STATEMAP
Pope County-BG

Bedrock Geology of Pope County, Illinois

W. John Nelson, Joseph A. Devera, and F. Brett Denny
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Prairie Research Institute
ILLINOIS STATE GEOLOGICAL SURVEY
615 East Peabody Drive
Champaign, Illinois 61820-6918
(217) 244-2414
http://www.isgs.illinois.edu

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BEDROCK GEOLOGY OF POPE COUNTY, ILLINOIS

By W. John Nelson, Joseph A. Devera, and F. Brett Denny

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INTRODUCTION

Geographic Setting

Situated in the southernmost part of the state of Illinois, Pope County has more in common with neighboring Kentucky than most of the rest of Illinois. Its steep, rocky ridges and deep ravines contrast with the fertile croplands that make up most of the Prairie State (Fig1.) The highest point in southern Illinois, Williams Hill (elevation 1,064 feet) is in northeastern Pope County, and nearly the lowest point in the state is the Ohio River shore in southern Pope County (normal pool 302 feet). Pope County owes its rugged topography to its geology: thick layers of Mississippian and Pennsylvanian sandstone that are highly resistant to erosion, coupled with the fact that the great Pleistocene continental ice sheets never encroached this far south.

The earliest white settlement took place at Golconda in 1798, where an Ohio River ferry port was established. Before Illinois gained statehood, Pope County was organized from parts of Gallatin and Johnson Counties. The namesake is Nathaniel Pope (1784-1850), territorial delegate to U.S. Congress, who "was instrumental in securing the admission of Illinois as the twenty-first state of the federal union in 1818. It was through his efforts that the boundary line between Illinois and Wisconsin was shifted about fifty miles north from the foot of Lake Michigan to its present location" (Callary, 2009, p. 283). Thus, if not for Nathaniel Pope, Chicago would be in Wisconsin.

Fig. 1. Location map of Pope County, Illinois which is highlighted by the yellow polygon. Figure edited and clipped from United States Geological Survey, Paducah 1:250,000 scale topographic map. Contour interval is 40 meters and the map was updated by the USGS in 1987.

Among 102 counties in Illinois, Pope has the second smallest population, with 4,470 residents in the 2010 census. Only neighboring Hardin County has fewer people. Pope has the lowest population density of any Illinois county, approximately 12 people per square mile, only slightly more than South Dakota. The only two incorporated communities are Golconda, the county seat (pop. 668) and Eddyville (pop. 101). Census records reveal that Pope County surpassed its present population in the 1860s and reached its highest level at more than 14,000 in 1890. It fell below 10,000 in the 1910s, bottomed out at 3,857 in 1970, and has rebounded slightly since. Sneed (1977) describes 61 "ghost towns" in Pope County, nearly all of which once had post offices, churches, schools, stores and other businesses, and today are reduced to at most small clusters of houses. Labor-intensive mining of fluorspar, lead, and zinc probably was the main factor sustaining population during the late 19th and early 20th century. Also, along with the rest of southern Illinois, this county formerly had many more small farms than it does at present. Given the steep slopes and thin rocky soil that prevails in Pope County, most of these were subsistence farms. Dozens were abandoned or sold to the government, especially during the 1930s, and were incorporated into the Shawnee National Forest. A large part of Pope County is within the Shawnee National Forest, open to the public for recreation.

Today, large-scale row crop production is mostly confined to level alluvial soils in the Cache Valley and along the Ohio River. Some of the more gently rolling uplands support crop and livestock operations, mainly beef cattle. The University of Illinois maintains an agricultural experiment station north of Dixon Springs. Hardwood timber cutting is an important sideline. All the mines in Pope County closed decades ago, but several large limestone quarries remain active in Hardin County. Tourism that centers on outdoor activities such as hunting, fishing, hiking, and horseback riding brings in some money. Among the most scenic natural sites in southern Illinois are Dixon Springs State Park, Lusk Creek Canyon Nature Reserve, and Burden Falls. Many residents of Pope County, however, have settled here for the rural amenities and hold jobs larger towns outside the county.

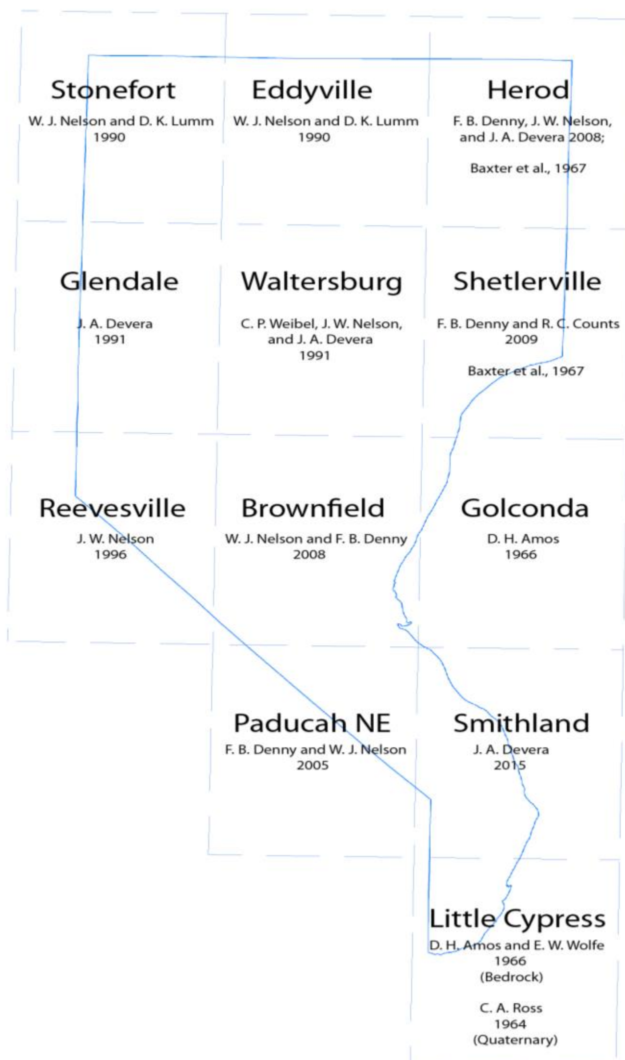

Figure 2. Individual 7.5-minute geologic quadrangle maps published for Pope County. The individual quadrangles are available on the ISGS website. http://www.isgs.illinois.edu/maps/isgs-quads

Previous Geologic Research

The geologic map and report of S. Weller et al. (1920) take in Hardin and eastern Pope Counties. Butts (1925) mapped geology of an area contiguous with northeastern Pope County. S. Weller and Krey (1939) published a geologic map of Mississippian rocks in an area that covers part of Pope County; a report by J.M. Weller (1940) includes a structure contour map that encompasses all of Pope County. Ross

(1963) investigated structural geology of southern Pope County and (1964) produced a geologic map that covers the same area.

Beginning in 1990, the ISGS published a series of new geologic maps at 1:24,000 scale (Fig. 2). The geologic map that accompanies this report has been compiled from these larger scale maps. In order to rectify discrepancies among these maps, considerable field checking was undertaken and some of the geologic contacts and faults on the geologic map have been modified accordingly.

Geologic Setting

Pope County straddles the border between the Shawnee Hills section of the Interior Low Plateaus and the Mississippi Embayment section of the Gulf Coastal Plain (Horberg, 1950). The Shawnee Hills are composed of Carboniferous sedimentary rocks that produce a series of south-facing escarpments and north-facing cuestas. This range of hills formed the ultimate barrier to southward advance of Pleistocene continental ice sheets, which never reached Pope County. Much less resistant to erosion, the unlithified and weakly lithified Cretaceous and Cenozoic sediments of the Mississippi embayment create gently rolling topography. The broad, level Cache Valley, which follows the northern edge of the Embayment across Pope County, represents a former course of the Ohio River.

Structurally, Pope County is situated along the southern margin of the Illinois basin. Paleozoic rock layers dip gently northward toward the basin center. Modifying regional dip is the array of northeast-trending folds and fault zones, which belong to the Fluorspar Area fault complex. Inherited from rifting during Cambrian time, these structures have undergone multiple episodes of activity. Complicating the structure is Permian Age igneous activity which uplifted and domed the area surrounding Hicks Dome. Together, these geologic features make up one of the most complex structural areas in the North American Midcontinent.

Cretaceous and Cenozoic sediments in the Mississippi embayment dip very gently southwest, down the axis of the trough. Post-Cretaceous movement on some of the faults in southern Pope and Massac Counties has deformed these deposits.

STRATIGRAPHY

Carboniferous System

Mississippian Subsystem

Mammoth Cave Group

As redefined by Nelson (1995), the Mammoth Cave Group is the succession of dominantly limestone formations in the middle part of the Mississippian System of the Illinois basin. In Pope County, the Mammoth Cave comprises the Fort Payne Formation (oldest) and the Ullin, Salem, St. Louis, and Ste. Genevieve Limestones. Among these, only the upper part of the St. Louis and all of the Ste. Genevieve are at the surface in Pope County (Fig. 3).

St. Louis Limestone

Denny et al. (2008) mapped the upper part of the St. Louis Limestone along the eastern border of Pope County in the Herod quadrangle, where the rocks dip westward off the flank of Hicks Dome. The entire thickness of the St. Louis, along with older formations, crops out immediately to the east in Hardin County around the circumference of the dome. As exposed there, the St. Louis is estimated to be 300 to 400 feet thick and is composed of limestone with interbeds of dolostone and thin layers of shale. Baxter et al. (1967, p. 9) stated, “The St. Louis Limestone typically consists of thin- to medium-bedded, brownish gray, sublithographic to fine-grained limestone with characteristic heavy bands and nodules of chert. However, the St. Louis is lithologically variable, having interbedded fossiliferous limestone, fine-grained dolomites, dolomitic limestone, and oolitic limestone." The contact to the Ste. Genevieve Limestone is marked by a transition to limestone that is lighter colored, more conspicuously oolitic and bioclastic, and less cherty than that of the St. Louis.

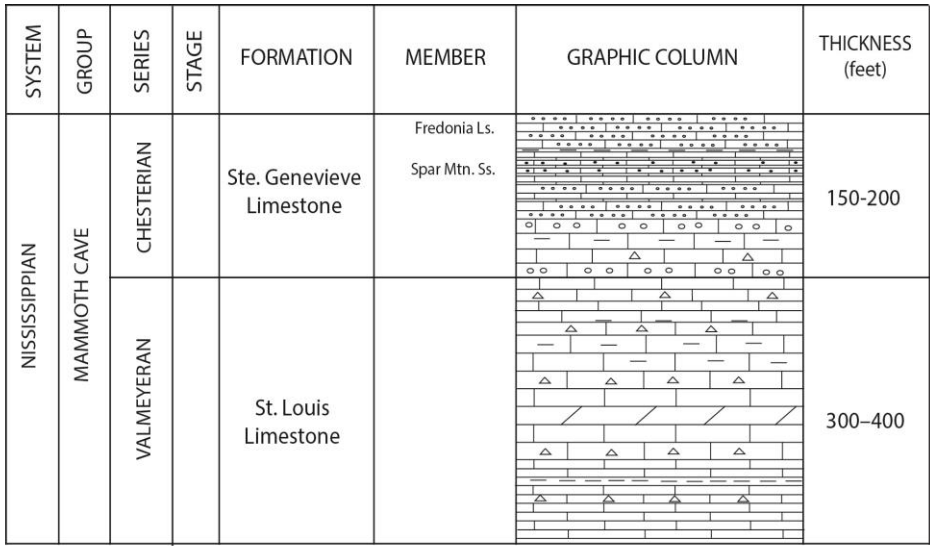

Figure 3. Graphic column of the Mammoth Cave Group in Pope County.

Two narrow fault slices along the Lusk Creek fault zone in western Pope County bring the St. Louis and/or Ste. Genevieve Limestone to the surface. One of these slices is south of Lake Glendale, on the Glendale quadrangle (Devera, 1991). Identification was based on small outcrops and float observed during mapping and on logs of cored mineral-exploration borings on file at the ISGS. The other occurrence of St. Louis and/or Ste. Genevieve is at "Clay Diggings", an abandoned mine and quarry on the north side of Lusk Creek just east of the Eddyville-Golconda blacktop. The quarry face shows thick light gray, cherty lime mudstone of St. Louis aspect along with fine-to medium-grained oolitic and skeletal grainstone more typical of the Ste. Genevieve. These rocks are steeply dipping and extensively fractured. Conodont biostratigraphy supports the lithologic identification of formations at Clay Diggings (Weibel et al., 1993). These slices of older rocks are structurally significant and will be revisited in the chapter on Structural Geology.

Ste. Genevieve Limestone

The Ste. Genevieve crops out in a strip about three miles long on the eastern edge of Pope County between Hicks Branch on the north and Hobbs Creek on the south (Denny et al., 2008; Denny and Counts, 2009). Exposures continue into Hardin County, following the flanks of Hicks Dome. Additional outcrops occur along the upthrown side of a fault about two miles northwest of Hamletsburg in southern Pope County (Devera, 2013). The Ste. Genevieve Limestone also has been identified in small fault slices along the Lusk Creek fault zone.

On Hicks Dome the formation is 150 to 200 feet thick and consists mainly of limestone, having interbeds or lenses of dolostone, sandstone, and shale. The most characteristic rock type is light gray, medium- to coarse-grained oolitic and crinoidal grainstone that is commonly sandy and exhibits large-scale crossbedding. This limestone alternates with layers of darker packstone, wackestone, lime mudstone, and microgranular dolostone, some of which is cherty and resembles parts of the St. Louis. According to Baxter et al. (1967, p. 10) the most persistent sandy zone is the Spar Mountain Sandstone Member, which occurs about 60 feet below the top of the formation and ranges up to 7 feet thick. Other sandy lenses in the Ste. Genevieve "appear to be erratically distributed". Shale is generally green to gray, calcareous, and less than 3 feet thick. The contact with the overlying Aux Vases Formation, basal unit in the Pope Group, is reported to be generally conformable but locally shows evidence of erosion at a minor disconformity (Baxter et al., 1967).

Pope Group

As modified by Nelson (1995), the Pope Group is the succession of alternating sandstone, shale, and limestone formations that overlie limestone of the Mammoth Cave Group and underlie Pennsylvanian rocks that are dominantly sandstone and shale. The unit was named for Pope County, where many of the best exposures occur. The Pope Group is distinguished from the Chesterian Series, which is a chronostratigraphic unit based on biostratigraphy. As presently construed, the Chesterian Series includes all of the Pope Group along with the Ste. Genevieve Limestone (Maples and Waters, 1987). In Pope County, the Pope Group comprises all formations from the Aux Vases Formation (oldest) through the Kinkaid and Grove Church Formations.

Aux Vases Formation

The Aux Vases crops out in a narrow strip near the eastern border of Pope County in the Herod and Shetlerville quadrangles, continuing around the flanks of Hicks Dome into Hardin County (Denny et al., 2008; Denny and Counts, 2009). Baxter et al. (1967, p. 10) described “very fine-grained, gray or greenish gray, calcareous sandstone or calcareous siltstone with interbedded oolitic limestone. The sandstone is commonly cross-bedded and in some cases ripple marked. The oolitic limestone is commonly silty or sandy. A foot or more of sandy greenish gray shale commonly occurs at the base of the member.” Thickness varies from about 15 to 40 feet. The contact with the overlying Paoli Limestone is generally sharp and conformable to slightly disconformable (Fig. 4).

Paoli Limestone

Nelson et al. (2002) extended the Paoli Limestone from Indiana into southeastern Illinois as the unit of largely limestone with lesser claystone, shale, and sandstone lying between the Aux Vases Formation below and the Bethel Sandstone above. These rocks previously were assigned to three formations: Renault Limestone below, Yankeetown Shale or Sandstone in the middle, and Downeys Bluff Limestone above. The Renault in turn was divided into older Levias and younger Shetlerville Members. These units are lithologically distinctive, but so thin that when mapped at a 1:24,000 scale as Baxter et al. (1967) did, they are practically pin stripes on the map. On the Paducah Northeast (Denny and Nelson, 2005) and Brownfield (Nelson and Denny, 2008) quadrangles, the Paoli Limestone was mapped as a single unit and subdivided into Levias, Shetlerville, Yankeetown, and Downeys Bluff Members. However, Denny et al. (2008) and Denny and Counts (2009) called the interval “Downeys Bluff Limestone, Yankeetown Sandstone, and Renault Limestone [undivided]” on the Herod and Shetlerville quadrangles, respectively. Thus, they acknowledged that the “formations” used by Baxter et al. are too thin to be practical mapping units at this scale, and effectively the three are treated as a single formation.

The Paoli Limestone and its constituent Levias Limestone, Shetlerville Limestone, Yankeetown, and Downeys Bluff Limestone are carried forward in the present report (Fig. 4). The Paoli is shown as a single unit on the geologic map. The units totals 120 to 150 feet thick in southern Pope County, thinning to 55 to 100 feet in the northeastern part of the county. Outcrops of the Paoli occur on the west flank of Hicks Dome in the Herod quadrangle, northeastern part of the county. The Paoli is extensively mineralized in this area, and numerous mines formerly operated along its outcrops (Denny et al., 2008). The other area of Paoli outcrops is along the south bluff of the Cache Valley near the Ohio River and southward along Burke Creek and adjacent ravines on the west side of the Compton Mine fault zone (Denny and Nelson, 2005; Nelson and Denny, 2008).

Renault Limestone Member

The Renault was formerly a Formation (Willman et al., 1975). In this publication we place the Renault as a Member of the Paoli Formation, which then lowers the two Members of the Renault (Levias and Shetlerville) to Bed status.

Levias Limestone Bed

Basal member of the Paoli, the Levias is limestone that is white to light gray oolitic grainstone that contains scattered red to pink oolites. Thickness varies from 15 to 22 feet in the southern area. In the Herod and Shetlerville Quadrangles the Levias is 15 to 35 feet thick, and averages 25 feet thick (Baxter et al. 1967, p. 11). The authors state the unit consists of relatively thick-bedded limestone with only minor amounts of greenish gray shale, and the limestone is commonly light brownish gray, medium grained, and partly oolitic. Some beds are medium gray, fine grained to sublithographic. The beds are usually somewhat fossiliferous, and pink crinoid fragments or in some cases, pink oolites are

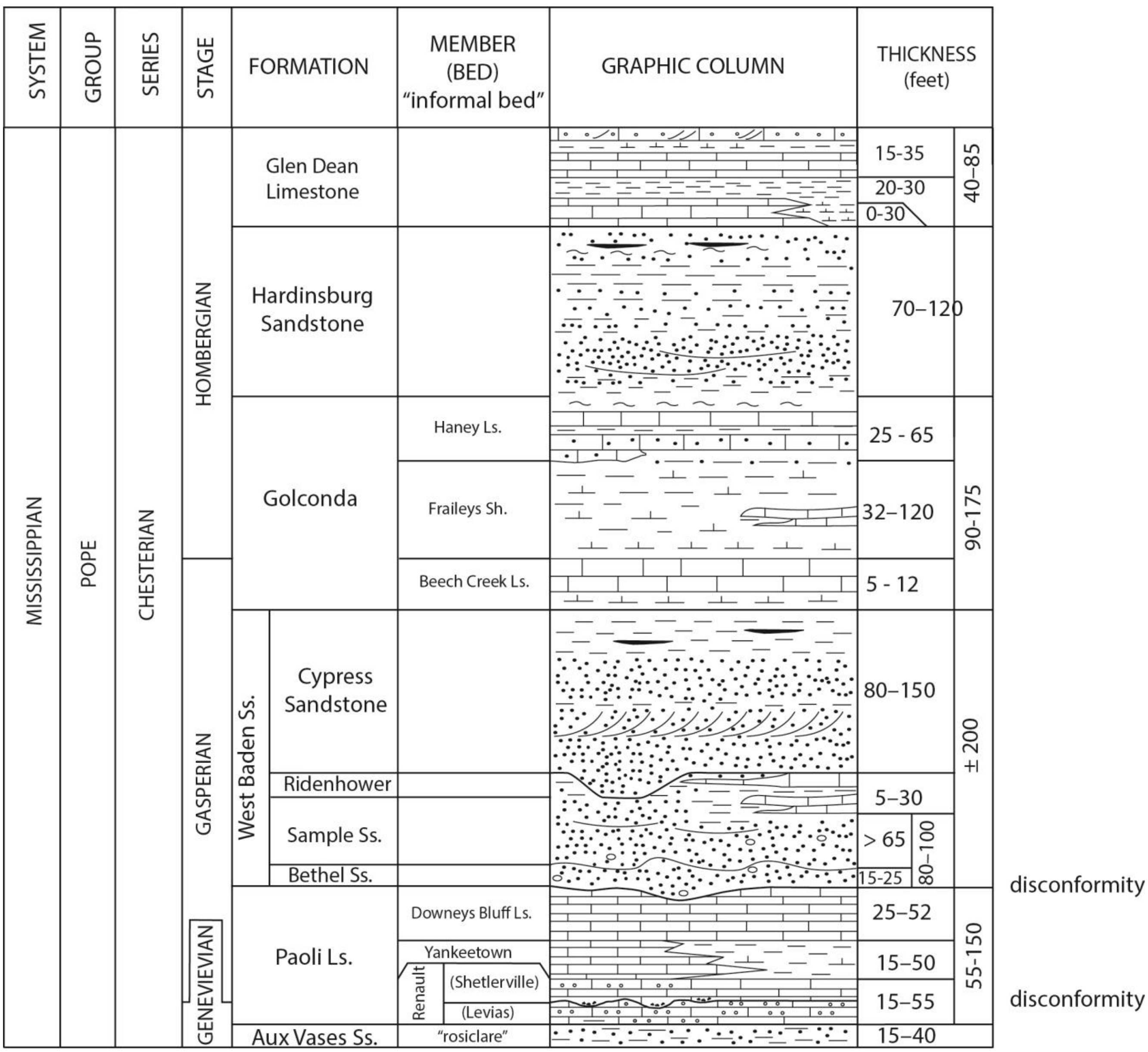

Figure 4. Graphic column of the lower part of the Pope Group in Pope County.

diagnostic. Baxter et al. (1967) regarded the Levias-Shetlerville contact as a regional unconformity, marking the boundary between Meramecian and Chesterian Series. Our observations indicate this contact to be a minor disconformity.

Shetlerville Limestone Bed

In the Paducah Northeast and Brownfield quadrangles, the Shetlerville is 25 to 45 feet thick and seems to record an upward transition from clear, well-agitated water to quieter, more turbid conditions. Light-colored crinoidal and oolitic grainstone at the base transitions upward to darker, argillaceous lime mudstone and wackestone that has laminae and interbeds of dark gray to black shale. Baxter et al. (1967) reported 15 to 25 feet of Shetlerville Member in the Herod and Shetlerville quadrangles, but a succession different from that observed in the Brownfield area. Baxter et al. (1967) identified a lower silty to argillaceous limestone that is oolitic or a medium to coarse grained packstone in places that is about 1 to 4 feet thick. The upper 10 to 20 feet are relatively pure oolitic limestone to sublithographic limestone with an occasional thin interbed of gray shale (Baxter et al., 1967). The upper contact may be sharp or gradational.

Yankeetown Member

The Yankeetown is an interval of shale, limestone, and mudstone that ranges from about 15 to 50 feet thick. The lower part is mostly shale that is dark gray and greenish gray, fissile, and calcareous. Beds of limestone, dolomite, and calcareous siltstone alternate with limestone in the middle Yankeetown. Textures vary from carbonate mudstone to skeletal and oolitic grainstone. Colors are shades of gray to yellow and brown, with red mottling. Distinctive in the upper 5 to 10 feet of the Yankeetown is non-fissile claystone that is variegated in red, green, and gray. The upper contact is conformable, and may be either sharp or gradational.

Downeys Bluff Limestone Member

The upper member of the Paoli Limestone is 25 to 52 feet thick and is dominantly limestone, with lenses and interbeds of shale and claystone. Limestone textures vary, but much of the Downeys Bluff is light colored, medium to coarse grained, crinoidal and oolitic packstone and grainstone. Diagnostic for this unit in Pope County and much of southern Illinois are lenses of pink chert and pink to orange crinoid fragments, which are readily observed in well cuttings as well as in cores and outcrops. Limestone of the upper Downeys Bluff commonly is crossbedded and contains fine, rounded quartz sand grains that are likely of eolian origin (Nelson et al., 2002). Limestone in the lower part of the Downeys Bluff tends to be darker and more micritic. Red and green mottled blocky claystone and fissile shale occur at various levels in the member, but are especially common at the top. The upper contact to West Baden (Bethel) Sandstone is generally disconformable.

West Baden Sandstone

Cole and Nelson (1995, p. 6) proposed using the name “West Baden Sandstone” for an undivided interval dominantly composed of sandstone that lies between the Downeys Bluff Limestone and the Golconda Formation in areas of the Illinois basin. The name previously had been used in the form “West Baden Group” (Cumings, 1922; Gray et al., 1960) and “West Baden clastic belt “(Sullivan, 1972). In other areas of the basin, the West Baden unit can be subdivided into Bethel Sandstone (oldest), Sample Sandstone, Ridenhower Formation, and Cypress Formation (Fig. 4). Nelson et al. (2002) showed that the West Baden interval contains three depositional sequences. The West Baden clastic belt of Sullivan (1972) is a linear band that extends southwest through Indiana into southeastern Illinois, passing through Pope County. Nelson (1996) mapped “West Baden Sandstone” along the axis of the clastic belt in the Reevesville quadrangle. Other quadrangle map authors mapped the Bethel, Sample, Ridenhower, and Cypress Formations in various combinations. Because differences among the mapping styles are difficult to resolve without extensive new field work, the West Baden has been mapped as a single unit on the map that accompanies this report. The West Baden Sandstone is resistant to erosion and its outcrops are widespread in Pope County. It forms the west bluff of the Ohio River from Golconda to 3 miles south of Bay City, and the south bluff of the Cache Valley from the Ohio to the Massac County line. Another belt of West Baden runs from the Ohio River at Shetlerville, and 9 miles north around the west flank of Hicks Dome.

Bethel Sandstone

The Bethel has been distinguished from the younger Sample Sandstone only in the Brownfield and Paducah Northeast quadrangles of southern Pope County. Here the Bethel is 15 to 25 feet thick and is composed of quartz arenite that is very fine to fine-grained, rarely having medium sand. Laminae and interbeds of gray and greenish gray siltstone and shale occur in the upper part. Ripple and cross lamination are developed. Herringbone (bidirectional) cross lamination and marine bioclasts (Nelson, 1996) indicate marine influence. Calcite cement, marine bioclasts, and bidirectional cross lamination point to shallow marine deposition of much of the Bethel Sandstone. In places, the sandstone grades upward to sandy limestone. The Bethel commonly occurs as a series of coalesced convex-upward sand bodies, which likely were shaped by tidal currents (Nelson et al., 2002). Both the lower and upper contacts are erosive.

Sample Sandstone

The Sample Sandstone or Formation was named in western Kentucky (Butts, 1917) and quickly adopted in Indiana (Cumings, 1922), but was not extended into Illinois until Nelson et al. (2002). In southern pope County, the Sample Sandstone is 40 to 125 feet thick and lies on the Bethel Sandstone with erosional contact. The Sample is an upward-fining interval of quartz arenite. The lower part consists of medium to coarse sand that has a sugary texture and contains scattered quartz granules, a feature not found in any other Mississippian formation. A basal conglomerate having clasts of limestone, chert, shale, and coal along with casts of fossil logs locally is present. In the Brownfield quadrangle, the lower Sample exhibits planar crossbedding that dips west and southwest (Nelson and Denny, 2008). Upward the sandstone becomes fine grained and more thinly layered, showing planar, wavy, ripple, and cross lamination along with horizontal burrows.

The Sample and Bethel Sandstones have not been differentiated in northern Pope County, where the combined thickness is 80 to 100 feet. Coarse sand and quartz granules, characteristic of the Sample, are locally present.

The upper part of the Sample Sandstone appears to intertongue on a large scale with finer grained strata mapped as Ridenhower Formation. The Sample appears to wedge out westward in Massac and Johnson Counties, where thick Ridenhower Formation overlies this (10 to 30 feet) Bethel Sandstone (Devera and Nelson, 1997; Nelson and Hintz, 2007).

Ridenhower Formation

The Ridenhower is a unit of shale, siltstone, fine-grained shaly sandstone and limestone that varies from 0 to roughly 30 feet thick in Pope County. Exposures generally are poor and descriptions are largely based on core records. In the Brownfield quadrangle, the lower Ridenhower is mostly dark greenish gray, non-calcareous shale that intergrades with the upper part of the Sample Sandstone. Above this is sandy limestone or calcareous sandstone 5 to 10 feet thick. Limestone is dark gray skeletal wackestone that contains echinoderms, bryozoans, rugose corals, brachiopods, and a few goniatite cephalopods. Continuing up section is dark gray, fissile, slightly silty shale having numerous siderite nodules. At the top of the Ridenhower is laminated, very fine-grained, calcareous sandstone that is burrowed and contains brachiopods and echinoderm fragments. The contact with the overlying Cypress Sandstone is sharp and generally erosive.

Cypress Formation

The Cypress ranges from 80 to 150 feet thick in Pope County and usually composed of a lower thick, bluff-forming sandstone and an upper thinner, slope-forming shaly unit. The lower sandstone is white to light gray, weathering buff or yellowish gray, very fine to fine-grained quartz arenite that is well sorted and has subangular grains. Bedding is mostly medium to thick and crossbedding is prominent. Bedding becomes thinner and interbeds of shale and siltstone appear in the upper part of the lower bluff-forming unit. The upper shaly unit is commonly 15 to 30 feet thick and includes gray and greenish gray shale, siltstone, and thinly layered shaly sandstone. Sedimentary structures include planar, wavy, ripple, and cross lamination along with small-scale slumped lamination and ball-and-pillow features. Burrows and trace fossils are plentiful, the most common forms being *Lockiea, Planolites,* and features believed to represent shrimp resting traces. A short distance west of Pope County at New Columbia Bluff (Reevesville quadrangle), the upper Cypress yielded crinoid columnals and a variety of brachiopods (Cole and Nelson, 1995). Red and green blocky mudstone occurs in the upper Cypress in northeastern Pope County. Rarely exposed, the upper contact of the Cypress is generally a sharp, planar to slightly uneven surface at the base of the Beech Creek Limestone Member.

