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GENERAL GEOLOGY

Miami County constitutes an area of about 590 mi² (1,500 km²) in east-central Kansas. The surficial sedimentary rocks—alternating beds of limestones and shales, representing cyclothems—are Pennsylvanian (Missourian Stage) in age and comprise the majority of the Kansas City Group and Lansing Group (Zeller, [1968] 2018; Oborny et al., 2022a). The oldest rocks (Hertha Limestone) crop out in river valleys in the southeastern part of the county, whereas the youngest rocks (Stanton Limestone) form the uplands in the northwest and are commonly mantled by clayey alluvium interbedded with chert gravels. Quaternary loess deposits are mostly found in the northeast part of the county. Holocene sediments occur as colluvial slope deposits, alluvial fans, and terrace and floodplain fills in stream valleys.

GEOMORPHOLOGY AND GEOGRAPHY

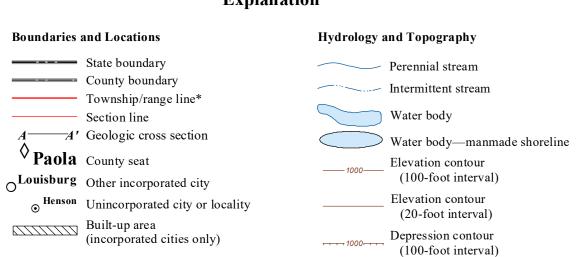
Miami County is located in the Osage Plains section of the Central Lowlands physiographic province. Gently dipping Pennsylvanian limestones and shales underlie the entire county and have been eroded to create cuestas with broad, flat to gently undulating dip slopes and steep scarp slopes. Natural vegetation is a mixture of tallgrass prairie and oak-hickory woodland. Topographic relief is 369 ft (113 m); the lowest point (788 ft [240 m]) is located in the Marais des Cygnes River valley where the river exits the county at its southern boundary, and the highest point (1,157 ft [353 m]) is in the northeast part of the county near the town of Louisburg. The county is primarily drained by the Marais des Cygnes River and its tributaries, which include Bull, Wea, Pottawatomie, and Middle creeks. The county has no major aquifers and so the area is highly dependent on surface water supplies, with reservoirs supplying much of municipal water needs. Hillsdale Lake, a federal public water supply reservoir operated by the U.S. Army Corps of Engineers, is the largest lake in the county.

STRUCTURAL GEOLOGY

Miami County is located within the Pennsylvanian-aged Forest City basin (Lee, 1943). During deposition of strata in the county, many units were relatively flat apart from complex build-ups of carbonate mounds deposited during the Zarah Subgroup interval. Today, strata within the county tend to dip to the northwest at about 20 ft (6 m) per mile and strike southwest-northeast along the length of the post-Permian Prairie Plains monocline (Prosser and Beede, 1904). Because of the presence of prominent carbonate mounds in the southwestern and northeastern parts of the county, strike and dip directions vary significantly. These mounds acted as topographic highs accompanied by low lying areas in which later sediments were deposited. As such, sediments often drape away from mounded areas. A number of minor faults that tend to have a northwest-southeast or southwest-northeast orientation have been documented in the county, in particular around the towns of Somerset, Hillsdale, Paola, and approximately 5 miles west of Louisburg (Miller, 1966).

MINERAL RESOURCES

Agriculture is an important part of the economy of Miami County. Upland soils, developed in residuum and loess, support pasture and a variety of cultivated crops. Alluvial soils in river valleys are used mainly for cultivated crops. Several carbonate rock units in the county, such as the Lower Farley, Upper Farley, and Argentine Limestones, provide an important source of building stone as well as crushed rock for road construction. Oil and gas production in Miami County comes from the Forest City Coal Gas Area. Oil and gas fields in the county include Beagle, Black, Block, Louisburg, and Paola-Rantoul. In 2021, 2,517 wells produced 162,940 barrels of oil and no gas (Kansas Geological Survey, 2022). Total cumulative production for the county through December 2021 is 30,825,547 barrels of oil and 3,020,339 thousand cubic feet (mcf) of gas.



Depression contour

Disturbed area or fill material

were excluded from the U.S. Public Land Survey, resulting

partial sections in parts of the river's course through the count

Geologic Unit Boundaries

----- Observed contact

---- Inferred contact

Resource Development

• Henson Unincorporated city or locality ■ 50 ■ Interstate and U.S. highway (divided) primary road _____ Medium-duty

secondary road ——— Light-duty road ====== Unimproved road -+---- Railroad ====== Unpaved landing strip ——— Airport

Index shows the names and locations of the 15

USGS 7.5-min 1:24,000-scale quadrangles used

in the digital compilation of the Miami County

map. The geology was mapped in the field using

these topographic maps.

Index to 1:24,000-scale USGS quadrangle maps

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Survey, Bulletin 189, 81 p. SUGGESTED REFERENCE TO THIS MAP

Layzell, A. L., Newell, K. D., Oborny, S. C., Mandel, R. D., and Dunham, J. W., 2022, Surficial Geology of Miami County, Kansas: Kansas Geological Survey, Map M-126, scale 1:50,000.

Elevation contours are presented for general reference. Used in the U.S. Geological Survey's current US Topo 1:24,000-scale topographic map series, they were generated from hydrographically improved 1/3 arc-second National Elevation Dataset (NED) data and smoothed during processing for use at 1:24,000 scale. In some places, the contours may be more generalized than the base data used for compilation of geologic outcrop patterns. Outcrop patterns on the map will typically reflect topographic variation more accurately than the associated contour lines. Repeated fluctuation of an outcrop line across a contour line should be interpreted as an indication that the mapped rock unit is maintaining a relatively constant elevation along a generalized

Roads and highways are shown on the base map as represented by data from the Kansas Department of Transportation (KDOT), U.S. Census Bureau, and other sources. U.S. Department of Agriculture – Farm Services Agency (USDA-FSA) National Agriculture Imagery Program (NAIP) imagery also was used to check

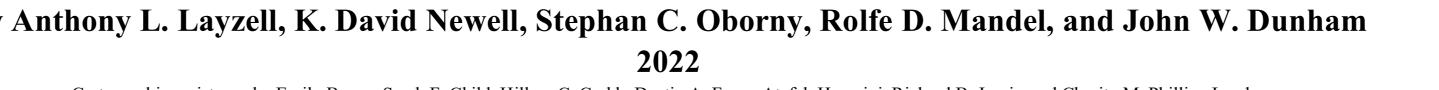
Shaded relief is based on 1-meter hydroflattened bare-earth DEMs from the State of Kansas LiDAR Database. The DEM images, in ERDAS IMAGINE format, were mosaicked into a single output DEM, downsampled to 5meter resolution, and reprojected to decimal degrees. The output DEM was then converted to a hillshade, a multidirectional shaded-relief image using angles of illumination from 0°, 225°, 270°, and 315° azimuths, each 45° above the horizon, with a 4x vertical exaggeration.

