

STATEMAP
Hardin Co-BG

Bedrock Geology of Hardin County, Illinois

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1. Introduction

This report accompanies a 1:48,000 scale map of Hardin County, Illinois. Hardin County is situated in southeastern Illinois, bordered on the west by Pope County, on the north by Saline and Gallatin Counties, and on the south and east by the Ohio River (Fig. 1). Fieldwork was conducted in 2013 and 2014. Outcrops were common along steep slopes but were concealed by soil cover in the sinkhole plain in the southeastern portion of the map area. Faults were rarely exposed and often inferred by interpolating the locations of fluorite mines. The oldest rocks of Devonian age are exposed at Hicks Dome, in the northwestern part of the county. Mississippian rocks crop out in an oval-shaped belt around the central uplift. Pennsylvanian rocks occur in the northern and eastern parts of the county, as well as in the Rock Creek Graben. Permian igneous intrusions occur as dikes or narrow sub-vertical “pipe-like” intrusions and in thin layered sills. These rocks are ultramafic lamprophyres, autolithic breccias, and diatremes and are present throughout Hardin County. The igneous rocks trend north-northwest and are also clustered around the periphery of Hicks Dome.



Figure 1 Project location map.

2. Background and Methods

The Hardin County geologic map utilizes data from eight 7.5-minute quadrangle maps: Shetlerville, Herod, Rosiclare, Karbers Ridge, Cave-in-Rock, Saline Mines, Repton, and Dekoven. Recent 1:24,000 scale maps of each of these quadrangles have been completed within the past decade through a joint initiative between the ISGS and USGS (Denny et al. 2008a, 2010, 2011b, 2013; Denny and Counts 2009; Seid et al. 2013a, 2013b; Seid and Denny 2014). These 1:24,000 scale maps were combined, and the scale was reduced to 1:48,000. Outcrop studies were conducted along quadrangle boundaries to rectify interpretations from different authors. Thin map units were combined, and closely spaced faults were omitted for clarity.

Oil and gas test holes, water well descriptions, mineral exploration borings, and stratigraphic core holes, core descriptions, sample studies, electric logs, and drillers’ logs supplemented outcrop data. Historical field notes from other ISGS geologists provided valuable information and aided geologic interpretations. The bedrock geology of Hardin County was previously studied by Worthen and Engelmann (1866), Weller et al. (1920), Baxter et al. (1963), Baxter and Desborough (1965), and Baxter et al. (1967). Reports on the igneous rocks were previously undertaken by Bradbury and Baxter (1992) and Moorehead (2013). Reports on the Illinois-Kentucky Fluorite District and its mines and minerals were completed by Bastin (1931), Weller, Grogan and Tippie (1952), Heyl and Brock (1961), Brecke (1962), Hutcheson (1973), Heyl et al. (1974), and Goldstein (1997). The new Hardin County geologic map utilizes data from these previous reports and incorporates newly acquired data based on field work from 2007 to 2014 into an updated map and accompanying report.

All of the geologic data was compiled using ArcGIS. The geodatabase includes additional information not depicted on the geologic map, including brief details of the mineral prospects and mines.

3. Stratigraphy

The bedrock exposed in the quadrangle ranges from Lower and Middle Devonian cherty limestone to Middle Pennsylvanian sandstone and shale. A thin cap of Quaternary alluvium and loess covers parts of the quadrangle. Cahokia alluvium was mapped in well-developed stream valleys and terraces along the Ohio River terraces, but loess was not mapped. Lithologic descriptions of each mapping unit starting with the oldest Devonian formation is described in the following section.

Devonian

The Clear Creek Chert, Grand Tower Limestone, and St. Laurent Formations (Du) are combined together and are not differentiated since identification of individual formations is difficult in their outcrop area at the center of Hicks Dome. They all consist of cherty limestone and dolostone that have been silicified and weathered to a cherty white residuum in a dark reddish brown clayey soil. Their combined thickness is estimated to be over 400 feet thick.

The Clear Creek Chert is composed of cherty limestone and dolostone. The chert is light gray to white, and the limestone has been altered to a siliceous porous rock with clasts containing the brachiopods *Amphigenia curta* and *Eodevonaria arcuata*. The underlying Grassy Knob Chert may be present since the Clear Creek and Grassy Knob are difficult to separate, although the Grassy Knob does not contain many brachiopod molds and contains very few bioclasts. The

Backbone limestone is present between the Grassy Knob and Clear Creek Chert in the northern portions of Illinois which allows the Grassy Knob and Clear Creek to be differentiated. The top of the Clear Creek Chert marks the top the Lower Devonian in this area of the state. The thickness of the Clear Creek is estimated to be greater than 200 feet. The Grand Tower Limestone is dominated by light gray lithographic and siliceous limestone and dolostone. Workers in other parts of the state have reported a basal sandstone which is differentiated as the Dutch Creek Sandstone and a bentonite bed called the Tioga Bentonite which is at the top of the unit. The Dutch Creek is less than 20 feet thick and the Tioga, if present, is less than 6 inches thick (Willman et al. 1975). The base of the Grand Tower marks the base of the Middle Devonian in this region of Illinois. The grand Tower is estimated to be 120 to 200 feet thick in this area. The St. Laurent Formation is composed of cherty and siliceous limestone, dolostone, and shale. The unit was originally limestone but has been mostly silicified to a cherty or siliceous residuum at the surface. Subsurface data indicate that the unit is a cherty argillaceous limestone. The St. Laurent is equivalent to the Lingle and Alto Formations, but due to stratigraphic complexities and miscorrelation Weller (1944) recommended combining the units into the St. Laurent Formation. Nelson et al. (1995) combined the Alto and Lingle into a single formation and adopted the St. Laurent nomenclature in southwestern Illinois. A diagnostic fossil for the lower St. Laurent is *microcyclus discus* which is a button coral (Nelson et al. 1995). Few exposures of this unit are available, but a two holes drilled by the ISGS on the Doug Deal property (30-T11S-R8E) probably encountered this unit. The St. Laurent is estimated to be 70 to 110 feet thick in this area.

Devonian-Mississippian

The boundary between the Devonian-Mississippian is difficult to determine in this region but exists within the New Albany Shale (Fig. 2). Collinson (1961) utilized conodonts to redefine the boundary to include the upper part of the New Albany Shale Group and stated that the boundary was generally conformable except along the flanks of the Ozark uplift.

The New Albany Shale and Chouteau Limestone (MDcn) were combined and together attain a thickness of about 320 to 420 feet. The New Albany Shale was considered a group by Willman et al. (1975) and there are probably marked contrasts between the individual formations that Willman cites. Regardless, these formations are very difficult to separate while mapping and given the similarities between these units, ranking them at group level is questionable. Nelson et al. (1995) also concluded that group status was improper and lowered the group to formation status. We have followed the nomenclature of Nelson et al. (1995), lowering the status of the New Albany from group to formation. These units are easily eroded, forming a valley of low topographic relief encircling Hicks Dome. The New Albany Shale crops out in active stream cuts along Goose Creek and is well exposed along Hicks Branch Creek southeast of Hicks Dome. The top

SYSTEM	SERIES	FORMATION	
		Member or Bed	
Mississippian	Valmeyeran	Fort Payne	
		Springville Shale	
	Kinderhookian	Chouteau Limestone	
		Upper	Hannibal Shale mbr.
Saverton Shale mbr.			
Grassy Creek Shale mbr.			
Sweetland Creek Shale mbr.			
Devonian	Upper	Blocher Sh. mbr.	
		Middle	St. Laurent Formation
			Tioga Bentonite bed (0-0.6 ft.)
			Grand Tower Limestone
	Lower	Dutch Creek SS. mbr. (0-30 ft.)	
Clear Creek Chert			

Figure 2
Classification of the Devonian and Lower Mississippian in Hardin County.

of the New Albany Shale and its contact with the Chouteau Limestone can also be observed in Hicks Branch on the southwest side of Hicks Dome, although the Chouteau is only a few feet thick in this exposure.

The New Albany Shale is divided into several members, from base to top: the Blocher Shale member, Sweetland Creek Shale member, Grassy Creek Shale member, Saverton Shale member, and the Hannibal Shale member. The shales are black to greenish and bluish-gray, fissile, and may be either silty or calcareous. Some of the more calcareous layers may grade into argillaceous limestones, but these are thin and rare. The unit is dominantly black fissile shale with pyrite and few macrofossils. The Blocher is a black fissile shale that may include some gray silty shale at the top. The Blocher may be difficult to distinguish from the remaining New Albany Shale. The Sweetland Creek Shale is composed of gray and green fissile shale. Above the Sweetland Creek is a dark gray to black fissile shale called the Grassy

Creek. Above the Grassy Creek is the Saverton Shale, which is bluish gray to greenish gray silty shale and in southern Illinois is normally combined with the Hannibal Shale of Mississippian age (see correlation chart on map sheet). The Hannibal Shale is composed of thin grayish-green siltstones and black fissile shales. The best exposures of the New Albany Shale are present along a tributary of Hicks Branch. At that location the shale emits a moderate petroleum odor when cracked. Individual thicknesses of the members in this unit are difficult to distinguish, and the unit is mapped with the overlying thin Chouteau Limestone. The Chouteau Limestone is a medium greenish gray micritic to bioclastic limestone. The only known exposure of this unit was observed along Hicks Branch where it is a few feet thick.

Mississippian (Valmeyeran)

Springville Shale and Fort Payne Formation (Mfps): The base of the Springville Shale forms the base of the Valmeyeran Series (Fig. 3). This combined Springville-Fort Payne unit ranges from 310 to 530 feet thick. The easily eroded Springville Shale is poorly exposed and has been combined with the Fort Payne. The Springville Shale is greenish gray clay shale. The only known outcrop is along Hicks Branch. Since this unit is poorly exposed, its thickness is difficult to ascertain but the unit is probably less than 25 feet thick. The siliceous limestone of the Fort Payne Formation forms a rim of steep, erosion-resistant hills around Hicks Dome and is fractured in many places. The Fort Payne Formation is composed of fine grained limestone, dark gray chert, and shale. It also contains light-gray siltstone interbedded with shale. The unit has been altered and silicified, and few, if any, macrofossils are observable. Outcrops near Hicks Dome are composed of a very cherty, iron-rich, siliceous fractured limestone. An outcrop of this unit along Hicks Branch includes a non-calcareous siliceous residuum with interbeds of clay.

The Ullin Limestone (Mu) is light gray with dark gray fossil grains and appears to be speckled. The appearance is due to disarticulated bryozoan and echinoderms surrounded by white “chalky” calcite cement with disarticulate crinoidal debris. The texture is diagnostic for this unit. Although the Ullin attains a thickness of over 700 feet in southeastern Illinois, it ranges from 125 to 200 feet thick in Hardin County. The Ullin is conformable with the underlying unit.