Golconda Formation

Named for Golconda in Pope County, this formation comprises three members: the thin Beech Creek Limestone at the base, the Fraileys Shale, and the Haney Limestone (Fig. 4). These rocks are weakly resistant to erosion and generally poorly exposed in valleys and on slopes beneath resistant sandstone bluffs of the overlying Hardinsburg Formation. The Haney Limestone locally forms ledges, especially on south-facing slopes. Outcrops of the Fraileys and Beech Creek Members are few and fortuitous. Descriptions of the Golconda thus are largely based on borehole records, especially cores drilled for mineral exploration. Thickness of the formation ranges from 90 to 175 feet in Pope County. No regional trend in thickness is apparent, and the reasons for local thickness variations have not been sorted out.

Beech Creek Limestone Member

The Beech Creek (“Barlow lime” of petroleum operators) is lenticular in Pope County, having maximum thickness of about 12 feet. Core records and a few outcrops reveal limestone that is largely dark brownish-gray. Texture varies from dolomitic lime mudstone through argillaceous wackestone and packstone to grainstone. Crinoid fragments and brachiopods are the most common bioclasts. The limestone is commonly sandy, grading to calcareous sandstone. The upper contact is sharp and may be erosional, as one core showed conglomerate at the base of the Fraileys.

Fraileys Shale Member

Ranging from 32 to 120 feet thick, the Fraileys is largely shale but also contains limestone, siltstone, fine sandstone, and non-fissile mudstone. The lower part is consistently dark colored, fissile, calcareous shale that contains siderite nodules along with lenses and thin interbeds of fossiliferous limestone. In the Smithland quadrangle, “the lower part of the unit differs from the upper shale in that it contains more fissile shale that is dark greenish gray, is calcareous, and has siderite nodules and thin pavement layers of fossils made up of disarticulated crinoids, including *Pterotocrinus capitalis* ‘wing plates’ and rhomboporoid bryozoans” (Devera, 2013).

The upper part of the Fraileys is a conspicuous interval of multi-colored shale and mudstone 2 to 10 feet thick. The lower part tends to be fissile shale, whereas the upper part if blocky mudstone Topping off the Fraileys Member in some areas is greenish to olive-gray fissile, calcareous shale as thick as 15 feet. The contact between the Fraileys and Haney Members is gradational and in some cases arbitrary.

An interval of limestone that ranges from less than 10 to about 45 feet thick makes up the middle part of the Fraileys. This tends to change from dark colored, shaly lime mudstone and wackestone in the lower part to light-colored, coarse, highly fossiliferous packstone and grainstone in the upper part. Overlying the limestone in parts of southern Pope and adjacent counties is greenish gray, calcareous, burrowed siltstone to very fine sandstone that is apparently the thin edge of the Big Clifty Sandstone Member, a unit that thickens toward the southeastern part of the basin (Nelson et al., 2002). At or near the top of the Fraileys is a conspicuous interval of multi-colored shale and mudstone 2 to 10 feet thick. The lower part tends to be fissile shale, whereas the upper part if blocky mudstone that represents a paleosol and a sequence boundary (Nelson et al., 2002).

Haney Limestone Member

The upper member of the Golconda is 25 to 65 feet thick. Limestone is prevalent in outcrops, but shale can make up as much as half of the thickness of the Haney. Like limestone in the Fraileys, that in the Haney tends to grade from dark, shaly micritic rock in the lower part to lighter colored, coarser packstone and grainstone in the upper part. Also present in places are layers of brownish colored microgranular dolostone. Shale in the Haney is similar to that in the Fraileys: dark gray and olive-gray, slightly silty to silt-free, thinly fissile, and calcareous. The upper contact may be gradational or sharp and erosive, a minor disconformity.

Hardinsburg Formation

The Hardinsburg Formation crops out extensively in Pope County. From the north, the main outcrop extends as a narrow strip that widens southward along Big Grand Pierre Creek. Exposures continue along the Ohio River bluff to Golconda, where they curve inland and cap the bluffs on the north side of Cache Valley. The formation also crops out near Reevesville (mostly in Johnson and Massac Counties) and along Barren Creek and near the mouth of Dog Creek, south of the Cache Valley. The Hardinsburg ranges from 70 to 120 feet thick, averaging about 100 feet; but it attains 185 feet in Johnson County a short distance west of Reevesville.

The Hardinsburg comprises a lower shaly unit that is poorly exposed, a thick middle bluff-forming sandstone unit, and an upper unit of shale, siltstone, thin-bedded sandstone, mudstone, and coal. In the Reevesville quadrangle (Nelson, 1996), the lower Hardinsburg is dark gray to black, fissile, calcareous shale that contains siderite nodules and is as thick as 30 feet. The middle sandstone can be 20 to 80 feet and exhibits an upward-fining profile. Sandstone is very fine to medium-grained, well sorted quartz arenite that is locally calcareous and contains a few percent of mica and dark opaque minerals. The lower part of the sandstone is medium-to thick-bedded and exhibits trough and planar crossbedding. Upward the bedding becomes thinner and the sandstone has planar, ripple, and cross lamination along with load casts and slumped lamination. Marine influence is evident from bidirectional cross lamination, tidal rhythmites, and echinoderm fragments and casts of brachiopods. The middle sandstone has an erosive lower contact that is scoured into the Golconda Formation in many places. Good exposures of the lower contact and the basal conglomerate may be seen along the western part of Brownfield Bluff. Shale and sandstone pebbles, coal stringers, and casts of fossil logs include in the basal lag deposit.

The upper Hardinsburg, 20 to 80 feet thick, includes medium to dark gray shale, gray to greenish gray siltstone, and light gray, very fine-grained, laminated and flaggy-bedded sandstone. These rocks commonly are arranged in upward-fining sequences, each capped by rooted mudstone and thin, lenticular coal. As many as three paleosols and thin coal layers were observed in the Brownfield quadrangle. Coal beds are shaly and rarely exceed a few inches thick, but a coal layer 1 foot thick was observed in the Glendale quadrangle. The contact to the Glen Dean Limestone is conformable and sharp to gradational.

Glen Dean Limestone

Composed of limestone and subordinate shale, the Glen Dean ranges from 40 to 85 feet thick in Pope County. It is weakly resistant to erosion, eroding to valleys and slopes. The Glen Dean commonly occupies a slope between ledges of the more resistant Hardinsburg Formation below and Tar Springs Formation above. Nevertheless, Glen Dean outcrops are plentiful, especially on south-facing slope where the limestone forms small ledges, and along actively eroding drainages. From northeastern Pope County, the main outcrop belt extends southward, passing west of Shetlerville and Golconda and turning west along the north side of the Cache Valley. Additional exposures occur near Reevesville, Dixon Springs, and Bay City.

In most of the county, the Glen Dean is informally divisible into a lower limestone, a middle shale, and an upper limestone. The lower Glen Dean limestone is generally thinner than the upper limestone and is absent in places, but the lower unit can be as thick as 30 feet. In the Brownfield quadrangle, the unit is composed of dark gray to nearly black, argillaceous lime mudstone having thin interbeds of hard, dark gray, calcareous shale. These rocks contain a sparse fauna of derbyid and spiriferid brachiopods, echinoderm fragments, and conularia (Nelson and Denny, 2008). In the Herod and Shetlerville quadrangles, Baxter et al. (1967) described the lower limestone as brown, fine to coarse crinoidal grainstone with bryozoans. Dark olive to greenish gray, calcareous shale less than 10 feet thick occurs at the base of the Glen Dean in parts of the Brownfield quadrangle. The shale becomes increasingly silty downward, grading into siltstone of the upper Hardinsburg.

The middle shale of the Glen Dean is soft, fissile or platy, calcareous clay shale (little or no silt), ranging in color from olive to greenish gray and dark gray. Lenses and thin interbeds of fossiliferous limestone are interspersed. The brachiopod *Anthracospirifer increbescens,* the triangular bryozoan *Prismopora sp*., and sharks' teeth were found in this shale in the Smithland quadrangle (Devera, 2013).

The upper limestone is 15 to 35 feet and generally grades from brownish gray lime mudstone and wackestone in the lower part to light gray, crossbedded, oolitic and skeletal packstone and grainstone in the upper part. This is the youngest widespread crossbedded, oolitic limestone in the Pope Group. Fossils include *Pterotocrinus* and other crinoids, the blastoid *Pentremites sp.,* a variety of brachiopods and bryozoans, and rugose corals. The contact to the overlying Tar Springs is gradational in some places, erosional elsewhere.

Tar Springs Formation

Like the older Hardinsburg Formation, the Tar Springs is a unit of sandstone that contains layers of siltstone, shale, mudstone, and thin coal largely in the upper part. Thickness in Pope County averages a little less than 100 feet and ranges from 70 to 130 feet (Fig. 5). Because the overlying Vienna Limestone and Waltersburg Formations are relatively thin and poorly exposed, these units were combined with the Tar Springs as a single mapping unit in the Herod (Denny et al., 2008) and Shetlerville (Denny and Counts, 2009) quadrangles. The same procedure has been followed on the county-wide map that accompanies this report.

The Tar Springs holds up a west-dipping cuesta that extends southward from near the northeast corner of Pope County toward Golconda, where it swings to the west along the north side of Cache Valley. Other outcrops of the Tar Springs occur west and southwest of Dixon Springs and south of the Cache Valley, especially near Bay City.

Because of discontinuous exposures and scarcity of good borehole records, internal stratigraphy of the Tar Springs has not been thoroughly sorted out in Pope County. Chesterian sandstone bodies in general are more or less lenticular and commonly grade laterally to finer clastics. Most quadrangle maps depict the Tar Springs as a sandstone-dominated unit that has a locally erosional lower contact and grades upward to finer-grained, shaly strata. Stratigraphic columns for the Reevesville (Nelson, 1996) and Smithland (Devera, 2013) depict two shale-over-sandstone intervals of roughly equal thickness. Using abundant well logs, Morse (2001) determined that the Tar Springs in Gallatin County (diagonally northeast of Pope County) displays from one to as many as six sandstone-shale intervals, although two are commonly present. Lacking continuous outcrop or core, two or more sandstone bodies that "stack up" appear to represent a single sand body.

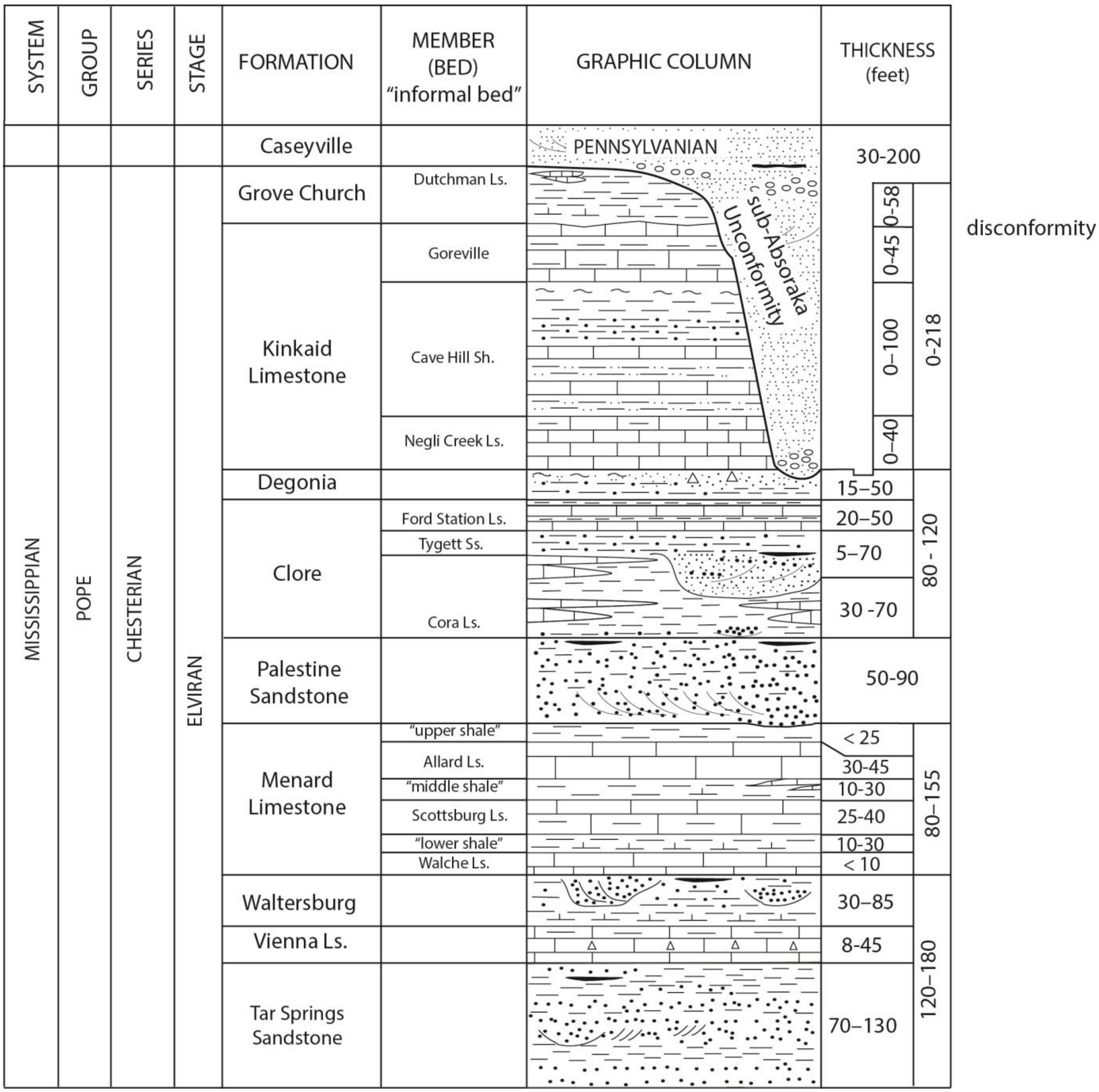

Figure 5. Graphic column of the upper part of the Pope Group.

Sandstone of the Tar Springs is white to light gray, weathering light to medium brown and brownish orange. Grains are subangular to subrounded and well sorted, dominantly very fine to fine-grained, but some medium sand is present. Like other sandstone of the Pope Group, that of the Tar Springs is quartz arenite. Sandstone sequences tend to become finer and more thinly bedded upward. Massive and medium to thick-bedded, crossbedded sandstone gives way upward to thin bedding and lamination with numerous interbeds of shale and siltstone. Thinly layered clastics display planar lamination, current and interference ripples, contorted lamination, small load casts, and nondescript burrows. The only fossils noted are finely divided plant remains.

Shale and siltstone of the Tar Springs occur in various shades of gray and tend to be interlaminated. As many as three thin coal layers may be present, but the most persistent one is at or near the top of the formation. Dark gray, rooted mudstone accompanies coal beds. The contact to the Vienna Limestone is generally sharp or gradational within a few inches vertically.

In an outcrop-based investigation of the Tar Springs in southern Illinois, Wescott (1982) delineated four lithofacies: (A) erosive-based, channel-form, upward-fining crossbedded to laminated sandstone, (B) upward-coarsening, laminated sandstone having a variety of small-scale sedimentary structures, (C) sandstone with shale interbeds showing bidirectional current indicators and trace fossils that have marine affinities, and (D) shale with sandstone interbeds and laminae, largely planar laminated, commonly burrowed and yielding occasional marine fossils. Paleocurrents in facies (A) were unidirectional toward the southwest, whereas other facies exhibited bidirectional, northeast and southwest paleocurrents. Wescott envisioned a delta complex prograding toward the southwest and associated shoreface and tidal-flat environments. Morse's (2001) Gallatin County study took a less regional view, focusing on a single oil field. Morse's environmental interpretations generally mirror those of Wescott. Neither author addressed the subject of eustacy. Considering eutascy as a factor, we suggest that the thick channel-form sandstone of the lower Tar Springs filled valleys that were incised during regression and lowstand. Under this model, the lower valley-fill deposits are fluvial (flow toward the southwest), whereas the upper valley-fill transitions to tidally influenced, estuarine settings. This theme seems to be repeated in clastic units from the Chesterian through the Pennsylvanian. However, a proper assessment of Tar Springs depositional processes requires a more concerted effort than is normally carried out during a quadrangle mapping project.

Vienna Limestone

The Vienna is a thin but regionally persistent unit of limestone and marine shale that separates the siliciclastic Tar Springs and Waltersburg Formations. As mentioned above, these three formations are shown as a single unit on the geologic map.

Reported thickness of the Vienna varies from 8 to 45 feet in Pope County, without obvious geographic trends. The formation is mostly limestone, with shale found as interbeds and at the top of the Vienna. The limestone is dominantly medium to dark gray and brown lime mudstone and skeletal wackestone, but light-colored crinoid-bryozoan packstone and grainstone locally occur near the top. The micritic limestone is siliceous and contains large bands and nodules of dark colored chert. Weathering creates residuum of angular blocks of chert that has a porous rind of microgranular silica. Float of this material is distinctive and where found the chert float enables mapping the Vienna in areas where limestone outcrops are concealed. Fossils of the Vienna are mainly echinoderm fragments, fenestrate bryozoans, and small brachiopods such as cleiothyridinid types. Shale in the Vienna is generally dark gray, calcareous and fissile. Silt-free shale at the top of the Vienna grades to silty shale and siltstone of the overlying Waltersburg Formation.

Based on its lithologic succession and limited fauna, the Vienna is believed to record a rapid transgression to relatively deep water, followed by a gradual regression. The nature of the abundant dispersed silica in the limestone has received little attention. An influx of clastics shut off carbonate production at the start of Waltersburg deposition.

Waltersburg Formation

Now virtually a ghost town, the former post-office community of Waltersburg in western Pope County gave its name to this formation. The type section, north of Waltersburg townsite, now is completely covered by soil and vegetation (Weibel et al., 1993). Thickness of the formation in Pope County ranges from 30 to 85 feet. The Waltersburg is combined with the Vienna Limestone and Tar Springs Formation on the geologic map. Composed largely of shale and siltstone, this formation produces few outcrops. Sandstone in the upper part erodes to broken ledges and holds up a small cuesta.

A single upward-coarsening sequence prevails in Pope County. The lower Waltersburg is shale that is dark gray to olive-gray, somewhat silty, platy or fissile, and contains ironstone nodules. This gives way upward to siltstone that is dark olive or greenish gray and thinly bedded. Some siltstone weathers to rhombohedral, angular rusty brown slabs that are distinctive in float. Sandstone of the upper Waltersburg is very fine to fine-grained, argillaceous quartz arenite that displays planar and ripple lamination. A layer of impure coal as thick as 1 foot occurs in places near the top of the formation. No fossils other than plant fragments have been identified. The contact to the overlying Walche Member of the Menard Limestone is typically sharp and planar.

P.E. Potter (1962, 1963) mapped the Waltersburg Formation on outcrop and in subsurface across the southern part of the Illinois basin. Prominent on Potter's maps are a series of southwest-trending, elongate, arcuate to slightly sinuous sand bodies, several of which serve as petroleum reservoirs. Potter (1962, p. 80) suggested that these represent "pro-delta marine deposits". Later Potter (1963, p. 15) revised his opinion slightly, writing, "Although origin as a beach deposit seems remote, it is difficult to distinguish definitely between either a fluvial or an off-shore marine bar origin". One of the large Waltersburg sand bodies crops out in eastern Johnson County, where its large-scale planar and trough crossbeds consistently dip west, southwest, and south, as Potter (1962) determined. Flanking the big sandstone body are finer, laminated clastics having impure coal and shale with fossil land plants near the top (Nelson, 1993). These observations suggest that Waltersburg sedimentation took place during marine regression, with deltas prograding toward the southwest. The coastline gradually emerged in a complex of swamps and mud flats. The big southwest-trending sandstone bodies are probably either deltaic distributary channels or incised valleys.

Menard Limestone

The Menard is a distinctive and persistent unit of limestone and shale in the southern part of the Illinois basin. Thickness in Pope County ranges from 80 to 155 feet and overall increases toward the west. This thickness trend agrees with an isopach map in Willman et al. (1975, p. 160), which shows maximum Menard thickness in western Pope and eastern Johnson County.

Broken by numerous faults, the outcrop belt of the Menard trends in a general southwesterly direction from Herod toward Brownfield and Dixon Springs. The Menard also crops out in several down-faulted blocks south of the Cache Valley. This formation underlies slopes near the bases of plateaus and cuestas capped by sandstone of the Palestine Formation. As is the case with other limestone-shale units, exposures are sporadic and discontinuous, but ledges of limestone can be found in most places where the Menard has been mapped. One of the best outcrop areas is a north-facing bluff on the south side of the Cache Valley about one mile east of State Rt. 145.

Core records and borehole logs show that in southern Illinois, the Menard is consistently divisible into six members, three of which have been named formally. Although these members are difficult to identify in scattered outcrops, they are believed to be present throughout Pope County (Fig. 5) and can be picked out wherever suitable outcrops and drilling records are available.

Walche Limestone Member

The Walche Member, basal unit of the Menard, is probably less than 10 feet thick in Pope County. Dark gray, argillaceous lime mudstone to wackestone with interbeds of dark gray shale is the typical lithology. Gastropods and echinoderm fragments are the most common fossils.

Lower shale member

Overlying the Walche Limestone is an interval of mostly shale that varies from roughly 10 to 30 feet thick. Exposures are few, and detailed descriptions from Pope County are not available. In the Bloomfield quadrangle of Johnson County, the lower shale is largely greenish gray, soft, weakly fissile, and calcareous. Yellow-orange weathering, coquinoid limestone occurs as lenses and slabby beds a few inches thick. Fossils include spiriferid, compositid, and other types of brachiopods along with bryozoans, echinoderms, and rugose corals (Nelson, 1993).

Scottsburg Limestone Member

Ranging from about 25 to 40 feet thick, the Scottsburg is an interval of limestone with minor interbeds of shale and dolostone. The limestone is largely dark gray to brownish-gray, sublithographic lime mudstone and skeletal, pelletal wackestone. Many of the limestone beds contain bands and nodules of chert. Dolostone or dolomitic limestone is microgranular and weathers buff, yellow, or orange. Observed in the Bloomfield quadrangle west of Pope County were rhythmic planar laminations, algal structures, polygonal mud cracks, and intraformational conglomerate (Nelson, 1993). Brachiopods are abundant in the lower Scottsburg; other fossils include gastropods, bryozoans, rugose corals, and echinoderm fragments.

Middle shale Member

Separating the Scottsburg and Allard Limestone Members is an interval of shale, mudstone, and thin limestone 10 to 30 feet thick. The only complete exposure is in the railroad cut that serves as the type section of the Allard Member, 4 miles northwest of Dixon Springs. Here, the shale is greenish to bluish gray and dark gray, fissile and calcareous, and contains many interbeds of limestone ranging from less than an inch to about 3 feet thick. Drill cores elsewhere in southern Illinois indicate that green claystone commonly occurs at or near the top of the middle shale member. The claystone is blocky to massive, slickensided, and commonly has gray and red mottling.

Allard Limestone Member

Swann (1963) named the Allard Member and described the type section in a railroad cut four miles northwest of Dixon Springs, just over the line in Johnson County. Another excellent exposure is farther west in Johnson County at the interchange of Interstate 24 and State Rt. 146, on the east side of Vienna. Here and elsewhere in Pope County, the Allard is 30 to 45 feet thick and composed mostly of medium to dark brownish and olive-gray lime mudstone and skeletal wackestone and packstone. Bedding surfaces are wavy or hummocky and individual beds range from a few inches to about 2 feet thick. Small chert nodules are plentiful in some beds. Also found in the Allard is microgranular dolostone or dolomitic limestone that weathers yellowish brown. Coarse crinoidal grainstone and finer-grained oolitic packstone and grainstone, with dark colored oolites, is found at the top of the Allard in some places. The most common fossils are spiriferid, compositid, and atrypid brachiopods; fenestrate bryozoans, rugose corals, and blastoids.

Upper shale member

At the top of the Menard is an interval of mostly shale that ranges up to about 25 feet thick. The upper shale is locally missing because of erosion at the base of the Palestine Formation. Dark gray, greenish gray, and olive gray are the usual colors. The shale is soft, fissile, calcareous, and contains little or no silt. Limestone occurs as scattered nodules, lenses, and thin interbeds. Both limestone and shale are richly fossiliferous. A favorite collecting locality is the upper part of the highway cut east of Vienna, mentioned above.

In some places the contact with the overlying Palestine Formation is gradational from calcareous, silt-free shale below to non-calcareous, silty shale and siltstone above. At other localities, the contact is erosive between shale and limestone below and sandstone above.

Palestine Formation

The Palestine Formation exhibits a succession similar to the older Hardinsburg, Tar Springs, and Waltersburg Formations, as well as the Tygett Sandstone Member in the overlying Clore Formation. Lithologies of these units are so closely similar that identification hinges upon position relative to limestone formations, which have many more distinguishing features. In most areas of Pope County, the Palestine can be identified with confidence by referring to the Menard Limestone below and Cora member of the Clore above. Isolated sandstone slices within a fault zone may be impossible to identify. Also, the Palestine and Clore were not mapped consistently between the Waltersburg (Weibel et al., 1991) and Glendale (Devera, 1991) quadrangles. Additional field work was undertaken here to resolve the differences for the present project.

Thickness of the Palestine ranges from about 50 to 90 feet in Pope County. Sandstone of the Palestine forms a low escarpment or series of ledges, whereas shaly strata erode to slopes and are seldom seen. Dissected by numerous faults, the Palestine outcrop belt extends southwestward across the county from Herod to the Johnson County border southwest of Glendale. It also caps bluffs that extend westward from Brownfield toward Reevesville, along the north side of the Cache Valley, and it is present in down-dropped blocks within the Compton Mine and Alcorn Creek fault zones in the southern part of the county. Some of the best exposures are on the southeast face of Stafford Bluff near Reevesville.

Variable proportions of sandstone, siltstone, and shale make up the Palestine. Bluff-forming sandstone is in the middle to lower part of the unit, fining upward from an erosive lower contact. The lower portion is white to light gray, fine to medium-grained quartz arenite that has medium to thick bedding and is commonly cross bedded. This rock transitions upward to very fine-grained, laminated to thinly bedded, shaly sandstone that tends to weather brown or brownish gray. Planar and wavy lamination, current and interference ripples, and rare mud cracks have been observed in laminated strata. Burrows and other trace fossils are common, including *Lockeia, Cochlichnus,* and *Planolites.*

Carbonaceous shale and impure coal are common near the top of the Palestine. A cored test hole near Glendale encountered a 19-inch layer of shaly, pyritic coal (Devera, 1991). Root traces in siltstone or sandstone beneath coal beds indicate in situ peat formation. Other plant remains are fragmentary and unidentified. The only marine fossils found during mapping were echinoderm fragments in calcareous siltstone in the Reevesville quadrangle (Nelson, 1996). The horizon was believed to be upper Palestine, but might better be assigned to the basal Clore Formation. The Palestine-Clore contact is poorly exposed within an interval of siltstone, shale, and thin limestone layers. The contact was mapped at the lowest occurrence of limestone or shale having marine fossils.

Little has been published about the Palestine for half a century. A regional sandstone thickness map by Potter (1962) shows a bifurcating system of southwest-trending, linear to slightly sinuous sandstone bodies in southern Illinois. The pattern suggests deltaic distributary channels. Potter (1963) presented the same maps at smaller scale and covering a larger area of the basin, and reiterated his deltaic distributary model. Swann (1963) envisioned a "Michigan River system" operating throughout Chesterian time, delivering sediment from the Canadian Shield into the Illinois basin. The models of Potter and Swann were heavily influenced by concurrent investigations of the Mississippi River delta, which is likely not an appropriate modern analogue. As an alternative, the channel-form sandstone bodies of the lower Palestine might represent incised valleys rather than deltaic distributaries. Coal and rooted zones near the top of the Palestine attest to regression and subaerial exposure, terminated by marine transgression that ushered in Clore deposition.

Clore Formation

The Clore is a complex formation that is divisible into three members in most of southern Illinois. These are (1) the Cora Member, a lower unit of shale with limestone interbeds, 2) the Tygett member, which includes one to three sandstone bodies separated by limestone and shale, and (3) the Ford Station Member is dominantly a limestone with shale at the top (Fig. 5). In the past, geologists commonly confused the Tygett sandstones with the Palestine below and the Degonia above. To resolve these discrepancies, additional field work was carried out for this report. However, the Clore and Degonia have been combined into a single unit on the geologic map. Because the Degonia is thin and generally poorly exposed, and some of the 1:24,000-scale maps from which we compiled the geologic map did not differentiate the two formations.

Thickness of the Clore varies from about 80 feet in the Smithland area to 120 feet or more in the Glendale and Waltersburg quadrangles. The latter is close to a maximum thickness for the basin. The Clore has been mapped in a series of fault blocks and slices extending diagonally across the county from northeast to southwest. Some of the best exposures are in a railroad cut west of Glendale and in the bluff on the north side of the Cache Valley just east of Renshaw. Cores and other borehole records provide additional data. Where well developed, sandstone bodies in the Tygett hold up small plateaus and cuesta. The remainder of the Clore, being shaly, erodes to slopes and valleys and is seldom well exposed.

Cora Member

The Cora Member ranges from about 30 to 70 feet thick and is composed largely of shale, with interbeds of limestone less than 5 feet thick and local siltstone or sandstone in the lower portion. The shale varies from medium gray and olive gray to nearly black and is fissile to platy, partly silty, and partly calcareous. Limestone beds, which occur mostly in the upper part of the member, are medium to dark gray, argillaceous lime mudstone to wackestone that weathers yellowish to olive gray. Large blocks of limestone commonly slump down slope due to soil creep. Both shale and limestone contain a variety of marine fossils. Among them are brachiopods *Composita sp., Anthracospirifer increbescens,* and *Cleiothyrodina sp.,* the corkscrew-shaped *Archimedes sp.* and other bryozoans, the crinoid *Agassizocrinus sp.,* the razor clam *Pinna missouriensis,* the cephalopod *Platyceras sp.,* gastropods, and rugose corals (Devera, 1991; Weibel et al., 1993). Thin sandstone reportedly occurs 5 to 10 feet above the base of the Cora Member in northeastern Pope County (Baxter et al., 1967).

Tygett Member

The Tygett is present in most of Pope County, ranging in thickness from a few feet to as much as 70 feet near Glendale. The member contains one to three sandstone bodies that generally coarsen upward and are separated by short intervals of limestone and shale similar to that of the Cora. Channel-form sandstone bodies that become finer upward occur in the Glendale and Reevesville quadrangles. Sandstone may be light to medium gray, brownish gray, or olive-gray and is very fine to fine-grained, well-sorted quartz arenite. Most of it is thinly bedded or laminated and has planar, ripple, and cross lamination. A transition from lower sandy shale or siltstone to upper sandstone commonly is seen. Stigmarian roots and the horseshoe-shaped trace fossil *Rhizocorallium* commonly are found at the tops of Tygett sandstone bodies. Other trace fossils include *Cochlichnus* and *Phycoides*-like tubes. In a few places, thin coal is found overlying sandstone.