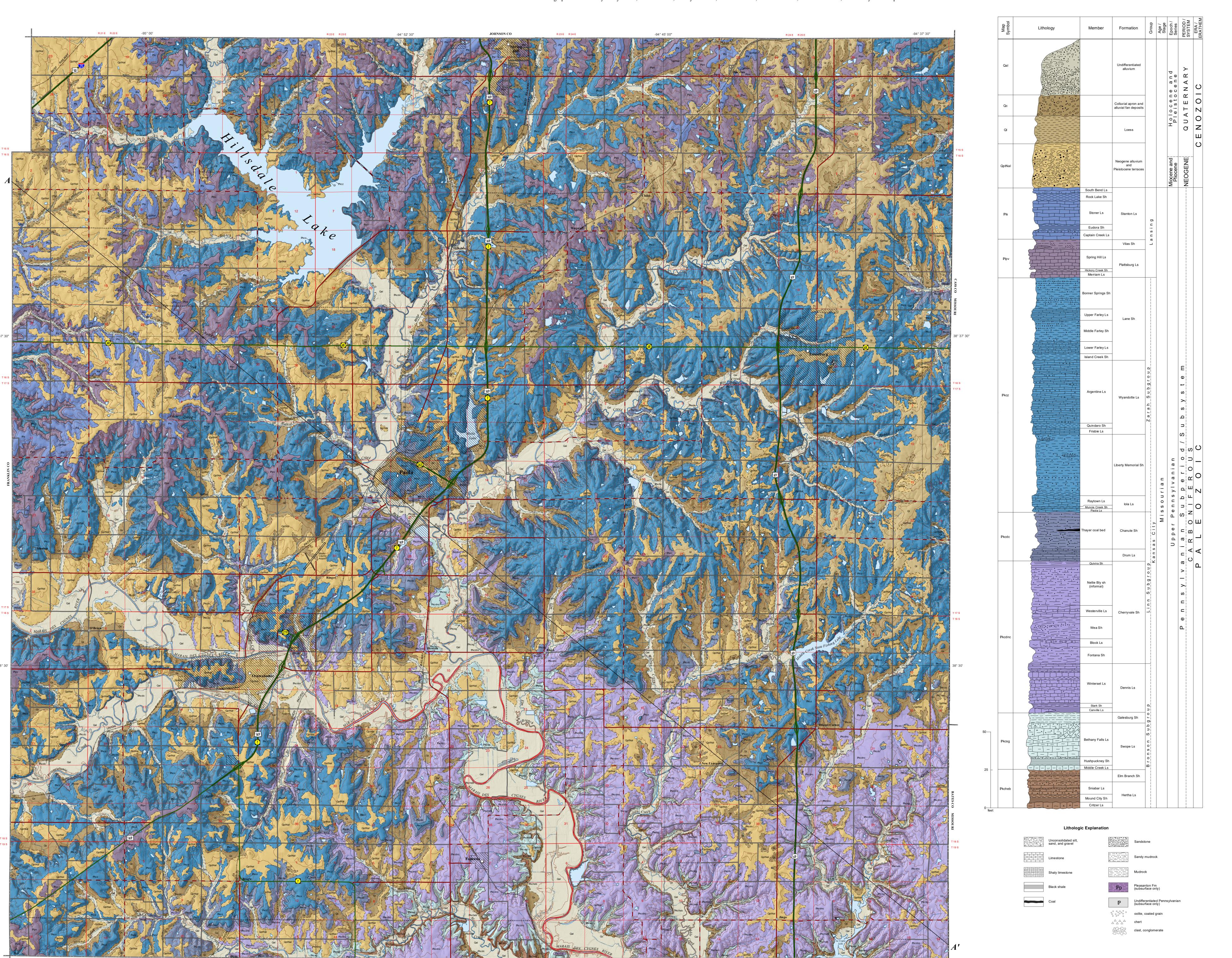
This geologic map was funded in part by the USGS National Cooperative Geologic Mapping Program. Supplemental mapping was conducted by James R. McCauley in 2007–2008.

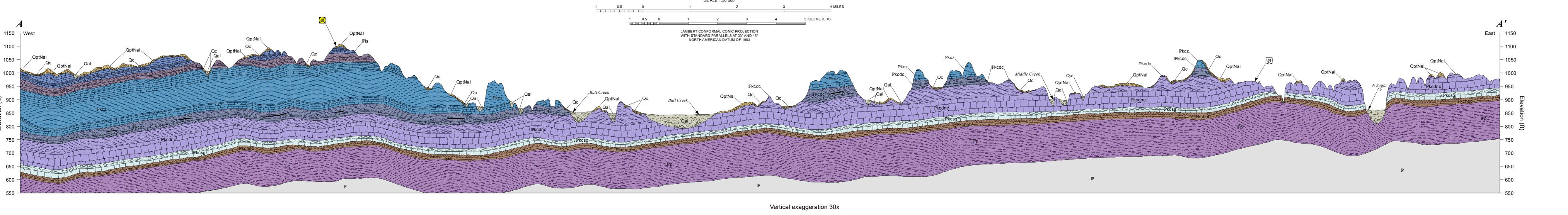
any responsibility or liability for interpretations made from the map or decisions based thereon.

The Miami County map was produced using the ArcGIS system developed by Esri (Environmental Systems Research Institute, Inc.).

