STATEMAP
Shetlerville-BG

Bedrock Geology of Shetlerville Quadrangle

Pope and Hardin Counties, Illinois

F. Brett Denny and Ronald C. Counts

2009

ILLINOIS
UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN

Institute of Natural Resource Sustainability
William W. Shilts, Executive Director
ILLINOIS STATE GEOLOGICAL SURVEY
E. Donald McKay III, Interim Director
615 East Peabody Drive
Champaign, Illinois 61820-6964
(217) 244-2414
http://www.isgs.illinois.edu

Introduction

The Shetlerville 7.5 Minute quadrangle covers portions of northeastern Pope and western Hardin counties in southern Illinois and a portion of Livingston County Kentucky. The map area lies in the southern part of the Illinois Basin and near the western end of the Rough Creek Graben, a late Precambrian to Middle Cambrian failed rift structure. Recurrent tectonism combined with Permian ultramafic igneous activity and Permian and younger mineralization renders this one of the most complex areas, in terms of geologic structure, in the North American Midcontinent. Portions of this area were previously was mapped by Butts (1917 and 1925), Weller et al. (1920), Weller (1940), Amos (1965), and Baxter et al. (1967). Additional reports on the Illinois-Kentucky Fluorite District and its mines and minerals have been completed by Heyl et al. (1974), and Goldstein (1997). The mapping of the Illinois portion of this map was completed by F. Brett Denny of the Illinois Geological Survey while the Kentucky portion was completed by Ron Counts of the Kentucky Geological Survey. The recent mapping was conducted in 2008 and 2009.

Structure and Tectonics
The oldest rocks that crop out in the quadrangle are Mississippian Age and outcrop in the northeastern corner of the quadrangle along the southwest flank of Hicks Dome. Hicks Dome, an uplifted circular dome, lies along a broad northwest-trending structural arch named the Tolu or Kutawa Arch (Baxter et al., 1967). Structural uplift at Hicks Dome appears to be related to a crypto-volcanic event that produced dikes, sills, and pipe-shaped diatremes which vented gases to the surface (Brown et al. 1954; Heyl and Brock, 1961). Radiometric dating indicates an early Permian age, about 270 Ma. years ago (Fifarek et al., 2001; Zartman et al., 1967). This ultramafic igneous activity underlies the mineralized area of the Illinois Kentucky Fluorite District from northwestern Kentucky into southeastern Illinois. The tectonic fabric of this quadrangle is complicated by recurrent tectonic movement and igneous activity.

The general structural fabric in the Shetlerville Quadrangle is primarily northeast to southwest. Overall faulting is high angle normal or dip-slip and produces a series of grabens which are typically thought to be a result of regional extension. There is some evidence of strike-slip movement. The maximum dip-slip displacement on some of these faults in the region may reach 3000 feet (Nelson, 1995). The maximum displacement in the Shetlerville Quadrangle is along the Wallace Creek Fault Zone which bounds the northwest side of the Rock Creek Graben. Maximum vertical offset approaches 1000 feet along this fault zone. The southerly projection of these faults is in-line with faults of the Reelfoot Rift and the New Madrid Seismic Zone. Neotectonic research along these faults less than 10 miles to the southwest indicate movement may have occurred in Quaternary sediment and definitely in Cretaceous units (Nelson et al., 1997).

The major faults located in the Shetlerville Quadrangle are discussed below. These faults are listed in a geographic order starting with northwestern-most fault and preceding southeasterly. These faults are very poorly exposed. Information concerning these features was extracted from both the literature and recent geologic mapping activities.

Dixon Springs Graben
The Dixon Springs Graben is about 4 miles wide and is bounded on the southeast by the Hobbs Creek Fault Zone and on the northwest by the Lusk Creek or Herod Fault Zones (see cross section). Nelson (1995) suggests that this graben has undergone 4 and maybe 5 periods of movement.