Ford Station Member

The Ford Station Member may range from 20 to 50 feet thick and consists of limestone with shale interbeds. Most of the limestone is medium to dark gray lime mudstone, wackestone, and packstone. Also present are beds of microgranular dolomite that weathers yellowish orange. Shale in the Ford Station is similar to that in the Cora Member. Fossils identified in the Ford Station from the Smithland quadrangle are brachiopods *Composita sp, Spirifer sp., Anthracospirifer increbescens,* and derbyids; the crinoid *Agassizocrinus sp.*, blastoids, *Archimedes sp.* and ramose bryozoans, and rugose corals (Devera, 2013).

Degonia Formation

The Degonia is a relatively thin unit (15 to 50 feet) of fine-grained clastic rocks in Pope County. It is weakly resistant to erosion and not prominent in the landscape, producing small and scattered exposures. For this reason, the Degonia was combined with the underlying Clore Formation on the geologic map.

Sandstone, siltstone, laminated shale, non-fissile mudstone, and bedded chert make up the Degonia. Bedded chert that ranges up to about 5 feet thick commonly occurs at the base. Colors range from nearly white to gray mottled with yellowish-brown and orange; texture may be dull to vitreous. Ripple marks are commonly present and some of the chert exhibits internal brecciation. Baxter et al. (1967) stated that bedded chert as thick as 7 feet also occurs in the upper part of the Degonia in the Herod and Shetlerville quadrangles, but they did not mention where in Hardin or Pope County such chert was observed.

The middle part of the Degonia is silty shale, siltstone, and very fine sandstone that tends to coarsen upward. Colors are mostly dark greenish, brownish, and olive gray. Sandstone has thin to medium, tabular bedding and exhibits wavy lamination, ripple marks, and small load casts. Burrows and trace fossils are plentiful, including *Lockeia* and a variety of crawling traces.

Consistently present at the top of the Degonia is blocky to weakly fissile mudstone that is variegated in greenish and bluish gray, reddish brown, and maroon. Thickness ranges from about 2 feet to 14 feet. In the ISGS Core (Gd-2), greenish gray, calcareous shale 8 feet thick overlies the variegated mudstone. Small bivalves are common in the upper part of the shale. The contact to the overlying Kinkaid Limestone is abrupt. Lower Pennsylvanian paleochannels truncate all of the Kinkaid and at least part of the Degonia Formation about two miles east of Glendale and south of Gibbons Creek near the northeast corner of Pope County.

The ripple-marked chert at the base of the Degonia clearly originated as water-laid sediment, probably calcareous siltstone or very fine sandstone. It is likely a silcrete that was silicified during pedogenesis, although no definite indications of subaerial exposure were observed. Laminated, upward-coarsening clastics of the upper Degonia, capped by variegated paleosol, seem to continue the common theme of shoaling and progradation culminating in soil formation. Calcareous shale in the uppermost Degonia with a brackish-water (?) bivalve fauna records the beginning of another marine transgression.

Kinkaid Formation

The Kinkaid Formation is composed of limestone, shale, and mudstone divisible into distinctive, widely continuous members. Throughout the basin, Pennsylvanian rocks unconformably overlie

Mississippian rocks. Although the Kinkaid is present in most of Pope County, it is locally absent where Pennsylvanian paleovalleys cut through into older units. Two areas where this has taken place are two miles east of Glendale and along Gibbons Creek near the northeast corner of the county. Thickness of the Kinkaid in Pope County thus varies from zero to a maximum of 218 feet in a drill hole near Glendale.

Like other limestone-shale formations, the Kinkaid is weakly to moderately resistant to erosion. The thicker limestone intervals commonly form ledges on hillsides where not excessively mantled by Pennsylvanian talus and slope wash. Gullies and artificial cuts are the only places to see the shaly portion of the Kinkaid. One belt of Kinkaid outcrops begins northwest of Glendale and extends east and northeast toward Eddyville, terminating against the Lusk Creek fault zone. Another outcrop belt, considerably chopped up by faulting, extends from Dixon Springs toward the northeast corner of the county. The Kinkaid also has been mapped in the Alcorn Creek graben in southern Pope County.

Members of the Kinkaid are the Negli Creek Limestone (oldest), the Cave Hill Member, the Goreville Limestone, and the Grove Church Member (Figs. 5 and 6). The youngest member, the newly recognized Dutchman Limestone Member (Nelson et al., 2004), is absent here because of sub-Pennsylvanian erosion.

Negli Creek Limestone Member

Among all Chesterian limestone units in the Illinois basin, the Negli Creek is perhaps the most consistent in thickness and lithology, and is widely used for subsurface mapping. It is consistently 25 to 35 feet thick, but may reach 40 feet south of Dixon Springs in the Reevesville quadrangle. This member is almost entirely limestone that is medium to dark brownish or bluish gray, tending to weather lighter gray. Dense, slightly argillaceous lime mudstone in the lower part tends to transition upward to skeletal wackestone and packstone. Bedding is uneven or hummocky, most layers being 0.5 to 1.5 foot thick. Crinoidal packstone at the top is locally crossbedded. Lenses or nodules of light to dark gray chert are common. Dark gray, calcareous shale occurs as partings, laminae, and discontinuous interbeds. Both contacts of the Negli Creek are planar to gently rolling and sharp. Among fossils, large bellerophontid gastropods are plentiful in the lower Negli Creek, accompanied by *Girvanella* oncloids and the demosponge, *Chaetetella.* Although all three are long-ranging, their occurrence together is diagnostic for the Negli Creek. Also identified in this member are chonetid and spiriferid brachiopods, trepostone and fenestrate bryozoans and the corkscrew-shaped *Archimedes,* the crinoid *Agnostocrinus sp.*, the blastoid *Pentremites sp.,* rare corals and cephalopods, and the trace fossils *Chondrites, Zoophycos*, and horizontal burrows (Weibel et al., 1993).

Cave Hill Member

Where not truncated by sub-Pennsylvanian erosion, the Cave Hill Member is 70 to 100 feet thick in Pope County. As in much of southern Illinois, the Cave Hill can be subdivided here into lower shale, middle limestone and shale, and upper variegated mudstone and shale.

The lower shale is 10 to 30 feet thick and thickens toward the northeast. The dark olive- to greenish-gray shale is calcareous, moderately fissile, and tends to coarsen upward, grading to siltstone in the upper part. The shale is fossiliferous (brachiopods, bryozoans, echinoderms) and contains lenses of impure limestone.

The middle Cave Hill consists of limestone interbedded with lesser proportions of shale. Much of the limestone is dark gray, dense, sublithographic lime mudstone that weathers to rounded, light gray surfaces. Bands and nodules of dark gray to black, vitreous chert are numerous. Other rock types include skeletal wackestone and packstone, light gray crinoidal grainstone, and buff-weathering microgranular dolostone. Shale in the middle Cave Hill is dark gray to greenish and olive-gray, fossiliferous and calcareous. The middle Cave Hill is richly fossiliferous. Nelson et al. (1991, p. 14) wrote, “Some of the more common fossils are the brachiopods *Spirifer increbescens, Composita sp.,* and *Diaphragmus sp.,* the bryozoans *Archimedes sp., Fenestella sp.,* and *Eridopora sp.,* and the gastropods *Platyceras* and dwarf *Bellerophon.* The shells are commonly whole and articulated, but they do not appear to be in life position. Most *Archimedes* axes are intact, although the fronds are detached. Most echinoderm remains, except for those of a few *Pentremites* calices, are disarticulated”.

The upper Cave Hill, 10 to 20 feet thick, consists of variegated shale and claystone overlain in places by gray, fossiliferous shale having lenses of limestone. Colors of the mudstone include greenish gray, maroon, reddish brown, and mustard yellow. Although portions are fissile, the variegated mudstone is largely massive to blocky and appears to represent a paleosol. The overlying shale is dark gray, calcareous, and contains mainly bivalves of the genera *Myalina* and *Edmondia.* Limestone lenses near the top of the Kinkaid have a more normal marine fauna that includes *Composita* (brachiopod) and the bryozoans *Archimedes* and *Rhombopora.* Contact to the Goreville Member is sharp or rapidly gradational.

Goreville Limestone Member

The Goreville Member is 35 to 45 feet where fully present and is composed of limestone with a few thin layers of shale. The limestone is medium to dark gray and brownish gray and is mostly fine to coarse, partly dolomitic crinoidal wackestone and packstone, plus a little grainstone. Fossil fragments are commonly silicified, giving weathered outcrops a rough surface. Bedding varies from thin to thick and tabular to slightly uneven. A moderate amount of chert occurs as bands, lenses, and nodules. Large articulated crinoid stems and *Archimedes* spires as long as 12 inches commonly are found in the Goreville. Other fossils are chonetid, spiriferid, and productid brachiopods; fenestrate, rhomboporid, trepostome, and fistuilporid bryozoans; wing plates of the crinoid *Pterotocrinus*, the rugose coral *Trilophyllites*, the sponge *Chaetetella*, and sharks’ teeth. The contact of the Goreville to the Grove Church is sharp or rapidly gradational.

Grove Church Shale

The Grove Church Shale is composed of shale, mudstone, and thin limestone layers. Only a few outcrops of this non-resistant member have been found in Pope County, in ravines southeast and south of Eddyville and in an old quarry on the south face of Millstone Bluff, northwest of Goreville. A drill core near Goreville recovered 48 feet of Grove Church, compared to the 70 feet found north of Vienna (in Johnson County) where the Dutchman Limestone Member conformably overlies the Grove Church (Nelson et al., 2004). In the core, the Grove Church is mostly shale that is gray and greenish gray, partly calcareous and fossiliferous, and partly silty, with siltstone laminae. Red and green variegated, blocky mudstone has been observed in Grove Church outcrops. Limestone ranges from lime mudstone to crinoidal grainstone and occurs in beds a few inches to about 4 feet thick. Fossils are abundant, including spiriferid, compositid, and productid brachiopods, fenestrate bryozoans, bivalves, rugose corals, and echinoderm fragments.

The Grove Church was originally a Member of the Kinkaid Formation. Swann (1963) split out the Grove Church as a formation because the Kinkaid is dominantly limestone, while the Grove Church is dominantly shale. Rexroad and Burton (1961) determined that the conodont fauna of the Grove Church Shale is distinctly different from the Kinkaid. The conodont fauna being markedly different along with the difference in lithology argues in favor of classifying the Grove Church as a Formation. Nevertheless there is also a case to be made to classify the Grove Church as a member of the Kinkaid (Nelson et al., 2004). On the geologic map we include the Grove Church Shale with the Kinkaid, but on the column it will separated out as a Formation.

Sub-Pennsylvanian unconformity

A major regional unconformity separates Pennsylvanian from older rocks throughout the Illinois basin. Characterizing this erosional surface is a system of southwest-trending paleovalleys (Bristol and Howard, 1971, 1974). The depth of valley incision is less in Pope County than most other areas of the basin. Except in two small areas, basal Pennsylvanian strata lie on various members of the Kinkaid Formation. The two areas of deeper incision are near the northeastern corner of the county in NW¼ SW¼ of Section 5, T11S, R7E (Baxter et al., 1967), where a paleovalley cuts into the upper part of the Clore Formation; and about two miles east of Glendale (Devera, 1991), where the Degonia Formation was partly eroded (Figs. 5 and 6).

Pennsylvanian Subsystem

Raccoon Creek Group

The Raccoon Creek Group comprises the Tradewater and the Caseyville Formations in the Illinois Basin Consortium Study 5 (Tri-State Committee, 2001). The Raccoon Creek Group was first used by Weir and Gray (1961) in a geologic map of the Indianapolis 1 degree by 2 degrees Quadrangle. This group is composed primarily of sandstone and shale with lessor amounts of clay, coal, and limestone.

Caseyville Formation

The older part of the Pennsylvanian System in Pope County is assigned to the Caseyville Formation (Fig. 6). Usage of this name dates back to Owen (1856), in the form “Caseyville conglomerate”. Glenn (1912) was the first geologist to use Caseyville in a formational sense. Lee (1916) described the type sections, which is along the bluffs of the Ohio River in Hardin County, Illinois. The name refers to a small community in Kentucky directly opposite the type section. A series of cuts along the Canadian National (formerly Illinois Central) Railroad in northwestern Pope County constitute the principal reference section of the Caseyville (Kosanke et al., 1960).

Thickness of the Caseyville in Pope County ranges from approximately 200 to 450 feet. The formation is thinnest along the crest of the McCormick anticline in the northwestern part of the county, and thickest near the northeast corner and in places where sub-Pennsylvanian paleovalleys cut deeply into Mississippian strata. Limited data suggest that the Caseyville thins across anticlines and thickens into synclines, implying tectonic activity during sedimentation (Nelson et al., 1991).

Sandstone, siltstone, shale, minor mudstone, thin coal, and rare limestone constitute the Caseyville. Intervals of crossbedded and massive, cliff-forming sandstone exceed 100 feet thick in places. Key factors that distinguish Caseyville from Pope Group are virtual absence of limestone and common occurrence of coarse sandstone that contains plentiful quartz granules and small pebbles. Among Mississippian sandstones, only the Sample contains scattered, small quartz granules. However, fine-grained clastics of the Caseyville are lithologically indistinguishable from their Mississippian counterparts. Atherton et al. (1960) presented many more criteria useful for distinguishing between Caseyville and Chesterian rocks in the outcrop and subsurface.

The Caseyville crops out extensively in Pope County. The main belt extends from north of Glendale through Eddyville to the northeast corner of the county; another belt comprises a series of fault blocks within the Dixon Springs graben. The formation also comes to the surface in several places along the McCormick anticline in northern Pope County. The thick, well indurated sandstone units cap many of the highest hills in the region and form many scenic attractions, including Garden of the Gods State Park, Lusk Creek canyon, Natural Bridge, and Burden Falls.

Four divisions of the Caseyville can be recognized in much of southern Illinois. In ascending order, these are the Wayside Member, the Battery Rock Sandstone, an unnamed shaly member formerly known as the Drury Member, and the Pounds Sandstone Member (Fig. 6). The Battery Rock and Pounds Sandstone are cliff-and ledge-forming members, whereas the other two are less resistant to erosion and generally underlie slopes.

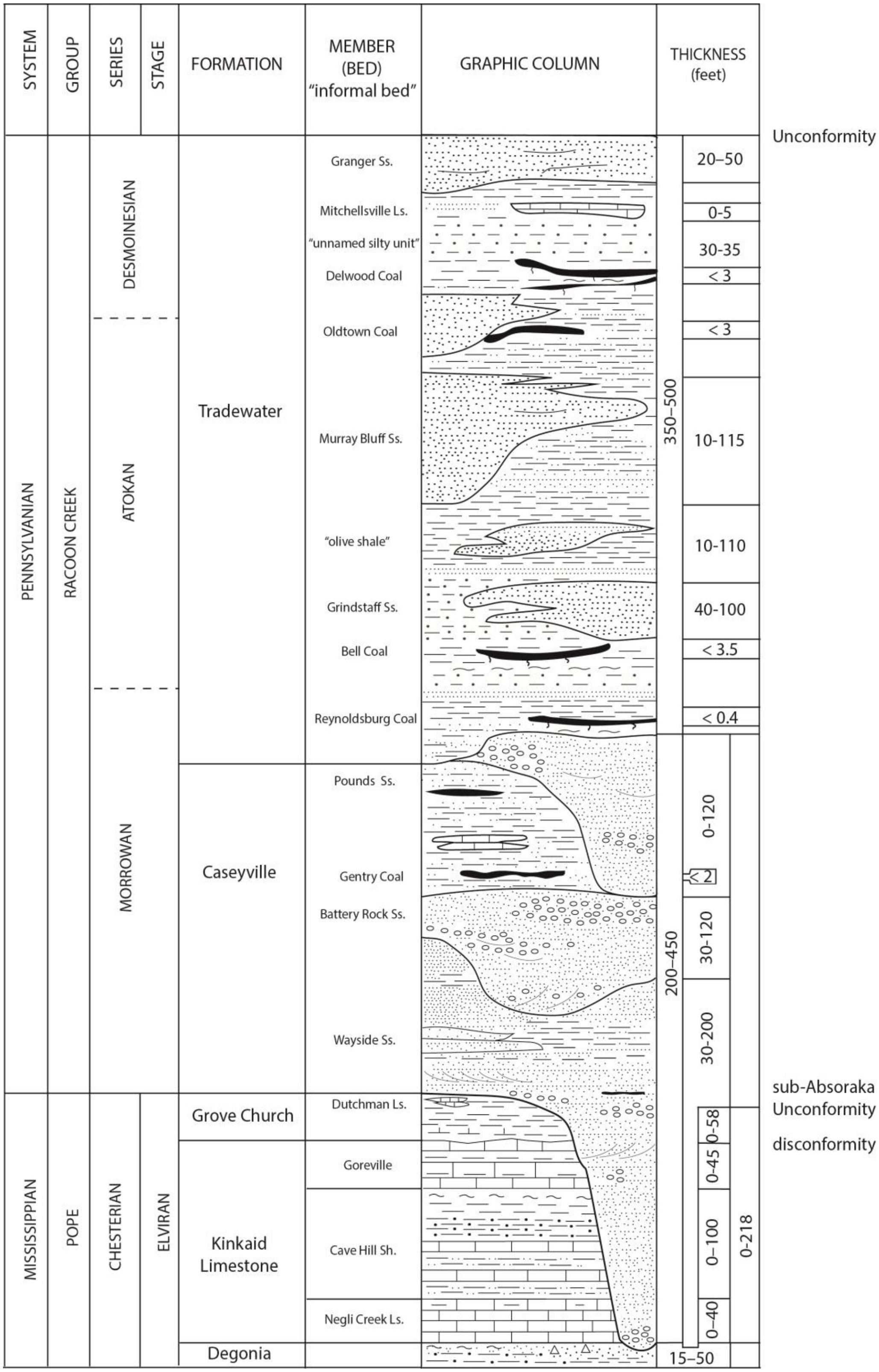

Fig. 6. Graphic column of the Pennsylvanian System in Pope County.

Wayside Member

Comprising all Caseyville strata below the Battery Rock Sandstone, the Wayside Member is largely fine-grained, thinly layered clastic rocks, but it includes thick, lenticular bodies of cliff-forming sandstone. Baxter et al. (1967) referred to these rocks as the Lusk Shale Member, a name that is no longer used because Wayside has priority. In Pope County, the Wayside Member ranges from about 30 to 200 feet thick, most of the variation reflecting the deeply channelized sub-Pennsylvanian surface. In the Waltersburg quadrangle, the Wayside is thicker in the Dixon Springs graben than it is outside the structure.

Medium to dark gray shale and siltstone and light gray, very fine to fine-grained, thin- to medium-bedded sandstone make up the bulk of the Wayside Member in most places. These rocks are interlaminated and interbedded in varying proportions. Ripple marks, tool marks, and small load structures are well developed. Also commonly seen is slumped and contorted lamination. Trace fossils identified in the Glendale quadrangle include *Calycraterion sp., Aulichnites sp., Teichichnus sp., Eiona sp., and Cochlichnus auguineus.* Also in the Glendale quadrangle, dark gray to black, sideritic shale near the base of the Wayside yielded gastropods and the trace fossils *Teichichnus sp.* and *Conostichus stouti* (Devera, 1989, 1991). Lentils of thick-bedded to massive sandstone in the Wayside range up to as much as 80 feet thick, but lateral continuity is less than a mile. Such sandstone tends to be fine-grained and contains only scattered quartz granules. Crossbedding tends to be less prominent in the Wayside than in younger parts of the Caseyville.

The Wayside commonly has a basal conglomerate composed of limestone and chert clasts, quartz pebbles, and silicified marine fossils in a sandstone matrix. Higher in the Wayside, occasional layers of coarse, intraformational conglomerate less than 3 feet thick are intercalated with fine-grained, thinly layered strata. Clasts of mudstone, siltstone, sandstone, and ironstone range up to small cobble size and float in a matrix of sandstone heavily impregnated with iron oxide (Nelson et al., 1991; Weibel et al., 1993). No coal has been reported from the Wayside in Pope County, although thin layers occur elsewhere in southern Illinois. Plant remains are present, but they are fragmentary.

Battery Rock Sandstone Member

Ranging from 30 to 120 feet thick, this member forms cliffs and steep ledges throughout its extent in Pope County. The bulk of the member is thick-bedded, conspicuously crossbedded, fine to coarse-grained quartz arenite that has a sugary texture caused by quartz overgrowths on the sand grains. Quartz pebbles are larger (commonly 1 inch across) and more numerous in the Battery Rock than in other Caseyville sandstone. Most of the crossbedding is wedge-planar and tabular-planar style, with foreset beds dipping to southwest, west, and northwest. The lower contact is erosive, whereas the upper contact is gradational into fine-grained, thinly layered quartz arenite. Casts of lycopod and calamite trunks occur here and there. Vertical burrows believed to be *Skolithos* were observed near the railroad close to the northern border of the Glendale quadrangle.

Unnamed shaly member (Formerly Drury Shale)

Separating the Battery Rock and Pounds Sandstone Members is an interval of shaly strata that formerly was called the Drury Shale Member. Use of the name "Drury" has been discontinued because new mapping in the area south of Carbondale, where the Drury Member was named, showed that this unit lies largely in the Tradewater Formation above the Caseyville (Nelson and Weibel, 1996).

The unnamed shaly member may be as thick as 120 feet in the Waltersburg quadrangle, but is locally absent in parts of Pope County because of erosion at the base of the Pounds Sandstone. As in the Wayside Member, the dominant lithologies are gray shale, siltstone, and very fine to fine-grained, thinly layered sandstone. Features of the fine clastics include planar, ripple, and cross lamination along with nondescript burrows and other trace fossils. Lenticular bodies of ledge-forming, thickly layered sandstone are less than 25 feet thick. Distinctive features include at least two thin coal beds and a significant body of dark shale that contains marine fossils.

The most persistent coal layer in the Caseyville of Pope County occurs 3 to 10 feet above the top of the Battery Rock Sandstone. Stratigraphic position and fossil spores analyzed by R.A. Peppers indicate that this is probably the same as the Gentry Coal Bed, as found in the Caseyville type section of Hardin County. In northwestern pope County, the Gentry Coal is as thick as 2.0 feet, and the seam was mined underground on a small scale. Only the upper few inches of the coal is bright-banded; the remainder is shaly. The coal rests on rooted mudstone and is topped by shale containing fossil plants.

A second coal seam as thick as 2.0 feet occurs near the top of the unnamed shale member on both sides of the Pope-Johnson County line in the Stonefort quadrangle. Palynology of this bed was distinctly different from that of the Gentry, according to R.A. Peppers.

Dark gray to black, partly calcareous shale containing thin bands and nodules of limestone and a suite of marine fossils overlies the Gentry Coal (or its position) in the southern Eddyville and northern Waltersburg quadrangles. Observed both in outcrops and in drill cores, the shale has yielded a fauna of goniatite and nautiloid cephalopods, gastropods, bivalves, brachiopods, and conodonts along with fossil spores (Devera et al., 1987). The fossiliferous shale in Pope County is at the same stratigraphic position as the Sellers Limestone Bed, a marine unit previously known from a single locality in Hardin County. Although some previous authors such as Wanless (1956) believed that the Sellers underlies the Gentry Coal, re-evaluated data show the marine shale overlies the coal and occurs in the lower part of an upward-coarsening clastic succession in both area (Fig. 6).

Pounds Sandstone Member

The Pounds Member, at the top of the Caseyville Formation, is a prominent cliff-and ledge-making unit lithologically similar to the Battery Rock Member. Thickness of the Pounds varies from zero at Williams Hill near the northeast corner of Pope County to roughly 120 feet on the escarpment near the northern border of the Glendale quadrangle. In most places, the Pounds is finer grained and contains fewer, smaller quartz pebbles than the Battery Rock. Large-scale wedge- and tabular-planar crossbedding is prominent. Fossils include casts of lycopod and calamite stems, and a few simple burrows and bivalve resting traces. The lower contact may be locally conformable but more typically it is erosive. Near the top, grain size becomes finer and bedding changes to thin and flaggy. The upper contact, to shaly strata at the base of the Tradewater Formation, thus tends to be gradational.

Tradewater Formation

The youngest Paleozoic bedrock in Pope County belongs to the Tradewater Formation. Classification of these rocks has changed over the years. Usage of “Tradewater Formation” dates back to Lee (1916, p. 19-29) and refers to the Tradewater River, which forms the border between Crittenden and Union Counties, Kentucky. As Lee described it, the Tradewater type section is in Kentucky directly opposite the Caseyville type section. In Illinois the Tradewater became a group comprising several cyclothemic formations (cf. J.M. Weller, 1940). Later, Kosanke et al. (1960) discarded the Tradewater in Illinois, erecting the new Abbott (older) and Spoon Formations. Baxter et al. (1967), Nelson and Lumm (1990a, 1990b), and Nelson et al. (1991) carried the Abbott and Spoon forward during mapping projects in Pope and adjoining counties. Finding the Abbott and Spoon difficult to differentiate in the field, Jacobson (1991, 1992) reverted to the Tradewater Formation, a move endorsed by other quadrangle mappers in southern Illinois and formally extended across the Illinois basin by Tri-State Committee (2001).

Numerous sandstone, limestone, and coal members and beds have been named in the Tradewater Formation (Fig. 6). Except in the uppermost part of the Tradewater, all of these are more or less lenticular and are difficult to identify and map across large areas. Because previous authors who mapped in Pope County designated these units inconsistently, none of them are shown on the county-wide map.

The Tradewater Formation is at the surface in much of northern Pope County, along with a rectangular strip in the Dixon Springs graben between the Lusk Creek and Raum fault zones. It erodes to a series of rounded escarpments and cuestas held up by resistant sandstone and separated by slope-forming shale and siltstone. The upper Tradewater being eroded throughout the county, nowhere is the complete thickness preserved. The greatest thickness is roughly 500 feet in a down-faulted segment of a syncline northeast of Delwood. This compares with approximate total formation thickness of 650 feet a short distance north in Saline County.

Outcrops of the Tradewater are predominantly sandstone, but the formation contains a substantial proportion of siltstone and shale, along with layers of non-fissile mudstone, lenticular coal, and one limestone member. The overall lithology is similar to that of the Caseyville, and because none of the beds or members are continuous, distinguishing the two formations can be difficult. Character of the sandstone is the most useful point of distinction. Sandstone of the Caseyville, like that of the Pope Group, is almost entirely quartz arenite; that is, 95% or more of the grains are quartz. Feldspar, mica, and other lithic fragments make up 5% or less of rock volume. Clay matrix is generally absent, and the sandstone has a sugary texture, sparkling in sunlight due to silica overgrowths on quartz grains. Although quartz pebbles are common, they are not diagnostic for the Caseyville because many Caseyville sandstones lack pebbles, whereas some sandstone in the lower Tradewater contains plentiful quartz pebbles and granules.

Feldspar, mica, other lithic grains, and interstitial clay (largely derived from weathering of feldspar) become increasingly prevalent upward through the Tradewater. Although some lower Tradewater sandstone is quartz arenite, sandstone of the middle and upper Tradewater is classified as sublitharenite or litharenite (Potter and Glass, 1958; Nelson, 1989). No useful field criteria have been developed, however, to distinguish shale and siltstone of the Tradewater from their counterparts in the Caseyville.

In Pope County, the top of the Caseyville has generally been mapped at the top of the Pounds Sandstone Member, which is the youngest sandstone that is consistently quartz arenite. Because the Pounds is not a continuously mappable sandstone body, its definition becomes somewhat circular. Undoubtedly, sandstone bodies of different ages have been mapped at the Caseyville-Tradewater contact in different areas of southern Illinois. Moreover, the Pounds is locally absent at localities such as Williams Hill, and the formation contact must be projected or interpolated (Baxter et al., 1967). Providing a partial check against gross error is palynology of coal, as determined by Russel A. Peppers of the ISGS during much of the quadrangle mapping program. The Gentry Coal Bed in the Caseyville and the Reynoldsburg and Bell Coal Beds in the Tradewater each contain distinct assemblages of fossil spores (Peppers, 1996).

Reynoldsburg Coal Bed

A discontinuous coal layer that lies 5 to 30 feet above the base of the Tradewater is identified with the Reynoldsburg Coal Bed, which formerly was mined on a small scale in southern Johnson County. The Reynoldsburg is a 5-inch layer of shaly coal about 10 feet above the base of the Tradewater near Bear Branch about a mile northeast of Eddyville. The coal also has been identified in several drill holes in northwestern Pope County. Younger than the Reynoldsburg is a thin coal bed that occurs 50 to 60 feet above the base of the Tradewater along Hunting Branch in Sections 27 and 28, T11S, R5E. Russel A. Peppers reported an abnormal spore assemblage, and one sample contained achritarchs, marine microfossils rarely found in coal. These observations suggest that the coal along Hunting Branch consists of transported plant material (Nelson et al., 1991).

Bell Coal Bed

The Bell Coal, identified as the Western Kentucky No. 1a coal, was named for Kentucky mines owned by Col. John Bell, who unsuccessfully ran for U.S. President against Abraham Lincoln in 1860. Lee (1916) considered the Bell to mark the base of the Tradewater Formation, but in Illinois the Bell occurs 40 to 80 feet above the top of the Pounds Sandstone, mapped as the Caseyville-Tradewater contact. Russel A. Peppers established presence of the Bell Coal in Pope and Johnson Counties, Illinois via palynology, but Nelson et al. (1991) referred to the unit as the Tunnel Hill Coal Bed. The correlation is considered secure, so “Bell” is used in preference to “Tunnel Hill” here. Tentatively identified with the Bell is a coal bed that lies 50 to 100 feet above the base of the Tradewater and crops out intermittently for 5 miles in the Dixon Springs graben, southeast of Eddyville. This bed had been mined in several small drifts and reportedly reached a thickness of 3.5 feet (Weibel et al., 1991, 1993).

Grindstaff Sandstone Member

Butts (1925) named the sandstone for Grindstaff Hollow, about 7 miles northeast of Herod in southern Gallatin County. Sandstone similar to the type Grindstaff occurs widely in southern Illinois, but it forms a series of elongate lentils that may not all be precisely the same age. Where well developed, the sandstone is white to light gray, fine- to medium-grained, well sorted, and contains scattered granules and small pebbles of quartz. Bedding is thick to massive; structures include large-scale crossbeddding and contorted lamination. In composition the Grindstaff is borderline quartz arenite, containing noticeably more mica and interstitial clay that Caseyville sandstone. The Grindstaff is well developed along the McCormick Anticline from north of Delwood westward to Ogden Branch, where it forms rounded bluffs that range from 40 to 100 feet high (Nelson et al., 1991).