The Kansas Geological Survey does not guarantee this map to be free from errors or inaccuracies and disclaims







GEOLOGIC UNITS CENOZOIC ROCKS

Pleistocene-Holocene Undifferentiated alluvium—Undifferentiated alluvium comprises valley fills beneath an extensive alluvial terrace (T-1) and the modern floodplain (T-0) of the Marais des Cygnes River and its tributaries. T-1 alluvium consists of clay, silt, sand, and gravel, with the coarsest sediments comprising the lower 3–6 ft (0.9–1.8 m) of the alluvial fills. The fine-grained alluvium is mostly brown, dark yellowish-brown, and yellowish-brown silty clay loam. These deposits can reach thicknesses greater than 70 ft (21 m) in the Marais des Cygnes River valley and typically are 4,000 to 11,000 years old. Younger alluvial deposits comprise the valley fills beneath the modern floodplain. The fine-grained floodplain facies are mostly dark gray, gray, dark grayish-brown, and grayish-brown silty clay, and silty clay loam.

Colluvial apron and alluvial fan deposits—Deposits of clay, silt, sand, and gravel occur on footslopes and toeslopes in valley landscapes. These deposits mostly accumulated during the early and middle Holocene, although some may date back to the terminal Pleistocene, and they comprise both colluvial aprons and alluvial fans. The colluvial aprons consist of massive deposits of poorly sorted sediments that include many angular, bedrock-derived pebbles and cobbles. The alluvial fans formed where small, intermittent streams enter the Marais des Cygnes River valley and the valleys of its major tributaries. The fan deposits are stratified and consist of well-sorted alluvium dominated by brown, dark yellowish-brown, and yellowish-brown silty clay, silty clay loam, and silt loam. Thin lenses of gravel are common, and buried soils often occur at the top

Loess—Deposits of grayish-brown and reddish-brown loess cover hilltops and high alluvial terraces in portions of Miami County. Deposits of grayish-brown silt loam make up the Peoria Loess, which dates between ca. 25,000 and 11,000 B.P. In some areas, erosion has stripped off the Peoria Loess and exposed reddish-brown silty sediment comprising the Loveland Loess. The distribution of the Loveland Loess is indicated by the Welda soil series. The Loveland Loess accumulated between ca. 160,000 and 130,000 B.P. and from ca. 90,000 to 75,000 B.P. in some areas. Deposits of loess more than 10 ft (3 m) thick were mapped. Neogene and Quaternary Systems

Neogene alluvium and Pleistocene terraces—Clayey alluvium often interbedded with cherty gravel is common beneath high terraces and on hilltops in Miami County. The age of these alluvial deposits is unknown. However, based on their position in the landscape, the deposits on the hilltops probably aggraded during the Neogene (Aber, 1998), and it is likely that the high-terrace fills date at least to the middle Pleistocene. The lower 3–6 ft (0.9–1.8 m) of the terrace fills and hilltop deposits consist of cherty gravel. The overlying fine-grained alluvium mostly consists of dark gray, gray, dark grayish-brown, and pale brown silty clay. The distribution of fine-grained alluvium interbedded with cherty alluvial gravels is indicated by the Kenoma soil series (Penner, 1981). Redoximorphic features, including strong brown and reddish-brown mottles and iron and manganese oxide concretions, are common in the upper 3-10 ft (0.9-3 m) of the finegrained alluvium. Alluvial deposits comprising the fills of high terraces are typically 20–30 ft (6–9 m) thick, but the alluvial deposits on hilltops generally are less than 15 ft (4.5 m) thick. A veneer of loess that is less than 3 ft (0.9 m) thick often caps the high-terrace and hilltop alluvial deposits.

Carboniferous System—Pennsylvanian Subsystem

The following unit descriptions are compiled from Newell (1935), Miller (1966), and Oborny et al. (2017) unless noted otherwise in the text. Unit thicknesses and depositional trends are from both Oborny et al. (2017) and this study. Descriptions made by Newell (1935) and Miller (1966) of strata within the Zarah Subgroup interval are herein adjusted to accommodate new unit correlations made by Heckel and Watney (2002) and Oborny et al. (2017). Thirty-three drill cores and 256 geophysical oil well logs were used in assessing subsurface character and distribution of units in the county. These data are provided in the accompanying open-file report (Oborny et al., 2022a).

Stanton Limestone—The Stanton Limestone (typically about 35 ft [10.7 m] in thickness) is the uppermost formation in the Lansing Group. This formation is absent throughout much of the county due to erosion and is restricted to the far north-central and northwestern parts of the county. It contains five members that are represented by three limestones interbedded with two shales. In ascending order, these members are the Captain Creek, Eudora, Stoner, Rock Lake, and South Bend. The Captain Creek Limestone Member (5-12.25 ft [1.5–3.7 m]) is commonly a pale yellowish-brown to light gray, medium-grained, massive-bedded imestone. A mottled dark gray to blue intraclast facies is often observed in the unit's upper part, which ma be silty and cherty. Crinoids, brachiopods, bryozoans, and phylloid algae are common in this unit. The basal contact is often smooth, yet abrupt, whereas the upper contact is more gradational with the overlying Eudora. The **Eudora Shale Member** (3.7–8 ft [1.1–2.4 m]) is well known for its black fissile pyritic shale facies that locally makes up 40–60% of the middle part of the unit. The lower and upper parts are typically gradational with the Captain Creek and Stoner, respectively, and composed of non-fissile fossiliferous shale that is gray to light yellowish-brown in coloration. This unit produces a prominent gamma-ray peak in geophysical logs that makes it readily correlative in the subsurface throughout the region and contains important zonal conodont species Idiognathodus eudoraensis (Barrick et al., 2013; Oborny et al., 2017). The Stoner Limestone Member (consistently about 16 ft [about 4.9 m] in thickness) is poorly exposed in Miami County but develops prominent escarpments in Johnson County to the north, where it has been extensively quarried near Olathe. There, the unit is composed of a bluish-gray to white-buff, wavy, thin-bedded to blocky limestone with numerous shale partings. The unit is fine grained and may host calcite-filled vugs. Prominent fauna documented in the unit include phylloid algae, Triticites sp. (fusulinids), crinoids, and, less frequently, gastropods, brachiopods, sponges, and solitary rugose coral. In many places within Johnson County and the surrounding area, the upper contact of this unit with the overlying Rock Lake is irregular and abrupt. Approximately 4 ft (1.2 m; a consistent thickness for the unit) of the Rock Lake Shale Member is poorly exposed in the northwestern part of the county, where it is composed of weathered gray shale. The unit's upper contact is abruptly terminated by fine-grained sandstone of the overlying South Bend. The **South Bend**

