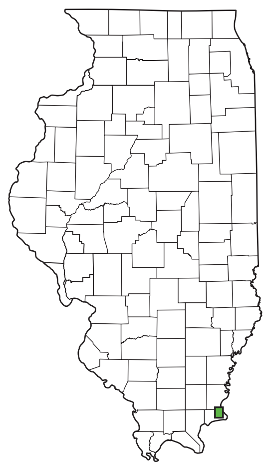
Illinois Geologic Quadrangle Map
IGQ Saline Mines-BG

Bedrock Geology of Saline Mines Quadrangle

Gallatin and Hardin Counties, Illinois

F. Brett Denny, Joseph A. Devera, and Adam Kittler

2013



ILLINOIS STATE GEOLOGICAL SURVEY
PRAIRIE RESEARCH INSTITUTE

ILLINOIS
UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN

Prairie Research Institute
ILLINOIS STATE GEOLOGICAL SURVEY
615 East Peabody Drive
Champaign, Illinois 61820-6964
(217) 244-2414
http://www.isgs.illinois.edu

Introduction

This report accompanies a geologic map of the Saline Mines 7.5-minute Quadrangle. The Saline Mines Quadrangle was included on previous geologic maps by Weller et al. (1920), Butts (1925), Weller (1940), Weller et al. (1952), and Baxter et al. (1963). Reports on the Illinois-Kentucky Fluorspar District (IKFD) and mines were completed by Bastin (1931), Heyl and Brock (1961), Heyl et al. (1974), Brecke (1962), and Hutcheson (1973). A map of the coal mines of this quadrangle was completed by Myers and Chenoweth (2009). Original geologic mapping for this project was completed in 2011 and 2012.

Structure and Tectonics

The map area lies within the Fluorspar Area Fault Complex, one of the most intricately faulted areas in the North American interior (Denny et al. 2008). Although reverse, strike-slip, and oblique-slip faults are important, high-angle normal faults prevail. 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. This quadrangle lies along the eastern flank of a regional igneous arch called the Tolu (or Kutawa) Arch (fig. 1). Regional dip and some of the faulting is inherently related to this regional igneous activity.

Maximum displacement in the Saline Mines Quadrangle is along the Rock Creek Graben, where Lower Chesterian units are juxtaposed with the Lower Pennsylvanian Caseyville Formation, producing more than 1,000 feet of vertical offset. The fault segments here are extremely complex, and, in many cases, rock units that occupy narrow fault slices cannot be identified with confidence. The authors have conducted field work in these complexly faulted areas and have utilized mineral exploration borings to assist with structural interpretations. Nevertheless, these fault zones are probably more complex than we depict on this geologic map.

Rock Creek Graben

The Rock Creek Graben bisects the Saline Mines Quadrangle from the southwest corner of the quadrangle trending in a northeasterly direction. The graben is approximately 2 miles wide and can be traced to the Saline River, where the structure is projected under the floodplain of the Ohio River. The Hogthief Creek Fault Zone and Goose Creek Fault Zone bound the northwest edge of the graben, and the Peters Creek Fault Zone bounds the southeast side.

Peters Creek Fault Zone

This fault zone extends across the Saline Mines Quadrangle and demarcates the southeast edge of the Rock Creek Graben. The fault 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 (1974) mapped faults that appear to line up with the Peters Creek Fault in the Kentucky portion, an adjacent quadrangle. Exposures of this fault zone are few, but mineral exploration tests have intersected the fault at Sec. 23, T11S, R9E (SW¼) 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 in this quadrangle.

Hogthief Creek Fault Zone

This fault zone demarcates the northwest edge of the Rock Creek Graben and is also poorly exposed. Fractured beds were observed at several locations, but exposures of the fault surface were not observed. The Hogthief Creek Fault was mapped by Weller et al. (1920) and Baxter et al. (1963) as a complex series of parallel faults merging into two parallel faults near Rock Creek. A segment of the fault appears to be connected to the Goose Creek Fault Zone to the north. 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. We mapped a fault along this area merging into the Goose Creek Fault Zone to the north.