In northeastern Pope and western Hardin County, Baxter et al. (1967) mapped a unit they called the Finnie Sandstone Member. Although reference to such a unit dates back to Owen (1856, No. 1 vertical column, “sandstone of Finnie Bluff”), no type section was ever described and descriptions of the Finnie sandstone are vague. Nelson et al. (1991) observed a series of sandstone lentils that grade laterally to shale and siltstone in the supposed interval of the Finnie. We conclude that the name “Finnie Sandstone Member” serves no useful purpose and should be abandoned.

Olive shale member (informal)

Above the Grindstaff Sandstone Member in northwestern Pope County is an interval of shaly strata 10 to 100 feet thick that Devera (1989) and Nelson et al. (1991) informally called the “Olive Shale member”. Composition varies from dark gray, sideritic, silt-free shale to medium and dark gray, silty shale interlaminated with siltstone and very fine-grained sandstone. Impure limestone and shale containing marine fossils occurs locally in the Olive Shale in outcrops along Blackman Creek in Section 34, T10S, R6E and in two drill cores. Possibly, the limestone is correlative with the Lead Creek Limestone, which is well developed along the eastern margin of the Illinois basin in southern Indiana and western Kentucky. Elsewhere, the Olive shale is commonly burrowed and contains a variety of trace fossils, including *Planolites, Lockeia, Cochlichnus, Zoophycos,* and *Conostichus,* which together suggest a variety of brackish-water to marginal marine environments (Devera, 1989).

Murray Bluff Sandstone Member

Named for a locality in northwestern Pope County (J.M. Weller, 1940), the Murray Bluff Sandstone is well developed north of the McCormick anticline and probably occurs elsewhere in Pope County, but its identity becomes less secure with distance from the type area. The sandstone ranges from less than 10 to at least 115 feet thick and erodes to rounded cliffs and ledges. Where it is thick, the sandstone is coarser grained and exhibits large-scale bedforms. Color is light to medium gray fresh, weathering yellowish brown to dark brown and commonly displaying Liesegang bands. Sand is fine to coarse-grained, moderately to poorly sorted, and contains scattered quartz granules and small pebbles in places. In hand specimens, Murray Bluff sandstone appears to be sublitharenite, containing noticeable mica, feldspar, lithic grains, and interstitial clay. Thick bodies of Murray Bluff Sandstone probably fill channels or valleys incised into the Olive shale member. The coarser, thickly bedded rock grades upward and laterally to fine-grained, thinly layered, shaly sandstone.

Oldtown Coal Bed

A coal bed that ranges up to 3 feet thick was formerly mined on a small scale at the northwestern corner of Pope County. Named the Oldtown Coal Bed (Nelson et al., 1991), this unit has been mapped about 2 miles near the Canadian National Railroad in Pope County and also occurs along the ridge north of Caney Branch several miles east. Based on fossil spores, Russel A. Peppers correlated the Oldtown with the Rock Island Coal of northwestern Illinois and the Minshall Coal of Indiana.

Delwood Coal Bed

The Delwood Coal is moderately widespread in northern Pope County and was mined on a small scale in several places. The type locality is southeast of Delwood in the NW¼ NW¼, Section 3, T11S, R6E, Pope County. Thickness is commonly 2 to 3½ feet, and reaches nearly 6 feet in a borehole in Johnson County. A claystone layer that ranges from 3 to 30 inches thick commonly occurs near the middle of the Delwood. Overlying the coal is a succession 30 to 35 feet thick, composed of dark gray shale that grades upward to siltstone and is topped by the Mitchellsville Limestone. In some places, however, the Granger Sandstone fills channels that truncate these strata.

Mitchellsville Limestone Bed

Nelson et al. (1991) gave the name Mitchellsville to a unit that was previously misidentified as the older Curlew Limestone. Correct placement of the Mitchellsville was established via outcrop mapping, core drilling, fusulinid study, and palynology of associated coal by R.A. Peppers. The Mitchellsville may occur in northernmost Pope County, although no outcrops have been observed here. To the north in Saline County, the limestone ranges from 1 to 5 feet thick and is generally micritic, containing scattered crinoid fragments, corals, brachiopods, and other marine fossils. Large nodules of chert are plentiful and weather to a porous residuum containing molds of fossils.

Granger Sandstone Member

The youngest Pennsylvanian bedrock in Pope County is sandstone that Nelson et al. (1991) informally called “Golden sandstone”, and is identified here with the Granger Sandstone Member. The Granger caps several hills in the northeastern part of T11S, R5E, where it is probably 20 to 50 feet thick. The sandstone is fine to coarse-grained, poorly sorted, and contains rare quartz granules. It tends to be friable and erodes to smooth, rounded ledges that weather golden brown to dark brown, commonly having thick crusts of iron oxide. It is litharenite to sublitharenite, containing plentiful mica, feldspar, carbonaceous grains, and clay matrix. The Granger fills channels or valleys that truncate the Mitchellsville Limestone and may cut out the Delwood Coal.

Permian System
Igneous Intrusive Rocks

Cisuralian to Guadalupian Series

Ultramafic igneous rocks occur widely in the Illinois-Kentucky Fluorspar District, but only two igneous bodies are mapped in Pope County. These are the Chamberlain diatreme (NW¼ SE¼, Section 19, T11S, R7E) and a smaller unnamed intrusion (SW ¼ NE ¼, Section 19, T11S, R7E), both in the Herod quadrangle (Baxter et al., 1967; Denny et al., 2008). A small igneous dike, named the Mix Dike was reported to occur in the NE¼, Section 18, T13S, R7E (Weller et al., 1920). Another dike named the Golconda Dike was reported to be present in the (NW¼ of Section 25, T13S, R7E) by Weller (1920). This particular dike was reported in the dump from a fluorite exploration pit. These igneous rocks typically weather easily and turn to clay in the oxidation zone. Additional dikes are undoubtedly present in Pope County.

These dark-colored rocks form dikes and sills and are composed of olivine (usually altered to serpentine), phlogopite, pyroxene, apatite, magnetite, sphene, chlorite, and calcite (Denny, Nelson, and Devera, 2008). Alteration makes classification difficult, but these rocks have been classified as mica peridotite, monticellite-alnöite (Sparlin and Lewis 1994), and lamprophyre (Johannsen, *in Bain* 1905). Diatremes and breccias are also present which incorporate clasts of country rock into their mass with fine grained igneous material between breccia clasts. Where the clasts are rounded most authors use the term diatreme to describe the intrusion.

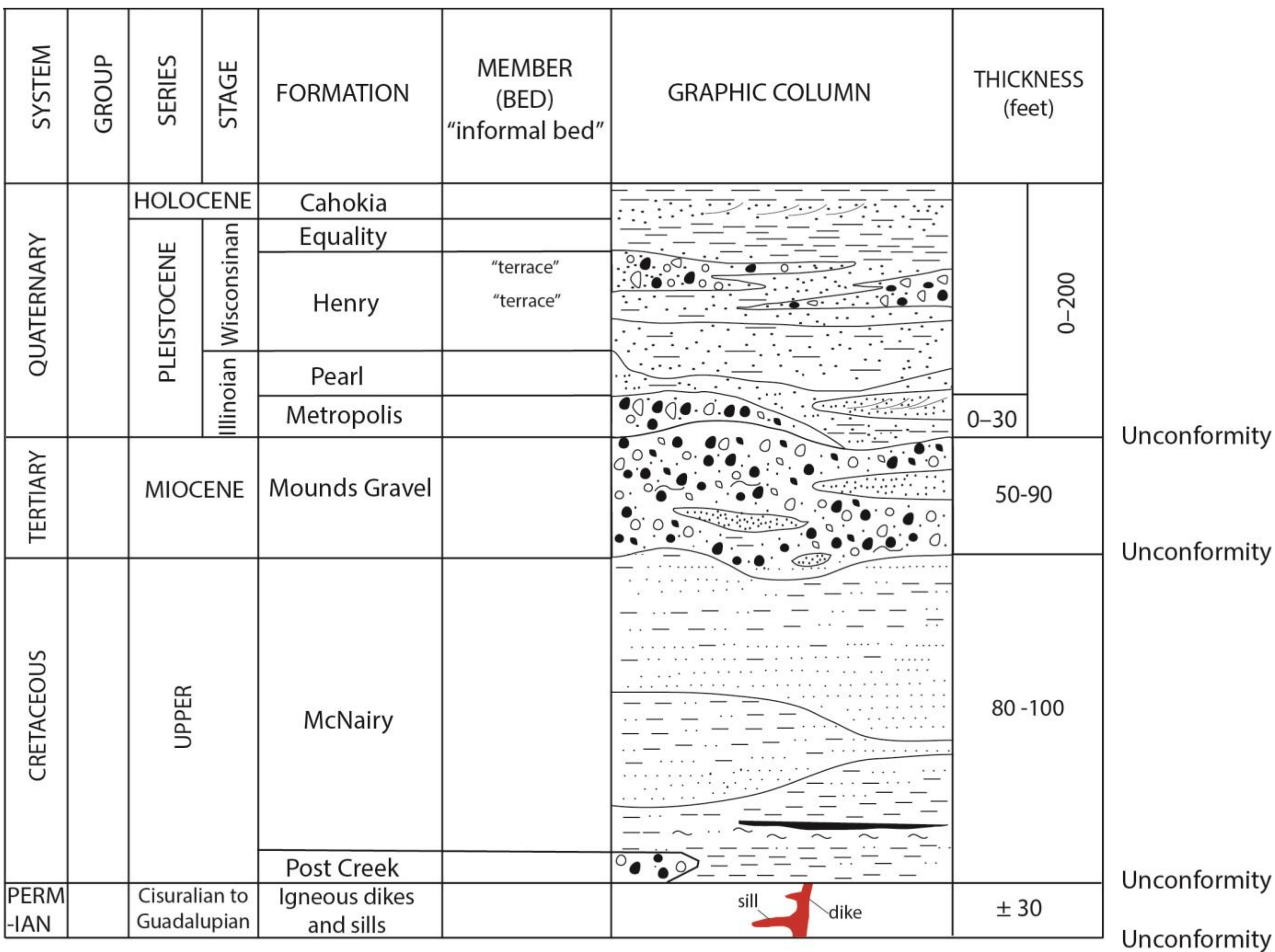

Fig. 7 Graphic column of the Permian, Cretaceous, Tertiary, and Quaternary Systems in Pope County.

Radiometric age dates have determined the igneous rocks were emplaced during the Permian. Goldhaber et al. (1997) recorded concordant $^{40}Ar/^{39}Ar$ plateau age dates in amphibole within the Downeys Bluff Sill in Hardin County, Illinois at 272.1 ± 0.7 Ma and age dates of 272.7 ± 0.7 Ma in phlogopite. These dates correspond well with ultramafic rocks analyzed in Saline, Gallatin, and Hardin Counties. These rocks were probably emplacement at the end of the Cisuralian to the beginning of the Guadalupian Series of the Permian System.

Several publications provide further information on intrusive rocks of the Illinois-Kentucky district, including Trace (1974), Trace and Amos (1984), Bradbury and Baxter (1992), Potter et al. (1995), and Denny and Seid (2014). The rocks are part of a large igneous uplift called the Kuttawa or Tolu Arch that uplifted southeastern Illinois and northwestern Kentucky. The apex of the Arch lies several miles to the east in Hardin County and the culmination of the uplifting event is present at Hicks Dome in Hardin County. The strata a Hicks Dome has been uplifted several thousand feet exposing Devonian age rocks at the center. Most geologists agree that the uplifting force was produced by Permian Age igneous activity which near Hicks Dome suggests an explosive phase. Fluorite and rare earth element mineralization is also associated with the igneous activity at Hicks Dome. The structural effects of the igneous activity in Pope County occur along the northeastern edge of the county. In this area concentric faults are present that encircle Hicks Dome. Only the western portion of the concentric faults are present in Pope County.

Cretaceous System

Upper Cretaceous

McNairy Formation

Overlying Mississippian rocks with profound unconformity south of the Cache Valley are largely unlithified sand, silt, clay, and gravel assigned to the Upper Cretaceous McNairy Formation (Fig. 7). The McNairy has been mapped in parts of the Smithland (Devera, 2013), Paducah Northeast (Denny and Nelson, 2005), Brownfield (Nelson and Denny, 2008) and Reevesville (Nelson, 1996) 7.5-minute quadrangles. Bedding of the McNairy lies close to horizontal, truncating tilted and faulted Mississippian rocks. The base of the McNairy drops gradually in elevation toward the southwest, reflecting regional structure of the Embayment. A drill hole in Section 16, T14S, R5E, Reevesville quadrangle, penetrated sediments believed to be McNairy underlying Quaternary alluvium near the border of the Cache Valley. These sediments may occupy a small down-faulted slice within the Hobbs Creek fault zone (Nelson, 1996). Because McNairy deposits are unlithified or weakly lithified, they erode to a gently rolling landscape, and outcrops are few. Most exposures are in stream banks or roadcuts. Borehole logs, mainly driller's logs of water wells, provide scanty lithologic information. Thickness of the McNairy reaches 200 feet on the Paducah Northeast quadrangle in Massac County, but maximum thickness within Pope County is close to 100 feet.

Sand of the McNairy may be white, gray, and yellowish brown, and in places it is stained bright shades of red, yellow, and orange. The sand is very fine to medium-grained, generally well sorted, and subangular to well rounded. Quartz is the primary constituent, but mica is abundant and conspicuous. The sand varies from laminated to thickly bedded and commonly contains laminae, beds, and lenses of silt and clay. Locally, the sand has been tightly cemented by silica and iron oxide. In the Paducah NE quadrangle, loose float blocks of well indurated sandstone containing fossil root casts were observed at several localities low in the McNairy. Silt and clay of the McNairy range from white to medium and dark gray, and generally are interlaminated with fine, micaceous sand. Gravel is found locally at or near the base of the formation. Small quartz pebbles, cobbles and pebbles of chert, and occasional pieces of petrified wood are present. At least some of this gravel may properly belong to the Post Creek Formation, as described by Harrison and Litwin (1997) based on exposures in Pulaski County, Illinois.

Aside from rare petrified wood, no fossils have been observed in the McNairy from Pope County. Age of the unit (Campanian or younger, Late Cretaceous) is based on fossils and lithologic relationships elsewhere in the Embayment.

Quaternary and Tertiary Systems

Miocene Series ?

Mounds Gravel

The only known representative of the Tertiary System in Pope County is the Mounds Gravel (**Fig. 7**). Named for the town of Mounds in Pulaski County, Illinois (Willman and Frye, 1970), the Mounds is part of a distinctive suite of gravel deposits that extend, under a variety of names, down the greater Mississippi Valley from Wisconsin to Louisiana.

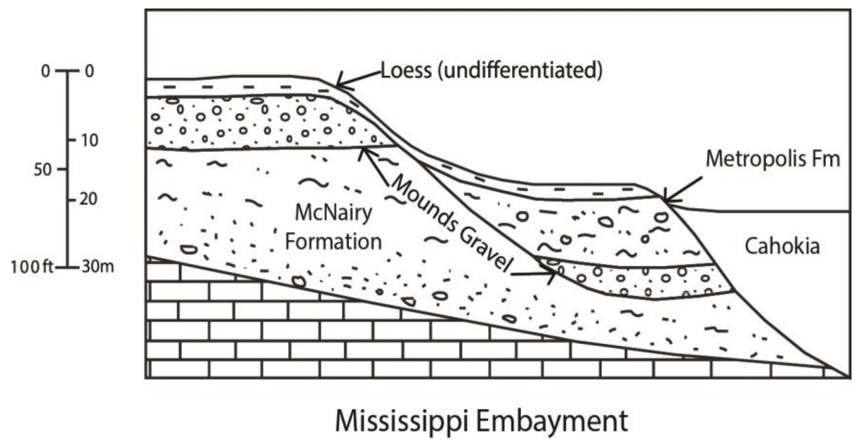

Figure 8. Relationship of the Mounds Gravel and the Metropolis Formation.

In Pope County, the Mounds is an upland deposit that unconformably overlies the Cretaceous McNairy Formation south of the Cache Valley (Fig. 8). Elevation of the base of the Mounds is between 500 and 540 feet in most of the county. The base of the Mounds rises to about 570 feet near the Cache Valley bluffs in the Brownfield quadrangle, and drops to 440-450 feet in the southern part of the Smithland quadrangle. Drilling indicates that the Mounds underlies the Metropolis Formation along a terrace bordering the Ohio River near the southern tip of the county. Also, the gravel has been faulted to lower elevation in grabens along the Barnes Creek fault zone in the Brownfield quadrangle (Nelson and Denny, 2008). Thickness of the Mounds reaches a maximum of about 90 feet in the Reevesville quadrangle. Although largely unlithified, the Mounds Gravel is more resistant to erosion than the McNairy Formation, so the Mounds tends to erode to steeper slopes. Exposures occur in roadcuts, gravel pits, and gullies. In many places, outcrops are lacking and the Mounds was mapped on the basis of float and water well records.

The Mounds is composed dominantly of chert gravel, with layers and lenses of sand. Subrounded to well rounded pebbles 1 to 3 inches across predominate, but occasional cobbles reach 6 inches. Diagnostic for the Mounds is a glossy bronze to yellowish brown patina on the pebbles. This is not mere surface polish, but a coating that permeates the outer rinds of the clasts. Intermixed with chert pebbles are small pebbles of quartz and occasional clasts of sedimentary rocks. The matrix consists of yellow to orange-brown and deep red sand and clay. Sand is fine to coarse, poorly sorted, subrounded to well rounded, and composed of quartz and chert grains with little or no mica. Mounds outcrops exhibit crude subhorizontal layering and crossbedding. The sand and gravel are largely unlithified, but the base of the deposit can be heavily cemented by iron oxide.

Aside from Paleozoic bioclasts within the chert clasts, fossils are rare in the Mounds. None have been reported from Pope County. Based on fossil pollen from two sites in Kentucky, age of the Mounds is loosely constrained as late Miocene(?) to early Pleistocene (Olive, 1980).

Quaternary System

This report is primarily concerned with bedrock geology of Pope County, because Quaternary sediments in the county have not been mapped or described systematically. The only published 1:24,000-scale maps that focus on the Quaternary sediments are those of Henderson et al. (1992) and Lannon et al. (1992), covering the Eddyville and Stonefort quadrangles, respectively. Descriptive text on Quaternary sediments in these quadrangles is in Nelson et al. (1991). LaBrecque (1999) completed a Master's thesis on Quaternary geology of the Brownfield quadrangle, but his geologic map lacks an explanation, making interpretation difficult. In the present report, we have elected to map only lowland or valley-filling Quaternary deposits. These are Quaternary terraces (Qt), and undifferentiated alluvial sediments (Qc) elsewhere in the county. The relatively thin Quaternary sediments that mantle upland areas are not shown on the geologic map.

Metropolis Formation

Nelson et al. (1999) gave the name Metropolis Formation to weakly stratified, poorly sorted deposits of silt, sand, and gravel that underlie terraces along the Ohio River west of Metropolis, Massac County. Denny and Nelson (2005) mapped the Metropolis Formation in the Paducah Northeast Quadrangle, whereas Devera (2013) mapped the same sediments as "terrace deposits, undifferentiated" in the Smithland quadrangle. Because the two units match at the quadrangle border, the terrace deposits in the Smithland quadrangle, southern Pope County, are probably equivalent to the Metropolis Formation. On the geologic map that accompanies this report we mapped the terrace along the Ohio River near Hamletsburg as the Metropolis Formation. It is possible that this terrace is a Wisconsinan Pleistocene terrace as suggested by Ross (1964). More data is needed to resolve the two different interpretations and to determine the age of the terrace along the Ohio River near Hamletsburg.

The Metropolis Formation forms a low terrace that rises above the Holocene floodplain of the Ohio River at elevations of approximately 350 to 400 feet. The terrace surrounds the hills west of Hamletsburg and borders the southeast side of the ridge southeast of Alcorn Creek. As in its type area of Massac County, the Metropolis is composed of silty sand and sandy silt with lenses of gravel. Colors are strongly mottled in shades of yellow, gray, brown, and red. The Metropolis is indistinctly stratified, showing in places large-scale inclined layering believed to reflect lateral accretion of point bars in small meandering streams. Gravel in the Metropolis resembles that of the Mounds except that the bronze patina has been partially abraded and bleached, signifying that the gravel was reworked from the Mounds. Multiple soil horizons are present, and the upper part of the Metropolis is strongly burrowed. Based on limited information, thickness of the Metropolis is 30 feet or less.

The Metropolis Formation is interpreted as fluvial sediments that accumulated in the Tennessee River Valley before the Ohio River shifted from the Cache Valley to its present course.

Pleistocene Series
Cache Valley sediments

A striking feature of southern Pope County is the 2-mile-wide, flat-bottomed Cache Valley (Fig. 1). As many geologists deduced, this is a former course of the Ohio River (J.M. Weller, 1940; Fisk, 1944; Alexander and Prior, 1968; Masters and Reinertsen, 1987; Esling et al., 1989). From its junction with the Ohio southeast of Homberg, the Cache Valley winds westward across Pope, northern Massac and Pulaski Counties into Alexander County, where it turns southward and joins the Mississippi Valley.

Small sluggish streams, Bay Creek on the east and the Cache River on the west, presently flow through the valley. Until the 20th century, the Cache Valley was largely swampland, and the Ohio River overflowed through it during floods. Levees and drainage ditches then were installed to facilitate agriculture.

Little information has been published about Cache Valley sediments within Pope County, but quadrangle maps farther west are informative (Nelson, Follmer, and Masters, 1999; Nelson and Hintz, 2007). In profile, the valley has a flat bottom and steep sides. The bedrock floor, 150 to 200 feet below the land surface, is at lower elevation than the bedrock floor of the modern Ohio River at Metropolis. Filling the valley is dominantly sand and gravel, in a series of upward-fining sequences. These deposits belong to the older Pearl Formation (Illinoian) and the younger Henry Formation (Wisconsinan) (Fig. 9). At the surface, arcuate sandy ridges represent fluvial point bars and mid-channel bars. Intervening swales contain organic-rich silt and clay, which accumulated as the Ohio River abandoned the Cache Valley. Side valleys off the Cache contain thick deposits of clay, silt, and minor sand and gravel of the Wisconsinan Equality Formation. The Parkland Sand, a unit of wind-blown Wisconsinan and Holocene sand, forms ridges in the Cache Valley near Homberg. Thickness is as great as 41 feet, according to LaBrecque (1999).

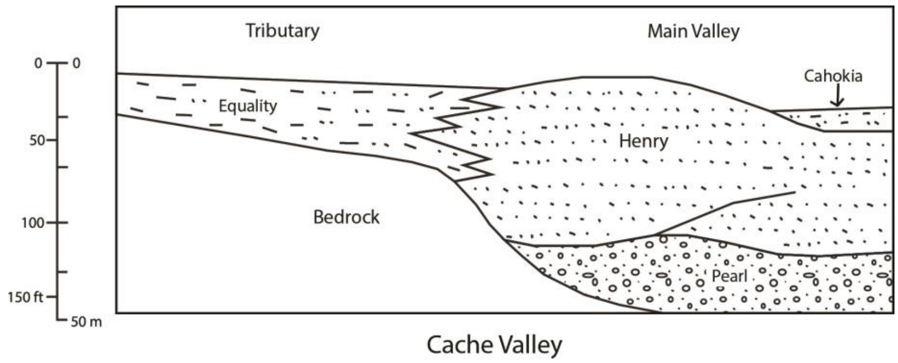

Figure 9. Relationship of the Peal, Henry, and Equality Formations in the Cache River Valley.

The Cache Valley may have been carved by an ancestral Tennessee or Wabash River as long ago as the Miocene (Nelson and Hintz, 2007). At this time, the ancestral Ohio River flowed far to the north through the Teays-Mahomet Valley (Melhorn and Kempton, 1991). Pleistocene glaciation buried the Teays-Mahomet Valley and forced the Ohio River into a southern course. The Cache Valley accommodated torrents of glacial meltwater, which rapidly filled the valley with sediments. By late Wisconsinan time, roughly 8,000 to 25,000 years ago, the lower Ohio gradually shifted out of the Cache Valley and into its present course (Esling et al., 1989).

Upland Deposits

The Pleistocene continental glaciers apparently never entered Pope County, attaining their southern limit a short distance north in Saline County (Willlman and Frye, 1980). However, these glaciers left their imprint in upland areas of Pope County as well as in the Cache Valley.

Loess, residuum, and colluvium cover upland areas of Pope County. Loess is predominantly massive silt that was deposited by the wind during interglacial stages of the Pleistocene. Three loess units have been identified in northern Pope County and occur regionally in southern Illinois. Oldest is the Loveland Silt, which is 1 to 4 feet thick and composed of yellowish to reddish brown, strongly mottled, silt loam and silty clay loam. The Loveland is Illinoian age and the Sangamon Soil is developed within it. The overlying Roxana Silt, of mid Wisconsinan age, is 1 to 6 feet of silt loam that is medium to dark yellowish brown with a distinct reddish hue. The Farmdale soil is developed in the upper Roxana. Capping the loess succession is the late Wisconsinan Peoria Silt, which is 1 to 4 feet thick and lighter colored than the Roxana (Nelson et al., 1991). Residuum simply consists of bedrock that has weathered in place. It is relatively thin over sandstone, thicker and clay-rich above shale, and can be thickest overlying limestone, being stiff red clay (terra rosa) commonly containing chunks of chert.

Colluvium refers to residuum that has crept down hillsides and become intermixed with loess (Fig. 10).

Holocene Series

Alluvium is found along all streams in Pope County. It is largely of Holocene age, and assigned to the Cahokia Formation (Willman and Frye, 1970). Older alluvial sediments underlie Cahokia along some of the larger streams. Silt and clay of the Equality Formation underlies Holocene alluvium along Little Saline River near the northwestern corner of Pope County (Lannon et al., 1992).

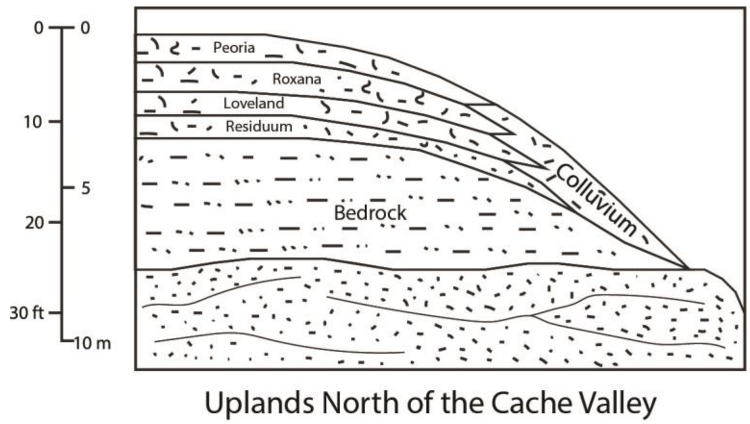

Figure 10. Succession of Loess in the cache Valley.

DEPOSITIONAL ENVIRONMENTS OF THE CHESTERIAN SERIES

Genevievian Stage

The Genevievan Stage is the oldest stage of the Chesterian Series (Swann, 1963). It includes the Ste. Genevieve Limestone at the base, the Aux Vases Sandstone in the mid-portion and the Levias Member of the Renault Limestone at the top (Fig. 11). As originally defined, the Genevievian Stage was the upper stage of the Valmeyeran Series, older stages not being named. Maples and Waters (1987) shifted the Valmeyeran-Chesterian boundary downward, transferring the Genevievian to the Chesterian Series. Lithologically, the Ste. Genevieve Limestone is more closely allied with the lower half of the Chesterian Series stages: Gasperian and Hombergian by having oolites, pink and red stained pelmatozoans, light green shales and clean quartz sand. However, the real basis for the Genevievian Stage is biostratigraphic and not lithologic. Based on the appearance of the foraminifera *Neoarchaediscus* and *Asteroarchaediscus* the Ste. Genevieve differs significantly from the St. Louis Limestone below (Armstrong and Mamet, 1977; Baxter and Brenckle, 1982; Maples and Waters, 1987). Also conodonts and corals show clear biostratigraphic boundaries at the base of the Genevievian Stage (Maples and Waters, 1987). The upper boundary of the Genevievian Stage is the last occurrence of *Platycrinites penicillus* in Genevievian strata (Levias Member of the Renault).

Facies deposited during the Genevievian Stage include: 1) cross-bedded, oolitic/skeletal grainstone shoals that were deposited on a shallow carbonate platform or ramp, 2) finer grained, inter-shoal fossil wackestones, 3) pelletal wackestone and fossil packstones, 4) lime-mudstones and 5) a boundstone facies composed of bryozoans and algal mud mounds are also present. Lesser amounts of calcareous cemented quartz arenite occurs in the upper part of the Ste. Genevieve Limestone along with light green shales and silts. The finer grained carbonate rocks show diagenetic alteration to sucrosic dolostone. In the study area, environments of the Ste. Genevieve Limestone appear to be subtidal, oolitic dominated mega-ripples or wave ripples on a shallow shelf. Interspersed with oolitic facies are quartz sand grains with quartz-rich tempestite beds (Spar Mountain Sandstone Member).

The Aux Vases Formation in Pope County interfingers and overlies the Ste. Genevieve Limestone and is sharply conformable to gradational at the base. It is cemented by calcite and represents sub-tidal sheets and lenses of sand redistributed off of tidal bars and long-shore current bars from up-ramp to the north and northwest. The earliest deposition of the Aux Vases is named the Spar Mountain Member within the Ste. Genevieve (Swann, 1963). The Spar Mountain Sandstone Member of the Ste. Genevieve Limestone represents the earliest deposition of sandstone in Chesterian rocks of the Illinois basin. Thin and discontinuous in Pope County, the Spar Mountain thickens toward the northwest and fills incised valleys. The Transcontinental arch, northwest of the Illinois basin, was the primary source of sand (Leetaru, 2000; Nelson et al., 2002).