is least sandy, fossils may be abundant, the most prominent of which include brachiopods (Meekella sp.) and fusulinids (Triticites sp.). The upper contact of the South Bend with the overlying Weston Shale Member of the Stranger Formation is not observed in the county. Though the Weston Shale Member is not observed in outcrop, due to cover by Quaternary sediments, it is documented within subsurface oil well data located in the northwesternmost few miles of the county. These oil well data suggest the unit is approximately 30 ft (9.1 Plattsburg Limestone and Vilas Shale—The lower part of the Lansing group is composed of the Plattsburg Limestone and overlying Vilas Shale. These formations are here collectively mapped as one unit (11.75 to 37 ft [3.6 to 11.3 m] thick) and are limited by erosion to the northern and western parts of the county. The Plattsburg Limestone (6.5 to 24 ft [2 to 7.3 m]) is composed of two limestone members and an intervening shale member. The base of this formation marks a major regional rise in sea level at the time of deposition (Heckel, 2013), and though the contact with the underlying Bonner Springs is rather uniform, it is equally abrupt. In ascending order, members of the Plattsburg are the Merriam, Hickory Creek, and Spring Hill. The **Merriam Limestone Member**, averaging 3.5 ft (1.1 m) but ranging from 0.5 to 9.5 ft (0.2 to 2.9 m), is commonly composed of one to two massive beds of bluish-gray to light gray, fine-grained, dense limestone; in several locations, a fossiliferous shale parting (less than 2 inches [5 cm]) occurs near the middle of the unit. The lower part of the Merriam limestone, below the shale parting, tends to be more fossiliferous than the unit's upper part. Both contain fusulinids, bryozoans, brachiopods, and crinoids; the lower part, at least within the vicinity of the town of Louisburg, also contains Osagia-coated grains. A cross-bedded ooid grainstone has historically been documented in the base of the unit in Johnson County to the north. Such a facies is not, however, characteristic of the unit in Miami County. The Hickory Creek Shale Member

Limestone Member (consistently 3-5 ft [0.9-1.5 m] in thickness within the subsurface) becomes

increasingly more interbedded upward with clean limestone, sands, and ooid grainstone. Where the member

(locally a feather's edge to 2 ft [0.6 m]) is a gray to black clayey calcareous shale that is fossiliferous in many parts of the county, containing crinoids and bryozoans. In at least the west-central part of the county, thin tongues of limestone (less than 0.5 ft [0.2 m]) that grade laterally into a nodular limestone horizon may be present in the unit. A diagnostic characteristic of the Hickory Creek that allows it to stand apart from underand overlying units is that it contains an exceptional abundance of conodont fauna, which includes the bent morphotype of Streptognathodus elegantulus (Barrick et al., 2013; Oborny et al., 2017). The Spring Hill Limestone Member (about 10 to 19.3 ft [about 3 to 5.9 m]) makes up a majority of the Plattsburg Limestone and is known regionally to form phylloid algal mound complexes (Heckel and Cocke, 1969). Such algal mound complexes within the unit are not common in Miami County, however, and where the unit thickens it is often accompanied by a thick grainstone (Oborny et al., 2022b). The unit is a light olive-gray to yellowish-gray color and may have an iron staining on its surface. The lower part of the unit tends to be fossiliferous and thin bedded, whereas the upper part tends to be blocky, massive bedded, and less fossiliferous except at its upper contact. These thin- and massive-bedded intervals are typically separated by a fossiliferous shale parting. Bryozoans, fusulinids, brachiopods, crinoids, and echinoderms occur throughout the member; sparse solitary rugose corals and phylloid algae are more characteristic of the lower thinly bedded interval. Immediately above the shale parting, a thick oolitic to fossiliferous grainstone is again overlain by a thin (about 2 in [5 cm]) compact horizon of Composita sp. (brachiopods). Locally, Osagia coatings and a thin shale have been documented in the upper part of the member above the horizon of Composita sp. The oolitic grainstone and overlying horizon of Composita sp. are a defining characteristic of this unit. Previous studies have described the unit as locally cherty. The Vilas Shale (5.25 to 13 ft [1.6 to 4.0 m], apart from in the northeast part of the county where it is 21 ft [6.4 m]) is predominantly composed of interbedded calcareous shale and siltstone with minor amounts of cross-bedded sandstone. Locally, a thin tongue of fossiliferous limestone occurs near the unit's base. In general, the unit is grayish-olive to light gray but may have a moderate yellowish-brown to orangish-gray coloration where sands are more common. Plant remains are common in some layers, but otherwise it is relatively unfossiliferous. The unit's upper contact is

Zarah Subgroup—The Zarah Subgroup (136 to 167 ft [41.5 to 51 m]) represents the upper third of the Kansas City Group and is composed of four formations—the Lane Shale, Wyandotte Limestone, Liberty Memorial Shale, and Iola Limestone—that collectively contain 10 interbedded limestone and shale units. Due to extensive phylloid algal mounding and the discontinuous nature of shale and limestone members within this interval, it is often difficult to differentiate individual units (Oborny et al., 2017). For this reason,

the interval is mapped as one unit. Of these formations, the Iola Limestone, Wyandotte Limestone, and Lane

Shale are further divisible into members.