The Salem Limestone (Ms) is light brown to very dark gray lime mudstone to grainstone composed of rounded and broken fossil fragments, siltstone, shale, and chert. The upper portion of this unit contains cherty gray lime mudstone and is very similar to the overlying St. Louis Limestone. Bedding is tabular to undulatory. The beds range in thickness from several inches to a few feet. The fossils are primarily small rounded disarticulated echinoderm and fenestrate bryozoan fragments. Other macrofossils include corals, brachiopods, and pentremites. Peloidal to oolitic limestone is present, and portions may be dolomitic. Chert is light gray,

SYSTEM	SERIES	FORMATION
Mississippian	Valmeyeran	St. Louis Limestone
		Salem Limestone
		Ullin Limestone
		Fort Payne Formation
		Springville Shale

Figure 3
Classification of the Mississippian Valmeyeran Series in Hardin County.

nodular, may be bioclastic, and may weather with a concentric porous rind. Dolostone is light brown and crystalline. Siltstone is brown to light gray and thinly bedded. The shale is bluish gray to greenish gray and may be fossiliferous. The Salem weathers to a reddish brown soil with abundant white chert. It is well-exposed in the Ohio River bluffs at Tower Rock near the west edge of Sec. 21, T12S, R9E, and in a concentric ring around Hicks Dome. It ranges from 425 to 525 feet thick in the county, although the upper portion is transitional into the St. Louis Limestone. The contact with the underlying unit is difficult to identify.

The St. Louis Limestone (Msl) is medium to dark gray lime mudstone to wackestone, although packstone beds occur locally. It also contains dolostone shale and some chert nodules. It is thick- to massive-bedded and contains bedding-parallel stylolites. The unit is cherty with gray to bluish gray chert nodules along bedding planes. It contains a diverse marine fauna including brachiopods, crinoids, and corals (colonial and solitary). *Acrocyathus* sp., a colonial coral, is common in this unit. Shales are thin and occur as partings between the thick limestone and dolostone beds. The St. Louis weathers to a dusky red soil with abundant white chert nodules. It is well-exposed in the Ohio River bluffs at Cave-in-Rock State Park near the center of Sec. 13, T12S, R9E. The lower 70-90 feet of this unit is gradational with the underlying Salem Limestone, which is darker gray and contains a greater percentage of coarse bioclasts. The St. Louis Limestone outcrop belt encircles Hicks Dome to the western boundary of the county and is also exposed in a broad belt from Tower Rock to Cave-in-Rock. Its upper portion is transitional into the Ste. Genevieve Limestone but its thickness is approximately 300 to 400 feet.

Mississippian (Chesterian)

The Ste. Genevieve Limestone (Msg) is the basal member

of the Chesterian Series (Fig. 4), according to the classification of Maples and Water (1987). The Ste. Genevieve is light gray to medium gray, oolitic to micritic limestone, and sandy or silty limestone. The unit also contains dolostone, shale, and chert nodules. Limestone beds are thick- to thin-bedded, and the oolitic beds may be crossbedded. The Spar Mountain Sandstone Member, a sandy limestone, is locally present about 60 feet below the base of the Aux Vases Sandstone (Baxter et al. 1963). The dolomite portion of the unit is fine-grained, and the shale is gray. The entire formation is composed of a diverse marine fauna, with crinoidal debris and oolites being the most common. Concentrically banded chert nodules occur occasionally and become more common lower in the unit. The Ste. Genevieve weathers to a soil that is dark reddish brown with bioclastic white chert nodules. The unit is well-exposed in several quarries to the north of Cave-in-Rock: D&S (Lafarge), Rigsby and Barnard (Lafarge), and Cave-in-Rock (Lafarge). The lower 60-80 feet of this unit is gradational with the underlying St. Louis Limestone, which contains more lime mudstone, dolostone, and chert. Ranging in thickness from 150 to 200 feet, the Ste. Genevieve Limestone forms a sinkhole plain north of Cave-in-Rock and in a semi-circular ring around Hicks Dome, but its outcrop belt is broken by northeast-trending faults.

The Aux Vases Sandstone (Mav) is composed of sandstone, shale, and siltstone. The sandstone is light greenish gray, fine-grained, and is calcareous in places. It is thin- to medium-bedded and ripple-marked; the thicker beds are usually crossbedded. Siltstones are also greenish gray and interbedded with the sandstone and dark gray shale. The Aux Vases Sandstone is well-exposed in the Ohio River bluffs just below the town of Rosiclare (Willman et al. 1975). Its thickness ranges from 10 to 40 feet. The lower contact can be gradational to sharp.

Renault Limestone, Yankeetown Formation, and Downeys Bluff Limestone (Mdyr): These formations are grouped together on the map since their combined thickness is only 60 to 100 feet. This unit is poorly exposed except in active quarries.

Renault Limestone is comprised of limestone, siltstone, and shale. The Renault is predominantly a light gray to brownish gray, fossiliferous, and sandy to oolitic limestone. Fossils include brachiopods, bryozoans, and echinoderms. The siltstone is coarse grained and calcareous and occurs near the base. The shales are calcareous and interbedded with limestone and siltstone. Numerous *Pentremites* sp. along with the crinoid *Talarocrinus* (in the Shetlerville Mbr.) and *Platycrinites* (in the Levias Mbr.) occur in the Renault. The contact between the Shetlerville and Levias Members is sharp and may be unconformable. The Yankeetown Formation is comprised of shale, limestone, and siltstone. The shale is dark gray, red, and green fossiliferous shale with interbedded dolomitic siltstone and thin beds of lime mudstone. The contact with the underlying unit is gradational. The Downeys Bluff

SYSTEM	SERIES	FORMATION
Mississippian	Chesterian	Kinkaid Limestone
		Degonia Formation
		Clore Formation
		Palestine Sandstone
		Menard Limestone
		Waltersburg Formation
		Vienna Limestone
		Tar Springs Sandstone
		Glen Dean Limestone
		Hardinsburg Sandstone
		Golconda Limestone
		Cypress Sandstone
		Ridenhower Formation
		Bethel Sandstone
		Downeys Bluff Limestone
		Yankeetown Formation
Renault Limestone		
Aux Vases Sandstone		
Ste. Genevieve Limestone		

Figure 4 Classification of the Mississippian Chesterian Series in Hardin County.

Limestone is composed of limestone, dolostone, shale, and chert. The limestone is light to dark gray crinoidal packstone to grainstone and brownish gray dolostone. Disarticulated crinoids may be replaced by pink chert, which is diagnostic for this unit. The upper portion is generally cherty, and the

lower part may be silty. Shale occurs in thin interbeds and constitutes a minor portion of the unit. Bedding-parallel stylolites occur at approximately a 1-foot spacing. The lower contact is gradational.

The Bethel Sandstone, Ridenhower Formation, and Cypress Sandstone (Mcrb): These units are combined and mapped as a single unit that is about 200 feet thick and dominated by sandstone.

The Bethel Sandstone is dominantly sandstone with minor shale. Sandstone is white to light brown, quartz arenite, fine- to coarse-grained, in coarsening-upward sequences. Beds are thin and laminar, but low-angle crossbedding is also present. The greenish-gray shale occurs as thin interbeds between thicker beds of sandstone. Near the base, shale and quartz pebbles may be present. The basal contact is gradational to erosional. The Ridenhower Formation is composed of shale, limestone, and sandstone. The shale is dark gray with a greenish tint and may be fossiliferous. It is thinly bedded and silty to finely sandy. Limestone up to several feet thick is locally present at the top of this formation. This unit is highly variable but is dominantly dark gray shale with interbeds of grayish green siltstone and fine-grained sandstone containing molds of brachiopods. It is poorly exposed and may not be present in parts of the county. The Cypress Formation is comprised of sandstone, shale, and siltstone. The sandstone is light gray to light brown fresh, dark brown to dark reddish brown weathered, fine- to medium-grained subangular quartz sandstone. The upper portion contains well-exposed bluff-forming sandstone in massive, rounded beds with conspicuous soft-sediment deformation; it also contains thin beds of siltstone interbedded with sandstone and shale. The lower portion is primarily thick beds of sandstone. Red and green shale may be present near the top of the formation. Locally, the contact with the underlying unit is unconformable and this unit may lie directly on the Bethel Sandstone.

The Golconda Formation (Mg) is comprised of Limestone, shale, and mudstone. The formation is divided into three members. The Beech Creek Limestone Member at the base is dark gray to brown, partly dolomitic, argillaceous limestone. The Beech Creek is commonly called the Barlow Limestone by petroleum geologists in the region. The Beech Creek (Barlow) is a laterally consistent unit in the Illinois Basin and regional structure contour maps are constructed on the top of this unit. The Fraileys Shale Member is largely olive gray to dark gray, calcareous, thinly fissile clay shale with limestone beds of varied texture as thick as several feet. Red shale or mudstone may occur near the top. The Fraileys Shale Member grades into the lower part of the Haney; this interval contains limestone and shale interbedded in roughly equal proportions. The Haney Limestone Member at the top is largely light to dark brownish gray, fine to coarse crinoidal wackestone to crossbedded grainstone and is oolitic in places. *Pterotocrinus capitalis* is highly characteristic of the Haney Limestone Member, and the wing plates of this cri-

noid are commonly found in the shaly part of this member. The Golconda is dominantly a limestone-shale formation that is 100 to 150 feet thick. The lower contact is sharp.

The Hardinsburg Sandstone (Mh) is primarily sandstone with interbeds of siltstone, and shale. The lower Hardinsburg contains two fluvial sandstone bodies. The sandstone is light brownish gray to white, very fine- to fine-grained quartz arenite that is thinly bedded to massive. Ripple marks and low-angle crossbedding are common. The siltstone and shale portions are light brown to medium gray and are commonly interbedded, rippled, and laminated. The thickness of the Hardinsburg ranges from 90 to 130 feet. The lower contact is generally conformable with the underlying unit.

The Glen Dean Limestone (Mgd) is generally composed of a lower limestone, a middle shale, and an upper limestone. The lower limestone is medium gray wackestone, containing crinoids and bryozoans, and is distinguished by a dwarfed crinoid fauna in the basal 5 feet. The lower limestone grades upward into the middle shale. The middle shale is thin, medium to dark gray and greenish gray, fossiliferous, and calcareous. The upper limestone is light brownish gray with a reddish tint, coarsely crinoidal packstone to grainstone, and may be oolitic. Fossils include crinoidal debris, fenestrate bryozoans, brachiopods, blastoids, and corals. The thickness of the Glen Dean ranges from 40 to 70 feet. The lower contact is sharp.

Tar Springs Sandstone, Vienna Limestone, and Waltersburg Formation (Mwvt): These formations were combined on the map and attain a thickness ranging from 120 to 180 feet.

The Tar Springs Sandstone is composed of sandstone, siltstone, shale, and thin coal. The sandstone is white when fresh, brown when weathered, very fine- to fine-grained quartz arenite. Bedding ranges from one inch to one foot thick and has ripple marks, crossbedding, small load casts, indistinct burrows, and shale rip-up clasts. Shale and siltstone are medium to dark gray, micaceous, and thinly laminated. Thin coal commonly less than one foot thick occurs near the top; the coal rests on dark gray mudstone. Dark gray claystone also occurs in the lower part of the unit. The lower contact can be gradational to sharp. The Vienna Limestone is composed of limestone, shale, and chert. The limestone is largely dark gray to brownish gray siliceous lime mudstone and wackestone. A few thin interbeds of dark gray sandy shale are present. Dark brown chert nodules are numerous and commonly weather with a porous rind. The white to brown weathered, porous blocks of fossiliferous chert are diagnostic. The Waltersburg Formation is composed of shale, siltstone, sandstone, and thin coal. The unit is mainly dark gray, thinly laminated clay shale that becomes silty upward and grades into siltstone. Sandstone is olive-gray to brownish gray, very fine-grained, shaly, and thinly bedded. Thin coal and greenish shale may be present near the top of

this unit.