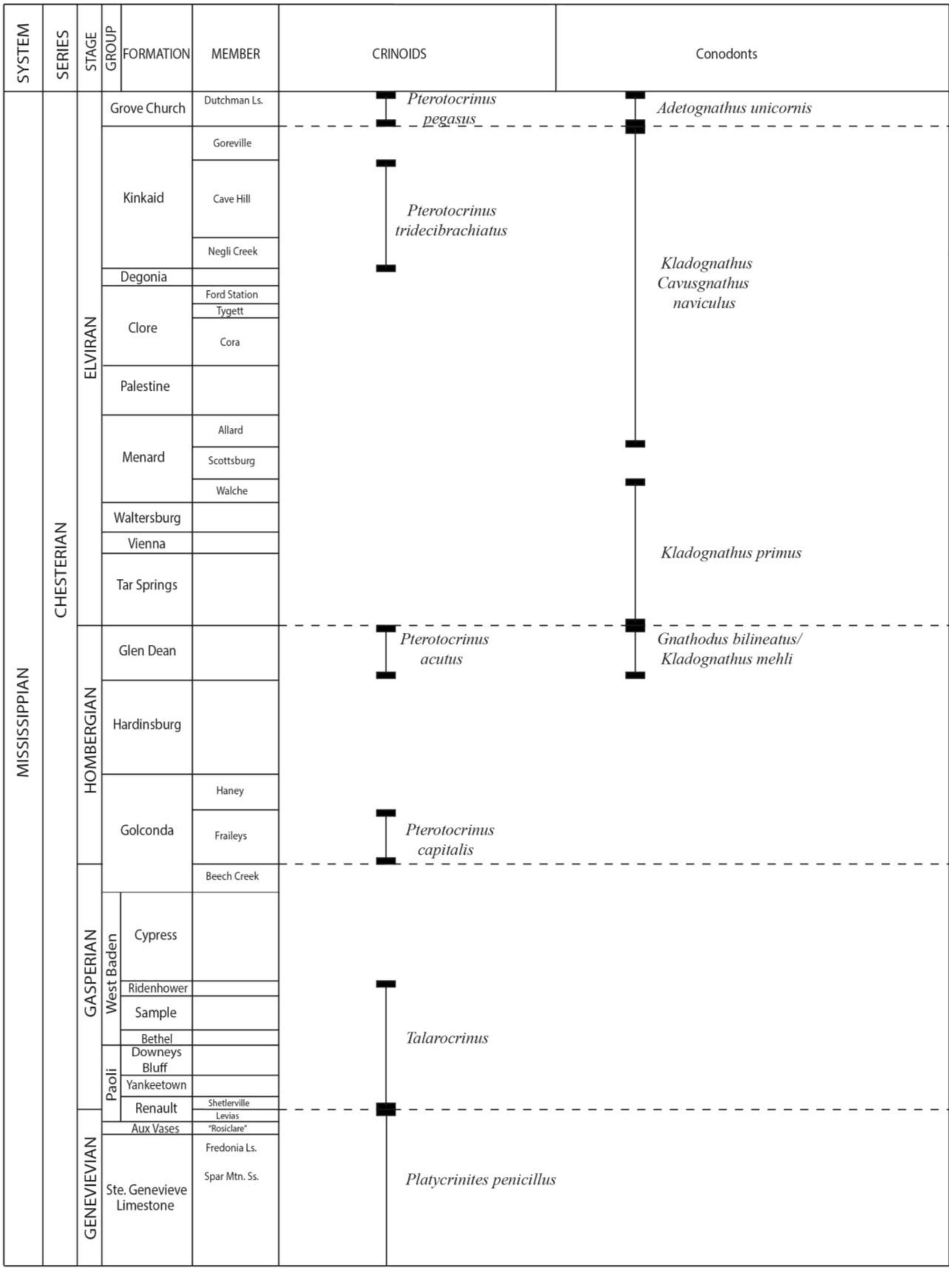

Fig. 11. Range of crinoids and conodonts within the Chesterian Series in Pope County

The top of the Genevievian Stage is represented by the Levias Bed of the Renault Limestone Member. Depositional setting is similar to Ste. Genevieve Limestone: cross bedded oolites some pink ooids with minor amounts of green shale. A few scattered crinoid columnals of *Platycrinites penicillus* show the diagnostic red and pink stain. Outcrops are rare in Pope County but an abandoned quarry a quarter mile south of Shetlerville, Illinois yields excellent exposures. The diagnostic red stains on fossil grains are suggestive of intertidal intervals where the sediment was oxidized. The Levias is disconformable with the overlying Shetlerville Bed of the Renault. Locally this interface is marked by breccia and other evidence of subaerial exposure, the Levias-Shetlerville contact has been interpreted as a sequence boundary (nelson et al., 2002).

Gasperian Stage

The Gasperian Stage consists of rocks from the base of the Shetlerville Bed of the Renault Limestone to the top of the Beech Creek Limestone Member of the Golconda Formation (Fig. 11). This stage is predominantly siliclastic: about two-thirds of the stage is composed of sandstones, siltstones and shale. The bottom of the Gasperian Stage is defined by the first appearance of the crinoid genus *Talarocrinus* (Weller, 1926). The top of the stage is defined by the first appearance of the crinoid *Pterotocrinus capitalis* in beds just above the Beech Creek Limestone in the Fraileys Shale Member of the Golconda Formation, which forms the base of the overlying Hombergian Stage. No *P. capitalis* has been observed in the Beech Creek. Another index fossil for the Gasperian Stage is the bryozoan *Cystodictia labiosa* which ranges from the base of the Shetlerville Member to the top of the Ridenhower Formation. This stage is weakly defined near the top because out of the nearly 300 feet of section in the stage 200 feet is sandstone. The last appearance of *Talarocrinus* is in the Ridenhower Formation. The Beech Creek Limestone is thin and extensive and therefore a good physical marker bed.

The environmental setting during Shetlerville deposition varies across Pope County. Exposures in the southern part of the county suggest higher energy shoaling environments that change upward into muddy, tidaly influenced lagoonal conditions some having poorly circulated to stagnant areas. Whereas, the northern part of the county yields a local inter-shoal low area between shoals. The overall depositional pattern during Shetlerville is one of a shallowing up with lateral migration north of oolitic sand waves. Conditions continue to shallow (Yankeetown) with thinner complex facies composed of dark gray to greenish gray terrigenous muds with interspersed skeletal and oolitic beds. Some of these beds are storm deposited on a shallow platform. At the end of Yankeetown deposition in Pope County red and green claystone is interpreted as the development of a paleosol.

Sea level rises with Downeys Bluff deposition. Oolitic and skeletal facies that formed on near-shore shoals with wind-blown rounded quartz grains derived from landward dust storms (Nelson et al. (2002). The shallow near shore nature of Downeys Bluff is also seen by the appearance of oxidized pink, red and rusty orange staining of pelmatozoan skeletal grains. These pink bioclasts are typically replaced by chalcedony. Appearance of red and green variegated claystone in the upper Downeys Bluff implies shoaling to intertidal conditions. A disconformity marks the top of the Downeys Bluff.

West Baden clastic belt

In view of regional investigations, it is clear that complexities of the West Baden Sandstone have not been fully resolved in Pope County. These complexities were studied earlier in Indiana, where Sullivan (1972) recognized the West Baden clastic belt resulted from "stacking" of the Cypress, Sample, and Bethel Sandstones and local elimination of the intervening shale-limestone formations. In linear fashion, the clastic belt trends south-southwest in Indiana and tracks directly through Pope County. Coincidence of the clastic belt here with the Dixon Springs graben implies an element of structural control.

Three depositional sequences are recognized in the West Baden interval (Nelson et al., 2002). The oldest contains the Bethel Sandstone, Beaver Bend Limestone, and older parts of the Ridenhower and Sample Formations. Within the middle sequence are valley-filling sandstones of the Sample (as observed in the Brownfield area of Pope County) along with the Reelsville Limestone and older parts of the Cypress Formation. The upper sequence comprises the remainder of the Cypress, where the thick lower sandstone fills valleys, along with part or all of the shaly upper portion of the Cypress.

Calcite cement, marine bioclasts, and bidirectional cross lamination point to shallow marine deposition of much of the Bethel Sandstone. In places, the sandstone grades upward to sandy limestone. The Bethel commonly occurs as a series of coalesced convex-upward sand bodies, which likely were shaped by tidal currents (Nelson et al., 2002).

The thick Sample Sandstone of eastern Pope County fills valleys deeply incised into Ridenhower and Bethel strata. The lower part of the Sample is likely a fluvial deposit, as evidenced by crossbedding that dips west-southwest, roughly parallel with the larger clastic belt. Upward the Sample transitions to marine shale and limestone of the Ridenhower, a change that suggests the gradual flooding of an estuary during transgression. Limestone overlying the Sample Sandstone would be the Reelsville Limestone of Indiana. The older Beaver Bend Limestone has not been identified in Pope County and probably was eroded beneath the Sample.

Comprising the upper of three depositional sequences, the Cypress Formation records another episode of valley cutting during regression and backfilling during transgression. In Pope County, the lower bluff-forming sandstone may include both fluvial and tidally influenced, estuarine facies. Regionally, Cole and Nelson (1995) divided upper Cypress strata into (1) a lower regressive portion containing thin coal, rooted zones, fossil plants, and paleosols, and (2) an upper transgressive portion having lenticular sandstone bodies that have marine trace and body fossils. These distinctions have not been clearly distinguished by quadrangle mapping in Pope County, although elements of both facies have been observed.

The Beech Creek Limestone marks the top of the Gasperian Stage. It probably represents a flooding surface over the West Baden siliciclastics. This is seen as reworked quartz sand within the limestone as sea level rose.

Hombergian Stage

This stage takes its name from Homberg, Pope County, Illinois (Swann, 1963). The Hombergian Stage is composed of rocks from the bottom of the Fraileys Shale to the top of the Glen Dean Limestone. The base of this stage is defined by the crinoid *Pterotocrinus capitalis,* a fossil zone proposed by Horowitz and Strimple, (1974). Mainly found only as wing plates, this fossil is common in the Fraileys Member of the Golconda Formation in Pope County. The upper part of the Hombergian Stage is defined by the conodont zones *Gnathodus bilineatus* and *Kladognathus mehli* (Rexroad and Scott, 1964, Collinson et al. 1971). Another biozone that terminates at the top of the Glen Dean Limestone is the *Pterotocrinus acutus* Zone (Horowitz and Strimple, 1974). The Hombergian Stage is highly fossiliferous. Lengthy fossil lists have been assembled from limestones and fossiliferous shales however, most of the invertebrate fossils found in this stage are long-ranging species that track paleoenvironments through-out the Chesterian Series (Fig 11).

The basal Fraileys Shale represents a high-stand event, deeper water over the Beech Creek Limestone. Many of the fossil lenses in the Fraileys yield a taphonomy that depicts disarticulation and transport into deeper water settings. At the Marina at Golconda, Illinois these shaly limestone lenses show disarticulated pavements of pelmatozoan debris, blastoid heads, fenestrate bryozoan debris and brachiopods but most important are the bulbous wing plates of *Pterotocrinus capitalis.* The Fraileys shallows upward to a wide-spread red paleosol.

The upper depositional sequence takes in the fossiliferous limestone and shale of the uppermost Fraileys, all of the Haney Member, and the lower part of the Hardinsburg Formation. The fossiliferous limestone and shale of the uppermost Fraileys, as observed in Pope County, has been called the Indian Springs Member in Indiana. It marks marine transgression at the start of the upper sequence. The overall transition from lower micritic limestone to upper packstone and grainstone signifies a regression during Haney deposition. In the upper interbedded shales of the Haney Member in the Mermet Quadrangle numerous large walnut-sized *Pentremites* sp. occur just below the Hardinsburg Sandstone (Devera and Nelson, 1998). Although not observed in Pope County, intertidal and supratidal carbonates and variegated mudstone (paleosol) has been observed elsewhere at the top of the Haney (Nelson et al., 2002).

The Hardinsburg Sandstone marks another low stand event, during which channels incised into underlying shales and the Haney Member of the Golconda Formation in places. The sandstone is dominantly composed of fluvial point bar sequences. As the effects of sea level rise returns the Hardinsburg deposition turns to tidally influenced estuarine to tidal flats, capped by coastal swamps that supported calamite and lycopod vegetation.

Sea level rise ushered in the Glen Dean Limestone and a sharp contact with the underlying unit. The basal limestone is a disarticulated pelmatozoan-bryozoan packstone transported from shallower ramp environments along with lime mud. The brown lime mud having abundant echinoderm fragments with their epitaxial cement gives the lower Glen Dean Limestone a crystalline appearance. The middle-portion of this unit is a dark gray calcareous shale with fossiliferous layers some containing the wing plates of *Pterotocrinus acutus* an important crinoid index fossil in the Glen Dean. The upper limestone depicts a shallowing cycle from brown gray lime mudstones to light gray oolitic fossil packstones and grainstones. Widespread shallow platform carbonates return with oolite shoals and carbonate sand waves at the close of the Hombergian Stage.

Elviran Stage

The Elviran Stage includes all rocks younger than the Glen Dean Limestone up to the top of the Grove Church Shale. It is the youngest stage of the Chesterian Series. Lithologically, all the carbonate rock of this stage are dominated by dark, argillaceous, lime mudstones. Biostratigraphically, the base of the Elviran Stage is defined by the first appearance of the conodont *Kladognathus primus* (Rexroad and Scott, 1964). There is also a diagnostic foraminiferal break at the Glen Dean/Tar Springs boundary (Baxter, Browne and Roberts, 1979). The most useful index fossil for the Menard and Clore is the crinoid *Pterotocrinus menardensis* (Devera, 2016). Other useful crinoids are *Pterotocrinus tridecibrachiatus* for the Kinkaid Limestone and *Pterotocrinus pegasus* limited to the Grove Church Shale. The top of the Elviran Stage is defined by the last occurrence of the conodont *Adetognathus*

The Elviran Stage in Pope County contains seven marine flooding surfaces, which occur at the bases of the: 1) Vienna Limestone, 2) Walche Member of the Menard Limestone, 3) Cora Member of the Clore Formation, 4) Ford Station Member of the Clore Formation, 5) Negli Creek Member of the Kinkaid Limestone, 6) Goreville Member of the Kinkaid Limestone and 7) the Grove Church Shale floods a documented unconformity. In most cases these are well developed parasequences with a fluvial scour base, estuarine to tidal influence an exposure or low stand with coal or red bed paleosol development followed by a marine flooding.

The Tar Springs Sandstone shows local scour with fluvial incision and point bar development in the lower part and a second sandstone can be seen in the Canadian National Railroad cut (old Illinois Central) in the Glendale Quadrangle just west of the Pope-Johnson County line. The second middle sandstone contains a shale layer with a thin coal bed. A third discontinuous sandstone is interpreted a tidal channel that laterally grades into a siltstone and shale. It forms elongate sandstone channels that parallel the Lusk Creek fault zone just a few miles to the southeast.

The first flooding surface includes the dark calcareous shales of the Vienna Limestone. The limestone is a brown-gray pelmatozoan-fenestrate bryozoan packstones to wackestones with thin dark gray shale partings. Much like the basal Glen Dean however no shallowing-up cycle was observed in the Vienna. *Sulcatopinna missouriensis* a bivalve occurs in the Vienna, which is common to all the muddy Elviran limestones.

The Waltersburg Sandstone is dominated by terrigenous mud but locally contains fluvial channel facies. At the base the Waltersburg a calcareous mud facies is present that grades into a carbonaceous mud facies, which is scoured out in places by a fluvial channel facies. Lateral to and overlying the elongate southwest trending cross bedded sandstone bodies are over bank muds with plant fossils. A coal thickens to over one foot in the area of Lake Glendale and was used by the local residents.

The second flooding surface enters the basin with dark fossiliferous muds and the Walche Member of the Menard Limestone. The initial carbonate unit has disarticulated pelmatozoan columnals in a clay-rich lime mudstone. Mud (shale) overlies the Walche Member that contains *Pterotocrinus* wing plates that are non-diagnostic long ranging species. The middle limestone (Scottsburg) is composed of dense lagoonal lime muds with laminated desiccation mud flat facies that may have cyanobacteria origins. Muds are interbedded with the middle limestone are known to contain *Pterotocrinus menardensis.* The middle shale member between the Scottsburg and Allard can have local paleosol development, however it is restricted and not basin wide. The upper limestone (Allard) is an argillaceous lime mudstone to packstone containing abundant invertebrate fauna typical of all of the Elviran limestones. Typical fossils include: the brachiopods, *Anthracospirifer increbescens, Composita subquadrata, Punctospirifer transverus, Diaphragmus nivosus, Diaphragmus fasciculatus, Orthotestes kaskaskia*, the bivalve *Sulcatopinna missouriensis* which can be abundant in places in life position, the blastoid *Pentremites* sp., the bryozoans *Rhombopora* sp., *Archimedes* sp., the crinoids *Agassizocrinus* sp., *Pterotocrinus menardensis* along with other species of the winged crinoid and rugose corals. The top of the Menard Limestone is a dark mud with thin lenticular fossil wackestones that can be locally cut out by the overlying sandstone.

The Palestine Sandstone like all of the aforementioned sandstones, exhibit u-shaped scoured bases infilled with stacked point bar sequences with lateral overbank muds. Upward-shoaling, laminated tidal flat environments have been documented (Devera, 1991). The top of the cycle is capped with a 19-inch thick rooted coal in the Glendale Quadrangle.

The third flooding surface is the Cora Member of the Clore Formation. The Cora Member consists of shallow lagoonal muds having tempestite winnowed, brachiopod pavement layers composed of spiny productid brachiopods and spiriferid brachiopods. The Cora is thickest (70 feet) on the western side of Pope County. It is interrupted by dominantly tidal flat deposits of the Tygett Member of the Clore.

The Tygett Sandstone is typically seen as a laminated tidal sand flat however, three conduits i.e. channels were discovered during the mapping of the Glendale, Waltersburg and Reevesville Quadrangles. So, local scour also occurs at the base of the Tygett. Stigmarian root casts and the horseshoe-shaped marine trace fossil *Rhizocorallium* are conspicuous near the tops of sandstone bodies, implying upward shoaling. Three pulses of sand are observed in the Tygett Member before the fourth flooding surface enters.

The Ford Station Member overtakes the Tygett with a dark subtidal lagoon lime mud. Fossil invertebrates are the same as for the Menard. “Birds-eye” structures indicative of gas escape from shallow organic-rich lagoons were found near the top of the Ford Station (Abegg, 1986).

The Degonia Formation differs from other Elviran siliciclastics of Pope County in that no scouring is observed. It represents shallow subtidal to intertidal flat deposits. No fluvial sandstones are known from this interval in Pope County. The basal chert was probably a calcareous ripple-laminated subtidal silt to fine sand. Above the chert is a gray silty shale that contains triangular-shaped bivalves called *Phestia* cf. *stevnsiana,* other bivalves include: *Dunbarella, Aviculopecten* and *Myalina elongata*. The straight cephalopod Orthoceras sp., and the brachiopod Lingula sp., were also found in the shale. The mid-portion of the Degonia is composed of stacked ripple-laminated sheets. This flaggy section yielded a rhizodont scale on Copperous Creek, in the Waltersburg Quadrangle during the fall mapping season of 2015. Rhizodonts were eight-feet-long lobed-fined fish previously unknown from Illinois. Similar large scales are known from the upper Mississippian deposits of Bear Gulch in Montana and Canada. These fish inhabited shallow muddy subtidal to intertidal environments. Lobe-fined fish had strong bones and muscles in the upper portion of the body. This enabled the fish to crawl on the tidal flat to ambush smaller tetropods or fish. At the top of this unit environments shallow to a well-developed paleosol seen as a red claystone.

The fifth marine flooding event of the Elviran is the Negli Creek Limestone Member of the Kinkaid Limestone. Muddy limestones containing a regionally consistent pattern of a specific faunal epibole can be observed in the lower Negli Creek. This epibole includes 1) large planispiraled gastropods of genus *Bellerophon*, (2) the shallow water demosponge *Chaetetella,* which occurs in subglobular masses, and (3) oncoids of the filamentous cyanobacterium *Girvanella.* This important faunal epibole can usually be traced across the entire basin in the basal Negli Creek.The parasequence shallows to red beds (paleosol) in the upper part of the Cave Hill Member of the Kinkaid Limestone. West of the study area in Johnson County the oldest known microsaurs have been associated with this red bed (Lombard and Bolt, 1999).

The sixth marine flooding surface is the Goreville Member of the Kinkaid Limestone. The Goreville Member is a shallow platform carbonate with some of the clearest water grainstones in the Elviran Stage. This member is unique to the typical muddy water settings of this stage, although wackestones and packstones do occur in the Goreville.

A disconformity between the Goreville Member of the Kinkaid and the Grove Church Shale marks the last cycle of the Mississippian Period. A small period of erosion or non-deposition occurred before the deposition of the Grove Church. Conodonts represent a break at this boundary. The uppermost *Kladognathus/Cavusgnathus naviculus* Zone terminates at the top of the Goreville Member (Rexroad and Scott, 1964, Collinson et al., 1971). The crinoid zone of *Pterotocrinus tridecibrachiatus* terminates before the deposition of the Goreville Member (Horowitz and Strimple, 1974, Devera, 2016). The seventh and final marine flooding surface in the Elviran Stage is the appearance of the Grove Church Shale. The Grove Church Shale contains the latest conodont zone *Adetodnathus unicornis* (Rexroad and Scott, 1964) in the Mississippian. Also the crinoid *Pterotocrinus pegasus* is only known from the Grove Church Shale (Devera, 2016). The trilobite *Paladin grovechurchensis* is only known to occur in this unit and has been found in the Grove Church of Pope County. While the Grove Church is separate from the Kinkaid Limestone it still clearly is Elviran because of the characteristic fauna: brachiopods *Diaphragmus fasciculatus, Composita subquadrata, Orthotestes kaskaskia,* bivalve *Sulcatopinna missouriensis,* and the cephalopod *Reticycloceras croneisi*. At the end of Grove Church deposition the sea exited Pope County and the Illinois basin.

GEOMORPHOLOGY

While geomorphology was not the focus of our investigations in Pope County, some striking landforms of the county are worthy of attention. The nature and origin of the Cache Valley has already been addressed. Another interesting geomorphic feature of Pope County will be taken up here: entrenched meanders.

Entrenched Meanders

Several of the larger streams in northern Pope County occupy narrow gorges deeply incised into bedrock. Taking tightly looping courses, these gorges represent entrenched meanders. The Lusk Creek canyon, about two miles northeast of Eddyville, is an outstanding example (Fig. 12). One of the meanders is nearly cut off, producing a small-scale version of the famous Goosenecks of the San

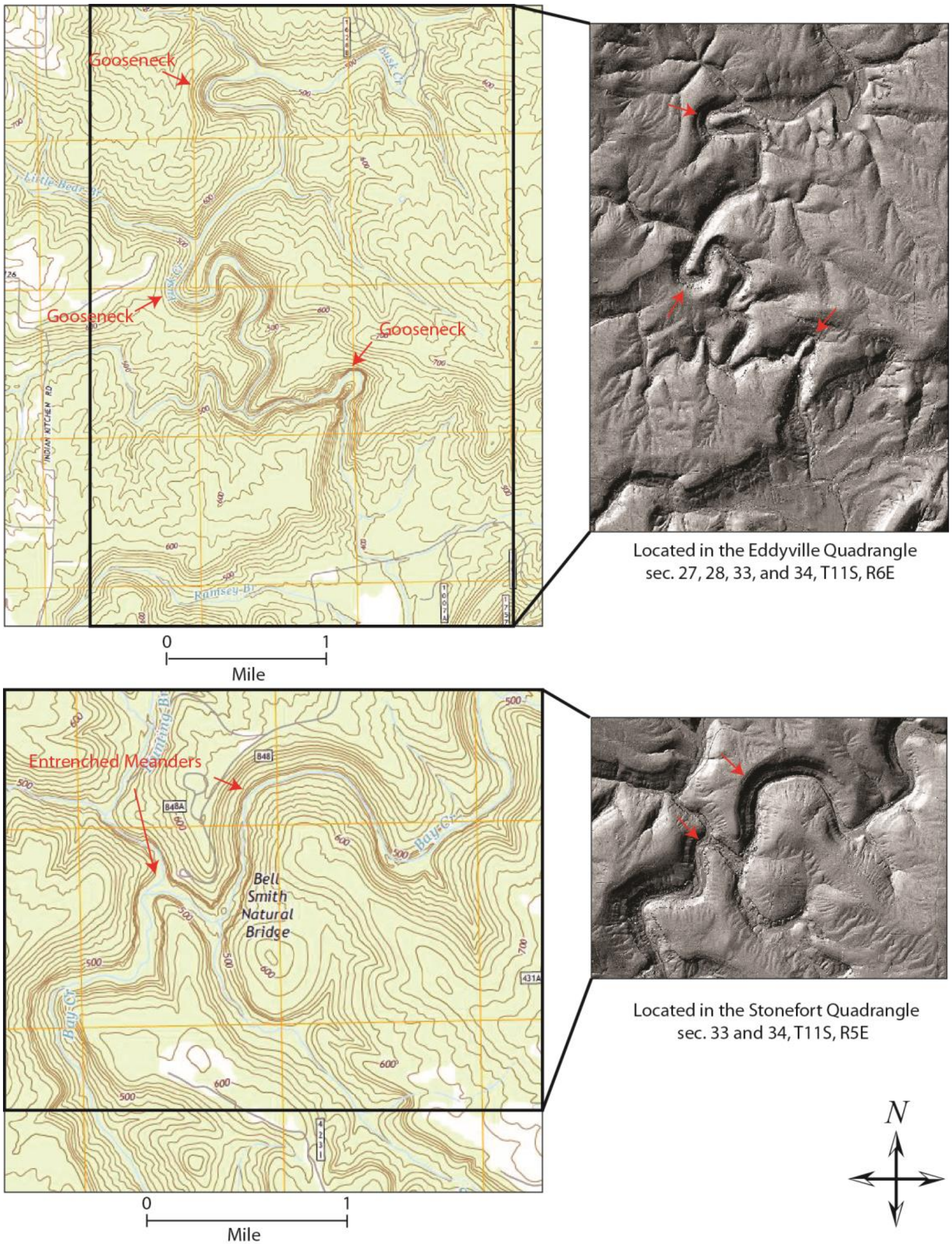

Figure 12. Entrenched meanders in the Stonefort and the Eddyville Quadrangles.

Juan River in southeastern Utah. Bay Creek near Bell Smith Springs also exhibits deeply entrenched meanders. Other examples occur along Lusk Creek east of Waltersburg and Hayes Creek southwest of Eddyville.

Topographic maps reveal similar examples of entrenched meanders throughout the Shawnee Hills, from Hardin County on the east to Jackson and Union Counties on the west. They are best developed in resistant Pennsylvanian sandstone, less strongly expressed in Mississippian rocks. Only segments of the larger streams exhibit rock-walled meanders. Smaller streams have mostly adjusted to geologic structure.

Meanders develop only on streams that have low gradients and easily eroded substrate, allowing the channel to migrate laterally and rework its own deposits. Meanders are a hallmark of old age in the fluvial cycle. Regional uplift or lowering of base level rejuvenates a river, forcing it to deepen its channel. When a winding stream encounters bedrock, it continues to cut downward, entrenching its meanders (von Engeln, 1942).

Practically nothing has been published about entrenched meanders in southern Illinois. Tarr (1924) described well-developed examples from the Ozark Plateau in Missouri, and attributed them to regional uplift. Tarr did not address the origin or nature of the surface from which the Ozark meanders were downcut. S. Weller (1924) identified four levels of “plains” or peneplains in Hardin County, but did not mention bedrock meanders.

Entrenched meanders in the Shawnee Hills imply the former existence of a level or gently sloping surface mantled in easily eroded sediments. Because the hills lie south of the limit of continental glaciation, the surface and sediment presumably is Pliocene or older. No remnants of the Mounds Gravel or older Cenozoic sediments have been observed north of the Cache Valley in Pope County. However, outliers of clay, sand, and gravel of probable Cretaceous and Eocene age occur in Union County. These cap ridges up to 700 feet above sea level and occur at lower elevations in sinkholes and grabens (Devera and Nelson, 1995; Nelson, Devera, and Masters, 1995). Closer to Pope County, the McNairy Formation (Cretaceous) and Mounds Gravel reside in a graben north of Cache Valley, northeastern Massac County (Devera and Nelson, 1997). Ridge-top outliers of Mounds Gravel are widely scattered across the Ozark Plateau in Missouri at altitudes ranging from 760 to 1,290 feet, mostly well above the highest points in Pope County.

We hypothesize that Cretaceous and Tertiary sediments, possibly as young as the Mounds Gravel, formerly lay across much of the present Shawnee Hills area, including northern Pope County. Rivers meandered across gently sloping surfaces on these unlithified deposits. Regional uplift and/or lowering of base level during the late Cenozoic rejuvenated these streams, forcing them to entrench themselves into bedrock. All but isolated remnants of the old sediment mantle subsequently were eroded.

GEOLOGIC STRUCTURE

Folds

Four prominent fold structures cross northwestern Pope County. From north to south, these are the New Burnside anticline, Battle Ford Syncline, McCormick Anticline, and Bay Creek Syncline (Fig. 13). In a category by itself is Hicks Dome, the western flank of which enters northeastern Pope County.