Lane Shale—In ascending order, the Lane Shale (less than 8.5 to more than 242.5 ft [less than 2.6 to more than 73.9 m]) is composed of the Island Creek, Lower Farley, Middle Farley, Upper Farley, and Bonner Springs members. The distribution and thicknesses of these units is primarily controlled by antecedent strata, in particular within the underlying lobate Liberty Memorial Shale and mounded Argentine Limestone Member (Oborny et al., 2017). The combined thickness of the Liberty Memorial and Argentine resulted in notable depositional highs in the east-central and northeastern part of Miami County upon which and along the flanks of algal limestones of the Lower and Upper Farley developed in greatest thickness. Comparatively, the Island Creek, Middle Farley, and Bonner Springs acted to fill in low areas around antecedent highs, reaching maximum thicknesses away from sites of mounding, and tend to be absent or relatively thin for each shale unit on top of these antecedent highs. The **Island Creek Shale Member** (0 to more than 11 ft [0 to more than 3.4 m]) is a greenish-gray to bluish unfossiliferous (except where it is thin) shale. What had been mapped as the Island Creek in the western part of Miami County in the past is now reassigned to the overlying Middle Farley Shale Member. The Island Creek reaches its maximum thickness around the flanks of the underlying mounds of the Argentine. Along these mound flanks, this shale can have interbeds of fossiliferous limestone, likely owing to wave washing of nearby mound surfaces at the time of deposition (Oborny et al., 2017). This shale can be absent or be a feather's edge atop the thickened Argentine in the eastern part of the county, which can make differentiation of the underlying and overlying limestones difficult (i.e., the Argentine and Lower Farley, respectively). In the western part of the county, the Island Creek varies but is typically less than 2 ft (0.6 m) in thickness. The Lower Farley Limestone Member (1 to about 32 ft [0.3 to about 9.75 m]) is a light olive-gray to gray, medium-grained, thin-bedded, wavy limestone. This limestone is dominated by phylloid algae and contains much the same fauna as the underlying Argentine. This unit develops mounds throughout parts of the region, in particular throughout Johnson County and northeastern Miami County (Heckel and Cocke, 1969; Oborny et al., 2017). Throughout western Miami County, the unit maintains a thickness of less than 2 ft (0.6 m). The Middle Farley Shale Member (less than 0.5 to 116.5 ft [about 0.2 to 35.5 m]) is predominantly composed of calcareous micaceous shale or silty-to-sandy calcareous shale, which may grade laterally into an ooid grainstone in its upper part (e.g., northwestern Miami County; Oborny et al., 2017). North of Miami County in Missouri, this unit is primarily a paleosol- and coal-bearing shale, but within the county it is largely shallow marine and contains numerous plant impressions, gastropods, and bivalves. The distribution and thickness of this unit appears to be controlled by both a syn-depositional structure that trends N35°E from the southwest corner of the county-traversing a few miles southeast of the towns of Osawatomie, Paola, and Spring Hill—and mounding in underlying units (Oborny, 2015). Along the length of the N35°E-trending structure, the Middle Farley thickens rapidly to the west-northwest by about 100 ft (30.5 m) in a few miles, whereas to the east-southeast of this structure the shale thins to less than 5 ft (1.5 m). In the northeastern part of the county, where antecedent mounding exists, the Middle Farley may be a feather's edge but averages about 1.5 ft (0.5 m) in thickness. The Upper Farley Limestone Member (2 to more than 26 ft [0.6 to more than 7.9 m]) is a light olive-gray to gray, medium-grained, thin-bedded, wavy limestone. This limestone is dominated by phylloid algae and contains much the same fauna as the underlying Argentine and Lower Farley limestones. Osagia-coated grains are also common within this unit. The unit develops mounds throughout the

region—the distribution of which is less predictable than those in underlying units—and several are documented within the southwest, west-central, northwestern, and east-central parts of Miami County (Oborny et al., 2017). The Bonner Springs Shale Member (5 to 57 ft [1.5 to 17.4 m]) is in large part composed of interbedded calcareous micaceous shale or silty-to-sandy calcareous shale. At least two coarsening upward successions are documented in the interval yet are rarely observed together in a single exposure. Though the unit's lithological and faunal characteristics are similar to that of the underlying Middle Farley, the silts and sands of the Bonner Springs tend to be coarser. One defining distinction for the Bonner Springs is that it contains a prominent variegated greenmaroon paleosol within Miami County and may host small siderite nodules, horizons of caliche, or both, such as those observed near Louisburg. Wyandotte Limestone—The Wyandotte Limestone (less than 2.6 to 66.8 ft [0.8 to 20.4 m]) is composed, in ascending order, of three members: the Frisbie, Quindaro, and Argentine. The Frisbie Limestone Member (locally absent to 3.8 ft [0 to 1.2 m]) is a light olive-gray to light brownishgray, fine-grained, massive limestone. Crinoid stems and small productid brachiopods are the most common fossils and may occur in abundance. The **Quindaro Shale Member** (0.6 ft to 3.0 ft [0.2 to 0.9 m]) is a dark to very dark gray, fossiliferous shale that can be silty in some areas. This shale unit contains an exceptional abundance of conodont fauna (Oborny et al., 2017), and locally, such as in the vicinity of Louisburg, may encompass a tongue of fossiliferous limestone (1.0 to 1.3 ft [0.3 to 0.4 m]) that has historically been included within the underlying Frisbie Limestone Member. Where the Frisbie is absent, the Quindaro cannot be readily differentiated from the underlying Liberty Memorial except through analyses of conodont fauna. A number of brachiopod genera are documented within the unit with Heterocoelia sp., Dielasma sp., and Phricodothyris sp. being the most common forms. Crinoid fragments and bryozoans are also abundant. The Argentine

