Hooven quadrangles, Boone County, Kentucky: U.S. Geological Survey Geologic Quadrangle Map GQ-989, scale 1:24,000.

Teller, J.T., 1973, Preglacial (Teays) and early glacial drainage in the Cincinnati area, Ohio, Kentucky, and Indiana: Geological Society of America Bulletin, 84, 11, p. 3677-3688.

Thompson, M.F., 2002, Spatial database of the Rising Sun quadrangle, Boone County, Kentucky: Kentucky Geological Survey, ser. 12, Digitally Vectorized Geologic Quadrangle Data DVGQ-929. Adapted from Swadley, W C, 1971, Geologic map of part of the Rising Sun quadrangle, Boone County, Kentucky: U.S. Geological Survey Geologic Quadranlge Map GQ-929, scale 1:24,000.

Tyra, M.A., 2002, Spatial database of the Patriot and Florence quadrangles, north-central Kentucky: Kentucky Geological Survey, ser. 12, Digitally Vectorized Geologic Quadrangle Data DVGQ-846. Adapted from Swadley, W C, 1969, Geologic map of parts of the Patriot and Florence quadrangles, north-central Kentucky: U.S. Geological Survey Geologic Quadrangle Map GQ-846, scale 1:24,000.

Weisenberger, B.C., Dowell, C.W., Leathers, T.R., Odor, H.B., and Richardson, A.J., 1989, Soil survey of Boone, Campbell, and Kenton Counties, Kentucky: U.S. Department of Agriculture, Soil Conservation Service, 69 p.

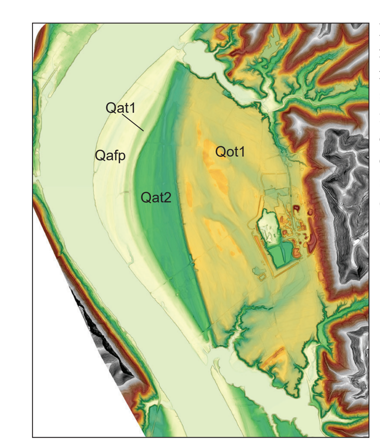


Figure 1. Relative elevation model of the Ohio River Valley near Steele Bottom. Color scale represents elevation in feet relative to the water level of the Ohio River. Notice the distinct breaks, which correspond to mapped terraces (Qafp, Qat1, Qat2, Qot1).

Figure 2. Detailed photograph of Qot1 outwash showing poorly sorted sand, gravel, and silt. Gravels are rounded, generally less than 1 in, and include igneous and metamorphic rocks, limestone, and coal.