The Menard Limestone (Mm) is composed of limestone and shale. The lowest member is the Walche Limestone Member, which is composed of argillaceous micritic limestone. The crinoid *Pterotocrinus Menardensis* is diagnostic of this limestone and is found in the shale layers above the Walche. The middle Scottsburg Limestone Member is a light to dark gray, sublithographic lime mudstone separated by thin shale layers. The upper Allard Limestone Member contains gray lime mudstone and fine to coarse skeletal wackestone and packstone with thin shale interbeds and scattered chert nodules. Fossils within the Menard include brachiopods, bryozoans, disarticulated crinoidal debris, and a very large cephalopod (greater than 18 inches in diameter) in the western part of the county. The thickness of the Menard ranges from 80 to 130 feet. The lower contact is conformable.

The Palestine Sandstone (Mp) is composed of sandstone, siltstone, shale, mudstone, and minor coal. Sandstone is light gray to white, very fine- to fine-grained quartz arenite. Bedding can be thin and tabular, flaggy and ripple marked, or crossbedded. The base of the formation is marked by a prominent sandstone bluff that is 10 to 25 feet thick. The sandstone bluff is massively bedded, cross-bedded and pock-marked on weathered faces. The shale and siltstone are white, brown, or olive gray; slightly micaceous; and contain minor amounts of interstitial clay and carbonaceous debris. At the top of the Palestine, carbonaceous black shale and coal overlie a rooted siltstone that grades downward into laminated shaly sandstone. The thickness of the Palestine ranges from 0 to 80 feet, and the entire formation has been removed by pre-Pennsylvanian erosion in the northeastern part of the county. The basal contact was not observed but is reported to be unconformable in places.

Clore Formation and Degonia Sandstone (Mdc): These formations were combined on the map and together reach a thickness of about 100 feet. In much of the county, these formations are partially or wholly eroded by the Caseyville Formation.

The Clore Formation is composed of limestone, shale, sandstone, siltstone, and chert. Limestones are mainly lime mudstones that are several feet thick, medium dark gray to olive gray, and weather to a light gray or orange-brown. Spiriferids, productid, and compositid brachiopods are common. The basal Cora Limestone Member contains thin beds and lenses of very fossiliferous limestone and greenish gray, silty, and weakly fissile shale or mudstone. A limestone bed at the top is a dark gray, very argillaceous brachiopod-bryozoan lime mudstone to wackestone that weathers yellowish gray. The middle Tygett Sandstone Member is light gray to light brown, very fine- to medium-grained quartz arenite, containing thin, ripple marked beds. The sandstone grades laterally into siltstone and shale. The upper Ford

Station Limestone Member is dark gray, calcareous, and fossiliferous limestone; its shaly portion ranges from platy clay shale to silty shale with laminae and thin interbeds of light gray siltstone and limestone. The lower contact is sharp but conformable. The Degonia Formation is composed of shale, sandstone, and siltstone. The Degonia is mostly shale that is dark gray, greenish gray, or reddish gray, partly silty, and moderately to strongly fissile. The sandstone portion is generally light brown, very fine-grained, clean quartz arenite with thin, planar to wavy bedding with ripple marks. Exposed sandstone bluffs erode out as long rectangular and wedge-shaped blocks bounded by joints. A portion of the sandstone and siltstone are dark olive to greenish gray, weathering rusty orange, a distinctive feature of this unit. Greenish gray siltstone to silty mudstone in the middle of the Degonia may be massive. The unit is poorly exposed and is mapped together with the underlying Clore Formation. The contact with the Clore is sharp to gradational.

The Kinkaid Limestone (Mk) is composed of limestone, shale, and mudstone. The Kinkaid Limestone consists of three members, from base to top: the Negli Creek Limestone, Cave Hill Shale, and Goreville Limestone. This formation is eroded by Lower Pennsylvanian units and is entirely missing in portions of the county. The Negli Creek is primarily a dark gray lime mudstone to wackestone. Fossils include brachiopods, fenestrate bryozoans, blastoids, bellerophonid gastropods, and *Girvanella* spherioids. The Cave Hill is composed of shale and mudstone with thin beds of limestone. The shale is dark gray, soft, fissile, calcareous, and may be laminated. The shale may grade to limestone that is mainly lime mudstone. The Goreville is a packstone to lime mudstone with a few thin shale breaks. It contains diverse marine fossils including fenestrate, trepostome, and fistuliporid bryozoans, spiriferids and other brachiopods, rugose corals, and crinoids. The bryozoan *Archimedes* can be abundant in the upper beds and *Pterotocrinus* wing plates have been described and studied in the formation (Gutschick, 1965). In much of the county, the Kinkaid is partially or wholly eroded by the Caseyville Formation.

Pennsylvanian (Morrowan)

The Caseyville Formation (Pcv) is the basal unit of the Pennsylvanian System (Fig. 5). The Caseyville is composed of sandstone, shale, siltstone, and conglomerate. The sandstone is usually white to gray on fresh surfaces and weathers to a brown or orangeish brown. The sandstone consists of well-rounded to subangular fine- to coarse-grained quartz arenite that has a sugary appearance. The Caseyville often forms massive ledges but also forms thin planar beds in some places. Outcrops are usually well-exposed bluffs showing diverse fluvial and tidal patterns, including stacked channels and unidirectional and bidirectional crossbeds. Iron-rich "liesegang banding" may be very common in some sandstone outcrops. Plant remains, such as *Stigmaria*, are occasionally found in the sandstone but are more common within the shale. The shale is dark gray and fissile. Plant

System	Series	Formation and members
Quaternary	Holocene	Quaternary Terraces
	Pleistocene	Quaternary undifferentiated
Permian	Leonardian	Permian Igneous dikes and sills
Pennsylvanian	Desmoinesian	Carbondale Formation
	Atokan	Tradewater Formation
	Morrowan	Caseyville Sandstone

Figure 5 Classification of the Pennsylvanian through Quaternary Series in Hardin County.

debris is common, and iron nodules or concretions may be present. Siltstone occurs in thin planar or wavy beds and is usually interbedded with shale. The conglomeratic portion most commonly contains milky white, well-rounded quartz pebbles within coarse-grained sandstone, although in some places, it contains gray shale clasts embedded in a sandstone matrix. The quartz pebbles may be several inches in diameter. The thickness of the Caseyville ranges from 300 to 565 feet. The lower contact is a major regional unconformity, and within the county, the Caseyville Formation rests on units as old as the Menard Limestone.

Pennsylvanian (Atokan and Desmoinesian)

The Tradewater Formation (Pt) is composed of sandstone, siltstone, shale, conglomerate, limestone, and coal. The sandstones are white to light brown, fine- to coarse-grained quartz arenite and sublithic arenite. Mica is usually present, and a small percentage of clay is present in the sublithic arenite. Sandstones are crossbedded and ripple marked. Ichnofossils are common and include both burrowing and feeding or grazing patterns. The siltstones are gray, and mica may be present on the bedding surfaces. The shale is gray to black and fissile. The few conglomerate layers probably consist of reworked quartz pebbles from the underlying Caseyville Formation into which the lower portion of this unit is incised. Thin and discontinuous coal seams are reported in this unit. Where present, the Bell Coal (W. Ky. No. 1b) marks the base of the Tradewater. In places, the Tradewater is unconformable with the underlying Caseyville. Where the lower quartz arenite of the Tradewater is deposited over an upper

Caseyville quartz arenite, it is difficult to define the contact. The thickness of the Tradewater ranges from 350 to 630 feet.

The Carbondale Formation (Pc) is composed of shale, sandstone, siltstone, coal, and limestone. Shale is a major component of this unit, ranging from gray to dark gray to black. Shale is typically fissile above the coal seams but occurs as massive and nonfissile underclay below the coal seams. Sandstones are sub-lithic arenites that are light brown to brown, well-sorted to moderately-sorted, fine- to medium-grained, micaceous, and contain interstitial clay. Siltstones are light greenish gray to brown and range from laminated to thick bedded. Coal is bright banded and vitreous. Limestones are thin, dark gray to black, argillaceous, ferruginous, brachiopod wackestones and lime mudstones. This formation contains most of the mineable coals in the Illinois Basin: the Davis Coal, the Springfield Coal, and the Herrin Coal. The base of the unit is sharp but conformable with the underlying Tradewater Formation and is defined by the base of the Davis Coal. The top of the formation is defined by the top of the Herrin Coal. The thickness of the Carbondale ranges from 345 to 410 feet.

Permian (Leonardian)

The Permian Igneous dikes and sills (Pi) are composed of ultramafic dikes, lamprophyre, autolithic breccia, diatreme, and sills. The igneous rocks are ultramafic lamprophyres that are dark greenish gray when fresh, light gray and sugary-textured when weathered, and have an inequigranular porphyritic texture. These rocks have been extensively altered, making classification difficult. The texture of the rocks is fine grained where highly altered to porphyritic with 1/4-inch phenocrysts. The rocks have a green tint that probably results from alteration of primary minerals to serpentine and chlorite. Replacement by calcite is extensive and the rocks will readily effervesce when dilute hydrochloric acid is applied. Calcite veining is also common. These rocks were examined through geochemical methods and indicate the presence of serpentine (altered from olivine), apatite, phlogopite, titanite, chromite, magnetite, chlorite, perovskite, garnet, and calcite (Denny 2005). Where the pipes contain rounded autolithic clasts and not angular breccia clasts, the pipes may be described as diatremes. Several subvertical tabular intrusive siliceous bodies occur around the periphery of Hicks Dome and appear to be aligned in a radial direction emanating from Hicks Dome. These intrusive explosive bodies are thought to be related to a single geologic event of a gas-rich alkalic magma originating from the upper mantle. Fluorite was observed enclosed within an ultramafic rock and has been reported between breccia clasts at depth beneath Hicks Dome. The igneous dikes and sills also form intrusive contacts with the sedimentary strata. The thickness of the Permian igneous intrusive bodies ranges from 0 to 30 feet wide.

Quaternary (Pleistocene to Holocene)

The Quaternary undifferentiated (Qu and Qt) units include Wisconsinan and Illinoian Episode terrace deposits,

lake deposits, colluvium, and Holocene alluvium (Cahokia Fm.). The maximum combined thickness is 150 feet. The sand is light brown very fine to coarse-grained quartz. The clay and silt are medium gray to light gray. Gravel and colluvium derived from local bedrock are common on the upland surfaces. The sand and gravel along the Ohio River may have been transported considerable distances. Along the Ohio River floodplain, a lower Holocene terrace is present between 340 and 350 feet in elevation and an upper Holocene terrace occurs above 350 feet in elevation. Higher elevation terraces may be the remnants of dissected Pleistocene-age units. Loess is present in the upland hills and is commonly 5-10 feet thick, but it is not shown on this map. The base of this unit is a major unconformity.