Goose Creek Fault Zone

The Goose Creek Fault Zone lies northwest of the Rock Creek Graben. The Goose Creek Fault Zone is a series of parallel normal faults showing as much as 700 feet of vertical offset (Nelson 1995). This fault zone can be seen along the road cut near the Goose Creek Mine. Vein fluorite mineralization is present along portions of the Goose Creek Fault Zone. Several drill holes verify the location of the faults near the Green and Hoeb Mines (Sec. 16 and 17, T11S, R9E). This fault can be projected to the northeast under the floodplain of the Ohio River. Kehn (1974) mapped a fault on the Kentucky side of the Ohio River that may project into this fault zone. Tracing this fault zone to the northeast is difficult.

Stratigraphy

The bedrock exposed in this area ranges from Mississippian to Pennsylvanian. The nomenclature for these units has changed through time, which complicates the stratigraphy. The current stratigraphic nomenclature can be viewed on the graphic column, and the previous stratigraphic nomenclature is well documented by Baxter et al. (1963). Baxter et al. (1963) also suggested that several hundred feet of Pennsylvanian McLeansboro Group sediments may be present in the downdropped Rock Creek Graben under the floodplain of the Ohio River. More data are needed in this area to decipher its Pennsylvanian stratigraphy.

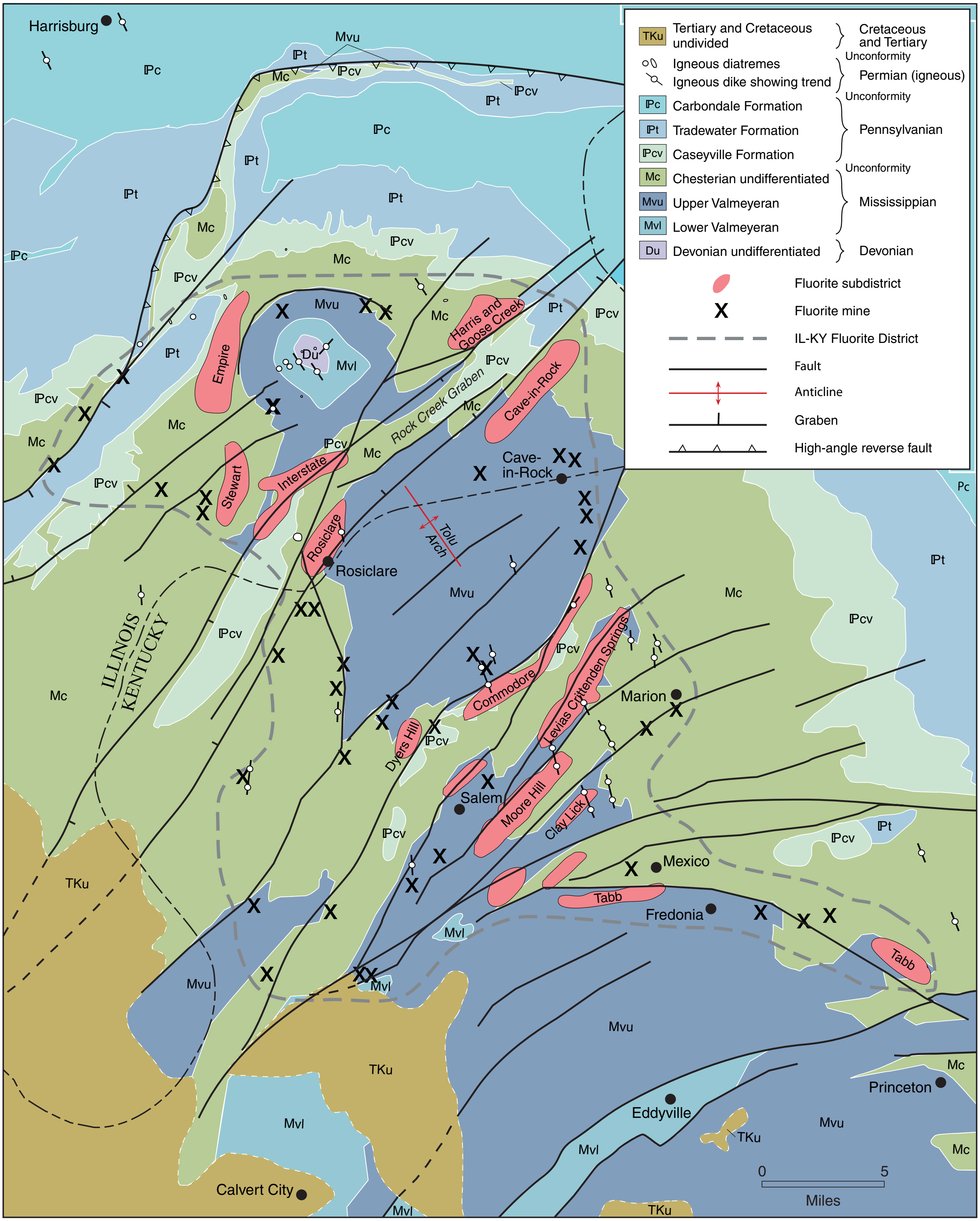


Figure 1 Geologic map of the Illinois-Kentucky Fluorite District. Edited from Denny et al. (2008).