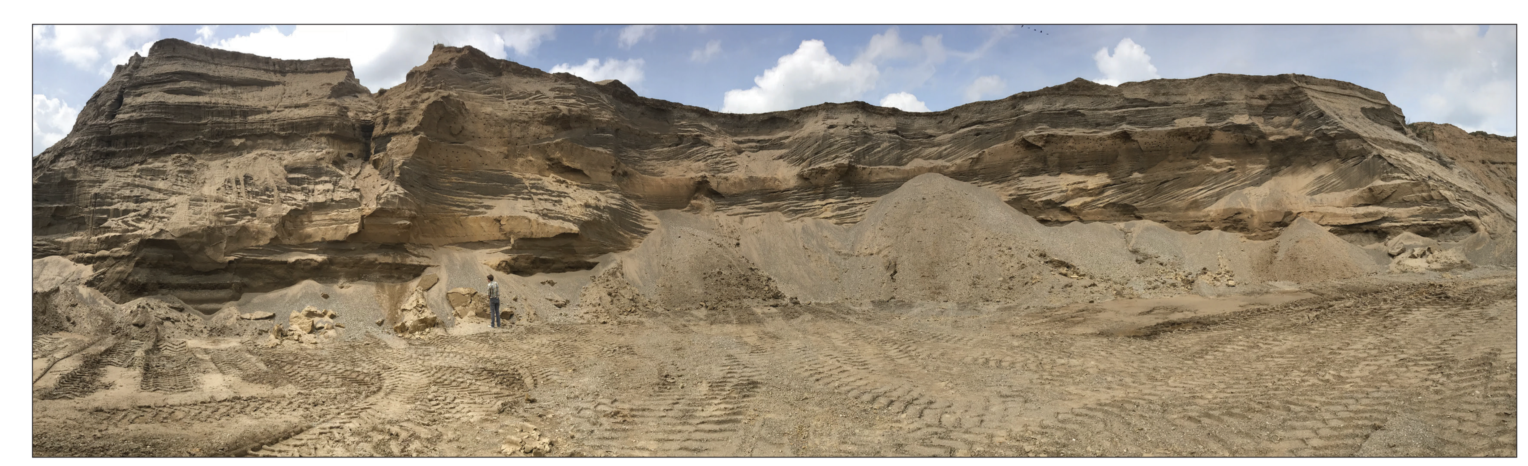


Figure 3. High wall of glacial outwash (Qot1) in a sand and gravel quarry near Warsaw. Notice the massive cross beds and sand-silt channel deposits. Geologist in middle left for scale.

Topographic lines and hillshading derived from KYAPED 5 Foot Digital Elevation Model and USGS 3DEP 1/3 arc-second digital elevation model.

Highways and roads from Kentucky Transportation Cabinet (KYTC) and Ohio Department of Transportation (ODOT). Railroads from OpenStreetMap.

Hydrography from National Hydrography Dataset High Resolution.

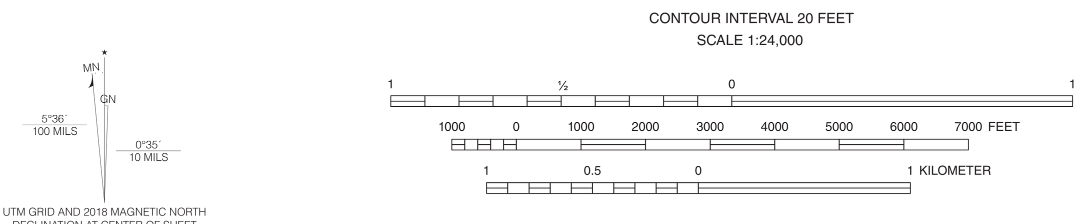
Digital data collected in Kentucky Single Zone State Plane Coordinate System. Lambert conformal projection, North American 1983 datum.

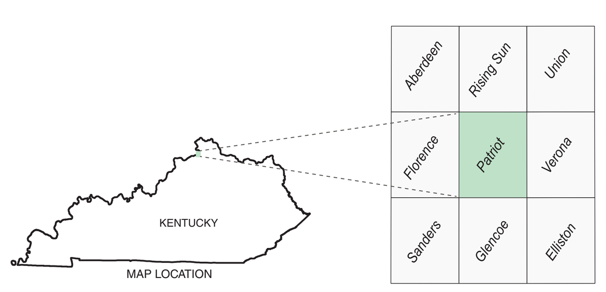
Topographic contours and hillshading may not be current within areas of artificial fill.

SURFICIAL GEOLOGIC MAP OF PART OF THE PATRIOT 7.5-MINUTE QUADRANGLE, NORTHERN KENTUCKY

Maxwell Hammond, III, Antonia E. Bottoms, and Steven L. Martin

CONTOUR INTERVAL 20 FEET
SCALE 1:24,000





Explanation of Map Symbols

- State boundary
- County boundary
- Interstate
- U.S highway
- State highway
- Local road
- Railroad
- Topographic contour
- Small stream or creek
- River or large stream or creek
- Water body; pond or lake
- Contact
- Approximate contact
- Inferred contact
- Gradational contact
- Gradational approximate contact
- Gradational inferred contact
- 9 — Drillhole data (Kentucky Transportation Cabinet; KGS water-well database; Price, 1964); number indicates depth to bedrock in feet
- 86+11 — Sample (Kentucky Geological Survey); numbers indicate silt+clay percentages
- Outcrop (Kentucky Geological Survey)
- Landslide (Crawford, 2014)
- Abandoned quarry/pit
- Active quarry/pit
- Photograph Location