Limestone Member (less than 2 to about 60 ft [less than 0.6 to about 18.3 m]) is the most prominent member of the Wyandotte and is lithologically similar to the overlying Lower Farley and Upper Farley Limestone Members. The Argentine is a light olive-gray to gray, medium-grained, thinbedded, locally cherty limestone. The unit is dominated by phylloid algae, but Osagia coatings are common. Regionally, this unit is known for its extensive phylloid algal mound complexes and rapid variability in thickness (Oborny et al., 2017). Mounding of the Argentine within Miami County (exceeding 60 ft [18.3 m] in thickness) is predominantly located in areas where the underlying Liberty Memorial is thick. The unit thins rapidly to the west by more than 40 ft (12.2 m) in central and north-central Miami County, approximately four miles east of the towns of Spring Hill and Paola. In locations overlying the thick lobate Liberty Memorial, the Island Creek and Middle Farley are often absent or of a feather's edge and the Argentine may be in direct contact with limestones of the Farley. In such cases, the upper surface of the Argentine may be iron-stained and appear rubbly, thereby permitting the contact to be identified. The Argentine has a varied fauna that include, among others, fusulinids (Triticites sp.), crinoids, and brachiopods, Brachiopod genera Composita sp., Echinaria sp., Antiquatonia sp., Enteletes sp., and Phricodothyris sp. are most common. Liberty Memorial Shale—The Liberty Memorial Shale (less than 0.5 to 64 ft [0.15 to 19.5 m]) is predominantly composed of silty- to non-silty shale containing thin drapes or lenticular calcareous siltstone that become more prominent in the unit's upper part. In some locations, brown nodular-tolenticular limonitic lenses can be observed within the unit's lower shale-dominated portion immediately overlying the crinoidal shale at the unit's base. The Liberty Memorial Shale is representative of a lobate distal deltaic deposit that thickens for some distance northeastward into Missouri. Two Liberty Memorial lobes exist in the area (i.e., Johnson and Miami counties); the most prominent of these lobes is located in eastern Miami County and reaches a maximum thickness of 64 ft (19.5 m) near the town of Louisburg (Oborny et al., 2017). The unit thins rapidly toward the

southwest, from 55 ft (16.8 m) to less than 5 ft (1.5 m), a few miles east of the town of Paola in the

central part of the county. The unit thins further to 0.5 ft (0.15 m) in and around the town of

Osawatomie in the southwestern part of the county.

Iola Limestone—In ascending order, members of the Iola Limestone (7–11 ft [2.1–3.4 m]; more than 15 ft [4.6 m] in parts) are the Paola, Muncie Creek, and Raytown. The Iola likely exceeds 15 ft (4.6 m) in the subsurface in the northeastern and southwestern parts of the county (observed in well data), but well data resolution does not permit member subdivision. The Paola Limestone Member (absent to about 3.0 ft [0.9 m]) is largely composed of a single massive dense bed of dark gray to brownish-gray, fine-grained, fossiliferous and phylloid-algae-bearing limestone. A thin crinoidal and productid-brachiopod-bearing packstone to argillaceous limestone is sometimes present at the unit's base. The contact with the underlying Chanute Shale marks a major regional rise in sea level (Heckel, 2013), and though fairly smooth, the contact is typically abrupt. The upper contact of the Paola quickly grades into a crinoid-bearing fossiliferous mudstone, which occurs at the base of the Muncie Creek Shale Member. The Muncie Creek Shale Member (about 0.5 ft [0.2 m]) is a bluishgray shale that is locally fossiliferous and has a dark gray fissile facies containing small (0.4 to 1.2 in [1 to 3 cm]) phosphatic nodules (Heckel, 2013). The shale contains an exceptional abundance of conodont fauna, which include important species Idiognathodus magnificus and I. post-magnificus (Barrick et al., 2013; Oborny et al., 2017). The overlying **Raytown Limestone Member** (6 to 7.5 ft [1.8 to 2.3 m]) is a light olive-gray to light gray fine-grained limestone that is dominated by phylloid algae. The unit grades into a clean non-algae crinoidal and brachiopod-bearing limestone in its upper part before transitioning into a crinoidal shale in the basal part of the overlying Liberty Memorial Shale. To the south, the Raytown is known to form phylloid algal mound complexes (up to 40 ft [12.2 m] in thickness; Heckel and Cocke, 1969), but within Miami County the unit is medium (northern part) to fine bedded (southern part) and varies minimally in thickness; however, the Raytown may mound in the southwest and northeast corners of the county where the unit is poorly exposed. Large productid brachiopods occur in the Raytown, with Echinaria sp. and Linoproductus

Drum Limestone and Chanute Shale—The upper part of the Linn Subgroup of the Kansas City Group is composed of the Drum Limestone and overlying Chanute Shale. These formations are here collectively mapped as one unit (10 to 56 ft [3 to 17 m] thick) because of the comparatively thin nature of the Drum Limestone and unique lithology and thickness of the Chanute Shale in comparison to underlying and overlying shale units. The **Drum Limestone** (1.7 to 14 ft [0.5 to 4.3 m]) consists of a single massive bed of yellowish-gray to reddish-brown fine- to medium-grained limestone that is uniform in lithology and weathers into thin slabs. Northward in Johnson County, the unit is often described as thin-to-wavy bedded. The unit also may contain a cross-bedded oolite in its upper part in some locations. Small crinoid segments, sponge Heliospongia sp., and brachiopods—Neospirifer sp., Marginifera sp., and Composita sp.—may be abundant in the unit. The basal contact of this limestone is typically uniform but abrupt, whereas the upper contact with the overlying Chanute Shale tends to be more gradational. The Chanute Shale (5 to 51 ft [1.5 to 15.5 m]) varies greatly in thickness and lithology over short lateral distances. It is largely composed of yellowishbrown to greenish-gray, calcareous, silty-to-sandy or clayey shale. The unit is relatively unfossiliferous except for plant impressions that are most common in its upper part overlying the Thayer coal bed. The Thayer coal bed (0 to 0.5 ft [0 to 0.2 m]) is typically 11 to 15 feet (3.4 to 4.6 m) above the formation's basal contact and occurs at differing stratigraphic positions in respect to the upper formational boundary. The coal may be absent where the Chanute is thinner than 11 ft (3.4 m).

sp. being the most common.