4. Igneous rocks

Ultramafic igneous rocks have been encountered in underground coal mines in southern Illinois and in several localities along the Tolu Arch. The Tolu Arch (Baxter et al., 1963) is a structural arch that extends in a north-northwest direction through Hardin County. Due to the presence of north-northwest trending ultramafic dikes and the attitude of sedimentary beds in the area, geologists postulate that the Tolu Arch also reflects a deep seated igneous uplift. The Coefield magnetic anomaly, also called the Lollipop magnetic anomaly (Hildenbrand and Ravat 1997), exhibits a large magnetic contrast. The Coefield anomaly, whose center lies in Kentucky, lies southwest of Cave-in-Rock and the northern edge of the uplift can be observed in the southeastern portion of Hardin County. Baxter et al. (1967) identified 25 separate dikes, sills, and breccia pipes in the vicinity of Hicks Dome. The apex of Hicks Dome was examined by Bradbury and Baxter (1992) who described three breccia types: 1) vent breccias, 2) carbonatitic breccias, and 3) shatter breccias. The explosive and ultramafic igneous activity in this region is speculated to be related to NE-SW extension of the N. American plate along the Reelfoot Rift accompanied by partial melting of the mantle during the Permian (Fifarek et al. 2001). Brown et al. (1954) suggested that igneous intrusions of this region interacted with near-surface groundwater to produce steam fed explosive phases. The amount of stratigraphic uplift at Hicks Dome is estimated to be over 4000 feet (Nelson, 1995). Moorehead (2013) determined that the igneous rocks at Hicks Dome were calc-alkaline lamprophyres and classified them as minette. The minette classification was derived mainly from geochemical relationships and the lack of perovskite, melilite, olivine, garnet and possibly feldspar. Denny (2005) identified perovskite, garnet, and olivine but could not positively identify melilite in a lamprophyre (alnöite) in Saline County, Illinois. This discrepancy either indicates a bias in sampling, different phases or differentiation of the magma, or separate magmatic sources. Morehead (2013) also suggested that the carbon and oxygen isotopic signatures originally reflected primary magmatic carbonate but were subsequently modified by magmatic-hydrothermal alteration, and proposed that a carbonatite was

associated with the ultramafic rocks at Hicks Dome. In summary, the igneous rocks of this region are very complex and have been extensively altered which makes classification problematic. These rocks may have been metasomatized at great depths prior to their ultimate emplacement at Hicks Dome. Rare earth elements (REEs) have been identified association with the lamprophyres in the region (Denny et al. 2011a; Moorehead 2013). REEs commonly form in carbonatites from a magma or from the interaction of magmatic-hydrothermal fluids (Mariano and Mariano 2012).

5. Structural Geology and Tectonics

Hardin County lies within the Fluorspar Area Fault Complex, one of the most intricately faulted areas in the North American midcontinent (Denny et al. 2008b). Within the county boundaries is also the northwestern-most extension of a regional igneous arch called the Tolu (or Kutawa) Arch (Baxter et al. 1967). Regional dip and some of the faulting is inherently related to this regional igneous activity. The southerly projection of the major northeast-southwest-trending faults is in line with faults of the Reelfoot Rift and the New Madrid Seismic Zone to the southwest. Neotectonic research along these faults less than 10 miles southwest of Hardin County indicates that movement definitely occurred in the Cretaceous units and may have occurred in the Quaternary sediments (Nelson et al. 1997).

Regional structures are described first, then faults, fault zones, and mineralized veins are discussed next, with the faults generally listed in a geographic order starting from the northwestern-most structure and proceeding to the southeast. Information concerning these features was extracted from both the literature and recent geologic mapping activities.

Regional Structures

The Fluorspar Area Fault Complex consists of many northeast-trending fault systems that cross-cut the Illinois-Kentucky Fluorspar District (IKFD). Faulting is generally high-angle normal or dip-slip and produces grabens, which are typically thought to be a result of regional extension. There is some evidence of strike-slip movement along some of the northeasterly faults and reverse movement surrounding Hicks Dome. Seismic reflection profiles reveal that faults originate in the Precambrian basement and bifurcate upward, and the fracture pattern becomes more complicated toward the surface (Potter et al. 1995). As mapped from outcrop data, faults are clustered into zones, which may outline horsts and grabens. Some faults in this region are mineralized with fluorite, and horizontal strata-bound fluorite is present near major fault blocks.

The Tolu Arch is a northwest-trending broad regional uplift that brings Salem Limestone to the surface near the town of Tolu, Kentucky (Baxter and Desborough 1965). The arch extends southeast into Kentucky for 6 miles where it is transected by a younger northeast-trending graben of the

Fluorspar Area Fault Complex (Trace and Amos 1984).

Hicks Dome is an asymmetrical doubly-plunging anticline that lies at the northwest end of the Tolu Arch. Structural uplift of over 4,000 feet at Hicks Dome (Nelson 1995) appears to be related to a crypto-explosive event that produced dikes, sills, and pipe-shaped diatremes, which vented gases to the surface (Brown et al. 1954, Heyl and Brock 1961). Radiometric age dating indicates an early Permian age of about 270 million years ago for these igneous intrusions (Zartman et al. 1967, Fifarek et al. 2001).

The Rock Creek Graben preserves the Caseyville and Tradewater Formations between the Hogthief Creek Fault Zone and the Peters Creek Fault Zone. The strata are tilted northwestward by about 5°, except along faults, where much steeper dips may occur.

Faults, Fault Zones, and Mineralized veins

The Hobbs Creek Fault Zone is named for Hobbs Creek in Pope County (Sec. 10, T12S, R7E). It enters Hardin County in the western part of Sec. 2, T12S, R7E and dies out in Sec. 36, T11S, R7E. The fault zone consists of several sub-parallel high-angle normal faults that trend approximately N 50° E. In the Hardin County portion of the fault zone, displacement is approximately 300 feet. The Pope County portion of the fault zone is down to the northwest, which indicates that the Hobbs Creek Fault Zone is a scissor fault.

The Stewart Fault is a high angle normal fault that strikes N 25° E to N 30° E and dips to the southeast at about 80°. It comprises three sub-parallel faults that enter Hardin County along the center of the west line of Sec. 23, T12S, R7E and crossing Route 34 near the Stewart Mine, for which the fault is named (center of Sec. 14, T12S, R7E). Although the fault is 7.5 miles long, the Hardin County portion is only 3.5 miles long. Baxter et al. (1967) report 100 feet of displacement. Displacement dies out to the northeast before intersecting the center of Hicks Dome. Many mines and prospect shafts have been worked along a 1.5 mile-long segment of the fault.

The Shetlerville Fault trends N10°W through the town of Shetlerville and extends north-northwest for one mile from the Ohio River bluff. The Bethel Sandstone is downthrown about 50 feet on the west side of the fault.

The Wallace Branch Fault Zone originates in Kentucky and crosses into Illinois where Wallace Branch Creek drains into the Ohio River. The fault zone forms the western edge of the Rock Creek Graben. The Wallace Branch Fault Zone bends to a N45°E trend and becomes the Interstate Fault. Maximum displacement is about 1,000 feet near the Interstate Prospects in Sec. 17, T12S, R8E, where the Caseyville Sandstone is downdropped on the southeast side to the level of the lower St. Louis Limestone. The Interstate Fault becomes the Iron Furnace Fault Zone in Sec. 9, T12S, R8E, continues its N45°E trend for about 2 miles, then dies out to

the northeast.

The Lee Fault is named for the Lee Mine (Sec. 14, T11S-R8E). Weller et al. (1920) states “The Lee fault may be the continuation of the Hobbs Creek Fault and connects through the Hicks Dome to the southwest.” The vertical offset at the Lee Mine is about 400 feet, with southeast-side-down normal movement. Several smaller faults trend parallel with the master fault. The fault is mineralized, and several pits and sealed shafts were observed. A good exposure of the fault surface showing dip-slip striations dipping steeply to the southeast can be observed in the sandstone footwall of an abandoned pit at the Lee Mine. The fault bends to the west as it approaches Hicks Dome but then becomes difficult to trace. We assume the Permian uplift near Hicks Dome has created a complex fault zone that is difficult to reconstruct. Baxter and Desborough (1965) mapped the Lee Fault through the Hamp Fault and terminated the Lee into the Ridge Fault.

The Ridge Fault was first mapped by Baxter and Desborough (1965), and it is named for the Ridge Mine (Sec. 10, T11S, R8E). The fault strikes northeast and displacement is down to the northwest. The fault is poorly exposed, but fluorite prospecting around the Ridge Mine helped in mapping its extent. Baxter and Desborough (1965) show the displacement diminishing to the southwest with a maximum offset of 50 feet, although the fault is very poorly exposed. Nelson (1995) states that it is an extension of the Hobbs Creek Fault Zone and that it merges with the Lee Fault to the south. We could not trace this fault with assurance and indicated its location by a dashed line parallel with the Lee Fault. The Lee Fault exhibits a much larger displacement and is more likely to be the continuation of the Hobbs Creek Fault Zone than the Ridge Fault. The Ridge Fault is certainly the result of a similar stress regime that created the Lee Fault. The Ridge Fault may merge into the Lee Fault to the northeast, near Sparks Hill, but we could not find evidence for the fault to the north of the Ridge Mine.

The Hamp Fault trends in an arc from the west to east just north of Hicks Dome. It is very poorly exposed and is mapped mostly on the basis of mine notes and previous studies (Baxter and Desborough 1965, Weller et al. 1920, Bastin 1931). The fault is probably a result of the vertical uplift at Hicks Dome, and the amount of displacement is less than 100 feet. This fault is extensively mineralized and has been mined along its strike. Bastin (1931) described the veins along the fault to be dipping 60° to 75° to the south. Therefore, this fault is likely a reverse fault with the south side being upthrown. The fault apparently dies out to the east where it cannot be accurately located. The west end of the fault apparently terminates into a N15° W fault that is mineralized but shows only minor offset of the strata (Bastin 1931).

The Goose Creek Fault Zone begins in Sec. 35, T11S-R8E and trends N55°E for about 11 miles until it passes beneath the Ohio River into Union County, Kentucky. Multiple

intersecting faults outline rhombohedral grabens. Several abandoned fluorite mines occur along fault splays of the main zone.

The Wolrab Mill Fault Zone trends N50°E to N55°E, passing along the southeast flank of Hicks Dome. To the northeast, it trends parallel to the Lee Fault. It is about 14 miles long, and downthrow is to the southeast. Displacement reaches a maximum of 300 feet where the fault crosses Goose Creek in the NW corner of Sec. 4, T12S, R8E. Previous authors disagree upon whether or not the Wolrab Mill Fault Zone begins as a splay from the Stewart Fault (Weller et al. 1920, Weller et al. 1952, Baxter et al. 1967). The abandoned Cobb Mine and Jarrells Fluorite Prospect occur along the Wolrab Mill Fault Zone.

The Hogthief Creek Fault Zone (Weller et al. 1920) defines the northwestern edge of the Rock Creek Graben. This fault zone is named for Hogthief Creek, which it parallels for several miles southeast of Hicks Dome. The zone is a complex series of parallel faults merging into two parallel faults near Rock Creek. The overall trend is northeast-southwest with the southeastern side downthrown. Fractured beds were observed at several locations, but exposures of the fault surface were not observed. Maximum displacement of about 1,600 feet occurs where the St. Louis and Salem Limestones are juxtaposed with the Caseyville Sandstone, displacing the entire Chesterian Series. Weller et al. (1952), Baxter et al. (1963), and Baxter and Desborough (1965) all suggested that high-angle reverse faulting might be involved, but none of these authors provided any details. No evidence for compressional structures was observed during the present study; however, Potter et al. (1995) interpreted high-angle reverse faults in the Rock Creek Graben from a seismic reflection profile that passes through the Rosiclare Quadrangle. Denny et al. (2011b) suggested that faults underwent normal movement. Reverse and normal movements are possible if the fault zone underwent several periods of faulting. The Hogthief Creek Fault Zone merges to the southwest into the Interstate Fault Zone. A segment of the fault appears to be connected to the Goose Creek Fault Zone to the northeast. Although no commercial development for minerals is known along this fault zone, a piece of limestone replaced with fluorite was observed in a creek near the center of Sec. 20, T12S, R9E, just west of the unnamed prospect pit.