The Raum Fault Zone clips the extreme northwestern edge of the Shetlerville Quadrangle and is mapped in adjacent quadrangles to the north and west. The fault zone consists of two parallel faults trending northeast-southwest bounding a 300-500 feet wide uplifted center block. The northwest side is downthrown approximately 200 feet relative to the southeast side of the fault zone. Beds on the northwest side of the fault dip to the northwest from a few degrees up to 60 degrees near the fault boundaries. The central up-thrown slice strikes north 60-70 degrees east and dips to the southeast up to 20 degrees. The central block appears to dip back to the northwest in some places. Beds on the southeast side of the fault dip gently to the northwest. The central slice is up thrown juxtaposing the Upper Clore Formation with lower Caseyville Formation. The fault surface was not observed in this quadrangle but Nelson (1995) depicts the master fault dipping steeply to the northwest. Weibel et al. (1991) suggested this fault zone is high-angle reverse with the southeast side being uplifted followed by a later period of extension, probably coincident with the extension that produced the Dixon Spring Graben. The easternmost fault is mapped as a high angle reverse on the geologic map. The cross section shows the complex relationship of this fault zone.

Southeast of the Raum Fault an unnamed fault is projected. The evidence of this fault is meager, but the Kinkaid Limestone appears to terminate along the south facing bluff (13-12S-6E; NW, NE, NE). Fluorite was observed in float blocks in this area, but these limestone blocks may have been dumped for road aggregate. This fault is concealed to the northeast and may be present along a spring that flows near the base of the Menard Limestone (8-12S-7E; 2300 ft. WL, 1000 ft. NL). The Menard Limestone dips very steeply to the northwest and may be dipping into the fault near this spring. The fault surface was not observed but this fault projects to the northeast into the Herod Quadrangle and is in-line with mineralized northeasterly trending faults radial to Hicks Dome. This is probably the best "wildcat" target for fluorite mineralization that we observed mapping this quadrangle. This area needs to be mapped in greater detail to determine the potential of this fault to carry fluorite in this region.

The Hobbs Creek Fault Zone is named for Hobbs Creek (10-12S-7E). The fault is exposed along the creek in the northwest quarter of section 10. The Hobbs Creek Fault Zone comprises high angle normal faults that trend approximately north 50 degrees east and bound the southeastern edge of the Dixon Springs Graben (Baxter et al. 1967). The Dixon Springs Graben extends from the northeast corner of Pope County southwestward to Bay City Bottoms, where it is concealed by Cretaceous and younger sediments of the Mississippi Embayment area (Baxter et al, 1967). The most recent movement along the Dixon Springs Graben is post Cretaceous, as shown by faulted Cretaceous sediment in the Reevesville Quadrangle (Nelson 1996). The Shelby Fault (9-12S-7E) appears to be near the northwestern boundary of the Hobbs Creek Fault Zone where the fault crosses Big Grand Pierre Creek.

The southeast side of the Shelby Fault is downthrown and the fault plane dips southeast at an angle of about 60 degrees (Weller, Grogan, and Tippie, 1952). The fault extends southwesterly and can be seen along a tributary to Big Grand Pierre Creek (16-12S-7E; 500 ft. WL, 400 ft. NL). The faults appear to be interconnected and merge into other faults along strike of the Hobbs Creek Fault Zone.

The Flick Branch Fault Zone was named by Weibel et al. (1991) for a northeasterly trending fault along Flick Branch in the Waltersburg Quadrangle southwest of the Shetlerville quadrangle. The northwest side of this fault is down with less than 100 feet of displacement. The fault is very poorly exposed in the Shetlerville Quadrangle but probably connects with the US-Hann Fault. The US Hann fault was identified by mineral prospecting and diamond core drilling activities and is fairly accurately located southeast of the Henson Mine (20-12S-7E). The US-Hann fault apparently merges into the Hobbs Creek Fault Zone to the northeast. There are probably several interconnected small faults that are present along this trend that apparently merge northeasterly into the Hobbs Creek Fault Zone. These fault zones are extremely complex and are difficult to depict at a scale of 1:24,000. Due to the potential economic minerals along these faults, they are projected to the best of our knowledge into areas with little control.