Dennis Limestone and Cherryvale Shale—The contact between these two formations represents the Bronson-Linn Subgroup boundary of the Kansas City Group. Due to difficulty differentiating boundary defining units within the county, these two formations are here collectively mapped as one unit (70 to 122 ft [21.3 to 37.2 m] thick). The lowest of these units, the **Dennis Limestone** (28 to 39 ft [8.5 to 12 m]) is a resistant unit that forms prominent scarps. It is composed of three members—in ascending order, the Canville, Stark, and Winterset. The Canville Limestone Member is predominantly absent in Miami County but may be represented locally in the southern part of the county by a thin tongue of argillaceous or nodular limestone. In its absence, the underlying Galesburg and overlying Stark cannot be readily differentiated apart from a distinct fossiliferous shale horizon (likely representative of the Canville) or change in color at the base of the Stark. The **Stark Shale Member** (4 to 9 ft [1.2 to 2.7 m]) is typically about 5 ft (1.5 m) in thickness and is well known for its non-fossiliferous black fissile facies that contains lenticular, laminated, or nodular phosphate (Heckel and Watney, 2002). This black fissile shale comprises a majority of the unit's lower part and grades upward into a non-fissile olive to greenish-gray fossiliferous shale, which again transitions into the limestone of the overlying Winterset. This unit produces a prominent gamma peak in geophysical logs that makes it readily correlative in the subsurface throughout the region and contains important zonal conodont species *Idiognathodus confragus* (Barrick et al., 2013; Oborny et al., 2017). Chonetid brachiopods e common within the upper fossiliterous shale interval. The **Winterset Limestone Member** (21.5 to 3) ft [6.6 to 10.9 m]) makes up a majority of the Dennis Limestone and is similar in some characteristics to the Spring Hill Limestone Member of the Plattsburg Limestone. The Winterset is known regionally to form within the county is not characteristic of the unit. Here, the member can be divided into two separate informal

phylloid algal mound complexes to the south of Miami County (Heckel and Cocke, 1969), yet mounding depositional units (Heckel, 1988) separated by a non-fossiliferous calcareous gray shale (less than or equal to 1.5 ft [0.5 m]). The lower division tends to be light gray to olive-gray in color, makes up 60–70% of the member, and represents three comparatively minor fluctuations in sea level that together show progressive shallowing. These three minor cycles are not set apart by shale of any significant thickness within the region, though fossiliferous shale partings are common between each minor fluctuation. In total, this lower Winterset division is predominantly composed of fine-grained, sparsely fossiliferous limestone that often contains phylloid algae; however, each of the three minor sea-level fluctuations tends to grade upward into an oolitic limestone, a clean limestone bearing snails and birds-eye (i.e., preserved air bubbles) features, or a mottled dark gray to blue cherty intraclast facies. The upper informal division of the Winterset, making up 30–40% of the unit, often contains a blocky oolitic limestone to grainstone in its lower part that is overlain by fossiliferous shale that grades upward into a thinly bedded phylloid-algae-bearing limestone that becomes increasingly fossiliferous in its upper part. This division of the Winterset is often dark bluish-gray in coloration and sometimes cherty and hosts large productid brachiopods and locally an abundancy of gastropods. Triticites sp. (i.e., fusulinids) is also very abundant in the upper part. The Cherryvale Shale (40 to 76 ft [12.2 to 23.2 m]) comprises a shale-dominated interval between the top of the Dennis Limestone and he base of the Drum Limestone. It includes six members (five formal and one informal)—in ascending order the Fontana, Block, Wea, Westerville, Nellie Bly, and Quivira. The Fontana Shale Member (4 to 17 ft [1.2 to 5.2 m]) varies upward in its color and lithology. At its base, the unit is a dark gray shale that is predominantly non-fossiliferous apart from sparse chonetid brachiopods and thin (less than 0.5 ft [0.15 m]) fossiliferous shale at its basal contact. Similar to the Liberty Memorial Shale, brown nodular-to-lenticular limonitic lenses occur within this lower interval. The unit grades upward into a more fossiliferous, calcareous, silty-to-sandy shale that is greenish-gray to olive-gray in color and is capped by a thin fossiliferous shale that grades into the overlying Block. The **Block Limestone Member** (absent to 6 ft [1.8 m]) is a bluish-gray to olive-gray, medium-grained, thin-bedded fossiliferous limestone that contains numerous thin fossiliferous shale partings. The upper and lower contacts of the limestone tend to be gradational. *Triticites* sp. is the most

characteristic fossil, but Marginifera sp. and Syringopora sp. are also abundant. The Wea Shale Member (absent to 30 ft [9.1 m]) is poorly exposed but is characteristically olive to dark gray, non-silty to silty, fossiliferous shale within Miami County. This unit is thickest in the northwesternmost part of the county and continues to thicken northward into Johnson County, where it exceeds 36 ft (11 m). In Miami County, the unit is on average about 2 ft (0.6 m) thick in the western part and often absent in the eastern part. Modern studies of this unit are in conflict with historical descriptions of the unit's distribution and lithological character. In short, numerous historical observations for the Wea are now more appropriately attributed to an altogether new informal member termed the Nellie Bly that occurs between the Westerville and the Quivira (Heckel and Watney, 2002). In some locations, the Westerville, which overlies the Wea, is absent due to nondeposition or erosion. Historically, in such cases, the Wea and the shale overlying the correlative position of the absent Westerville were described collectively as the Wea-Quivira shale interval. A majority of this interval is now attributed to the informal Nellie Bly shale member that is prominent south of Miami County. The Westerville Limestone Member (absent to 20 ft [6.1 m]) is poorly exposed but where present is composed of conglomeratic limestone containing abundant limonite nodules and quartz sand. It can laterally transition to yellowish-gray marly limestone. The **Nellie Bly shale member** (informal; 5 to 51 ft [1.5 to 15.5 m]) is primarily composed of calcareous silty or silt-to-sandy shale that coarsens upward from the unit's base. In some locations, a dark blue to gray shale in the unit's upper part contains plant material, thin coal partings, or tongues of thin limestone that may give way to a maroon clayey shale. The Quivira Shale Member (absent to 7 ft [2.1 m]) is the uppermost member of the Cherryvale Shale. Its lower part (0.5–1 ft [0.2–0.3 m]) is composed of black, carbonaceous, fissile shale that grades upward into an olive-gray silty shale. In many cases, the unit cannot be readily differentiated from the underlying Nellie Bly except through analyses of conodont fauna that occur in exceptional abundance within the Quivira, a diagnostic characteristic of the unit. One key distinction of the unit is that it contains important conodont species *Idiognathodus* cherryvalensis (Barrick et al., 2013; Oborny et al., 2017). The Quivira is unfossiliferous with regard to shelly

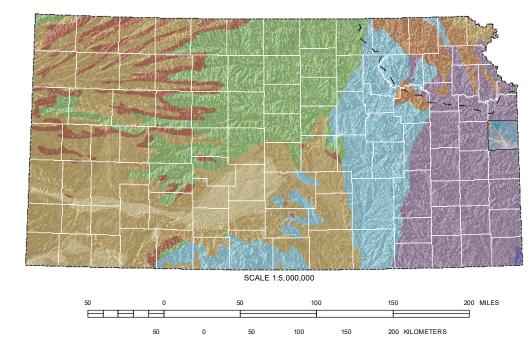
fauna except for sparse inarticulate brachiopods.