This Iron Furnace Fault can be observed south of the preserved 19th-century Illinois Iron Furnace (4-12S-R8E; 1600 ft. El, 300 ft. SL) along the gravel road that follows the southwest side of Big Creek. At this locality, the fault trends N45°E and bears a gouge and breccia zone nearly 75 feet wide. The fault juxtaposes Salem Limestone with lower Chesterian formations, for a minimum throw of 600 feet. The fault cannot be traced with assurance south of this point because it lies under the alluvial sediment of Hogthief Creek. Weller et al. (1952) suggested reverse faulting, although we were unable to confirm such. The Iron Furnace Fault joins

the Interstate Fault Zone to the southwest. This fault zone probably merges into the Hogthief Creek Fault Zone or Goose Creek Fault Zone to the northeast.

The Big Creek Fault is a high-angle normal fault with the northwestern side downthrown. Near Rosiclare, the Menard Limestone is faulted against the Hardinsburg and Golconda Formations, resulting in over 350 feet of vertical offset. The zone is more complex than can be portrayed on this map. This fault apparently merges into the Hogthief Creek Fault Zone to the north. Mineralization occurs between the Big Creek Fault and the Hillside Fault in the vicinity of Rosiclare.

The Argo Fault hosts the Argo Vein (See Denny et al. 2011, fig. 2) and strikes N 20° E, with the northwest side downthrown about 75 to 100 feet (Bastin 1931). Weller et al. (1952) reported that the fault plane was nearly vertical, whereas Bastin (1931) stated that it dipped steeply to the northwest.

The Blue Diggings Fault hosts the Blue Diggings Vein and is located between the Argo and Rosiclare Faults. It strikes N30°E to N50°E and dips 65° to 70° southeast, with the southeast side downthrown approximately 100 feet (Fig. 6).

The Daisy Fault strikes N20°E and dips 70° to 80° northwest, with up to 350 feet of normal displacement (Weller et al. 1920). It hosts the Daisy Vein which dominantly contains fluorite mineralization. Bastin (1931) reported that post-mineralization movement brecciated the ore, and the plunge of striations varied from 10° north to 80° south. These observations indicate multiple periods of movement, with a component of strike-slip displacement.

Situated along the southeast side of the Rock Creek Graben and passing through Rosiclare, the **Hillside Fault** was formerly exposed in the Hillside Mine, which started producing fluorite in the 1920s. Based on underground exposures, Bastin (1931) described the fault as trending north-south and dipping 65° to 70° west, with normal offset. Brecciated fluorite along the eastern footwall indicates that movement occurred after mineralization. Bastin (1931) also described two sets of slickensides—one set vertical and the second set plunging 20° to 30° south. Thus, this fault has undergone at least two episodes of displacement.

The Peters Creek Fault Zone trends northeast and demarcates the southeast edge of the Rock Creek Graben. It is a high angle normal fault and is downthrown about 600 feet on the northwest side. The faults are poorly exposed, although faulting was inferred from steeply dipping beds and silicified sandstone with secondary quartz overgrowths. The fault zone bifurcates to the southwest along Peters Creek into several parallel faults that are difficult to trace. The northeastern extension appears to merge into a single fault that can be traced into the alluvial sediment of the Ohio River. Kehn

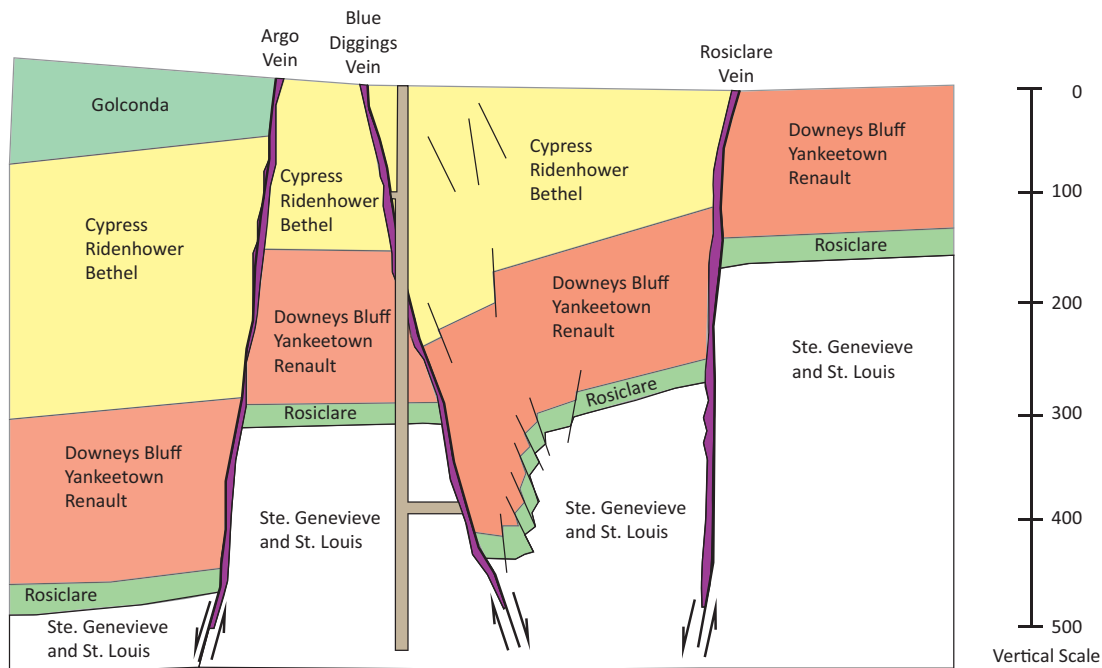


Figure 6 Idealized cross section across the Argo - Blue Diggings - Rosiclare Veins (adapted from Weller et al. 1920), looking northeast.

(1974) mapped faults in Kentucky that appear to line up with the Peters Creek Fault Zone. Exposures of this fault zone are few, but mineral exploration tests have intersected the fault in the SW $\frac{1}{4}$ of Sec. 23, T11S-R9E and near the center of Sec. 6, T12S-R9E. The fault is mineralized in places, but no commercial development for minerals is known along its length.

Trending N33°E from Sec. 19, T12S-R9E, the **Tower Rock Fault** connects several occurrences of fluorite mineralization hosted in the St. Louis Limestone. Baxter et al. (1963) showed a similar trend but traced the fault 1,500 feet south-east of our location based on breccia, intense silicification, and mineralization in a series of pits and shafts.

6. Economic Resources

Mineral Deposits

The Illinois-Kentucky Fluorspar District (IKFD) was formerly the leading source of fluorite in the United States, but production since the early 1990s has been limited. The term fluorspar is commonly used as a synonym for fluorite. Other minerals identified in this district in addition to fluorite include galena, sphalerite, barite, pyrite, chalcopryrite, quartz, celestite, cerussite, greenockite, malachite, smithsonite, witherite, strontianite, benstonite, and alstonite (Goldstein 1997). Mine-run ore commonly contained 30 to 40% fluorite, as much as 2 to 3% zinc, and small amounts of galena. The amount of sphalerite in some ore bodies within the IKFD is considerable. Some deposits contained small values of silver in galena, along with recoverable cadmium and germanium in the sphalerite (Trace and Amos 1984). Ore bodies are of three types: (1) bedded replacement deposits that formed by selective replacement of limestone strata, (2) vein deposits along faults and fractures, and (3) residual gravel deposits derived from veins or beds. The best indica-

tion of replacement type ore is remnant textures of limestone observed within fluorite crystals. These include fossils, stylolitic sutures, primary bedding, and other sedimentary structures. Mineralization within the IKFD probably resulted from acidic basinal brines charged with fluorine and carbon dioxide that were derived from Permian alkaline magma (Plumlee et al. 1995). The ore fluid is a low temperature hydrothermal fluid which has some affinities to Mississippi Valley Type (MVT) mineralization. The identification of rare earth minerals in igneous diatremes at Sparks Hill and Hicks Dome suggests the possibility of a carbonatite body associated with the regional ultramafic activity. The late stages of this carbonatite activity may have provided some fluorine which then mixed with MVT brines. The acidic, saline fluids were funneled along northeast-trending fractures and fault zones concurrently as oblique extension was occurring in the region. The ore of the IKFD is almost always in contact within or adjacent to a carbonate host rock, specifically: the upper part of the Ste. Genevieve Limestone, Renault, and Downeys Bluff Limestone units of early Chesterian age. These rocks mark a transition from dominantly limestone below (Mammoth Cave Group) to alternating limestone and siliciclastic units above (Pope Group). The permeable rocks within the Ste. Genevieve to Downey's Bluff interval are the first permeable rocks overlying a thick succession of mostly "tight" carbonates.

Mining districts, subdistricts, and individual mines of the IKFD within Hardin County are discussed below. Mines are sometimes named after the landowners, but others mines are given various monikers, such as Black Jack and Interstate. Portions of the following information were extracted directly from ISGS 7.5-minute ISGS quadrangle bedrock maps (Denny et al. 2008a, 2010, 2011b, 2013; Denny and Counts 2009; Seid et al. 2013a, 2013b; Seid and Denny 2014).

Hamp District

The Hamp mines first extracted residual ore (gravel spar) that was produced by weathering of veins at the surface, and when that resource became scarce shafts were sunk. The ore mainly filled open spaces along faults and fractures, but replacement ore was also present and Bastin (1931) noted that blastoids replaced by fluorite and quartz were found in residual soils at this mine. The ore was mainly fluorite which occurred along an east-west fault that dipped to the south at 60° to 75°. Several shafts were driven along this fault. The eastern shaft was called the Wormach which was 140 feet deep. The next shaft to the west was the Hamp #1 which was 100 feet deep. The westernmost shaft was the Hamp #2 which was 30 feet deep (Bastin 1931). A topographic map from 1930 (Bastin 1931) shows an east-west orientated gravel road just north of the fault. The current gravel road in this area appears to bend slightly to the south, which indicates that this road has been altered since 1930. The numerous small exploration pits in the area and the relocation of the roads makes locating the abandoned mining pits cited by Bastin (1931) and Weller et al. (1952) very difficult.

Several shallow shafts and prospects are located along a north-northwesterly trending fault near Hamp #2. This fault probably intersects the east-west trending Hamp Fault. The Hamp Fault is a concentric fault, and the north-northwest fault may be a radial extensional structure that was produced by the uplift at Hicks Dome. In addition to the main Hamp shafts, there are a few other prospect pits in this region.

The Empire District located at the western edge of Hardin County is composed of several mines along northeasterly trending faults. This is also referred to as the Empire-Knight-Douglas group (Hatmaker and Davis 1938).

Rosiclare District

The Rosiclare District consists of the Rosiclare, Argo, Daisy, and Blue Diggings veins, all of which trend from north-south to N 45°E. The mines within the Rosiclare District are discussed below.