The Stewart Fault is a high angle normal fault that strikes N25°E to N30°E and dips to the southeast at about 80°. The southeast side is downthrown but at the extreme northern end the northwest side is reportedly downthrown (Nelson, 1995). The reversal of dip along the extreme northern extent is related to uplift at Hicks Dome. The uplift along a concentric fault near Eichron seems to fit with the apparent reversal of dip along the northern portion of the fault. Subsidiary faults are mapped east of the main fault are probably related to the compress ional forces along Wallace Branch-Interstate Fault Zone. The Stewart Fault lies in the center of the horst block that separates the Dixon Spring Graben from the Rock Creek Graben (see cross section). The Stewart Fault is not well exposed and is mostly described from mine notes and exposures in abandoned underground mines which are not currently accessible. This fault zone is mineralized and dozens of abandoned fluorite mines are present along the fault zone.

Rock Creek Graben

The Rock Creek Graben is about 2.5 miles wide. The northwest boundary fault of this graben is located in the Shetlerville quadrangle. Most of the faults are high-angle normal but reverse movement is reported. Reverse movement is located in along a portion of the complex that bends from N30°E to N50°E. It is interesting to note that the Base of the Pennsylvanian is nearly the same elevation in both the Rock Creek and Dixon Springs Graben along the cross section line A-A' (see geologic map sheet). This may indicate that the horst block between these two grabens has been uplifted. This uplift is probably a result of the Permian igneous activity and the domal uplift at Hicks Dome and to the west along the Regional Tolu Arch. This observation also agrees with the reversal of dip along the Stewart Fault Zones northern most extent.

The Wallace Branch Fault Zone forms the western boundary of the Rock Creek Graben and is the southern offset continuation of the Illinois Furnace-Interstate Fault trend (Baxter et al., 1967). This Wallace Branch Fault is located along the western edge of the Dixon Springs Graben where the western edge of the graben curves from N30°E to N50°E. Several mines have operated along segments of this fault zone. The fault probably was high angle reverse followed by a normal extension. Vertical movement is down to the southeast up to 1700 feet. This fault zone can be traced to the southwest into Kentucky portion of the map.

Several faults with slight offset are mapped between the Stewart Fault and the Rock Creek Graben. Most of these faults were identified by Baxter et al (1967) during their mapping efforts. Recent field mapping verified some of these faults but others could not be verified by the current mapping.

Economic Geology

Illinois Kentucky Fluorite District

Economic minerals in the Illinois Kentucky Fluorite District (IKFD) is dominantly fluorite with lesser amounts of sphalerite, barite, and galena. Other minerals identified in this district are pyrite, chalcopyrite, quartz, celestite, cerussite, greenockite, malachite, smithsonite, witherite, strontianite, benstonite, and alstonite (Goldstein, 1997). The ore bodies occur as bedded deposits, formed by selective replacement of limestone strata, vein deposits along faults and fractures, and residual deposits derived from veins or beds. Known deposits within the area of this map are mainly of the vein type along faults of slight to moderate displacement. In some workings, however, a small amount of replacement ore has been observed along the wall rock. The best indication of replacement type of ore deposition is the identification of remnant textures present in the fluorite that was formerly present in the limestone. Replaced fossils, styolitic sutures, and primary bedding characteristics have been reported being present in replacement ore in this region. Mine run ore commonly contains from 30 to 40 percent fluorite and at places it contains 2-3 percent zinc. In some deposits it contains a small percentage of silver in the galena and recoverable cadmium and germanium in the sphalerite (Trace and Amos, 1984). The amount of sphalerite in some ore bodies within the IKFD is considerably. The ore at the Hutson Mine near Salem Kentucky was almost exclusively sphalerite and was associated with ultramafic igneous dikes (Osterling 1952).