New Burnside Anticline

From southernmost Saline County, the New Burnside Anticline trends slightly south of west, crossing the northwestern corner of Pope County and curving toward the southwest into Johnson County (Denny et al., 2007; Nelson and Lumm, 1990a, 1990b; Trask and Jacobson, 1990). The fold axis is slightly sinuous. The anticline is a compound fold, comprising a series of elongate domes separated by divides or saddles. The northwest flank is steeper, having dips mostly in the range of 10° to 25° and local dips as steep as 60°. Dips on the southeast flank are mostly less than 10°. Structural relief along most of the anticline ranges from 200 to 300 feet. At both ends, the New Burnside Anticline

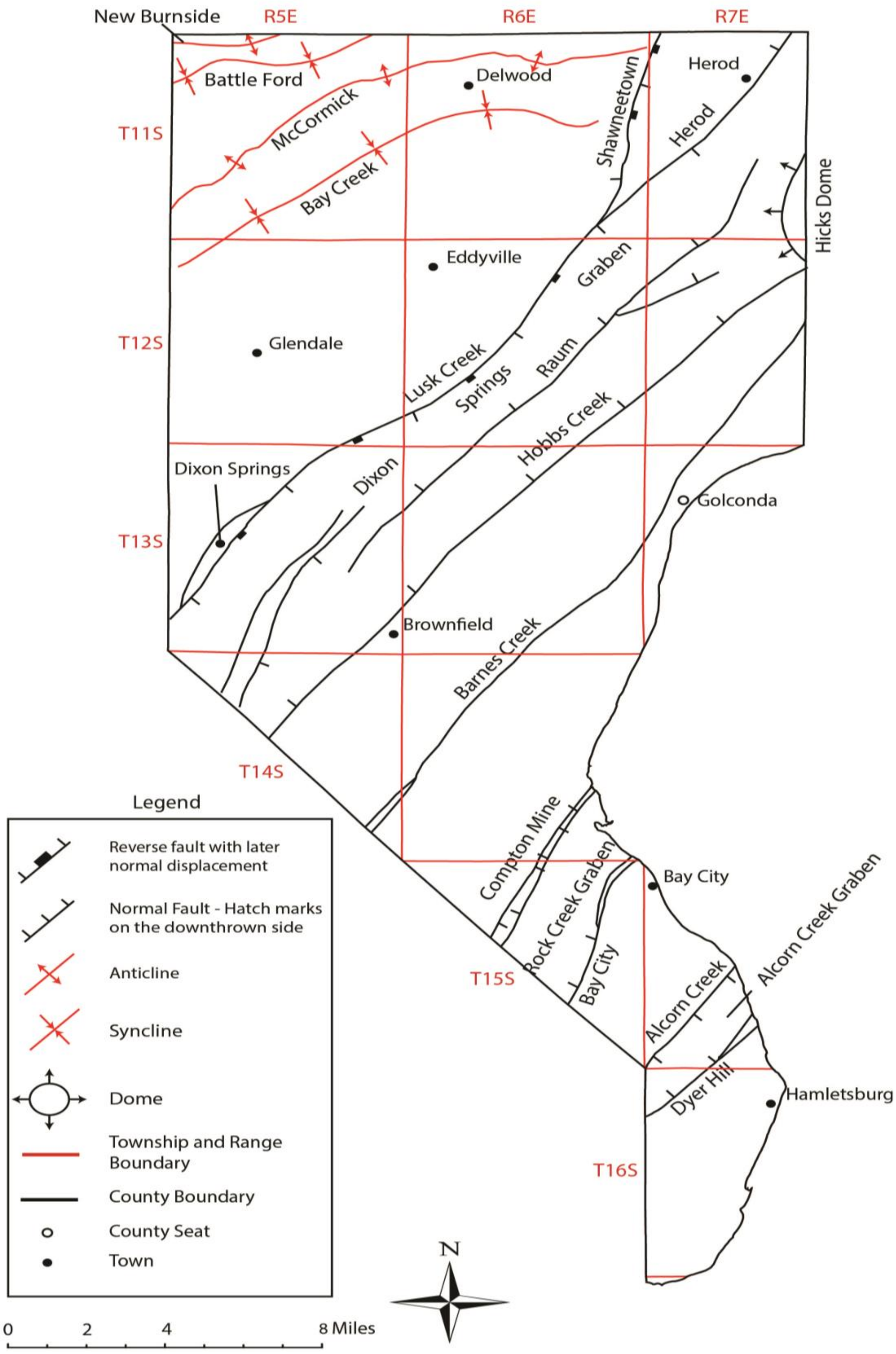

Fig. 13. Major tectonic structural features in Pope County, Illinois

gradually plunges and dies out. As mapped at the surface, the fold affects only the Tradewater Formation (Pennsylvanian).

A series of faults accompany the anticline. Some parallel the fold axis, but most trend northeasterly, crossing the axis obliquely. The majority are high-angle normal faults, but high-angle reverse faults are present. Northwest and southeast dips are about equally represented. Along trend, some faults pass into sharp-crested chevron or box folds. Also present are “trace-slip” faults that strike perpendicular to the fold axis, dip vertically, and bear horizontal or gently plunging striations. Offset of the fold axis along Bill Hill Hollow, just north of the Saline-Pope County border in Section 35, T10S, R5E, suggests a concealed right-lateral tear fault (Nelson et al., 1991).

Battle Ford Syncline

Named for Battle Ford Creek, the Battle Ford syncline parallels the southeast side of the New Burnside anticline. The fold has a sinuous axis and is asymmetrical. The northwest limb is short and relatively steep, whereas the southeast limb is broad and dips less than 1° in most places, then steepens on the northwest flank of the McCormick anticline.

McCormick Anticline

The McCormick anticline parallels the curving trend of the New Burnside fold (Fig. 13) and has greater relief. From its eastern terminus in the Herod quadrangle, the McCormick courses west across northern Pope County, curving toward the southwest into Johnson County and finally dying out southeast of Vienna (Nelson, 1995). Like the New Burnside structure, the McCormick has a steeper northwest flank, where dips range from 12° to 45° but are mostly in the range of 20° to 35°. Strata on the southeast flank dip mostly less than 10°. The McCormick comprises several elongate domes, which tend to overlap one another in *en echelon* pattern. Some of the domes are smoothly arches, whereas others are chevron or box folds. The Caseyville Formation and Mississippian rocks crop out along the fold crest while the Tradewater Formation is mapped along the flanks.

Numerous faults have been mapped along the McCormick structure. Some parallel fold axes, others cross them obliquely. Normal faults that dip 45° to 80° northwest or southeast prevail, but high-angle reverse faults have been observed. In several cases, the geometry of faults indicates that they underwent two episodes of movement. The first episode involved reverse faulting that raised the southeastern block; normal faulting lowered the southeastern block in the second episode (Fig. 13). Small trace-slip faults like those found on the New Burnside anticline also accompany the McCormick anticline. None of these faults could be traced beyond a single outcrop, and displacements evidently are small (Nelson et al., 1991). In summary, the New Burnside and McCormick anticlines have nearly identical structures.

Bay Creek Syncline

Analogous to the Battle Ford Syncline, the Bay Creek Syncline parallels the southeast side of the McCormick anticline. Average distance between anticline and syncline axis is about two miles. Dips on both flanks are barely noticeable in the field, being mostly in the range of a few degrees.

Hicks Dome

Situated largely in Hardin County, Hicks Dome is a nearly circular uplift approximately 8 miles in diameter. Its western flank extends into Pope County, expressed by semi-circular outcrop belts of outward-dipping strata. Dips gradually diminish westward from 15° to 20° along the county line to a few degrees at the vaguely defined outer margin. Numerous faults run radial and circumferential to the dome whereas others cross obliquely on northeasterly trends (Baxter et al., 1967; Denny et al., 2008; Denny and Counts, 2009).

Across more than a century, many authors have described the dome and discussed its role in regional tectonics and economic mineralization (S. Weller, 1920; Trace, 1974; Trace and Amos, 1984; Bradbury and Baxter, 1992; Denny and Seid, 2014). Present consensus attributes doming to deep-seated explosive Permian igneous activity.

Faults

One of the most intricately faulted regions of the North American Midcontinent lies partly in Pope County. Structures within this region display evidence for multiple periods of activity, dating from Cambrian to Quaternary. Additional interest focuses on economically valuable deposits of fluorite, lead, zinc, and other commodities hosted in veins along some of the faults. The blanket term "Fluorspar Area fault complex" is commonly applied to the overall system of mineralized fractures, which have an overall northeasterly trend. Fault zones in Pope County will first be described in order from north to south (Fig. 13), and then a tectonic synthesis will be presented.

Shawneetown Fault Zone

The westernmost 5 miles of the Shawneetown Fault Zone are in Pope County in the Eddyville and Herod quadrangles. From its juncture with the Lusk Creek Fault Zone, the Shawneetown trends nearly north, and curves toward the northeast into Saline County, where it turns to the east and becomes part of the Rough Creek fault system, a major regional structure that extends more than 100 miles into Kentucky.

As mapped in Pope County, the Shawneetown Zone is about 500 to 2,000 feet wide. The largest component is a southeast-dipping, high-angle reverse fault; other segments appear to be normal faults. Net throw is 300 to 500 feet down to the northwest, juxtaposing the Caseyville or uppermost Mississippian units on the southeast with the lower part of the Tradewater Formation on the northwest. However, within the fault zone is a narrow strip of Mississippian strata older than (and uplifted relative to) the rocks on either side of the zone. Baxter et al. (1967) identified Clore and Palestine Formations in part of the upthrown strip and depicted the rest as undivided Mississippian rocks "probably all above Vienna Limestone". Assuming Menard Limestone to be present, upthrow may be as great as 900 feet. Bedding attitudes in the Mississippian slices range from gentle east dips to vertical, and in one place bedding is overturned, dipping 60° west (Baxter et al., 1967).

Similar slices of older rocks occur in a number of places along the Shawneetown-Rough Creek fault system. At the "Horseshoe Upheaval" near the Gallatin-Saline County line, the Upper Devonian New Albany Shale is at the surface, roughly 3,500 feet above its normal elevation. This unusual configuration has been explained by invoking two episodes of movement. Initial displacement involved reverse faulting that raised the southern or southeastern block. Following this compressional event came extension (or relaxation of compression), which allowed the hanging wall to backslide down the fault zone. During this section action, slices of older rocks from the hanging wall sheared off and remained wedged in the upper part of the fault zone (Smith and Palmer, 1974 and 1981; Nelson and Lumm, 1984, 1987; Nelson, 1987). This theme of a reversal of displacement continues in the Lusk Creek and Raum fault zones.

Herod Fault Zone

The Herod fault zone extends northeast as a direct continuation of the Lusk Creek fault zone beyond its intersection with the Shawneetown Fault Zone. It consists of either a single fault or two or more closely spaced, subparallel faults. Displacement is down the southeast in the area southwest of

Herod, changing to northwest side downthrown northeast of the village. The zone continues northeast into Saline County, dying out near the western end of the Eagle Valley syncline. Exposures in surface coal mines near the northern terminus reveal high-angle normal faults having nearly vertical striations (Nelson and Lumm, 1984, p. 95). Other faults are poorly exposed, but appear to dip steeply. No indications of reverse or strike-slip faulting have come to light. The Chamberlain diatreme and a smaller diatreme about 1 mile south of Herod lie within or adjacent to the Herod fault zone.

Lusk Creek Fault Zone

From its junction with the Herod and Shawneetown Fault Zones, the Lusk Creek Fault Zone extends about 30 miles southwest to the Ohio River in western Massac County. The Lusk Creek marks the northwestern boundary of the Fluorspar Area Fault Complex, and is a key structure of the region. Because the Shawneetown and Lusk Creek zones exhibit closely similar geometry and a common structural history, they may well be regarded as a single fault zone.

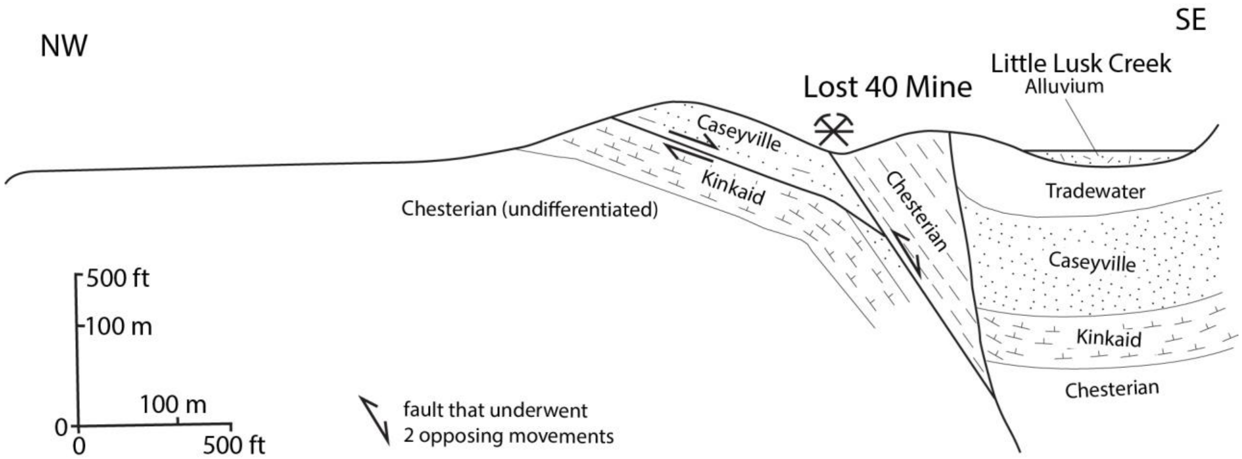

Figure 14. Cross section along the Lusk Creek Fault Zone showing 2 directions of movement.

The Lusk Creek is composed of parallel normal and reverse faults that dip steeply southeast, bounding the northwest side of the Dixon Springs Graben. Net throw is 600 to 900 feet down to the southeast through the Glendale and Waltersburg quadrangles. Flanking the northwest margin of the fault zone is an anticline; a syncline also parallels the southeast side. Thus, for the most part bedding within and adjacent to the Lusk Creek fault zone dips southeast, consistent with downthrow of the southeastern block.

Complicating the structure is a series of narrow slices of Mississippian rocks within the fault zone, older than the rocks on either side. A nearly continuous strip of Mississippian slices extends 4 miles northeast from Copperous Branch in the Waltersburg quadrangle. The most extreme example is at “Clay Diggings”, an abandoned mine and limestone quarry just northeast of the Eddyville-Golconda blacktop. Here, a slice of St. Louis and Ste. Genevieve Limestone is faulted against Tradewater Formation on the southeast and middle-upper Pope Group strata on the northwest. The limestone slice is 800 to 1,500 feet above its normal position relative to the rocks on either side (Weibel et al., 1993). In similar fashion, outcrop and borehole data reveal a slice of St. Louis and Ste. Genevieve south of Lake Glendale, juxtaposed with Caseyville on the southeast and middle Pope Group on the northwest (Devera, 1991). These “upthrown” slices of Mississippian rock closely mirror slices found along the Shawneetown fault zone to the northeast, and they probably originated in the same fashion. The fault zone also contains narrow wedges of younger rocks, mainly Caseyville Formation, that have dropped downward relative to the strata on either side. In some cases, “upthrown” and downthrown slices exist side by side (Fig. 14). The youngest rocks demonstrably faulted in Pope County are

Middle Pennsylvanian age, but the Lusk Creek zone displaces much younger units in Massac County. Drilling and seismic reflection investigations near Maple Grove School, west of Joppa, reveal offsets of units as young as the Mounds Gravel and possibly the Pleistocene Metropolis Formation (McBride et al., 2002; Nelson and Masters, 2008). No displacement of Illinoian or younger sediments has been detected.

Raum Fault Zone

Two to three miles southeast of the Lusk Creek fault zone is the parallel Raum Fault Zone. In most of Pope County the Raum is either a single fault or a zone of fractures less than 500 feet wide, having overall throw down to the northwest. Thus, the Raum fault zone outlines the southeast side of the more deeply downdropped portion of the Dixon Springs graben. Net throw is generally in the range of 100 to 300 feet. At One Horse Gap in the Herod quadrangle, the Raum splits into two branches. The southern branch is the mineralized, which dies out on the western flank of Hicks dome. The northern branch follows strike of bedding tangential to Hicks dome for several miles (Baxter et al., 1967; Denny et al., 2008).

In most places, the Raum fault zone exhibits features of normal faulting, including steep northwest-dipping fault surfaces and narrow zones of drag and brecciation. A regional seismic reflection profile that runs north-south through Pope County crosses the Dixon Springs graben south of Eddyville (Bertagne and Leising, 1991, Fig. 15-4). As interpreted, this profile depicts the Raum fault zone dipping northwest and intersecting the Lusk Creek fault zone near the base of the Cambro-Ordovician Knox Group. Under this interpretation, the Raum is secondary and antithetic to the Lusk Creek.

Outcrops along the border between the Shetlerville and Waltersburg quadrangles indicate that the Raum includes an element of reverse faulting. In this area, the Raum fault zone contains an elongate slice 200 to 500 feet wide of Upper Mississippian rocks (mostly if not entirely Kinkaid, Degonia, and Clore Formations) between Pennsylvanian Caseyville Formation strata on either side (Fig. 15). In some places, the strongly sheared, fractured Mississippian rocks dip steeply northwest, parallel with the bounding fault planes. In other places, the Mississippian rocks in the central slice dip southeast. In either case, the configuration indicates an early episode of reverse faulting that raised the northwestern block, followed by normal faulting that dropped the block back down. In this regard, the Raum is a mirror image of the Lusk Creek, having smaller overall displacements.

Continuing southwest into the Reevesville quadrangle, the Raum fault zone widens to more than a mile and becomes more complex. Three faults have been mapped along the bluffs north of the Cache Valley, outlining a pair of horsts (Nelson, 1996). An anticline parallels the southeast side of the northwestern fault, suggesting an episode of compression. South of the Cache Valley, a series of faults outline lozenge-shaped grabens of Mississippian rocks. One of these grabens ("Reineking Hill" of Nelson et al., 1997) contains Cretaceous McNairy strata downthrown more than 100 feet relative to Mississippian sandstone on either side. The former Illinois Central, now Canadian

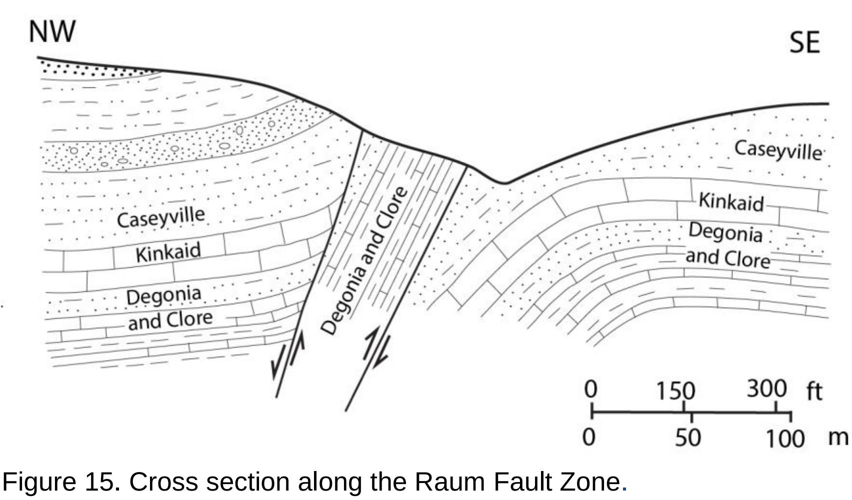

Figure 15. Cross section along the Raum Fault Zone.

National railroad line follows the linear valley that was eroded along this structure.

Farther south in Massac County, the Raum fault zone assumes a heading of S20°W and outlines a complex graben as wide as 1.0 mile. These faults displace Cretaceous and Cenozoic units, including the Mounds Gravel and overlying Metropolis Formation. Surface exposures, boreholes, and a seismic reflection survey provide evidence for multiple episodes of movement between Cretaceous and Pleistocene time. Horizontal, unfaulted Loveland Silt and younger sediments truncate older deformed units, so the latest fault movements were pre-Illinoian (Nelson et al., 1999; McBride et al., 2002; Nelson and Masters, 2008).

Hobbs Creek Fault Zone

The Hobbs Creek fault zone extends from the southwest flank of Hicks dome to the city of Metropolis, a distance of 30 miles. Width varies from tens of feet to about 1½ miles; overall throw is down to the northwest. Where multiple faults are present, they either outline grabens or step down toward the northwest. The Hobbs Creek zone forms the southeastern border of the Dixon Springs graben.

High-angle normal faults constitute the zone. They are marked by outcrops of recrystallized silicified sandstone, angular breccia zones, and mineralized veins. One of the last active underground fluorspar mines in Illinois, the Henson Mine (Section 20, T12S, R7E, Shetlerville quadrangle) worked vein deposits along a segment of the Hobbs Creek fault zone. Drag folds are minimal. Throws are generally in the range of tens of feet to a few hundred feet. The largest throw is approximately 700 feet near the south edge of the Cache Valley in the Reevesville quadrangle. Formations offset at the surface range from the Mississippian Ste. Genevieve Limestone to the Pennsylvanian Caseyville Formation.

Where the Hobbs Creek zone crosses into Massac County, its trend changes to south-southwest and the zone outlines a series of narrow, linear grabens that offset Cretaceous and younger sediments. A series of investigations were carried out using drilling, trenching, and high-resolution seismic reflection surveys. These revealed a history of multiple fault movements through the Tertiary and into the Quaternary Period. The Mounds Gravel and overlying Quaternary sediments (dated by fossil pollen) are downthrown 500 feet in a graben in the southern Reevesville quadrangle. Wisconsinan loess and Holocene alluvium are not displaced, so the last movements took place during Illinoian or earlier time (Nelson et al., 1997, 1999; McBride et al., 2002).

Barnes Creek fault zone

The Barnes Creek fault zone takes its name from a stream northeast of Metropolis in Massac County, where units as young as the Pleistocene Metropolis Formation have been offset (Nelson et al., 1997, 1999, 2002). In Pope County, the Barnes Creek zone maintains across the Brownfield Quadrangle, curving slightly northward and merging with a broader zone of faults that extend toward the apex of Hicks Dome in the Shetlerville Quadrangle. The Barnes Creek Fault Zone projects to the northeast between the Stewart Fault and the Hobbs Creek Fault Zone. The Barnes Creek structure is expressed as either a single break or as a zone of two or three subparallel faults that outline a graben as wide as 1,800 feet. Where a graben is present, strata on either side stand at nearly the same elevation. Throws on individual faults are modest, 300 feet or less.

As expressed in Chesterian rocks, the Barnes Creek fault zone exhibits features typical for the district: steeply dipping (70° to 90°) fault planes, minimal drag, narrow zones of breccia and silicified sandstone, mineralized veins, and mostly vertical or steeply plunging striations. Fluorspar veins along segments of the Barnes Creek zone were mined underground during the early 1980s in Section 28, T12S, R7E, Shetlerville quadrangle. Obliquely plunging striations and mullion on faults surfaces in the mines indicated right-lateral/normal oblique slip (Nelson and Lumm, 1984, p. 91). Crossing into

Massac County, the Barnes Creek zone curves to a more westerly heading, and intersects the Hobbs Creek fault zone north of Metropolis.

The Cretaceous McNairy Formation, Cenozoic Mounds Gravel, and Quaternary Metropolis Formation have been displaced along the southwestern portion of the Barnes Creek fault zone, in Massac County and adjacent Pope County. Narrow grabens are the typical structure. Test drilling along Barnes Creek revealed a graben in which Metropolis sediments are displaced a minimum of 90 feet (Nelson et al., 1999). A drilling project near Homberg at the edge of the Cache Valley indicated no displacement younger than middle Wisconsinan (Nelson et al., 1997).

Compton Mine Fault Zone

This fault zone takes its name from the Compton Mine, which extracted lead and fluorspar from veins within the zone. The fault zone has a mapped length of about 5 miles in the Brownfield (Nelson and Denny, 2008) and Paducah NE (Denny and Nelson, 2005) quadrangles. The zone is nearly linear, outlining a graben that trends N30°E and widens from about 500 feet on the northeast to 2,000 feet on the southwest. Bedding in the central block is nearly horizontal. Throw is 800 to 1,000 feet on the northwest side of the graben, compared with 400 to 700 feet on the southeast side. Recrystallized sandstone and breccia mark fault traces at the surface. Fault surfaces bear striations that plunge vertically, or nearly so. A cross section of the northwest side of the fault zone in Taylor (1967) shows more than a dozen high-angle normal faults that produce stepwise displacement down to the southeast. When projected toward the northeast, the Compton Mine Fault Zone merges with a complex array of fractures along the northwest side of the Rock Creek Graben (Amos, 1966; Hook, 1974; Trace, 1974; Trace and Amos, 1984). It lines up fairly well with the Stewart Fault (Denny and Counts, 2009).

Deformed Cretaceous and Quaternary sediments were observed directly in line with the northwestern fault of the Compton Mine zone along Mallard Creek in Section 20, T15S, R6E, Massac County. Trenching and test drilling revealed a series of nearly vertical faults that offset the McNairy Formation and Metropolis Fornmation, including what is believed to be the Sangamon Soil (Nelson et al., 1999; Denny and Nelson, 2005). Offset of the Sangamon would indicate faulting during the Wisconsinan. Holocene alluvium along Mallard Creek is not deformed.

Bay City Fault Zone

The fault zone that intersects the Ohio River bluff at Bay City has been named the Bay City Fault Zone. It has been traced approximately 5 miles south-southwest of the river through the Smithland (Devera, 2013) and Paducah NE (Denny and Nelson, 2005) quadrangles. As depicted, the zone comprises two parallel faults that outline a graben 400 to 800 feet wide. The southeastern fault has larger throw, estimated at 300 to 400 feet. Throw on the northwestern fault increases from less than 50 feet at the river bluff to 100-150 feet two miles south, where Tar Springs and Hardinsburg Formations are juxtaposed. The McNairy Formation appears to be displaced in the same area, but possible offset is only a few tens of feet, much smaller than throw on Mississippian formations. Although the Bay City Fault Zone has not been traced beyond Dog Creek, linear ridges directly in line with the zone farther southwest suggest that it continues. Projected toward the northeast, the Bay City zone aligns with an intricate system of fractures that outline the southeastern margin of a major downdropped block, the Rock Creek Graben (Amos, 1966; Hook, 1974; Trace, 1974; Trace and Amos, 1984).

As is typically the case in this district, steep dips are confined to immediate proximity of faults. Dips of 70° to 80° northwest were measured in several places along the southeastern fault. On the river bluff at Bay City, three small anticlines that trend parallel with the main fault, signifying an element of compression. This fault zone probably has undergone more than one episode of displacement.

Paducah Graben

The southernmost faults in Pope County are the Dyer Hill Fault Zone and the Alcorn Creek Fault, which together outline a down-dropped block called the Alcorn Creek Graben (Devera, 2013). Previously, Ross (1963, 1964) mapped a feature that he labeled the Paducah Graben in approximately the position of the Alcorn Creek Graben. In Kentucky, Trace and Amos (1984) identified the Paducah Graben in line with the Alcorn Creek Graben as mapped by Devera (2013).

Geologic interpretation of the Alcorn Creek area differs substantially between Ross (1964) and Devera (2013). Ross showed Bethel Sandstone northwest of the Dyer Hill Fault Zone, whereas Devera mapped Clore, Degonia, and Kinkaid Formations in the same area. Also, Devera mapped younger Chesterian rocks northwest of Alcorn Creek, and identified a fault that Ross overlooked. We are confident in the rock unit identifications of Devera (2013), because they were based on characteristic limestone textures and fossils of the respective units.

As mapped by Devera, the Dyer Hill Fault Zone is a single fault on the southwest, bifurcating toward the northeast. Upper Chesterian formations northwest of the fault zone are downthrown at least 1,200 feet relative to the Ste. Genevieve Limestone southeast of the zone. A slice of Sample and Bethel Sandstone occupies the narrow triangle between the two branches of the fault. Fault surfaces are not exposed, but high-angle normal faulting is inferred because bedding dips are gentle in close proximity to the faults.

Within the graben is a syncline that has steeper dips on the southeast limb than the northwest, consistent with greater throw along the southeast margin.

Alcorn Creek Fault

The Alcorn Creek Fault strikes parallel with the Dyer Hill Fault Zone and outlines the northwest side of the Paducah Graben. Palestine and Menard Formations southeast of the Alcorn Creek Fault are downthrown 200 to 250 feet versus Tar Springs and Glen Dean strata northwest of the fault. Rocks dip less than 5 degrees southeast on both sides, except in immediate proximity of the main break, where dips of 60 to 70 degrees were observed. The Alcorn Creek is probably a high-angle normal fault. It aligns directly with a fault having the same sense of throw in Kentucky (Amos, 1967; Trace and Amos, 1984).

The Alcorn Creek and Dyer Hill fault zones project southwest into the Paducah Northeast quadrangle, but were not detected there (Denny and Nelson, 2005). No evidence was found for deformation within the Cretaceous or younger sediments.

Structural Interpretation

Faults and folds within Pope County record recurrent episodes of tectonic activity ranging from Cambrian through late Cenozoic time, more than 500 million years of Earth's history. Some of these faults displace Pleistocene sediments nearby in Massac County, and project directly toward the active New Madrid seismic zone.

The earliest known tectonic activity in Pope County involved development of the Reelfoot Rift, a failed rift structure that formed during breakup of the supercontinent Rodinia during latest Precambrian to Middle Cambrian time (Kolata, 2010; Kolata and Nelson, 2010). Direct evidence consists of a seismic reflection profile (Bertagne and Leising, 1991, Fig. 15-4) that shows pre-Knox layered rocks (of presumed Early to Middle Cambrian age) on the southeast side of the Lusk Creek Fault Zone. Hence, the crustal block southeast of the fault zone must have moved downward, an episode of normal faulting. Similar action took place farther east along the Shawneetown, Rough Creek, and Pennyrile faults, outlining a dogleg-shaped rift basin (Bertagne and Leising, 1991).

The next major tectonic event was northwest-directed reverse and thrust faulting that probably took place during the Permian Period in concert with the Alleghenian orogeny and ultramafic igneous activity. This action raised the formerly downthrown block southeast of the Lusk Creek fault zone, and created the antithetic Raum fault zone, which intersects the Lusk Creek at about the base of the Knox Group (Bertagne and Leising, 1991, Fig. 15-4). The same compressional event formed the McCormick and New Burnside anticlines northwest of the Lusk Creek fault zone. Geophysical data cited by Nelson et al. (1991) suggest that the anticlines formed about thrust or reverse faults that are detached within Paleozoic sedimentary cover. Potter et al. (1995) published a regional seismic profile that they interpreted in support of thrusting in basement beneath the McCormick anticline. The evidence either way is inconclusive, but there is little doubt that the anticlines formed under compression and that they relate to reverse or thrust faults that locally reach the surface.

Following the compressional event, the region was subjected to crustal extension, which produced the array of northeast-trending normal faults that comprise the Fluorspar Area fault complex. The previously uplifted keystone block between the Lusk Creek and Raum fault zones now sank, forming the Dixon Springs graben. Some of the faults associated with the McCormick and New Burnside anticlines also underwent normal movement, reversing earlier thrust displacement. Given the absence of rocks younger than Middle Pennsylvanian in northern Pope County, timing of the extensional event is poorly constrained. Clear-cut evidence for Cenozoic activity on portions of the Fluorspar Area fault complex is found in southern Pope and Massac Counties. Here, recurrent transtensional faulting (that is, normal faulting combined with strike-slip) took place, creating narrow grabens that contain various Tertiary and Quaternary sediments. The latest large fault movements were pre-Illinoian, but adjustments continued into the Wisconsinan (within about 75,000 years of present).

ECONOMIC MINERALS

Pope County incorporates the northwestern part of the Illinois-Kentucky fluorspar district, which had produced (as of 1974) more than three-fourths of the fluorspar mined in the United States together with associated lead, zinc, silver, copper, barite, and other commodities (Trace, 1974). Because of declining markets (especially of steelmaking) and influx of imported fluorspar, the district is dormant today. Small amounts of coal, limestone, sandstone, sand, and gravel have been extracted in Pope County, mainly for local use. Test holes for oil and gas include the deepest ever drilled in Illinois, but no production has been achieved.