Rosiclare Vein

The Rosiclare Vein (also called the Good Hope and Fairview Veins) was one of the most prolific of any vein in the Illinois-Kentucky Fluorite District. The vein was first mined as part of the Pell property in 1842-1843 (Weller et al. 1920). The mine was opened to extract galena and the fluorite was dumped and considered worthless gangue. Small amounts of fluorspar from the old mine dumps were recovered and sold during and after the Civil War until around 1900 (Bastin 1931). In the early 1900's the mines of the Rosiclare Vein started to ship fluorite in large quantities. Prior to World War I these early mines were mainly competing with fluorite mines in the English Derbyshire and Durham Districts (Weller et al. 1920). Manufacturing of steel was the primary use for fluorite, and large steel mills were located in eastern part of the United States. During World War I, the fluorite

ore of the Illinois-Kentucky District became the primary supplier to the United States steel mills. The proximity of the Rosiclare Vein to the Ohio River was a key factor that allowed the ore to be transported up the Ohio River relatively inexpensively. From 1914-1915 fluorite from the IKFD accounted for over 99% of nationwide production and the Hardin County mines produced about 80% of that (Weller et al. 1920). The Rosiclare Vein produced a substantial amount of the fluorite consumed in the U.S.A. during this early period. Several mines worked the Rosiclare Vein and many are described below.

This **Rosiclare Mine** was operated by the Rosiclare Lead and Fluorspar Company and the Franklin Fluorspar Company (Bastin 1931). This vein was reported to be 30 to 35 feet wide near the Rosiclare Main and Plant Shafts. Weller et al. (1920) reported that working levels were 235 (ft.), 320 (ft.), 420 (ft.), and 520 (ft.). Bastin (1931) reported several additional working levels and reported the main shaft was sunk to a depth of 720 feet. A diagrammatic cross section of this mine shows that the displacement along the fault at the Rosiclare Air Shaft is approximately 125 (ft.) down on the west side (Weller et al. 1920).

The **Fairview mine** was operated by the Fairview Fluorspar and Lead Company. In 1862 this company sunk the Good Hope Shaft to a depth of 503 feet and worked the property until 1874 (Weller et al., 1920). From 1890 to 1895, this mine was leased by the owners of the Rosiclare Mine. More production occurred from 1905 to 1913 until the original Good Hope Shaft began to cave in. The Good Hope Shaft was worked on at least 6 levels and the vein was reported to be 25 feet wide (Weller et al. 1920). In 1909, the Fairview Company re-opened an old shaft 1700 feet north of the Good Hope shaft, and in 1911, the Annex and Extension Shafts were sunk (Weller et al. 1920). Mining ceased in about 1924 when drifts apparently encountered water from the Ohio River. Just before the pumps were shut down, over 3,400 gallons per minute were being pumped from these mines (Bastin 1931).

The Hillside Mine shaft was sunk in 1919 by Inland Steel (Weller et al. 1920 and Bastin 1931). Working levels were 170 (ft.), 250 (ft.), 350 (ft.), and 450 (ft.). The mine complex consisted of the main plant shaft sunk to the (450 foot level), a south air shaft sunk to the (250 foot level), and north air shaft sunk to the (450 foot level). The vein was reported as nearly vertical, 5 to 35 feet wide, and trending generally north-south (Bastin 1931). The vein was mined continuously for over 1,600 feet. Bastin (1931) reported that post mineralization normal faulting was reported to be present with the west side being downthrown. The ore was primarily fluorite, but small amounts of galena were recovered. Bastin (1931) reports the Galena contained 5 ounces silver per ton.

The Daisy Mine was sunk by the Rosiclare Lead and Fluorspar Company prior to 1918 (Bastin 1931). The mine

worked the 150 (ft.), 180 (ft.), 300 (ft.), 412 (ft.), and 500 (ft.) levels. The vein strikes north 30°E and dips 70-80°W. The vein was approximately 8 (ft.) wide, but in places swelled to over 20 ft. The 412 (ft.) level extended southward into the Blue Digging Vein (Bastin 1931). The vein shows post-mineralization movement with the west side being down thrown (Bastin 1931). The pitch on slickensides show bidirectional movement with one set pitching 10°S and a second set 80°N.

The Blue Diggings Mine was located southwest of the Daisy Mine and was operated by the Fairview Fluorspar and Lead Company from 1910 to 1920. The mine was named for the pure white to light blue color of the fluorite extracted from this vein (Weller et al 1920). This mine worked 160 (ft.), 200 (ft.), 300 (ft.), 400 (ft.), and 500 (ft.) levels. The vein was narrow between 3 and 8 feet wide. The main shaft was driven on the hanging wall and passed through the vein at the 200 (ft.) level (Fig. 6). Weller et al. (1920) reported that this mine contained zones of intense fracturing and the strike and dip of the vein varied considerably. The offset along this vein is approximately 100 feet down to the east with normal displacement, and the dips are between 70 and 55° to the southeast (Bastin 1931).

The Argo Vein is about 450 feet northwest of the Blue Diggings Vein. It parallels the Blue Diggings Vein, trends N25°E and dips steeply to the west (Bastin 1931). The Franklin Fluorspar Company sunk the shaft in 1922 and in 1923, a cross cut from the 500 (ft.) level of the Blue Diggings Mine was driven into the vein. The vein was reported to have large “cavernous” openings sometimes lined with pyrite (Bastin 1931). The vein was reported to be on a normal fault with the west hanging wall being downthrown over 100 feet.

The Dimmick Prospects (also spelled Dimick) shafts were sunk approximately 1,400 feet north of the Daisy Vein. No mineralization was reported in either prospect but a small fault was encountered 30 feet from the shaft. Evidently two shafts were sunk at this location.

Several shafts and a few drifts were sunk west of Illinois Highway 34 and north of the Dimmick Prospects. These were called the Eureka prospects, and the Eureka #2 was formerly called the Cowsert Shaft (Bastin 1931).

The Clement Mine, also called the Clement-Dyspeck Prospect, was operated by the Rosiclare Lead and Fluorspar Company. The vein trended N45°E to N50°E east and was nearly vertical (Bastin 1931). These pits constitute the northern prospects along the Hillside Vein. Weller et al. (1920) suggested that the Rosiclare and Blue Diggings Vein come together just south of this prospect.

The Indiana Mine was owned by the Indiana Fluorspar and Lead Company but was operated by the Hillside Fluorspar Mines. It was also called the Hillside Mine #2. The mine

produced a small amount of fluorite from two parallel veins that trend N18°E and dip very steeply to the west (Bastin 1931).

The Martin Mine was operated by Rosiclare Lead and Fluorspar Company and is a series of pits and one shaft. The pits are aligned in a N20°E direction, which was assumed to be the trend of the vein (Weller et al. 1920). The general attitude of the bedrock observed here was N37°E dipping 80°NW. **The Austin Mine** lies along the major northeast-trending fault southwest of the Martin Mine. **The Interstate Prospect shaft** lies south of the Martin Mine. The Interstate Prospect shaft is at least 30 feet deep and contains moderately fractured sandstone with clear fluorite veins. The major fractures appear to parallel the major northeast-trending fault zone. These prospects are located in an extremely complicated tectonic zone where several fault zones converge. Several additional prospect pits were observed along this fault zone.

There are several unnamed prospect pits located near 17-12S-8E (3000 ft. EL, 1500 ft. SL) along a fault trending north 25°E to N30°E. No additional historical information was available. These prospects are along the southeast side of a fault block of Caseyville Sandstone. The fault drops the Caseyville down to the level of the Clore Formation. Colorless fluorite was observed as small veinlets along fractured fine grained sandstone. The fault block dips 50° to the northwest. The lack of roads into this site indicates that little production occurred at this location, although one pit was dug at least 10 feet deep along the trend of the fault. Several additional adits and prospect pits are marked on the geologic map, but no historical information concerning these operations could be obtained.

Cave-in-Rock District

The Cave-in-Rock District is the largest bedding replacement District within the IKFD. It trends in a northeasterly direction along the southeast side of the Rock Creek Graben, whereas the Harris Creek and Goose Creek Districts are present along the northwest side of the Rock Creek Graben. The individual mines and prospects of the Cave-in-Rock District are discussed, starting in the southwest and progressing northeast. The reports of Bastin (1931), Weller et al. (1952), and Brecke (1962) were utilized extensively for historical information on the individual mines. The map and report of Baxter et al. (1963) provided location information for mines but no historical information. The mine boundaries on the accompanying geologic map reflect the data the ISGS currently possesses; therefore, areas may be mined that are not depicted as mined on the map.

The bedding replacement ore was first mined at the surface in open pits. The miners followed the ore into the hillsides, employing a modified room-and-pillar underground mining method. The rooms were up to 150 feet wide and commonly trended in a northeasterly direction. Pillars were left in random configurations to extract as much fluorspar as possible

without causing roof failures. Some of the mines worked multiple stratigraphic levels. The most common ore levels were in the Renault Limestone, Ste. Genevieve Limestone, and Downeys Bluff Limestone. The levels were named for the roof rock present over the mineralized strata. It is important to document the roof rock because the ascending ore fluids are impeded when they come into contact with an impermeable roof material. Roof conditions may be the most important factor affecting the ascending ore fluids, although Weller et al. (1952) pointed out that many of the deposits are present without an impervious shale cap rock. The mineralization in the “Bethel Level” occurs within the underlying Downeys Bluff Limestone. The roof of the “Bethel Level” is usually thin, shaly sandstone with indurated gray sandstone above. The top of the Ste. Genevieve just below the Aux Vases Sandstone is called the “Rosiclare Level.” The Aux Vases was formerly called the Rosiclare Sandstone. The lithology of the strata occurring at the contact between the Aux Vases and Ste. Genevieve is variable. Brecke (1962) described the “Rosiclare Level” roof as green plastic shale, silty shale, and limestone interbedded with sandy limestone. The “sub-Rosiclare Level” occurs in the Ste. Genevieve within the Spar Mountain Sandstone approximately 60 feet below the base of the Aux Vases Sandstone. At this level, a calcareous sandstone is present above oolitic to dense limestone (Brecke 1962). This unit is not present in all parts of the region. The Spar Mountain Sandstone is 3 feet thick in the Hill Mine but absent at the Davis-Deardorff Mine. The Renault Limestone also hosts bedding replacement ore in at least two levels.

The Lead Hill Group Mines are located along the southwestern edge of the Cave-in-Rock subdistrict. The subdistrict is named for Lead Hill, which is a 3,000-foot-long north-south-trending oval hill. Galena associated with the fluorite was reported to be rich in these hillside mines. Early mining at Lead Hill and Spar Mountain was confined to adits along the hillsides. The early mines produced lead and wasted or stockpiled the fluorite because the market for fluorite was not yet developed. The mineralized units, which are at the surface along Lead Hill and Spar Mountain, dip to several hundred feet below the surface to the northeast. The shallower ore on the southwest side of this subdistrict was mined first, and the deeper mines in the northwest were mined last. The ore pods are variable in thickness; they can be as thick as 17 feet and are commonly less than 6 feet thick. The widths of the larger pods approach 500 feet but typically are less than 150 feet wide.