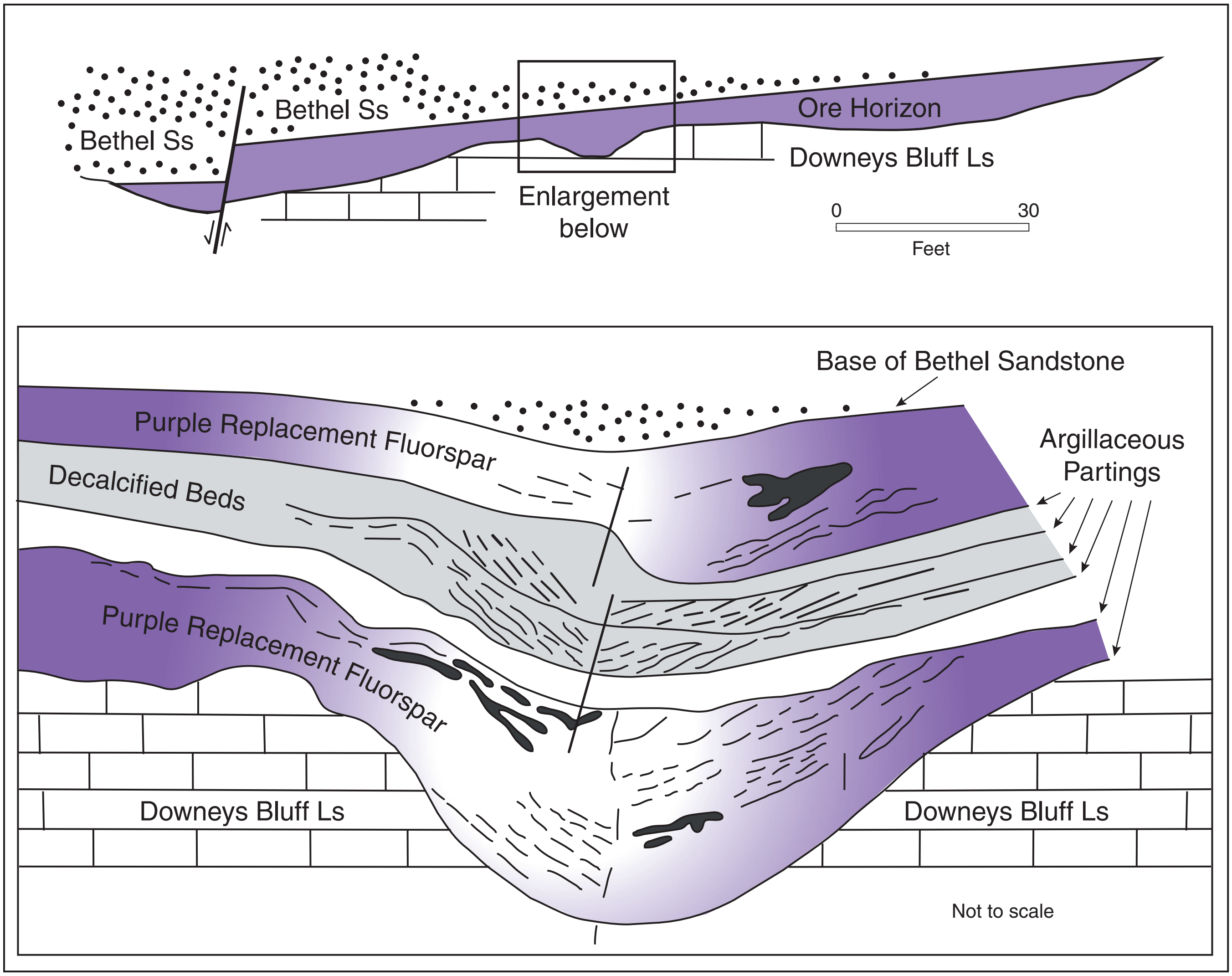


Figure 2 V-shaped structure, S.E. Oxford Mine, "Bethel Level" ore horizon. Adapted from Brecke (1962). Black areas and bands show acid spar (95% CaF_2) accumulations.