Swope Limestone and Galesburg Shale—The middle part of the Bronson Subgroup of the Kansas City Group is composed of the Swope Limestone and overlying Galesburg Shale (18 to 38 ft [5.5 to 11.6 m] thick). Due to the close genetic relationship of these units (i.e., deposited as the sea level rose and fell) and the comparatively thin nature of the Galesburg Shale, these formations are here collectively mapped as one unit. The **Swope Limestone** (17 to 37 ft [5.2 to 11.3 m]), the lower part of this map unit, is composed of two limestone members and an intervening shale member. In ascending order, they are the Middle Creek, Hushpuckney, and Bethany Falls. The **Middle Creek Limestone Member** (0.5 to 5 ft [0.2 to 1.5 m]) is a medium gray to bluish-gray, fine-grained, dense crinoid-bearing limestone that is commonly expressed in outcrop as a single massive bed, though a thin shale parting can be present approximately in the middle of the unit. The unit's basal contact is typically uniform but abrupt, whereas the upper contact with the overlying Hushpuckney is gradational. The **Hushpuckney Shale Member** (4 to 8 ft [1.2 to 2.4 m]) is typically about 5 ft (1.5 m) in thickness and is well known for its non-fossiliferous black fissile facies, which contains lenticular, laminated, or nodular phosphate similar to the Stark (Heckel and Watney, 2002). This black fissile shale comprises a majority of the unit's lower part—apart from a thin fossiliferous shale at its base—and grades upward into a non-fissile grayish to yellow, sometimes silty, fossiliferous shale that grades further into the limestone of the overlying Bethany Falls. This unit produces a prominent gamma peak in geophysical logs that makes it readily correlative in the subsurface throughout the region and contains important defining co-occurring conodont species Idiognathodus confragus, I. eccentricus, and I. cancellosus (Barrick et al., 2013; Oborny et al., 2017). Chonetid and productid brachiopods are common in the unit's upper fossiliferous shale interval. The **Bethany Falls Limestone Member** (15 to 28 ft [4.6 to 8.5 m]) is a light gray to light brownish-gray, medium-grained, medium- to thick-bedded limestone containing numerous thin shale partings. In most areas, the member can be divided into two distinct parts. The lower part (12 to 16 ft [3.7 to 4.9 m]) contains notable fusulinids and stylolitization, whereas the upper part (0 to 14 ft [0 to 4.3 m]) is cherty Falls. Where the pelletal or oolitic limestone is present, the upper part locally contains vertical, tubular cavities 3 to 4 ft (0.9 to 1.2 m) in length and 1 to 2 in (2.5 to 5 cm) in diameter containing iron-stained crystalline calcite. The Bethany Falls is a fossiliferous unit in which Meekella sp., Derbyia sp., Antiquatonia sp., and chonetid brachiopods are most common. *Triticites* sp. is found locally in the lower part of the unit. Phylloid algae are locally abundant. The **Galesburg Shale** (absent to 12 ft [3.7 m]), which overlies the Swope Limestone, consists of a greenish-gray to dusky yellow, blocky shale that is predominantly paleosol. Marine fossils may be present in the lower part of the unit below the paleosol profile.

Hertha Limestone and Elm Branch Shale—The lower part of the Bronson Subgroup of the Kansas City Group is composed of the Hertha Limestone and overlying Elm Branch Shale (18 to 38 ft [5.5 to 11.6 m] thick). Due to the close genetic relationship of these units (i.e., deposited as the sea level rose and fell) and the comparatively thin nature of the Elm Branch Shale, these formations are here collectively mapped as one unit. The lower part of this map unit, the **Hertha Limestone** (5 to 22 ft [1.5 to 6.7 m]), is commonly poorly exposed. Its members, in ascending order, are the Critzer, Mound City, and Sniabar. The Critzer Limestone Member (absent to 9 ft [2.7 m]) is the basal member of the Kansas City Group and is composed of light olive-gray, medium-grained, cherty limestone with abundant crinoid fragments and some bryozoans. The Mound City Shale Member (1.5 to 8 ft [0.5 to 2.4 m]), if exposed, is present only as a thin, dusky yellow, unfossiliferous shale; however, in the county's subsurface, and regionally (Heckel and Watney, 2002), the unit is known for its black fissile shale facies that produces a prominent gamma peak in geophysical logs, making it readily correlative in the subsurface. The unit contains important co-occurring conodont species Idiognathodus vorax and I. turbatus (Barrick et al., 2013; Oborny et al., 2017). The Sniabar Limestone Member (1.5 to 14 ft [0.5 to 4.3 m]) is a medium- to coarse-grained, medium- to thick-bedded limestone. It is oolitic at the top and contains chert in the lower part. Hematite pebbles and limestone conglomerate may be locally present at the base of this unit. Generally present over much of the county, the Sniabar is composed of two distinct limestone beds (both of which can be rich with gastropods) separated by a thin bed of shale. The Elm Branch Shale (0.5 to 11.4 ft [0.2 to 3.5 m]), which overlies the Hertha Limestone, is light gray to olive-gray and weathers to a yellowish-gray. It is usually sandy and in some localities calcareous, with a thin

limestone bed near the middle. It is unfossiliferous, except for plant impressions in the sandy layers. Formerly

the Ladore Shale (Zeller, 1968), the name Elm Branch Shale was proposed by Heckel and Watney (2002).



GENERALIZED GEOLOGY OF KANSAS CARBONIFEROUS SYSTEM Pliocene - Miocene Series

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