Pope County lies along the western edge of the Illinois-Kentucky Fluorspar District. Numerous prospect pits were developed and a few of the prospects in Pope County became productive fluorite mines. The fluorspar mines within Pope County are listed below and are divided into districts and outlying areas. The majority of the information cited below was extracted from Weller et al. (1952) and Bastin (1931). A table of all mines, quarries, and pits in Pope County is included as Appendix 1.

Fluorite and Associated Mines

Fluorite which is also called fluorspar is composed of calcium and fluorine (CaF_2). It has been mined in the Illinois since the 1800's, and the last mine operating in this district closed in the 1990's. Some fluorite production during the last few years has occurred in Hardin County at the Hastie Limestone Quarry and a new mine is being developed in Kentucky but production of ore has not yet developed. In Pope County several mines have operated and a significant amount of ore has been produced. Most of the mines in Pope County have been vein type mines and the ore is hosted along fault and fractures in thin vertical slices orientated along the fault plane. Some horizontal bedding replacement ore has also been recovered at the Gaskins Mine that was adjacent to a vein type deposit.

The mode of emplacement of the fluorspar in the Illinois-Kentucky District is not fully understood. Current research suggests the ore was emplaced by low temperature hydrothermal solutions that mixed with other solutions. It is theorized that connate and basinal brine fluids or Mississippi Valley-Type (MV-T) fluids all mixed with hydrothermal solutions heated by the Permian igneous activity. Fluid inclusion investigations of ore within the Cave-in-Rock district in Hardin County suggest the ore fluids were acidic and saline. The homogenization temperatures of fluid inclusions in fluorite were between 115° to 150° C, and 18.3% to 21% NaCl equivalent (Richardson and Pinkney, 1984). The concentration of fluorine in the fluids that precipitated the fluorite deposits in this area was undoubtedly large compared to normal basinal or other MV-T fluids. Mixing of hydrothermal fluids MV-T fluids at depth and later mixing with meteoric solutions has been suggested as a possible ore forming mechanism. The local hydrothermal fluids were probably heated and mobilized by Permian igneous activity which may have also leached fluorine from the ultramafic rocks in the region or the igneous crystalline basement complex. Another possibility is that the fluorine was originally sourced from a carbonatite system that is theorized to be present associated with the Permian ultramafic activity. Regardless of how these fluids gained their enriched fluorine levels, the ore fluid precipitated in most locations in contact with limestone or dolostone. The contact with carbonate rocks probably either supplied the necessary calcium or altered the chemistry of the fluids to encourage precipitation. In some cases the ore has replaced the limestone and texture and bedding of the original limestone is visible. Occasionally a fossil is present that has been replaced by fluorite.

The vein deposits are centered along faults or fractured rock parallel with fault zones. Previous workers have noted that the displacement along individual faults has some effect for the fault to host or carry fluorspar. Faults with large displacement, or greater than about 700 feet, seem to carry small amounts of fluorite. While ore does occur along small displacement faults and fractures the majority of the vein type ore seems to be located in faults with slight to moderate movements.

Early mines produced ore that was exposed at the surface. In some mines the ore at the surface was weathered into gravel spare deposits. Usually the surface gravel gavel spar gave way at depth to a solid vein or bed of fluorite. These veins were then followed downward until it became more cost effective to sink a shaft and drive entries into the ore body. The ore tends to pinch and swell in both horizontal and vertical directions. The veins typically would widen in contact with limestone either in the hanging wall or footwall, but there are exceptions to this general observation. The ore was dominantly fluorite with lessor amounts of galena, sphalerite, barite, calcite, and quartz.

Empire District

The Empire District is located in eastern Pope County and is composed of several vein mines along faults that trend in a general northeasterly direction. Several parallel faults are present and two prospects in the northern part of this district trend just slightly east of north. The Empire District is located less than 3 miles west of Hicks Dome. The vein deposits are located along fault of slight to moderate offset. Some bedding replacement ore has also been mined in this district. Nelson (1992) estimated the offset of the Pierce Fault to be less than 100 feet and the faults appear to be mainly normal, but some data suggests tectonic wrenching and horizontal movement also occurred (Saxby 1974). The faults may be radial fractures created by the vertical uplift at Hicks Dome, but probably are also related to the extensional forces that created the Dixon Springs Graben. Both surface and underground mines have extracted ore which is dominantly fluorite with only minor amounts of galena and sphalerite. The prospects and mines are listed below.

Empire Mine (section 27-11S-7E): This mine was composed of one two surface pits, or open cuts, and a series of shafts sunk along a fault that trends N55°E and dips 70°SE. This complex was documented to be active from 1924 through 1927 (Bastin 1931). The vein was estimated to be thee feet wide. The vein contained gray and purple fluorite along with calcite, galena, and sphalerite.

Shafts were from less than 20 feet deep to 180 feet and the ore was mainly within the Ste. Genevieve Limestone. The southwestern extension of this vein was mined by the A.D. Knight and E.A Knight.

Baldwin Mine (section 27-11S-7E): This mine was located near the northern edge of the Empire District. A small surface pit uncovered a vein less than 1 foot wide striking N50°E and dipping 70°SE. A shaft is located here that was sunk to about 50 feet deep. No production information was discovered relating to this mine. Another mine called the New Baldwin is located about 2000 feet just slightly west of north of the Baldwin Mine. The new Baldwin mined a gravel spar deposit.

There are several pits and prospects named Crabb: The Crabb Prospect (section 27-11S-7E): This prospect consists of a vertical shaft sunk 50 feet deep. Waste or spoiled material at the site consists of purple fluorite, sphalerite, calcite, and galena. Chas. Crabb (section 27-11S-7E) and two separate Oscar Crabb mines or pits (section 27-11S-7E).

Red Mine (section 27-11S-7E): This mine produced ore for several years and was also known as the Roberts, Knight, and Redd Mine. The vein averaged over 4 feet wide and the shaft was sunk to 120 feet.

O'Rear prospect (section 27-11S-7E): This prospect shaft was sunk to 70 feet and only veins about 3 inches were discovered.

Todd Mine (section 27-11S-7E): The Todd Mine produced only minor amounts of ore and was mainly prospects pits and a shaft sunk 60 feet deep. Veins were reported to be slightly over one inch wide.

Acup Mine (section 27-11S-7E): No further information available.

Davenport Mine (section 27-11S-7E): No further information available.

Big Joe Prospect (section 27-11S-7E): This prospect consists of a series of pits dug along the east hillside of Grand Pierre Creek. A 6 to 8 inch fluorite vein traced through these pits trends N20°E.

Douglass Mine (section 27-11S-7E): These shafts and pits are at the southern edge of the Empire District. The shafts and pits appear to be aligned in a north 42°E direction, which may indicate the strike of the fault these pits were dug along (Weller et al., 1952).

Knight Mine (section 34-11S-7E): This mine was also called the Red, Roberts, and H.C.B. Mining Company. The Knight Mine followed the same fault as the Empire Mine which trends N55°E and dips 80°SE at this location. The shaft was reported to be 120 feet deep and the vein was 2.5 to 4 feet (Weller et al. 1952).

Big Joe prospect (section 34-11S-7E): These prospects followed a vein approximately 6 inches wide along a fault or fractures striking N20°E.

McKee prospect (section 34-11S-7E): No mineralization has been reported at this site

Gullett Mine (section 34-11S-7E): The shaft at this location was sunk to 85 feet deep and possibly deeper. The vein trends N70°E and averages 6 feet wide.

Slapout Mine (section 34-11S-7E): The veins at the Slapout Mine were reported to follow a set of fractures. The fractures trend N25°E and the veins averaged about 3 feet in width. The shaft here was sunk to 130 feet.

Turner Mine, aka Turtle Mine (section 34-11S-7E): A series of fluorite veins were exposed in a prospect shaft which might be along strike and an extension of the Pierce Vein. The fractures strike N70°E and the shaft was sunk to about 60 feet.

Pierce Mine (section 34-11S-7E): The Pierce Mine extracted ore from surface pits and underground workings. The vein appears to trend about N45°E and was active prior to 1931 (Bastin 1931). Weller et al. (1952) indicated the fault trend was N70° to 80°E and was mined to depths of 200 feet.

Hicks Creek Mine (section 34-11S-7E): The Hicks Creek Mine operated along the same fault as the Pierce Mine. This mine was southwest of the Pierce Mine and shafts were sunk to depths of 70 feet. The average width of the vein was about 6 feet (Weller et al., 1952).

Gaskins Mine (section 34-11SR-7E): The Gaskins Mine was operated by Ozark Mahoning Company during the 1970's. Vein ore was mined within a fault from the base of the Bethel Sandstone for 250 feet down. The ore was present in two parallel veins averaging 5 feet wide. Bedding replacement ore was also present which averaged 35 feet wide. The faults are normal with 20 to 75 feet of vertical offset. Saxby (1974) also describes significant horizontal movement along the fault, which may be a result of radial stresses created by more than 3000 feet vertical uplift at Hicks Dome. Another possibility is the horizontal stress was related to the regional tectonic stress field.

Stewart District

The majority of the mines in the Stewart District are located in Hardin County, and only a few are located in Pope County. The Stewart District is aligned along a normal fault called the Stewart Fault which trends N25°E to N30°E and dips steeply to the southeast. The projection of the strike of this fault to the southwest lines up with the Compton Mine Fault Zone. Dozens of abandoned mine shafts have been sunk along the Stewart Fault Zone. The few that lie within Pope County are listed below.

Barnett complex (section 28-12S-7E). Ozark Mahoning sank a shaft at this location in 1966. The Barnett shaft connected to the sixth working level of the older Parkinson Mine. Two air shafts, now plugged, were identified during field mapping in the Shetlerville Quadrangle (Denny and Counts, 2009). The Barnett Mine had a main (production) shaft about 800 feet deep and three air shafts. Workings were on two parallel, northeast-striking veins about 1,800 feet apart. These veins were part of what we now call the Barnes Creek fault zone. The two mineralized faults dipped away from each other, outlining a horst. Throw on both faults was approximately 100 to 120 feet – normal faults with oblique-slip components as shown by slickensides and mullion. Ore was concentrated at the levels of the lower Paoli Limestone and Aux Vases Sandstone.

Although the underground fluorite mines were relatively safe, a fatality occurred underground in the Barnett Mine, which was a result of hydrogen sulphide (H_2S) gas. A water course was encountered by mining operations which temporally flooded the 800-foot south working area in the Barnett Mine. The area was temporally evacuated to allow the water to be pumped away from the working face. The presence of H_2S became concentrated enough to cause workers to experience eye and lung irritation the next day when the area was examined by workers. At some time after the water was encountered a ventilation fan for this area stopped working. Prior to the fan being repaired a worker went into the area to retrieve equipment. When this worker did not return another worker went to find the first miner. Several attempts to save the fallen miners resulted in the deaths of seven miners (Denny and Counts, 2009).

Henson Mine (section 20-12S-7E.): The Henson mine was operated by Ozark Mahoning. The vein ore was present along northeasterly trending faults. The Henson Mine was in operation during the 1980's. It operated along a fault west of and parallel with the Stewart Fault. The Henson Mine had a shaft 950 feet deep to what was called the Hobbs Creek vein, part of the Hobbs Creek fault zone. This was a normal fault striking northeast and dipping steeply northwest. Ore from the Henson Mine was trucked to the mill and concentrator in Hardin County at Rosiclare, Illinois.

Outlying Areas

Fairbairn shaft (section 22-12S-7E): No further information available about the Fairbairn Mine. Sam Parkinson Prospect (section 22-12S-7E): No further information available. S. Rotes prospect, aka Black Jack prospect (section 27-12S-7E): Prospect shaft is located near the base of a gulley. The pit was sunk to about 20 feet deep. Reed Shaft (section 27-12S-7E): No further information available about the Reed Shaft. Lake Glendale prospect (section 9-13S-5E): There are several prospect pit here that trend N40° to 45°E. Traces of fluorite and barite are reported, but no production has occurred at this prospect. Little Jean Mine (section 30-13S-5E): This mine produced barite and small amounts of fluorite. The vein was 1.5 feet wide and was oriented N70°W. Barite production was reported from 1918 to 1922. Compton Mine, aka Bay City Mine (section 26-13S-5E): Minor production was reported from this mine along a vein that strikes N45°E. The shaft was reported to be 60 to 300 feet deep.

Sand and Gravel

The land surface of Pope County is peppered with small pits and quarries, most of which are inactive. A few small pits have been dug to mine flat slabs of thin bedded sandstone mostly for local purposes. The thin layers of sandstone used for landscaping and are sometimes called flagstone. Gravel pits are located in the southern portion of the quadrangle that have mined the Mounds Gravel. The gravel from these pits is used as aggregate and road base for local roads and also for ground cover for landscaping projects. These gravel pits may be mined for a period of time and then are idle. Intermittent extraction of gravel from these pits is common. The Mounds is present in southern Illinois in three terraces. The upper terrace is present at elevations around 580-620 feet, a middle terrace is present around 450-500 feet, and a lower terrace is present around 380-400 feet (Willman et al, 1975). In the southern portion of Pope County the Mounds Gravel is present on hill tops at elevations around 520-530 feet (Denny and Nelson, 2005), while Devera (2013) mapped the Mounds Gravel at elevations of 530-500 feet and in a few places at 450 feet. Mounds “type” gravel is present in reworked younger Pleistocene terraces along the flood plain of the Ohio River. The Mounds Gravel at upper terraces is coated with a yellow-brown bronze patina. As this unit is reworked into lower terraces the distinctive yellow-brown bronze patina of the Mounds Gravel is somewhat eroded away.

Limestone

Pope County contains extensive deposits of limestone, but they are poorly situated for commercial quarries. A small cement plant and quarry operated into the 1960s about 1 miles southwest of Golconda. A 10-foot layer of coarse-grained limestone in the upper part of the Fraileys Member, Golconda Formation, was the source of stone. During the 1930s crushed stone was taken from a fault slice of St. Louis and Ste. Genevieve Limestone near the spot where the Eddyville-Golconda blacktop crosses Lusk Creek. Small pits long ago took limestone from the Kinkaid Limestone at Millstone Bluff (northwest of Glendale) and south of Eddyville, the Menard Limestone near Brownfield, and the Downeys Bluff Limestone along Cave Creek south of the Cache Valley.

Large commercial quarries are active in Hardin County, a short distance east of the study area. These operations extract limestone from the Paoli and Ste. Genevieve Formations for shipment via barges on the Ohio River.

Sandstone

Local residents long ago quarried sandstone from small pits in various parts of Pope County and used it for construction. Two small operations that quarried flagstone for such uses as patios and sidewalks were active into the 1990s. One of these quarries removed sandstone from the upper part of the Cypress Formation on a site 2 miles southwest of Golconda. The other operation was along the Golconda blacktop about 4 miles southeast of Eddyville in the Wayside Member of the Caseyville Formation.

Coal

Small-scale surface and shallow underground mining of coal formerly took place at numerous sites in Pope County. Most of these mines were mere “dogholes” where local residents dug coal for home heating. Among the coal beds worked were the Bell, Oldtown, and Delwood Coal Beds, together with unnamed seams in the Caseyville and Tradewater Formations. The most recent mining was shallow stripping of the Bell Coal in the graben northeast of Dixon Springs, during the late 1970s. Several adits or drifts have been sunk into the hillside in the northwestern portion of the quadrangle to mine the Oldtown Coal Bed. A few surface mines have mined coal including the Albrecht Mine, Mt. Zion Mine, E. & L. Mine, Shawnee Mine, and the Rock Mine. Although heating value is among the highest in the basin and sulfur content is low in some cases, the minimal thickness and limited extent of coal layers in Pope County preclude large-scale operations. A substantial increase in coal prices would be required to resurrect interest in these deposits.

WELLS and BORINGS

Oil and Gas

While there have been shows of oil and gas in 7 wells, but no commercial production of oil and gas has occurred in Pope County. Additionally, 4 of the oil tests were later converted to water wells and their status is currently listed as water. We did not plot all of the wells that have been drilled in Pope County on the geologic map that accompanies this report. Appendix 2 lists all the wells and borings that are documented in Pope County. This data was extracted from the ISGS Oracle database, ISGS geologic quadrangle maps, and other sources of information. Several additional confidential mineral exploration boring are known to have been undertaken which are not depicted on the map sheets. Additional information on many of the oil and gas and water wells can be obtained at the ISGS web site (http://www.isgs.illinois.edu/).

Water Wells

No water wells have been included on the geologic map of Pope County. Appendix 2 contain a table of all of the documented wells drilled in Pope County. Detailed information on these water wells can be obtained at http://www.isgs.illinois.edu/ilwater. To view the well information, first open the ILWATAER interactive map, then click the (Find) button bar, and then input the API number in the (Find Well by API Number) box. Additional information on the Oil and gas wells can be obtained by the same method at http://www.isgs.illinois.edu/illinois-oil-and-gas-resources-iloil-interactive-map. The spatial location of the wells in the ISGS water well database may not be accurate. If you will be using the data for site specific investigations, it is advisable to verify the well location. The ISGS takes no responsibility for the quality of the data, including errors and omissions.
Potential exists to quarry sand and gravel from Quaternary deposits along the Ohio River flood plain and in the Cache Valley. High water table and hazard of flooding are the main deterrents. The fine-grained, well-sorted Parkland Sand on the terrace near Homberg is perhaps the most attractive prospect.

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Appendix 1. Mine locations in Pope County			
Mine Name	**Mine Type and Status**	**Latitude**	**Longitude**
Rock Candy Mountain	Shaft mine abandoned	37.52923203	-88.49900055
Williams	Pit or quarry abandoned	37.57063293	-88.44115448
Big Joe Prospect	Pit or quarry abandoned	37.53371811	-88.42804718
Douglass	Shaft mine abandoned	37.5184288	-88.42353821
Pierce	Shaft mine abandoned	37.52284622	-88.42228699
O. Crabb	Shaft mine abandoned	37.52886581	-88.41957092
Pierce Mine PMT Shaft	Shaft mine abandoned	37.52235031	-88.42490387
Williams	Shaft mine abandoned	37.54296112	-88.417099
Rainey	Shaft mine abandoned	37.54236984	-88.41737366
New Baldwin	Shaft mine abandoned	37.53927994	-88.41825104
C. Crabb #1	Shaft mine abandoned	37.53850937	-88.41931152
Conrad #4	Pit or quarry abandoned	37.53909683	-88.42282867
Conrad #3	Pit or quarry abandoned	37.53670502	-88.41931915
Conrad #1	Pit or quarry abandoned	37.53736877	-88.42675781
Baldwin	Shaft mine abandoned	37.53427505	-88.41755676
O. Crabb	Shaft mine abandoned	37.53286743	-88.42037964
Davenport	Shaft mine abandoned	37.5300827	-88.4223175
Empire	Shaft mine abandoned	37.52741623	-88.42227173
Red	Shaft mine abandoned	37.526371	-88.42436218
Red	Shaft mine abandoned	37.52612305	-88.42542267
Red	Shaft mine abandoned	37.52428055	-88.42786407
Pierce Mine PMT Shaft	Shaft mine abandoned	37.52214813	-88.42620087
Slapout	Shaft mine abandoned	37.51950836	-88.42460632
Little Jean	Shaft mine abandoned	37.35354233	-88.48461914
Compton	Shaft mine abandoned	37.26634216	-88.52497864
DeSautels	Shaft mine abandoned	37.53194809	-88.4970932
Moore	Shaft mine abandoned	37.53130722	-88.49786377
Tripod	Shaft mine abandoned	37.5287056	-88.49811554
Williams	Shaft mine abandoned	37.5273819	-88.50196075
Acup	Shaft mine abandoned	37.53821945	-88.41899109
O'Rear	Shaft mine abandoned	37.538414	-88.42402649
Todd	Shaft mine abandoned	37.53779984	-88.42612457
McKee	Pit or quarry abandoned	37.51543045	-88.4238739
Hicks Creek	Shaft mine abandoned	37.52318192	-88.42405701
Gullett	Shaft mine abandoned	37.52581787	-88.42679596
Turner	Shaft mine abandoned	37.52178574	-88.4307785
Lost 40	Shaft mine abandoned	37.50422668	-88.52681732
Scott	Shaft mine abandoned	37.49141312	-88.53684998
Clay Diggings	Shaft mine abandoned	37.47511292	-88.54679871
Balfour	Pit or quarry abandoned	37.4758873	-88.41493988
Holloman	Shaft mine abandoned	37.46952438	-88.41844177

Stockton	Shaft mine abandoned	37.45750046	-88.43109894
Lake Glendale	Pit or quarry abandoned	37.40314484	-88.65883636
Bay City Mine	Shaft mine abandoned	37.2659111	-88.52508545
Luella Mine	Pit or quarry abandoned	37.48847198	-88.52773285
Hubbard Shaft	Shaft mine abandoned	37.51900101	-88.42551422
Shelby Mine	Shaft mine abandoned	37.4867363	-88.43946838
McGuire Prospect	Shaft mine abandoned	37.48487091	-88.44264221
Fairbairn Shaft	Shaft mine abandoned	37.46078491	-88.41509247
Sam Parkinson Prospect	Shaft mine abandoned	37.45425797	-88.42061615
Black Jack Prospect	Shaft mine abandoned	37.44960785	-88.42027283
Reed Shaft	Shaft mine abandoned	37.44826508	-88.42218781
Rotes Prospect	Shaft mine abandoned	37.44158936	-88.42685699
Parkinson Mine	Shaft mine abandoned	37.45858383	-88.42951202
Barnett Mine	Shaft mine abandoned	37.45004272	-88.43779755
Barnett Shaft	Shaft mine abandoned	37.44168854	-88.44961548
Gaskins Mine	Shaft mine abandoned	37.51990509	-88.42357635
Henson	Shaft mine abandoned	37.4659729	-88.46858978
Senior Prospect	Pit or quarry abandoned	37.4890213	-88.4300766
E. & L. Mine	Coal surface mine area	37.59465	-88.69661
Farway Mine	Coal surface mine area	37.57083	-88.54607
Shawnee Mine	Coal surface mine area	37.43957	-88.56534
Bowman Mine	Coal surface mine area	37.39907	-88.61567
Morse Mine	Coal surface mine area	37.39907	-88.61567
Sistler Mine	Coal surface mine area	37.39907	-88.61567
Albrecht Mine	Coal surface mine area	37.39749	-88.61567
Mt. Zion Mine	Coal surface mine area	37.39749	-88.61567
Rock Mine	Coal surface mine area	37.39540	-88.61278
Durfee Mine	Drift coal mine abandoned	37.58665085	-88.62632751
unknown	Drift coal mine abandoned	37.59607697	-88.53999329
unknown	Drift coal mine abandoned	37.59501266	-88.54193878
unknown	Drift coal mine abandoned	37.59558487	-88.5461731
unknown	Drift coal mine abandoned	37.58219528	-88.58911133
unknown	Drift coal mine abandoned	37.56847763	-88.55008698
unknown	Drift coal mine abandoned	37.46697998	-88.53054047
unknown	Drift coal mine abandoned	37.543293	-88.65309906
unknown	Drift coal mine abandoned	37.51744843	-88.61929321
unknown	Drift coal mine abandoned	37.51676178	-88.61191559
unknown	Drift coal mine abandoned	37.53467178	-88.58912659
unknown	Drift coal mine abandoned	37.54336929	-88.52639008
unknown	Drift coal mine abandoned	37.54421616	-88.50800323
unknown	Drift coal mine abandoned	37.5708313	-88.54607391
unknown	Drift coal mine abandoned	37.57602692	-88.59457397
unknown	Drift coal mine abandoned	37.51446152	-88.52062988
unknown	Drift coal mine abandoned	37.47634506	-88.52390289
unknown	Drift coal mine abandoned	37.4782486	-88.52414703

unknown	Drift coal mine abandoned	37.47965622	-88.52148438
unknown	Drift coal mine abandoned	37.47891617	-88.51885223
unknown	Drift coal mine abandoned	37.43956757	-88.56533813
unknown	Drift coal mine abandoned	37.4275589	-88.58267212
unknown	Drift coal mine abandoned	37.41192245	-88.58030701
unknown	Drift coal mine abandoned	37.59730148	-88.68149567
unknown	Drift coal mine abandoned	37.58923721	-88.63230133
unknown	Gravel pit or quarry abandoned	37.27017975	-88.57064056
unknown	Gravel pit or quarry abandoned	37.25621033	-88.60500336
unknown	Gravel pit or quarry abandoned	37.28038406	-88.56757355
unknown	pit or quarry abandoned	37.26756668	-88.57021332
unknown	Gravel pit or quarry abandoned	37.28166962	-88.5869751
unknown	Limestone pit or quarry abandoned	37.26834869	-88.53787231
unknown	Limestone pit or quarry abandoned	37.46681976	-88.68760681
unknown	Sandstone pit or quarry abandoned	37.34727097	-88.51776123
unknown	Shaft mine abandoned	37.51875687	-88.43260193
unknown	Pit or quarry	37.14688492	-88.48438263
unknown	Pit or quarry	37.15161896	-88.47898102
unknown	Pit or quarry abandoned	37.45567322	-88.41855621
unknown	Pit or quarry abandoned	37.44438553	-88.45936584
unknown	Pit or quarry abandoned	37.49002457	-88.43170929
unknown	Pit or quarry abandoned	37.46873474	-88.41918945
unknown	Pit or quarry abandoned	37.47536087	-88.41485596
unknown	Pit or quarry abandoned	37.4785347	-88.45410156
unknown	Pit or quarry abandoned	37.47805405	-88.45500946
unknown	Pit or quarry abandoned	37.43909073	-88.56439209
unknown	Pit or quarry abandoned	37.47579956	-88.52324677
unknown	Pit or quarry abandoned	37.47770309	-88.52355194
unknown	Pit or quarry abandoned	37.47907639	-88.52107239
unknown	Pit or quarry abandoned	37.48610687	-88.58065033
unknown	Pit or quarry abandoned	37.5112648	-88.52061462
unknown	Pit or quarry abandoned	37.28084946	-88.63157654
unknown	Pit or quarry abandoned	37.5088501	-88.42267609
unknown	Pit or quarry abandoned	37.60393906	-88.41851044
unknown	Pit or quarry abandoned	37.59459305	-88.42843628
unknown	Pit or quarry abandoned	37.35366058	-88.5144577
unknown	Pit or quarry abandoned	37.13577801	-88.4751877
unknown	Pit or quarry abandoned	37.17150879	-88.44438171

Appendix 2. List of wells and boring in Pope County

API Number	Status	Symbol ID	Total Depth	Latitude	Longitude
121512039800	COAL	Coal boring	141	37.583824	-88.569927
121512039900	COAL	Coal boring	141	37.58149	-88.543862
121510001200	COAL	Coal boring	46	37.398089	-88.611678
121510001300	COAL	Coal boring	28	37.395323	-88.610667
121510001400	COAL	Coal boring	53	37.405468	-88.61136
121510001600	COAL	Coal boring	74	37.398243	-88.608445
121510001800	COAL	Coal boring	75	37.396863	-88.608448
121510002000	COAL	Coal boring	60	37.399456	-88.610759
121510002100	COAL	Coal boring	45	37.394606	-88.612468
121510014600	COAL	Coal boring	60	37.595535	-88.686307
121510014700	COAL	Coal boring	65	37.598121	-88.681573
121510014800	COAL	Coal boring	39	37.591936	-88.681716
121510014900	COAL	Coal boring	75	37.595486	-88.678252
121510015900	COAL	Coal boring	67	37.594617	-88.635092
121510016100	COAL	Coal boring	37	37.59476	-88.628846
121512032200	COAL	Coal boring	240	37.505274	-88.709231
121510020600	COAL	Coal boring	200	37.41313	-88.5086
121510015500	COAL	Coal boring	1040	37.533017	-88.495705
121510015801	DA	Dry hole	4100	37.123556	-88.480254
121510000200	DA	Dry hole	1670	37.578756	-88.604741
121510002900	DA	Dry hole	1760	37.581781	-88.603985
121510018400	DA	Dry hole	610	37.379251	-88.609702
121510003000	DA	Dry hole	1398	37.542585	-88.693968
121510002800	DA	Dry hole	1692	37.57294	-88.637488
121512030600	DA	Dry hole	1165	37.309263	-88.668851
121510010600	DA	Dry hole	1800	37.339115	-88.676004
121510010700	DA	Dry hole	1000	37.383535	-88.583265
121510013300	DA	Dry hole	527	37.264693	-88.580941
121510003600	DA	Dry hole	455	37.598777	-88.45852
121510019600	DA	Dry hole	320	37.14641	-88.434315
121510015600	DA	Dry hole	2297	37.563793	-88.515859
121512030200	DAP	Dry hole	14942	37.589625	-88.512791
121512045900	DAP	Dry hole	362	37.507591	-88.5339
121510015300	DAP	Dry hole	1132	37.582398	-88.597824
121510024400	DAP	Dry hole	3802	37.400957	-88.531499
121510014500	DAP	Dry hole	800	37.48322	-88.436042
121510015100	DAP	Dry hole	2631	37.569273	-88.612068
121510003200	DAP	Dry hole	2204	37.539851	-88.693374
121510018600	TA	Dry hole	1375	37.297736	-88.539081
121510021100	TAP	Dry hole	550	37.338733	-88.591378
	DA	Dry hole	1065	37.28475952	-88.55690002
121510000100	DAG	Dry hole show of gas	1760	37.581786	-88.604332
121510018500	DAG	Dry hole show of gas	1450	37.173341	-88.456889
121510018201	DAGP	Dry hole show of gas	1100	37.351311	-88.609754
121510015800	DAO	Dry hole show of oil	2000	37.123556	-88.480254