Mineral Resources

The IKFD (fig. 1) was formerly the leading source of fluorite in the United States and also produced significant quantities of lead, zinc, and other commodities. The term fluorspar is commonly used as a synonym for fluorite. Economic mineralization in the IKFD is predominantly composed of fluorite and lesser amounts of sphalerite, barite, and galena. Other minerals identified in this district include pyrite, chalcopyrite, quartz, celestite, cerussite, greenockite, malachite, smithsonite, witherite, strontianite, benstonite, and alstonite (Goldstein 1997). 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 deposits derived from veins or beds.

The best indication of bedded replacement is remnant textures of limestone observed within fluorite crystals. These include fossils, stylolitic sutures, primary bedding, and other sedimentary structures. Mine-run ore commonly contained 30 to 40% fluorite, as much as 2 to 3% zinc, and galena. Some deposits contained small amounts of silver in the galena and recoverable cadmium and germanium in the sphalerite (Trace and Amos 1984). Galena was found in abundant amounts at Lead Hill and portions of the Cave-in-Rock subdistrict. The amount of silver in the lead was estimated to be 5 to 8 ounces per ton (Bastin 1931). The amount

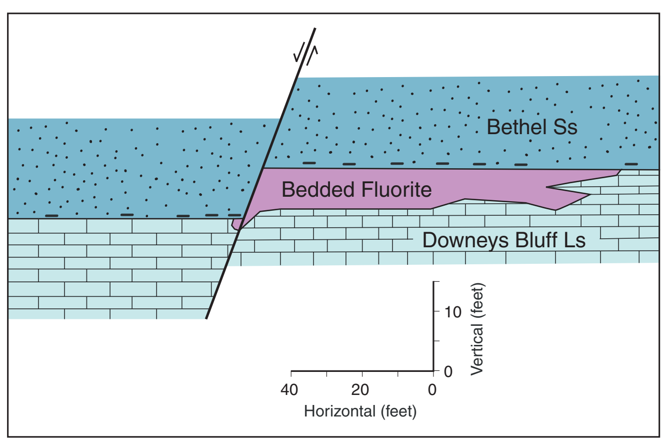


Figure 3 Stratiform or bedding replacement.

of sphalerite in some ore bodies within the IKFD is considerable and created milling problems for the early mines. During World War II, the demand for fluorite increased with the demand for steel. Fluorspar was utilized as a flux for the manufacturing of steel; ore specifications required a product of 85% CaF_2 and less than 5% SiO_2. A concentrating plant was erected in Rosiclare by the Ozark-Mahoning Company to process or concentrate the ore. Early mills and concentrating plants utilized jigs and shaking tables to sort the fluorite, calcite, and galena by specific gravities. The specific gravity of sphalerite is close enough to fluorite to require additional circuits in the milling process. Flotation circuits were utilized in the modern mills to allow the separation of sphalerite and create a higher-purity acid-grade fluorspar. The higher-purity product is required to manufacture a derivative hydrofluoric acid. This hydrofluoric acid is utilized in the processing of aluminum ore.

Mineralization within the IKFD probably resulted from acidic basinal brines (Hall and Friedman 1963) charged with fluorine and carbon dioxide derived from Permian alkaline magma (Plumlee et al. 1995). These basinal brine-type fluids were funneled along northeast-trending fractures and fault zones concurrent with the regional oblique extension, exemplified by multiple episodes of displacement. Brecke (1962) observed mineralized breccia pipes in the Cave-in-Rock subdistrict and suggested that the ore solutions rose through these pipes and migrated updip or southwesterly through faults, fractures, and permeable zones in the host rocks. Disequilibria within the fluorite-rich acidic fluids occurred when these fluids came into contact with the permeable calcium-rich formations where the ore precipitated (Denny et al. 2008). 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 Limestone, and Downeys Bluff Limestone of early Chesterian age. Brecke (1962) theorized that some ground preparation, which enhanced the permeability of the host rock, occurred prior to the deposition of the ore and that the ore fluids mixed with connate water.