The Robinson Mine operated prior to 1931 and was owned by George Robinson (Bastin 1931). Open pits and adits or drifts into the hillside owned by Fluorspar Products Mines and the Grischy Mines were reported as working in the same area (Weller et al. 1952). Two to 3 feet of bedding replacement ore below the Aux Vases Sandstone in the Ste. Genevieve Limestone along with a small 6-inch-wide vein of fluorite striking N45° E was present at the Robinson Mine

(Bastin 1931). Baxter et al. (1963) listed all the pits at this location as the Fluorspar Products Mines.

The Miller Mine (also called the C.M. Miller Mine) was reported to contain fluorite, galena, and sphalerite along with alteration products cerussite and smithsonite (Bastin 1931). Several small pits and drifts in the hillside mined 6-foot-thick white and purple bedding replacement ore. Clear optical-grade fluorite of high purity was reported in some of these mines (Bastin 1931). The ore was located below the Aux Vases Sandstone at the top of the Ste. Genevieve Limestone.

The Lead Hill Mine, Wolf Mine, Oxford Mine, Shipp and Convert Mines, and FPC Mines are listed by Myers and Chenoweth (2009) at Lead Hill. The locations of these mines could not be verified, but information in Illinois State Geological Survey files indicates the locations for these mines.

The Cave-in-Rock Group Mines were located northeast of Lead Hill and west of Spar Mountain. The first mine started as an open pit, and a drift or adit in the hillside followed. Bastin (1931) reported that two more adits were present 200 feet west of the open pit, and several adits were present near the top of the hill. The ore was bedding replacement type from a few inches to 3 to 4 feet thick, but generally the mineralization in this mine was poor (Bastin 1931). Weller et al. (1952) and Baxter et al. (1963) also listed the Grischy Mines at this location. The Hastie Quarry currently conducts open-pit mining of limestone throughout the area of these abandoned underground fluorspar workings and recovers fluorite left underground in pillars and sidewalls in the abandoned underground mines.

The Spar Mountain Group of mines is located northeast of the Lead Hill Mine and east of the Cave-in-Rock Mines. The Hastie Quarry currently conducts open-pit mining of limestone for aggregate at Spar Mountain. Weller et al. (1952) indicated that the Austin Mines were analogous to the Spar Mountain Group and that large-scale mining of these deposits began in 1919, when the Spar Mountain Mining Company purchased mineral rights. Fluorite was very pure in these early mines, and galena and sphalerite were present in restricted areas (Weller et al. 1952). Mines at this location first started as adits into the hillside and as small open pits.

The Cleveland-Illinois Fluorspar Company was mining galena at Spar Mountain as early as 1903 (Bain 1905). The mine was also operated by the Spar Mountain Mining Company. In 1926, the mine was sold to the Benzon Fluorspar Company (Bastin 1931). The early open-pit and shallow drift mines into the hillside were followed by vertical shafts along the top of Spar Mountain to extract ore below the Aux Vases Sandstone. The ore at this mine shows evidence of the fluorite being partially dissolved before another generation of fluorite and calcite was deposited. Bastin (1931) reported that surfaces of previously formed crystals showed a pitted

surface on which the later-formed crystals of calcite were precipitated. Barite was found as a late-forming mineral and, to some extent, may have replaced earlier-formed calcite (Bastin 1931). These early observations are in agreement with the paragenesis of mineralization reported by Hall and Friedman (1963), who reported barite and witherite as the last-forming minerals in the Cave-in-Rock subdistrict. The Cleveland Mine was listed as part of the Austin Mines by Baxter et al. (1963).

The Oxford Pits were located at the southwest portion of Spar Mountain and worked surface deposits below the Aux Vases Sandstone (Bastin 1931). The ore was highly weathered and contained large blocks of fluorite in residual clays. Weller et al. (1952) listed these pits as part of the Austin Mines complex.

The West Morrison Pits were located northeast of the Oxford Pits and worked similar residual material as was mined at the Oxford Pits. The West Morrison Pits also recovered fluorite from an unweathered ore zone in the Ste. Genevieve Limestone (Bastin 1931). Weller et al. (1952) listed these pits as part of the Austin Mines complex.

The Lead Mine was located northeast of the West Morrison Pits and also worked fluorite from below the Aux Vases Sandstone. This mine is also listed as the Austin Mines Lead Mine (Weller et al. 1952; Baxter et al. 1963). The bedding replacement ore in this mine trended to the southwest, which is perpendicular to the northeast trend of the majority of the ore shoots in this district. The Hastie Quarry has exposed underground drifts that are probably old workings from this mine.

The Green Mine was idle in the 1930s according to Bastin (1931). The ore was reported to be similar to the ore at the adjacent Cleveland Mine but was thinner and less productive. The property was listed as Green-Defender by Baxter et al. (1963). Weller et al. (1952) listed this mine as part of the Austin Mines complex.

The Defender Mine was about 400 feet north of the Green Mine and worked ore similar to that in the Green Mine. The mine apparently worked small adits in the hillside (Bastin 1931). Weller et al. (1952) listed this mine as part of the Austin Mines complex. It is unclear where the Defender Mine ceased operations and the Victory Mine began.

According to Bastin (1931), the **Victory Fluorspar Mine** began in 1926. This mine is one of the few westerly trending ore bodies in the Cave-in-Rock subdistrict. The ore occurs along a fracture and extends about 70 feet laterally (Brecke 1962). The ore zone was a single blanket up to 17 feet thick that split into two ore horizons in portions of the mine (Bastin 1931). The Victory Mine employed shafts along the top of Spar Mountain from which ore was hoisted to the surface. The Addison Shaft was on the west side of the

workings, and the Carlos Shaft was on the east side. Weller et al. (1952) reported that this mine was started by Outwater, Schwerin, and Barnett, who sank the Carlos Shaft along a westward continuation of the Green and Defender ore bodies. The ore occurs along and parallel to a structure (small fault or fracture), and the two mineralized ore levels come together along the structure to form a V style of enrichment (Brecke 1962). Baxter et al. (1963) listed this mine as Minerva Mines, Addison Shaft, Carlos Shaft, and North Victory Adit. A highwall at the Hastie Quarry has exposed two underground drifts that are probably extensions of the Victory Mine workings. A small fault with a few inches of offset can be observed in the floor of the quarry, fracturing the Aux Vases Sandstone. Fluorite can be observed along this fracture between the breccia clasts. Tracing this small fracture into the highwall is difficult, but it appears to project into the edge of a syncline.

The Crystal Fluorspar Mine began operations before 1931 (Bastin 1931) northeast of the Victory Mine near the Green, Defender, and Victory workings. The Crystal Mine entrance was near the base of Spar Mountain, where an incline was driven into the east side of the hillside. A shaft was later added at the top of the hill to extract ore. Baxter et al. (1963) listed this mine as Minerva Mines, Crystal adits and shafts. Weller et al. (1952) reported that seven shafts were present within this mine complex. Most ore bodies were in the "Rosiclare Level," but Weller et al. (1952) reported that one ore pod was present in the upper portion of the Renault.

The Wall Properties are several open pits along the north edge of the Big Sink adjacent to the Crystal Mines. Weller et al. (1952) reported that highly weathered deposits of fluorite in a clay matrix were mined along the northern rim of the Big Sink. The precise location of these working is difficult to determine but are based on the locations shown by Weller et al. (1952). Baxter et al. (1963) listed this property as the Frayser wall property.

The Mahoning Mines or Ozark-Mahoning Mines were a group of mines owned by the Ozark-Mahoning Company operating primarily northeast of Spar Mountain. The mines in the southwestern area connected workings of older adjacent Spar Mountain Group mines, making it difficult to identify individual mine boundaries. The Ozark-Mahoning Company was one of the largest producers of fluorite and was the last major producer to operate in the region. The Ozark-Mahoning Company was purchased by the Penwalt Company in 1974, which merged with Atochem North America in 1989 before finally ceasing mining operations in the 1990s. The Davis Mines W.L. Davis-Deardorff Mine, also known as the Davis-Deardorff Mine, was located north of the Victory Mine and was adjacent to a structure trending N55°E. The bedding replacement pods were elongate parallel to the N55° E structure. Small cross faults were described by Brecke (1962), with offsets of less than 1 foot. Enrichment of the ore to acid-grade fluorspar was present

where the two structures coincided. Cross sectional views of the enriched zones showed a V-shaped structure. Brecke (1962) reported that this mine was the only one that contains abundant quartz associated with the fluorite bodies. Several shafts are associated with this complex, and Baxter et al. (1963) identified the shafts as the Deardorff Mine, W.L. Davis Mine, W.L. Davis #2 Mine, and #16. The A.L. Davis Mine was located southeast of the Davis-Deardorff Mine and mined a continuation of the northwesterly-trending ore zones of the W.L. Davis #2 Mine. The Edgar Davis Mine was located northeast of the Davis Mines. The shaft at this location is labeled Mahoning Mine on the U.S. Geological Survey topographic map. Baxter et al. (1963) and Myers and Chenoweth (2009) listed the mine as E. Davis and as part of the Mahoning Mines. Weller et al. (1952) reported that the W.L. Davis-Deardorff Mine was one of the richest mines in the Cave-in-Rock subdistrict, with mine-run ore averaging 50 to 60% fluorite, 12 to 14% zinc, and 3 to 5% lead.

The Green Mines are located in the NE¼ of Sec. 35, T11S-R9E. These mines are sometimes referred to as the Saline Mines. The West Green Mine, the North Green Mine, and the East Green Mine were all owned by the Ozark-Mahoning Company. The North Green Mine contains a N60° E structure and a small thrust fault that uplifts the Renault (probably Downeys Bluff) over the Bethel Sandstone (Brecke 1962). This structure is minor and is probably a relief or accommodation structure associated with the Rock Creek Graben. Brecke (1962) observed no displacement along the northeast-trending structures, and the northwest-trending structures had only minor displacement. A pipe-like solution feature is located just north of the North Green Mine shaft, which probably served as a primary conduit for ore solu-

tions. Structure contours on the overlying Bethel Sandstone indicate that the unit has slumped downward approximately 100 feet (Brecke 1962). The East Green and North Green ore pods formed in a fracture zone extending away from the collapse feature (Brecke 1962) and contain up to 7% sphalerite, with mineralization in both the “Bethel Level” and the “Rosiclare Level.”

The Oxford Mine or S.E. Oxford Mine was located in the NW¼ of Sec. 25, T11S-R9E. This mine apparently extended along northeast-southwest trending fractures and was traced to the southwest into the southeast portion of Sec. 26. Records from a field trip guidebook indicate that this ore body connected with the Davis workings (Perry 1973). This ore pod was then called the Davis-Oxford ore body. The ore was confined to the “Bethel Level” and consisted of purple replacement fluorite along with yellow-colored high-grade zones (Perry 1973). Barite was concentrated along the periphery of the ore zones, and sphalerite was concentrated along minor faults or fractures (Perry 1973). This mine was studied by Brecke (1962), who speculated that the V-shaped structure over the ore zones was a result of volume reduction due to the replacement of limestone by fluorite (Fig. 7).