Fluorite Mines and Prospects
The numbering scheme (#) of the prospects and shafts on the Baxter et al. (1967) geologic map was also utilized for the current map. Additional unnamed mines or prospect pits in this quadrangle are labeled directly on the geologic map. Some of the information concerning individual mines discussed below is derived from Bastin (1931), Weller et al.(1920) and Weller and Butts (1950). Very little historical information is available concerning some of the prospects and mines. Currently there are no active fluorite mines located in the Shetlerville Quadrangle.

Shelby mine (#23, Section 9-12S-7E). The southeast side of the Shelby Fault is downthrown and the fault plane dips southeast at an angle of about 60 degrees (Weller, Grogan, and Tippie, 1952). This mine is located along a northwest boundary fault in the Hobbs Creek Fault Zone. Fluorite was observed in fractured sandstone scattered on the surface near this abandoned mine, but the fault is not well exposed. Fractures trending N40°E can be observed in the sandstone bluff southeast of the mine. Several small pieces of fluorite in fractured sandstone were found which are similar to the fractures sandstone observed at the McGuire prospect.

Senior prospects (Section 10-12S-7E). The Senior prospects were identified by (Weller et al., 1952). Senior #1 and Senior #2 are located along the northeasterly projection of the Shelby Fault. Senior #1 prospect was not observed during this mapping project. Senior #2 prospect was located in section 10-12S-7E (2800 ft. SL, 150 ft. WL). This prospect pit exposed a normal fault trending N 60 degrees east with vertical slickenside on the sandstone footwall. Sandstone also composed the hanging wall and the fault dipped slightly to the southeast. The amount of displacement was not readily observable as sandstone was on both sides of the fault. A vein of colorless and purple fluorite 1-2 inches wide was observed along the fractured sandstone in this pit. This prospect may be on a subsidiary fault to the Shelby Fault. The senior #3 prospect is represented by several small shallow pits located in Section 10-12S-7E (2500 ft. SL, 700 ft. WL). The pits contain gray fissile shale and porous weathered sandstone which contains thin layers (less than ½ inch) of purple fluorite. The fluorite appears to be horizontal along bedding surfaces. The senior #3 prospect is probably located along the southeast side of the Hobbs Creek Fault Zone while the Senior #1 and #2 are located along the northwest side of the Hobbs Creek Fault Zone. A trace amount of fluorite was observed in limestone at the surface along the northeast projection of the Shelby fault in section 3-12S-7E (1300 ft. WL, 200 ft. SL). It appears very little prospecting has occurred in this immediate area.

Baker mine No. 1 also called Eichorn mine (#25 and #26. Section 14-12S-7E). The older shaft here is reported to be sunk to 330 feet with some drifting into the 200 foot level. Cross cuts were run on both the 100 and 200 foot levels. The property was worked in 1923 by the Eichron Fluorspar Mining Company. In 1926 water was pumped from the shaft to examine the 100 foot level by Knight Brothers and E.C. Clark, but no mining of ore was recorded. Most ore is open space and fracture filling with little evidence of replacement style ore texture.

Stewart group (#27, Stewart mine No. 5; #28, Stewart mine No. 4; #29, Stewart mine No. 3; #30, Stewart shaft; #31, Stewart mine No. 2; #32, Stewart mine No. 1. Section 14-12S-7E). These shafts are located near the center of section 14. The property was operated in 1917 as an open pit but several shafts were later sunk to follow the 2 to 4 foot wide vein. The vein strikes N25°E and dips 80°SE and is reported to extend 75 to 100 feet below the surface. Some galena and pyrite was reported to be associated with this vein that was dominantly composed of fluorite and calcite within a fractured limestone host rock.