Small faults and fractures are present underlying and adjacent to the mineralized ore pods. Some of the N50° E to N60° E structures probably occurred prior to the deposition of the minerals and provided a conduit for initial ascending ore fluids. These faults are normally parallel to the long axis or northeasterly trend of the mineralized pods, but a few small structures trend southeasterly. Little information is available concerning vertical offsets on most of these structures, but structure locations were documented on several mine maps. Vertical offset on a fault trending southeast-northwest at the W.L. Davis-Deardorff Mine was less than 8 inches (Brecke 1962). Brecke (1962) also noted that many of the fractures trending N60° E in the area had little to no offset, but small displacements were observable on the southeast-northwest fractures and faults.

Synclinal features have been documented in several of the mines associated with mineralization. Mapping these synclines has been an effective exploration technique to define mineralized areas. Brecke (1962) theorized that these synclines are a result of volume reduction of the host rock through replacement of $CaCO_3$ with CaF_2, which he called decalcification. Brecke (1962) estimated that the decalcification could result in a volume reduction or shrinkage of about 25%. The volume reduction also created tension faults that formed along the boundaries of the slumping strata. The fractures and decalcification created permeable conduits for the ore fluids and enhanced the lateral extent of the mineralization. Mineralization also thickens where the crosscutting fractures intersect. Brecke (1962) noted that the mineralization thickened and formed a V along some faults and fractures (fig. 2).

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 (fig. 3). 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 interbedded limestone and sandy limestone. The “sub-Rosiclare Level” occurs in the Ste. Genevieve within the Spar Mountain 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 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.

Early mining in this quadrangle occurred at Lead Hill and Spar Mountain, where the ore was exposed along the hillsides. The early mines produced lead and wasted or stock-

Figure 4 Approximate formation boundaries at the Hastie Quarry. Note the subtle syncline in the center of the photo and the abandoned underground fluorite mines in the highwall. Photograph by John Rakovan.

piled 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, are 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 Cave-in-Rock subdistrict is the largest bedding replacement subdistrict 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 subdistricts are present along the northwest side of the Rock Creek Graben. The individual mines and prospects of the Cave-in-Rock subdistrict are discussed, starting in the southwest and progressing northeast. The reports of Bastin (1931), Weller et al. (1952), Brecke (1962), and Myers and Chenoweth (2009) 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.

Cave-in-Rock Subdistrict

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.

Robinson Mine 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.

Miller Mine 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 into 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.

Cave-in-Rock Group The Cave-in-Rock Mine was located northeast of Lead Hill and west of Spar Mountain. This first mine started as an open pit, and a drift or adit into 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 (fig. 4) 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.

Spar Mountain Group 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 small open pits.

Cleveland-Illinois Fluorspar Company, Benzon Fluorspar Company, and Austin Mines 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).

Oxford Pits 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.

West Morrison Pits 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.

Lead Mine 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 southeast, 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 for this mine.

Green 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 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.

Defender Mine The Defender Mine was about 400 feet north of the Green Mine and worked ore similar to that in the Green Mine. The mine was worked through a vertical shaft and apparently small adits in the hillside (Bastin 1931). Weller et al. (1952) listed this mine as part of the Austin Mines complex.

Victory Fluorspar Mine 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 structure and along the 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 where 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 (fig. 4).

Crystal Fluorspar Mines 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.

Wall Properties There 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 is based on the location by Weller et al. (1952). Baxter et al. (1963) listed this property as the Frayser wall property.

Mahoning Mines or Ozark-Mahoning Mines These mines were a group of mines owned by the Ozark-Mahoning Company operating primarily northeast of Spar Mountain. These mines on 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.

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 N55° E structure. 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 Deadorff 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.

Green Mines Three Green Mines are located in 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 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 pipelike solution feature is located just north of the North Green Mine shaft, which probably served as a primary conduit for ore solutions. 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."

Oxford Mine The Oxford Mine or S.E. Oxford Mine was located in 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 the V-shaped structure over the ore zones was a result of volume reduction or the replacement of limestone by fluorite (fig. 2).

Hill-Ledford Mine The Hill-Ledford Mine was operated from the late 1950s until the 1970s. This mine was located north of the Oxford Mine in 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 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 updip 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.

Minerva Mine 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.

Denton Mine The Denton Mine was the first mine opened in the Harris Creek subdistrict, and the main shaft was located in SW¼ of Sec. 9, T11S, R9E. The ore was bedding replacement 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 NE¼ 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.

Annabel Lee Mine 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.

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.