121510003100	DAO	Dry hole show of oil	1236	37.536231	-88.688266
121512028500	DAO	Dry hole show of oil	1203	37.36646	-88.662168
121512030700	DAOP	Dry hole show of oil	880	37.308491	-88.643986
121510002300	ENG	Engineering boring	25	37.581294	-88.65443
121512048800	ENG	Engineering boring	102	37.352092	-88.492884
121512049000	ENG	Engineering boring	50	37.358628	-88.600538
121512049400	ENG	Engineering boring	83	37.370627	-88.488075
121512050200	ENG	Engineering boring	23	37.256353	-88.508435
121512050400	ENG	Engineering boring	17	37.251294	-88.501304
121512048500	ENG	Engineering boring	42	37.225603	-88.556344
121512050100	ENG	Engineering boring	78	37.256066	-88.511671
121512051400	ENG	Engineering boring	24	37.368935	-88.615352
121512501600	ENG	Engineering boring	19	37.339272	-88.524066
121512051900	ENG	Engineering boring	54	37.319034	-88.551622
121512052100	ENG	Engineering boring	22	37.244191	-88.505839
121512061700	ENG	Engineering boring	54	37.227482	-88.549351
121512061300	ENG	Engineering boring	15	37.481689	-88.454611
121510004700	MINER	Mineral boring	150	37.536276	-88.426413
121510004800	MINER	Mineral boring	182	37.536276	-88.426413
121510005000	MINER	Mineral boring	149	37.529906	-88.417796
121510005100	MINER	Mineral boring	125	37.530359	-88.417512
121510005200	MINER	Mineral boring	105	37.53101	-88.416615
121510006800	MINER	Mineral boring	235	37.525252	-88.425772
121510007000	MINER	Mineral boring	180	37.52275	-88.423833
121510007100	MINER	Mineral boring	305	37.525398	-88.425111
121510007300	MINER	Mineral boring	272	37.523604	-88.423058
121510007400	MINER	Mineral boring	197	37.522291	-88.424384
121510007800	MINER	Mineral boring	187	37.485195	-88.44274
121510007900	MINER	Mineral boring	212	37.485195	-88.44274
121510008000	MINER	Mineral boring	133	37.484553	-88.442816
121510008100	MINER	Mineral boring	597	37.485496	-88.438285
121510008200	MINER	Mineral boring	398	37.485909	-88.438712
121510008500	MINER	Mineral boring	500	37.460191	-88.427362
121510008600	MINER	Mineral boring	350	37.461618	-88.424145
121510008700	MINER	Mineral boring	352	37.461484	-88.423953
121510008800	MINER	Mineral boring	506	37.461852	-88.4226
121510013100	MINER	Mineral boring	30	37.266257	-88.525064
121510015000	MINER	Mineral boring	853	37.511005	-88.519615
121510019900	MINER	Mineral boring	395	37.528393	-88.49922
121510020000	MINER	Mineral boring	441	37.52761	-88.499029
121510020100	MINER	Mineral boring	291	37.528932	-88.498356
121510020200	MINER	Mineral boring	264	37.529425	-88.497864
121510020300	MINER	Mineral boring	260	37.4867	-88.439476
121510021300	MINER	Mineral boring	597	37.484615	-88.43969
121512033000	MINER	Mineral boring	1123	37.459024	-88.477233
121512040700	MINER	Mineral boring	517	37.436677	-88.44063
121512041600	MINER	Mineral boring	368	37.466244	-88.458505
121512058300	MINER	Mineral boring	729	37.472619	-88.462282
121512054300	MINER	Mineral boring	1176	37.475009	-88.461015

121512058400	MINER	Mineral boring	931	37.465971	-88.468968
121512058600	MINER	Mineral boring	726	37.545067	-88.473687
121512058700	MINER	Mineral boring	952	37.487875	-88.533165
121512058800	MINER	Mineral boring	1417	37.470636	-88.51705
121512059000	MINER	Mineral boring	976	37.461492	-88.479483
121512059100	MINER	Mineral boring	1035	37.475386	-88.45997
121512059400	MINER	Mineral boring	904	37.461492	-88.479483
121512059600	MINER	Mineral boring	885	37.430078	-88.461703
121512059700	MINER	Mineral boring	1155	37.427965	-88.463738
121512059800	MINER	Mineral boring	1306	37.432266	-88.461049
121512058500	MINER	Mineral boring	1486	37.54686	-88.475981
121512059200	MINER	Mineral boring	778	37.472541	-88.46283
121512059300	MINER	Mineral boring	729	37.469241	-88.452124
121512059900	MINER	Mineral boring	1207	37.41927	-88.468306
121512059500	MINER	Mineral boring	915	37.431428	-88.460279
121512063500	WATER	Mineral boring	7	37.436849	-88.665454
	MINER	Mineral boring	194	37.26333618	-88.52936554
	MINER	Mineral boring	392	37.26631927	-88.52622223
	MINER	Mineral boring	124	37.26250458	-88.52848816
	MINER	Mineral boring	777	37.36835861	-88.58721161
	MINER	Mineral boring		37.31016541	-88.57424927
	MINER	Mineral boring		37.31101227	-88.57608032
	MINER	Mineral boring		37.30941391	-88.57723999
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	MINER	Mineral boring		37.31058502	-88.57510376
	MINER	Mineral boring		37.31041336	-88.57474518
	MINER	Mineral boring		37.46092224	-88.47562408
	MINER	Mineral boring		37.46179199	-88.47902679
	MINER	Mineral boring		37.46227264	-88.47843933
	MINER	Mineral boring		37.46276474	-88.47779083
	MINER	Mineral boring		37.46200562	-88.47545624
	MINER	Mineral boring		37.4616127	-88.47497559
	MINER	Mineral boring		37.46321106	-88.47706604
	MINER	Mineral boring		37.46380234	-88.47619629
	MINER	Mineral boring		37.46432877	-88.47556305
	MINER	Mineral boring		37.46293259	-88.47331238
	MINER	Mineral boring		37.46480942	-88.47489166
	MINER	Mineral boring		37.46521378	-88.47425079
	MINER	Mineral boring		37.46351624	-88.47210693
	MINER	Mineral boring		37.46409607	-88.47126007
	MINER	Mineral boring		37.46595383	-88.47333527
	MINER	Mineral boring		37.46482849	-88.47038269
	MINER	Mineral boring		37.46639252	-88.47270966
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	MINER	Mineral boring		37.46963882	-88.46685791
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	MINER	Mineral boring		37.47004318	-88.46281433
	MINER	Mineral boring		37.48662949	-88.43942261
	MINER	Mineral boring		37.4853363	-88.4383316
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	MINER	Mineral boring		37.46052551	-88.42712402
	MINER	Mineral boring		37.46166611	-88.42379761
	MINER	Mineral boring		37.46141815	-88.42263031
	MINER	Mineral boring		37.44051361	-88.49233246
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	MINER	Mineral boring		37.47422791	-88.4618454
	MINER	Mineral boring		37.47243881	-88.46533966
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	MINER	Mineral boring		37.47237778	-88.45370483
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	MINER	Mineral boring		37.4753418	-88.46031952
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	MINER	Mineral boring		37.42800522	-88.46385193
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	MINER	Mineral boring		37.42842102	-88.46420288
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	MINER	Mineral boring		37.43427277	-88.45821381
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	MINER	Mineral boring		37.4370575	-88.45675659
	MINER	Mineral boring		37.42740631	-88.46494293
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121510000300	JA	Other boring	660	37.568614	-88.641007
121510015700	JA	Other boring	225	37.136463	-88.475725
121510002200	JAP	Other boring	3075	37.58356	-88.670933
121510012900	STRU	Other boring	300	37.266812	-88.525416
121512045100	STRU	Other boring	181	37.519169	-88.570157
121512042400	STRU	Other boring	280	37.497652	-88.548498
121512054100	STRU	Other boring	943	37.464879	-88.470264
121512054200	STRU	Other boring	1185	37.464879	-88.470264
	COAL	Other boring	696	37.52200317	-88.43402863
121510004000	STRAT	Stratigraphic boring	133	37.576376	-88.429325
121510004200	STRAT	Stratigraphic boring	65	37.572477	-88.426299
121510004300	STRAT	Stratigraphic boring	162	37.567733	-88.430281
121510004900	STRAT	Stratigraphic boring	210	37.536276	-88.426413
121510006400	STRAT	Stratigraphic boring	254	37.519226	-88.422562
121510006500	STRAT	Stratigraphic boring	219	37.518063	-88.423657
121510006900	STRAT	Stratigraphic boring	196	37.525499	-88.42556
121510007500	STRAT	Stratigraphic boring	252	37.460577	-88.703304
121510007600	STRAT	Stratigraphic boring	680	37.435032	-88.66777
121510008400	STRAT	Stratigraphic boring	203	37.466792	-88.468419
121510015400	STRAT	Stratigraphic boring	122	37.52714	-88.501715
121510019700	STRAT	Stratigraphic boring	272	37.527411	-88.502062
121510020400	STRAT	Stratigraphic boring	95	37.471792	-88.417857
121510020500	STRAT	Stratigraphic boring	100	37.471792	-88.417857
121510020700	STRAT	Stratigraphic boring	104	37.440552	-88.492272
121510020800	STRAT	Stratigraphic boring	212	37.440732	-88.491127
121510020900	STRAT	Stratigraphic boring	226	37.425232	-88.513128
121512040000	STRAT	Stratigraphic boring	181	37.519976	-88.569575
121512052600	STRAT	Stratigraphic boring	1194	37.465425	-88.469581
121512057900	STRAT	Stratigraphic boring	18	37.36266	-88.61067
121512058000	STRAT	Stratigraphic boring	28	37.348167	-88.609706
121512058100	STRAT	Stratigraphic boring	9	37.37632	-88.487481
121512060000	STRAT	Stratigraphic boring	477	37.470303	-88.516535
121512060800	STRAT	Stratigraphic boring	166	37.474091	-88.512421
121512060900	STRAT	Stratigraphic boring	166	37.476464	-88.525797
121510011500	STRAT	Stratigraphic boring	14	37.416254	-88.489079
121510011600	STRAT	Stratigraphic boring	15	37.4057	-88.471056

121510011700	STRAT	Stratigraphic boring	23	37.364876	-88.486395
121510012000	STRAT	Stratigraphic boring	30	37.377716	-88.488399
121510012100	STRAT	Stratigraphic boring	31	37.375436	-88.485705
121510012200	STRAT	Stratigraphic boring	132	37.378071	-88.486138
121510012300	STRAT	Stratigraphic boring	182	37.376369	-88.489652
121512066900	STRAT	Stratigraphic boring	155	37.146557	-88.43316
121512068100	STRAT	Stratigraphic boring	121	37.152014	-88.426362
121512068200	STRAT	Stratigraphic boring	141	37.128838	-88.447943
121512068300	STRAT	Stratigraphic boring	78	37.124612	-88.44285
121512068500	STRAT	Stratigraphic boring	124	37.122795	-88.440586
121512068700	STRAT	Stratigraphic boring	142	37.121432	-88.438888
121512069400	STRAT	Stratigraphic boring	97	37.122488	-88.444749
121510006900	STRAT	Stratigraphic boring	195	37.53069687	-88.41648102
121510006600	STRAT	Stratigraphic boring	376	37.52521133	-88.42449188
121510006700	STRAT	Stratigraphic boring	282	37.52521133	-88.42558289
121510006400	STRAT	Stratigraphic boring	254	37.51904297	-88.42218018
121510006500	STRAT	Stratigraphic boring	219	37.5178833	-88.42337036
121512058500	STRAT	Stratigraphic boring	1486	37.54709244	-88.47782898
121512042000	STRATP	Stratigraphic boring	166	37.477007	-88.526411
121512040400	STRATP	Stratigraphic boring	316	37.465217	-88.659575
121512041900	STRATP	Stratigraphic boring	166	37.474257	-88.512354
	STRAT	Stratigraphic boring	225	37.53121185	-88.41559601
	STRAT	Stratigraphic boring	35	37.54506302	-88.47433472
	STRAT	Stratigraphic boring	488	37.5214653	-88.43282318
	STRAT	Stratigraphic boring	200	37.48973465	-88.43156433
121510018200	DAW	Water well	790	37.351311	-88.609754
121510024900	DRY	Water well	170	37.358368	-88.536705
121510021400	DRY	Water well	600	37.426559	-88.424835
121512065200	DRYP	Water well	61	37.145651	-88.434292
121512033900	WATER	Water well	260	37.529156	-88.690633
121512034300	WATER	Water well	328	37.136383	-88.459678
121512036600	WATER	Water well	328	37.1382	-88.450464
121512041700	WATER	Water well	147	37.506835	-88.417375
121512044200	WATER	Water well	420	37.46078	-88.41578
121512044500	WATER	Water well	450	37.297975	-88.578316
121512044700	WATER	Water well	596	37.175157	-88.463817
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121512045700	WATER	Water well	90	37.358646	-88.595884
121512046300	WATER	Water well	50	37.138292	-88.484878
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121512057400	WATER	Water well	786	37.275755	-88.587609
121512062100	WATER	Water well	412	37.136361	-88.443554
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121512066600	WATER	Water well	806	37.318133	-88.662417
121512066800	WATER	Water well	65	37.08105	-88.4714
121512047400	WATER	Water well	200	37.508027	-88.535457
121512047900	WATER	Water well	374	37.425411	-88.640824
121512036500	WATER	Water well	40	37.147536	-88.489455
121512036800	WATER	Water well	191	37.40833	-88.609536

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121512046000	WATER	Water well	340	37.539684	-88.67667
121512046100	WATER	Water well	136	37.318458	-88.673491
121512046800	WATER	Water well	234	37.266343	-88.557932
121512046900	WATER	Water well	165	37.26819	-88.560229
121512051300	WATER	Water well	170	37.206433	-88.527768
121512052300	WATER	Water well	38	37.177014	-88.459186
121512052400	WATER	Water well	45	37.17332	-88.461512
121512056600	WATER	Water well	160	37.152989	-88.45734
121512056700	WATER	Water well	333	37.179098	-88.509151
121512056800	WATER	Water well	452	37.186475	-88.504265
121512042100	WATER	Water well	203	37.3371	-88.705567
121512064600	WATER	Water well	242	37.54485	-88.47345
121512064500	WATER	Water well	320	37.518233	-88.686175
121512035800	WATER	Water well	572	37.402612	-88.579543
121512035900	WATER	Water well	330	37.410179	-88.591065
121512036200	WATER	Water well	40	37.314435	-88.557516
121512036300	WATER	Water well	54	37.308887	-88.550621
121512042300	WATER	Water well	65	37.597271	-88.455575
121512043200	WATER	Water well	350	37.529258	-88.477145
121512043400	WATER	Water well	188	37.277387	-88.55553
121512043900	WATER	Water well	750	37.525406	-88.430944
121512044400	WATER	Water well	54	37.311649	-88.549413
121512046200	WATER	Water well	210	37.268184	-88.557919
121512055100	WATER	Water well	370	37.31243	-88.52751
121272118300	WATER	Water well	162	37.158525	-88.483481
121512047300	WATER	Water well	200	37.215663	-88.52067
121512047700	WATER	Water well	354	37.301668	-88.659926
121512031600	WATER	Water well	100	37.180717	-88.463879
121512041500	WATER	Water well	270	37.308181	-88.632641
121512044000	WATER	Water well	390	37.494002	-88.41977
121512055200	WATER	Water well	50	37.305136	-88.546019
121512043600	WATER	Water well	56	37.154972	-88.480254
121512062500	WATER	Water well	560	37.401157	-88.646162
121512066100	WATER	Water well	302	37.196083	-88.477519
121512031700	WATER	Water well	300	37.188089	-88.459293
121512036100	WATER	Water well	55	37.31627	-88.550504
121512041400	WATER	Water well	513	37.210032	-88.496647
121512043300	WATER	Water well	189	37.505071	-88.424158
121512055800	WATER	Water well	51	37.154972	-88.480254
121512063800	WATER	Water well	75	37.321944	-88.676667
121512047200	WATER	Water well	227	37.329183	-88.557508
121510027900	WATER	Water well	128	37.246948	-88.502348
121512034800	WATER	Water well	340	37.546079	-88.473628
121512035100	WATER	Water well	103	37.473532	-88.70177
121512035300	WATER	Water well	600	37.431859	-88.534268
121512035500	WATER	Water well	170	37.357002	-88.501489
121512046400	WATER	Water well	598	37.552869	-88.6467
121512054500	WATER	Water well	172	37.595336	-88.455627

121512056300	WATER	Water well	313	37.156722	-88.489261
121512042700	WATER	Water well	163	37.39005	-88.607324
121512056500	WATER	Water well	148	37.156873	-88.468865
121512055900	WATER	Water well	255	37.2645	-88.555635
121512057000	WATER	Water well	193	37.140075	-88.461973
121512062900	WATER	Water well	190	37.282929	-88.546186
121512064900	WATER	Water well	460	37.138211	-88.445848
121512064200	WATER	Water well	386	37.438167	-88.493383
121512064400	WATER	Water well	265	37.328567	-88.528317
121512065700	WATER	Water well	462	37.573411	-88.666789
121512066000	WATER	Water well	860	37.203286	-88.486425
121512066300	WATER	Water well	50	37.092967	-88.4635
121512034000	WATER	Water well	515	37.534423	-88.685995
121512034400	WATER	Water well	75	37.583723	-88.435144
121512036000	WATER	Water well	165	37.356773	-88.600548
121512038100	WATER	Water well	53	37.402836	-88.574911
121512044300	WATER	Water well	90	37.337474	-88.502988
121512045400	WATER	Water well	270	37.435878	-88.561341
121512045500	WATER	Water well	210	37.490684	-88.442796
121512045800	WATER	Water well	374	37.573054	-88.483616
121512054400	WATER	Water well	320	37.543377	-88.678919
121512063200	WATER	Water well	156	37.44329	-88.617755
121512064100	WATER	Water well	129	37.360667	-88.594
121512065000	WATER	Water well	72	37.29875	-88.523083
121512065100	WATER	Water well	500	37.284	-88.5532
121512066200	WATER	Water well	375	37.1371	-88.4625
121512047100	WATER	Water well	230	37.213827	-88.520698
121512048000	WATER	Water well	245	37.408346	-88.618771
121512034200	WATER	Water well	360	37.552238	-88.580103
121512035600	WATER	Water well	314	37.41769	-88.446801
121512035700	WATER	Water well	125	37.344261	-88.555614
121512044600	WATER	Water well	456	37.268159	-88.52537
121512046500	WATER	Water well	456	37.262649	-88.53932
121512046600	WATER	Water well	210	37.262656	-88.553335
121512057300	WATER	Water well	415	37.465581	-88.487626
121512060300	WATER	Water well	280	37.222906	-88.496645
121512065500	WATER	Water well	328	37.401017	-88.64295
121512065600	WATER	Water well	140	37.158626	-88.461946
121512034500	WATER	Water well	110	37.56942	-88.485987
121512034900	WATER	Water well	202	37.537955	-88.435093
121512036400	WATER	Water well	89	37.260856	-88.546375
121512036900	WATER	Water well	420	37.261306	-88.603307
121512043700	WATER	Water well	180	37.52717	-88.424222
121512048100	WATER	Water well	170	37.445076	-88.617716
121512048200	WATER	Water well	213	37.262656	-88.553335
121512048300	WATER	Water well	294	37.262656	-88.553335
121512056100	WATER	Water well	253	37.286817	-88.57379
121512061900	WATER	Water well	585	37.226599	-88.496642
121512057100	WATER	Water well	250	37.439545	-88.570548

121512062400	WATER	Water well	293	37.260859	-88.551024
121512064000	WATER	Water well	165	37.391283	-88.585267
121512064800	WATER	Water well	342	37.573517	-88.597183
121512047000	WATER	Water well	90	37.145667	-88.478109
121512047600	WATER	Water well	130	37.262645	-88.546373
121512034100	WATER	Water well	300	37.585714	-88.505955
121512035000	WATER	Water well	55	37.534818	-88.486447
121512043000	WATER	Water well	310	37.492147	-88.419804
121512044100	WATER	Water well	125	37.460941	-88.422624
121512054900	WATER	Water well	65	37.3323	-88.646035
121512054600	WATER	Water well	232	37.523856	-88.706366
121512054800	WATER	Water well	65	37.332515	-88.655283
121512056400	WATER	Water well	35	37.325467	-88.557469
121512061800	WATER	Water well	380	37.460277	-88.65368
121512057800	WATER	Water well	297	37.264511	-88.560259
121512057200	WATER	Water well	402	37.190083	-88.475563
121512060100	WATER	Water well	248	37.534455	-88.424162
121512064300	WATER	Water well	120	37.388485	-88.669075
121512047800	WATER	Water well	2	37.262656	-88.553335
121512034600	WATER	Water well	35	37.595328	-88.448772
121512034700	WATER	Water well	32	37.589496	-88.451247
121512035200	WATER	Water well	125	37.445901	-88.665267
121512040300	WATER	Water well	493	37.421396	-88.451458
121512042900	WATER	Water well	165	37.383051	-88.678297
121512043800	WATER	Water well	260	37.585881	-88.519773
121512045200	WATER	Water well	168	37.599186	-88.460075
121512055400	WATER	Water well	252	37.179083	-88.511559
121512054700	WATER	Water well	65	37.350063	-88.653143
121512057500	WATER	Water well	55	37.136452	-88.471147
121512057600	WATER	Water well	61	37.138292	-88.484881
121512057700	WATER	Water well	300	37.539954	-88.649096
121512062800	WATER	Water well	170	37.310915	-88.582761
121512065400	WATER	Water well	300	37.438137	-88.633659
121512066500	WATER	Water well	75	37.347317	-88.6566
121512047500	WATER	Water well	152	37.391857	-88.586693
121512037000	WATER	Water well	109	37.281196	-88.569281
121512042800	WATER	Water well	140	37.469616	-88.674023
121512043500	WATER	Water well	89	37.338663	-88.489891
121512045000	WATER	Water well	27	37.327339	-88.552872
121512045300	WATER	Water well	882	37.558461	-88.479202
121512055300	WATER	Water well	252	37.264511	-88.560259
121512055500	WATER	Water well	101	37.218813	-88.470257
121512055600	WATER	Water well	190	37.164059	-88.454877
121512055000	WATER	Water well	60	37.323853	-88.596289
121512056200	WATER	Water well	80	37.341094	-88.682869
121512055700	WATER	Water well	128	37.393677	-88.59125
121512056900	WATER	Water well	620	37.211989	-88.520726
121512060400	WATER	Water well	477	37.186475	-88.504265
121512062700	WATER	Water well	350	37.536645	-88.481735

121512062600	WATER	Water well	210	37.31827	-88.666616
121512063000	WATER	Water well	49	37.308846	-88.545973
121512063100	WATER	Water well	620	37.228252	-88.496019
121512063300	WATER	Water well	300	37.572836	-88.692353
121512063400	WATER	Water well	160	37.596439	-88.453327
121512063700	WATER	Water well	250	37.37527	-88.588985
121512063900	WATER	Water well	48	37.141936	-88.466599
121512066400	WATER	Water well	230	37.5053	-88.569232
121512065900	WATER	Water well	222	37.200369	-88.528778
121512066700	WATER	Water well	382	37.553514	-88.459339
121510000400	WATER	Water well	275	37.415287	-88.660912
121510003400	WATER	Water well	73	37.524462	-88.662095
121510007700	WATER	Water well	257	37.497524	-88.588888
121510009100	WATER	Water well	124	37.411533	-88.663212
121510009200	WATER	Water well	104	37.412716	-88.662285
121510009300	WATER	Water well	395	37.424019	-88.675892
121510010400	WATER	Water well	235	37.384823	-88.672552
121510010900	WATER	Water well	77	37.373819	-88.556696
121510011000	WATER	Water well	485	37.372719	-88.519248
121510011100	WATER	Water well	54	37.3794	-88.498756
121510011900	WATER	Water well	151	37.372547	-88.485168
121510012400	WATER	Water well	565	37.31449	-88.629186
121510012500	WATER	Water well	397	37.299411	-88.62816
121510018300	WATER	Water well	365	37.40855	-88.668267
121510019500	WATER	Water well	485	37.376455	-88.661098
121510021500	WATER	Water well	100	37.429414	-88.433443
121510022500	WATER	Water well	116	37.497594	-88.41753
121510022600	WATER	Water well	110	37.581924	-88.690002
121510022700	WATER	Water well	80	37.393961	-88.472984
121510022800	WATER	Water well	385	37.386458	-88.486225
121510022900	WATER	Water well	134	37.374559	-88.487948
121510023000	WATER	Water well	89	37.468176	-88.570925
121510023100	WATER	Water well	185	37.469497	-88.664926
121510023200	WATER	Water well	110	37.441413	-88.666509
121510023300	WATER	Water well	215	37.468442	-88.674656
121510023400	WATER	Water well	90	37.455204	-88.654179
121510023500	WATER	Water well	158	37.228393	-88.482392
121510023600	WATER	Water well	188	37.366802	-88.689652
121510023700	WATER	Water well	112	37.450422	-88.668577
121510023800	WATER	Water well	130	37.464979	-88.668382
121510023900	WATER	Water well	275	37.347649	-88.68858
121510024000	WATER	Water well	60	37.454015	-88.668491
121510024100	WATER	Water well	325	37.354813	-88.679395
121510024200	WATER	Water well	120	37.571219	-88.497477
121510024300	WATER	Water well	35	37.123418	-88.45056
121510024500	WATER	Water well	200	37.33192	-88.500769
121510024600	WATER	Water well	100	37.270284	-88.5716
121510024700	WATER	Water well	65	37.138629	-88.431643
121510024800	WATER	Water well	382	37.358288	-88.53902

121510025000	WATER	Water well	230	37.364053	-88.534337
121510025100	WATER	Water well	225	37.335716	-88.569439
121510025200	WATER	Water well	35	37.491138	-88.414138
121510025300	WATER	Water well	160	37.466244	-88.458505
121510025500	WATER	Water well	110	37.45767	-88.668456
121510025700	WATER	Water well	150	37.486244	-88.59026
121510025800	WATER	Water well	135	37.450344	-88.654939
121510025900	WATER	Water well	90	37.446828	-88.668663
121510026000	WATER	Water well	485	37.364683	-88.515369
121510026100	WATER	Water well	100	37.394443	-88.674037
121510026200	WATER	Water well	250	37.381331	-88.68518
121510026300	WATER	Water well	253	37.456963	-88.683367
121510026400	WATER	Water well	145	37.370281	-88.678224
121510026500	WATER	Water well	125	37.16215	-88.445738
121510026600	WATER	Water well	100	37.159882	-88.464701
121510026700	WATER	Water well	210	37.457097	-88.465686
121510026800	WATER	Water well	118	37.385797	-88.677121
121510026900	WATER	Water well	90	37.420318	-88.518508
121510027000	WATER	Water well	110	37.401975	-88.518863
121510027100	WATER	Water well	140	37.262519	-88.583738
121510027200	WATER	Water well	65	37.531099	-88.481816
121510027300	WATER	Water well	120	37.34764	-88.496646
121510027400	WATER	Water well	185	37.536287	-88.433238
121510027500	WATER	Water well	105	37.361114	-88.673625
121510027600	WATER	Water well	675	37.391696	-88.57022
121510027700	WATER	Water well	95	37.249061	-88.499091
121510027800	WATER	Water well	200	37.373675	-88.655354
121510028000	WATER	Water well	100	37.449517	-88.667462
121510028100	WATER	Water well	125	37.442368	-88.6722
121510028200	WATER	Water well	200	37.336493	-88.522921
121512028300	WATER	Water well	850	37.376555	-88.495111
121512028400	WATER	Water well	355	37.136383	-88.43199
121512028700	WATER	Water well	100	37.418014	-88.648241
121512028800	WATER	Water well	105	37.561836	-88.423821
121512028900	WATER	Water well	100	37.403023	-88.500907
121512029000	WATER	Water well	300	37.387826	-88.563191
121512029100	WATER	Water well	200	37.336501	-88.520609
121512029200	WATER	Water well	180	37.578243	-88.439804
121512029300	WATER	Water well	430	37.316059	-88.511446
121512029400	WATER	Water well	390	37.31791	-88.509146
121512029500	WATER	Water well	276	37.520011	-88.560341
121512029600	WATER	Water well	150	37.351274	-88.59359
121512029700	WATER	Water well	390	37.534506	-88.435566
121512030100	WATER	Water well	185	37.402882	-88.520003
121512030300	WATER	Water well	175	37.53082	-88.624017
121512030400	WATER	Water well	85	37.576379	-88.425849
121512030500	WATER	Water well	200	37.551006	-88.414967
121512030800	WATER	Water well	435	37.336493	-88.522921
121512030900	WATER	Water well	333	37.552685	-88.685728

121512031000	WATER	Water well	75	37.585606	-88.432782
121512031100	WATER	Water well	200	37.474021	-88.610561
121512031200	WATER	Water well	230	37.377252	-88.641663
121512031300	WATER	Water well	80	37.391813	-88.598117
121512031400	WATER	Water well	142	37.334676	-88.501851
121512031500	WATER	Water well	200	37.27577	-88.589868
121512031800	WATER	Water well	200	37.136411	-88.464263
121512031900	WATER	Water well	100	37.137144	-88.432645
121512040600	WATER	Water well	235	37.374497	-88.483383
121512040800	WATER	Water well	78	37.583811	-88.434779
121512040900	WATER	Water well	461	37.435119	-88.668323
121512041000	WATER	Water well	30	37.500483	-88.587555
121512041100	WATER	Water well	250	37.43703	-88.482036
121512041200	WATER	Water well	250	37.419948	-88.487612
121512056000	WATER	Water well	172	37.302333	-88.537925
121510000500	WATER	Water well	142	37.382834	-88.657662
121512061500	WATER	Water well	95	37.379079	-88.641676
121510010500	WATER	Water well	95	37.35853	-88.683952
121512040500	WATER	Water well	130	37.453034	-88.653765
121512060200	WATER	Water well	0	37.444237	-88.679034
121512060500	WATER	Water well	220	37.542671	-88.643347
121512060600	WATER	Water well	276	37.520862	-88.657572
121510015200	WATER	Water well	293	37.378342	-88.667994
121512061400	WATER	Water well	94	37.409483	-88.656668
121512043400	WATER	Water well	188	37.27690125	-88.55136108
121512029300	WATER	Water well	410	37.31661987	-88.5105896
121510024800	WATER	Water well	555	37.3579216	-88.53804016
121510025300	WATER	Water well	160	37.46611023	-88.45877838
121512031800	WATER	Water well	200	37.13751984	-88.46269989
121512034300	WATER	Water well	328	37.13754272	-88.45902252
	WATER	Water well	600	37.48668289	-88.47366333
	WATER	Water well	38	37.24560165	-88.49247742
	WATER	Water well	40	37.2287941	-88.48369598

Appendix 2 was compiled from several sources in the ISGS records, including paper records, the ISGS Oracle database, oil and gas database (IL-OIL), Water well database (IL-WATER), and 7.5-minute geologic quadrangle maps. The data was extracted during the Spring of 2016.

The API field is the unique ID issued by the state of Illinois to conform to the American Petroleum Institute standards. 12 digit number assigned by the ISGS consists of "12" - state code / "151" Pope County code and a 5 digit unique number with a final 2 digit re-drill code. Some wells do not have an accompanying API number, but are within the ISGS records. The Status field is a unique ISGS abbreviation for the well type when it was drilled. The complete legend for the ISGS well status codes can be obtained at http://isgs.illinois.edu/well-location-questor-maps. The symbol ID field correlates with the well symbol on the map. Total depth is the depth drilled below the ground surface in feet. Latitude and longitude are in decimal degrees (NAD 1983).