The Hill-Ledford Mine was operated from the late 1950s until the 1970s. This mine was located north of the Oxford Mine in the SE¼ of Sec. 23, T11S-R9E. Based on structure contours of the Aux Vases Sandstone (Rosiclare), Brecke (1962) mapped a collapse structure or oval depression with a vertical offset approaching 75 feet. This brecciated collapse structure was located along a small fault adjacent to the ore zone. Brecke (1962) suggested that this depression was a collapse feature over a feeder pipe for the mineralizing fluids

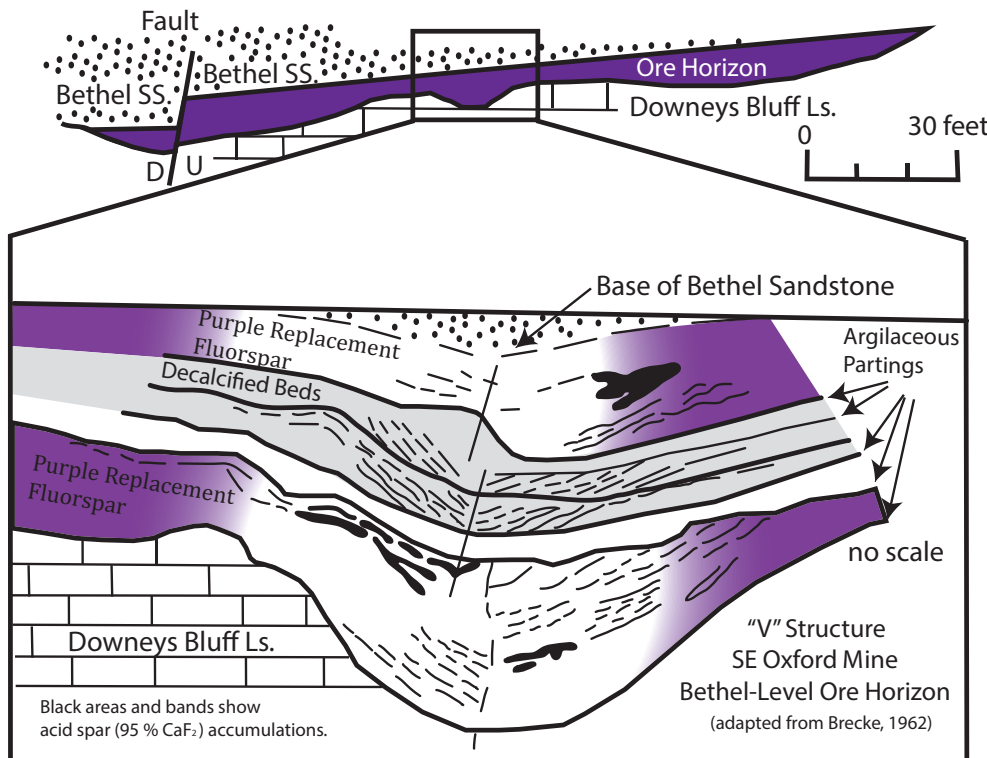


Figure 7 V-shaped structure, S.E. Oxford Mine, “Bethel Level” ore horizon. Adapted from Brecke (1962) and Denny and Counts 2009). Black areas and bands show acid spar (95% CaF₂) accumulations.

and was similar to the breccia pipe seen in the North Green Mine. The breccia pipe at this mine was at the northeast end of the mineralized area, and Brecke (1962) theorized that the ore fluids moved up-dip to the southwest. These structures are very local and extend for less than 400 feet across the mineralized zone. Drilling in the mine floor indicates that sphalerite-fluorite mineralization extends down into this feature for more than 170 feet.

The Minerva Mine was the last major mine operating in the Cave-in-Rock subdistrict. This mine operated from the late 1940s until the 1990s. It was first operated by the Minerva Oil Company and later by Ozark-Mahoning. It was idle for several years because of the amount of water in one of the deeper mines in this subdistrict. The Minerva Mine produced some of the finest crystals for mineral collectors and was known for fluorite, sphalerite, barite, witherite, alstonite, and benstonite crystals. The mine operated several working levels, including the “Rosiclare Level” (Aux Vases) and “Bethel Level.” Weller et al. (1952) reported that the ore at the Minerva mine averaged 4.2% zinc and that zinc concentrate obtained through processing was 63%. The mill was reported to be a flotation plant that was located at the mine site, and the hoisting shaft was 645 feet deep. No production has occurred at this mine since 1995.

Harris Creek Subdistrict

The Harris Creek subdistrict, located northwest of the Rock Creek Graben, was founded by the Ozark-Mahoning Company in the 1970s and is named for Harris Creek. No production has occurred in this subdistrict since the 1990s.

The Denton Mine was the first mine opened in the Harris Creek subdistrict, and the main shaft was located in the SW $\frac{1}{4}$ of Sec. 9, T11S-R9E. The ore was of the bedding replacement-type and was similar to the ore in the Cave-in-Rock subdistrict. The ore at the Denton Mine was located in the “Rosiclare Level”, with some in the “sub-Rosiclare Level.” The ore followed northeast-southwest fractures and extended to the southwest into the NE $\frac{1}{4}$ of Sec. 17, T11S-R9E. Drilling records from the Ozark-Mahoning Company indicate that some mineralization occurs in the “Bethel Level” in the southern portion of the mine, but it is unclear whether the company mined this area.

The Annabel Lee Mine was located northeast of the Denton Mine near the center of Sec. 10, T11S-R9E. The headframe is still standing at this location and can be observed from Illinois Highway 1. The mine operated from the early 1980s until 1995. The Annabel Lee ore pods were narrow, commonly less than 100 feet wide, and ran parallel to the major structures of the Rock Creek Graben. The ore was mainly in the “Rosiclare Level,” but some “Bethel Level” ore was mined.

Goose Creek Subdistrict

The mines within the Goose Creek subdistrict are vein-type

mines and are located along a northeast-trending fault that is the northwestern boundary for the Rock Creek Graben. The Goose Creek and Harris Creek subdistricts are sometimes considered a single subdistrict. The separation into separate subdistricts seems to be valid because the mines of the Goose Creek subdistrict are vein-type, whereas the Harris Creek mines are bedding replacement-type.

The Goose Creek Mine, Hoeb Mine, and Green Mines

are all located along a northeast-trending normal fault zone named the Goose Creek Fault Zone. The fault zone apparently comes together to the north, and several exploration drill holes help locate the fault on the accompanying geologic map. Little historical information concerning the Goose Creek mines could be obtained.

Sandstone Resources

Shawnee Stone operates a small pit to extract sandstone slabs mainly for landscaping purposes. The operation is located in the Bethel Sandstone north of the Lafarge Quarries and east of IL Route 1.

Limestone Resources and Quarries

Large resources of limestone in Hardin County are favorably located for barge transportation on the Ohio River. The St. Louis Limestone through Downey’s Bluff interval currently is being quarried in several areas of Hardin County. Stone from these Mississippian formations is suitable for a wide variety of purposes, including the manufacturing of cement, concrete aggregate, agricultural lime, rock dust, and crushed stone for surfacing secondary roads. Although portions of the resources lie within the Shawnee National Forest, most of the potential quarry stone near the Ohio River is on privately owned land. The stratigraphic interval for aggregates is primarily the Ste. Genevieve through the Salem Limestones, but lower formations may be suitable for a variety of purposes.

Krey and Lamar (1925) indicate that a quarry was present in the Western portion of the county near Shetlerville as early as 1921, being operated by the Golconda Portland Cement Company. Krey and Lamar (1925) also list Southern Illinois Limestone Company as operating a quarry in this area. Bush (1969) lists this quarry as River Sand and Stone Inc. This quarry was operated by Downen Enterprises, Barter Enterprises, Florida Rock Industries, and later by Vulcan. Materials. The quarries in this area are not currently active, but the loading dock is used by the American Coal Company. A quarry east of IL 34 and south of IL 146 was run as the Williams Quarry until the 1990s when Hardin County Materials Inc. consolidated and acquired it. This quarry is currently being operated by Lafarge. A small abandoned quarry along the Ohio River between Elizabethtown and Rosiclare is also present. This quarry was originated as the Bean Quarry and was later operated by Denny and Simpson (Bush 1969); it is sometimes referred to as the Jacks Point Quarry. This location is currently being utilized as a river loading dock.

Several open pit quarries have been developed in the eastern portion of the county. Hastie Mining and Trucking currently operates a quarry northwest of Cave-in-Rock. Lafarge operates a quarry east of Cave-in-Rock along the Ohio River and has the mining rights to the Rigsby and Barnard Quarry and the Denny and Simpson Quarry, which were previously operated by Hardin County Materials. Hardin County Materials subsequently sold their operations to Martin Marietta Materials in 1997 and Martin Marietta Materials then sold all of their Hardin County operations to Lafarge.

Oil and Gas Wells

The Illinois State Geological Survey oil and gas database indicates that 10 oil and gas wells have been drilled in Hardin County (Table 1). Only one well produced oil and the production was minimal. The productive well was drilled by Minerva Oil Company in 1949 and produced 5 barrels of oil from the Renault Formation. The hole was drilled to 1,102 feet below the surface and was plugged in 1949. The remaining wells were dry and abandoned.

Three wells were drilled near the crest of Hicks Dome (30-11S-8E). The first well drilled at Hicks Dome by Mareta Oil

Company in 1935 may have been an unsuccessful wildcat oil test that was dry and abandoned. The API number for a second hole at this location indicates that in 1944, the hole was deepened by Northern Ordnance to a final depth of 3,306 ft. A brief description in the ISGS records indicates that the hole was drilled to test the St. Peter Sandstone; this hole was also dry and abandoned. St. Joseph Lead Company may have been drilling to explore for minerals when they drilled the Hamp property at Hicks Dome. Records from the Hamp boring indicate that the hole bottomed in the Cambrian Knox Group sediments at 2,948 ft. below the surface.

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Table 1 Oil and Gas wells drilled in Hardin County.

Status	Longitude	Latitude	Location sec.-Twn.-Rng.	Company Name	Farm Name	API Number	Completion Date	Total Depth (ft)
Dry and Abandoned	-88.361808	37.52681	30-11S-8E	Northern Ordnance	Fricker	120690004301	1-Jul-44	3306
Dry and Abandoned	-88.361808	37.52681	30-11S-8E	Mareta Oil Co	Fricker	120690004300	1-Jan-35	2345
Dry and Abandoned	-88.176884	37.581837	11-11S-9E	Ashley Oil Company	Lacky, R.	120690009900	16-Nov-48	1885
Dry and Abandoned	-88.132474	37.553775	20-11S-10E	Minerva Oil Co.	Lane, Alva	120690040600	23-Aug-47	1102
Dry and Abandoned	-88.184511	37.585347	2-11S-9E	Todd James	Porter, Jim	120690009700	25-Sep-42	1822
Dry and Abandoned	-88.077785	37.494493	11-12S-10E	Lucas, W. O.	Herrin, Elsie	120690004900	20-Jun-54	1500
Dry and Abandoned	-88.130924	37.555794	17-11S-10E	Minerva Oil Co.	U. S. Bur. Land Manag.	120690040300	8-Jul-48	1265
Dry and Abandoned	-88.37216	37.532213	30-11S-8E	St. Joseph Lead Co.	Hamp, Henry Jr.	120690004400	27-Nov-52	2948
Dry and Abandoned	-88.077785	37.494493	11-12S-10E	Lucas, W. O.	Herrin, Elsie	120690004901	19-Jun-56	3000
OIL Productive	-88.132474	37.553775	20-11S-10E	Minerva Oil Co.	Lane, Alva	120690040601	4-Feb-49	1102

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