Mackey group (#33, No. 1; #34, No. 2; #35, No.3;#36, No. 4. Section 14-12S-7E). These mines are located along the Stewart fault zone southwest of the Stewart group mines. While there is very little information concerning these particular mines, they are within 1000 feet southwest of the Stewart group mines. The geology of these mines should be similar to the Stewart group complex.

Williams group (#37, No. 1 shaft; #38, No. 2 shaft; #39, No. 3 shaft. Sections 14 and 23-12S-7E) No additional data.

Humm mine and mill (#40, Section 23-12S-7E) No additional data available.

Jefferson mine (#41, No. 1 shaft; #42, No. 2 shaft; Section 23-12S-7E). No additional data.

Cobb mine (#43, Section 12-T12S-R7E). The mine here may be along the northward extension of the Pell Fault. Little information is available concerning this mine.

Pell mine (#44, Section 24-T12S-7E). The vein here appears to have been worked as early as 1928 with a shaft that was reported to extend to 95 feet below the surface. A mill was also present while this mine was active. The vein was dominantly calcite, fluorite, galena, and sphalerite. The trend of the vein was reported to be N25°-30°E.

Twitchell mine (#45, Section 24-T12S-R7E). The vein here is reported to run N 50°W to N10°E and dip 70° easterly. Three shafts have been developed with the deepest extending about 60 to 70 feet below the surface. Weller et al. (1920) suggested that the vein was not along a major fault. It is likely this zone of mineralization is along radial fractures which are a result of the uplift at Hicks Dome.

Parkinson mine (#46, Section 22-12S-7E). No further information available.

Barnett complex (#47, Section 28-T12S-R7E). Ozark Mahoning sank a shaft at this location in 1966. The Barnett shaft connected to the sixth working level of the older Parkinson Mine. The mine was operated for several years. Two air shafts, now plugged, were identified during field mapping. This mine is the only mine in the area where multiple underground fatalities are reported. The accident was a result of hydrogen sulphide gas that accumulated presumable from water that was encountered on the 800-foot south level. Hydrogen sulfide is a colorless gas which in low to moderate concentrations produces a “rotten egg” odor. The gas is water-soluble and according to a federal mine inspection was previously detected in other portions of the underground mine workings. A water course was encountered by mining operations which temporally flooded the 800-foot south working area. The area was temporally evacuated to allow the water to be pumped away from the working face. The presence of hydrogen sulfide became concentrated enough to cause workers to experience eye and lung irritation the next day when the area was examined by workers. At some time after the water was encountered a ventilation fan for this area stopped working. Prior to the fan being repaired a worker went into the area to retrieve equipment. When this worker did not return another worker went to find the first miner. Several attempts to save the fallen miners resulted in the deaths of seven miners.

Fairbairn shaft (#48, Section 22-12S-7E). No further information available.

Reed Shaft (#49, Section 27-12S-7E). No further information available.

Miller also called Tri State and Melcher Hills mine (#50, Section 25-12S-7E). This mine was operated in the early 1900’s. Horizontal drifts into the hillside east of Melcher Hill were first driven to mine the bedding replacement deposits. In 1917 a shaft was sunk and encountered veins trending in a northeasterly direction. The veins were reported to be unusually rich in galena (Weller, 1920).

Cox mine shafts (#51, Section 36-12S-7E). No further information available.

McGuire prospect (#77, Section 9-12S-7E). There is an abandoned shaft at this location, but little information concerning the production is available. The fault can not be seen at the surface near the mine, but drilling logs indicate there is at least 30 feet of normal dip slip offset on strata near the mine. This fault can be observed in section 16-12S-7E (400 ft. NL, 500 ft. WL) where fractures in the limestone trend N55°E. There are vertical slickensides and the unit is moderately brecciated and small veins of remobilized calcite are present. Baxter et al. (1967) indicate that portions of this fault are offset up to 200 feet. This fault is located near the northwestern edge of the Hobbs Creek Fault Zone. The Shelby mine is located 1200 feet northeast along the same fault zone.