Prospect Pits and Exploration Shafts Several small pits and abandoned exploration shafts are located in this quadrangle. Although these pits probably never produced economic amounts of ore, they may be useful to focus additional exploration efforts. A few of these shafts have been sealed, but many are unreclaimed open pits. Many of these sites were previously located by Baxter et al. (1963), Myers and Chenoweth (2009), and Weller et al. (1952).

Limestone Resources

Large resources of limestone in the Saline Mines Quadrangle are favorably located for barge transportation on the Ohio River. The Mississippian age St. Louis Limestone through Downeys Bluff Limestone interval currently is being quarried at the Hastie Quarry (fig. 4). Stone from these Mississippian formations is suitable for a wide variety of purposes, including concrete aggregate, agricultural lime, rock dust, and crushed stone for surfacing secondary roads. The Aux Vases Sandstone is being quarried in this region for a nonskid aggregate resource. In portions of this area, the Aux Vases Sandstone contains a carbonate matrix, making crushing this sandstone less expensive. An investigation concerning the lateral extent of this unit would be beneficial to the aggregate industry but is beyond the scope of this report.

Coal and Oil Resources

Coal has been mined in the northern portions of this quadrangle. Peabody Coal Company operated a surface mine called Eagle Surface or Eagle Strip Mine from 1966 through 1980, producing nearly 6.5 million tons of coal (Myers and Chenoweth 2009). Several other small mines were previously located in this area, and Myers and Chenoweth (2009) indicated that underground pillars were recovered as Peabody Coal surface-mined this area. Mine notes indicate that the Herrin, Briar Hill, Springfield, Dekoven, Davis, and Willis Coals were mined. The Boswell Coal Company mined a small area in about 1895, and the Independent Coal Company mined the Davis and Dekoven Coals sometime between 1875 and 1915 (Myers and Chenoweth 2009). Both these mines were apparently slopes or drift mines into the hillside.

Other coal mines in the Saline Mines Quadrangle identified by Myers and Chenoweth (2009) are as follows:

- Mine Index (6453) NW NE NW Sec. 17, T11S, R10E, drift, source: ISGS field notes (H.B. Stonehouse, 6-8-1954).
- Mine Index (7280) SE SW SW Sec. 32, T11S, R9E, old mine, 1.5 ft thick, source: ISGS field notes (H.B. Stonehouse, 6-25-1954).
- Mine Index (7281) NE SW NE Sec. 2, T11S, R9E, old shaft, source: ISGS field notes (H.B. Stonehouse, 6-8-1954).
- Mine Index (7282) NW SE NW Sec. 27, T10S, R9E, 5 ft. coal at local drift, source: ISGS field notes (Wallace Lee 1915).
- Mine Index (7283) SW SE SE Sec. 31, T11S, R9E, local coal bank, source: ISGS field notes (Wallace Lee 1915).

A few oil and gas tests have been drilled in this quadrangle, but only one well produced oil. This well was drilled by the Minerva Oil Company on February 4, 1949, in Sec. 20, T11S, R10E. The well is reported to have produced five barrels of oil per day from the Renault Formation and was plugged on November 25, 1949. Oil has been reported associated with the fluorite mineralization, which we suspect produces the fluorescence observed in some of the fluorite crystals.

Acknowledgments

We thank the landowners who gave us permission to cross their property to examine outcrops. This research was supported in part by the U.S. Geological Survey National Cooperative Geologic Mapping Program (STATEMAP) under U.S. Geological Survey award number G11AC20477. The views and conclusions contained in this document are those of the authors and should not be interpreted as necessarily representing the official policies, either expressed or implied, of the U.S. Government.

References

Bain, H.F., 1905, The fluorspar deposits of Southern Illinois: Washington, D.C., United States Geological Survey, Bulletin 255, 75 p.

Bastin, E.S., 1931, The fluorspar deposits of Hardin and Pope Counties, Illinois: Illinois State Geological Survey, Bulletin 58, 116 p.

Baxter, J.W., P.E. Potter, and F.L. Doyle, 1963, Areal geology of the Illinois fluorspar district. Part I. Saline Mines, Cave in Rock, Dekoven, and Repton Quadrangles: Illinois State Geological Survey, Circular 342, 43 p.; map, 1:24,000.

Brecke, E.A., 1962, Ore genesis of the Cave-in-Rock Fluorspar District, Hardin County, Illinois: Economic Geology, v. 57, p. 499–535.

Butts, C., 1925, Geology and mineral resources of the Equality-Shawneetown area: Illinois State Geological Survey, Bulletin 47, 76 p.

Denny, F.B., A. Goldstein, J.A. Devera, D.A. Williams, Z. Lasemi, and W.J. Nelson, 2008, The Illinois-Kentucky Fluorite District, Hicks Dome, and Garden of the Gods in southeastern Illinois and northwestern Kentucky, *in* A.H. Maria, and R.C. Counts, eds., From the Cincinnati Arch to the Illinois Basin: Geological Field Excursions along the Ohio River Valley: Boulder, Colorado, Geological Society of America, Field Guide 12, p. 11–24.

Goldstein, A., 1997, The Illinois-Kentucky Fluorite District: The Mineralogical Record, v. 28, p. 3–49.

Gutschick, R.C., 1965, *Pterotocrinus* from the Kinkaid Limestone (Chester, Mississippian) of Illinois and Kentucky: Journal of Paleontology, v. 39, no. 4, p. 636–646.

Hall, W.E., and I. Friedman, 1963, Composition of fluid inclusions, Cave-in-Rock Fluorite District, Illinois, and Upper Mississippi Valley Zinc-Lead District: Economic Geology, v. 58, p. 886–911.

Heyl, A.V., and M.R. Brock, 1961, Structural framework of the Illinois-Kentucky mining district and its relation to mineral deposits: Washington, D.C., United States Geological Survey, Professional Paper 424-D, p. D3–D6.

Heyl, A.V., G.P. Landis, and R.E. Zartman, 1974, Isotopic evidence for the origin of Mississippi Valley-type mineral deposits: A review: Economic Geology, v. 69, no. 6, p. 992–1006.

Hutcheson, D.W. (ed.), 1973, A Symposium on the Geology of Fluorspar: Proceedings of the Ninth Forum on Geology of Industrial Minerals: Kentucky Geological Survey, Special Publication 22, 107 p.

Kehn, T.M., 1974, Geologic map of parts of the Dekoven and Saline Mines Quadrangles, Crittenden and Union Counties, Kentucky: Reston, Virginia, U.S. Geological Survey, Geologic Quadrangle Map GQ-1147.

Myers, A. M. and C. Chenoweth, 2009, Directory of coal mines in Illinois 7.5-minute quadrangle series, Saline Mines Quadrangle, Gallatin and Hardin Counties: Illinois State Geological Survey, 28 p.

Nelson, W.J., 1995, Structural features in Illinois: Illinois State Geological Survey, Bulletin 100, 144 p.

Perry, B.L., 1973, The Davis-Oxford ore body, in A Geologic Excursion to Fluorspar Mines in Hardin and Pope Counties, Illinois, *in* J.W. Baxter, J.C. Bradbury, and N.C. Hester, eds.: Illinois State Geological Survey, Guidebook Series 2, p. 24–28.

Plumlee, G.S., M.B. Goldhaber, and E.L. Rowan, 1995, The potential role of magmatic gases in the genesis of the Illinois-Kentucky fluorspar deposits: Implications for chemical reaction path modeling: Economic Geology, v. 90, no. 5, p. 999–1011.

Potter, C.J., M.B. Goldhaber, P.C. Heigold, and J.A. Drahovzal, 1995, Structure of the Reelfoot-Rough Creek rift system, Fluorspar Area fault complex, and Hicks Dome, southern Illinois and western Kentucky—New constraints from regional seismic reflection data: Reston, Virginia, U.S. Geological Survey, Professional Paper 1538-Q, 18 p. and 1 plate.

Trace, R.D., and D.H. Amos, 1984, Stratigraphy and structure of the western Kentucky fluorspar district: Reston, Virginia, U.S. Geological Survey, Professional Paper 1151-D, 41 p.; map, 1:48,000.

Weller, J.M., 1940, Geology and oil possibilities of extreme southern Illinois—Union, Johnson, Pope, Hardin, Alexander, Pulaski, and Massac Counties: Illinois State Geological Survey, Report of Investigations 71, 71 p.

Weller, J.M., R.M. Grogan, and F.E. Tippie, 1952, Geology of the fluorspar deposits of Illinois: Illinois State Geological Survey, Bulletin 76, 147 p.

Weller, S., C. Butts, L.W. Currier, and R.D. Salisbury, 1920, The geology of Hardin County and the adjoining part of Pope County: Illinois State Geological Survey, Bulletin 41, 416 p.