Rahn Crystal prospect (#84, Section 24-12S-7E). No further information available.

Dubois Properties (#86, No. 4 Shaft; #87, No. 3 shaft; #88 Fisher Shaft, Section 19 12S-8E). No further information available.

Mackey Prospect (#89, Section 23 12S-7E). No further information available.

Sam Parkinson Prospect (#90, Section 22-12S-7E). No further information available.

Black Jack prospect (#91, Section 27-12S-7E). No further information available.

Rotes prospect (# 92, Section 27-12S-7E). No further information available.

Cox property-prospect shafts,(#93, Section 25-12S-7E). No further information available.

Henson Mine (Section 20-12S-7E). This mine was operated by Ozark Mahoning Company. There are several faults that have been identified by core drilling at this mine. The ore mostly vein type and was located along several parallel northeasterly trending faults.

Oil and Gas

The Illinois Oil and Gas database lists two holes that were drilled in this quadrangle to test for oil and gas. Horace Belt #1 (9 12S 7E) was drilled to 800 feet below the surface and was dry abandoned. This boring bottomed in the Lower St. Louis or Upper Salem Formation. A second test well (U. S. Forest Service, 34 12S 7E) was probably mislabeled as an oil test. Water well records also identify a well being drilled at this location for water. The depth of the well to 600 feet is deeper than normal in this area for a water well, which are usually drilled much shallower. This drilling company has drilled water wells (not oil wells), in the area for the US

Forest Service. This well is labeled as a water well on the geologic map.

Stone

Limestone has been mined in this quadrangle for nearly 90 years. Vulcan Materials currently operates a limestone quarry and a river loading dock along the Ohio River east of Shetlerville (Section 35-T-12S-R7E). The Parkinson Quarry produced limestone from the Renault Formation also where Vulcan Materials Quarry is currently located. Martin Marietta Rosiclare Quarry is located at the former site of Williams Quarry (Section 23-T12S-R7 E). A few operations in the vicinity of Rich Hill (Section 35-T-12 S-R7 E) including underground workings have occurred in the past. Most of these operations are quarrying the Ste. Genevieve and St. Louis Limestones. The Aux Vases Sandstone is not crushed at these plants, but the calcareous portions of the Aux Vase are mined at the Hastie Quarry near Cave-in-Rock Illinois. A small pit east of Goins (Section 29-12S-7E) produced a very small amount of limestone from the Glean Dean Limestone. A few abandoned sandstone quarries are located in this quadrangle, but are small pits for local uses.

Coal

The Gentry Coal member of the Caseyville Formation has been mined locally in Kentucky. It has not been identified on the Illinois portion of the Shetlerville Quadrangle but has been mined in several locations in Hardin County Illinois. Where this coal was identified it was reported to be 18-24 inches thick.

Acknowledgments

Small portions of the quadrangle were mapped by Joseph A. Devera. Eric Livingston of the Ozark-Mahoning Company supplied some advice concerning the location of faults in the area. We thank the numerous landowners in the Shetlerville Quadrangle who granted access to their property for geologic study.

This research was supported in part by the U.S. Geological Survey National Cooperative Geologic Mapping Program (STATEMAP) under USGS award number 08HQAG0084. 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.

This map has not undergone the formal Illinois Geologic Quadrangle map review process. Whether or when this map will be formally reviewed and published depends on the resources and priorities of the ISGS.

References

Amos, D.H., 1965, Geologic map of the Shetlerville and Rosiclare quadrangles, Livingston County, Kentucky: U.S. Geological Survey Geologic Quadrangle Map GQ-675, 1 sheet,scale 1:24,000.

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

Baxter, J.W., G.A. Desborough, and C.W. Shaw, 1967, Areal geology of the Illinois fluorspar district: Part 3, Herod and Shetlerville Quadrangles: Illinois State Geological Survey, Circular 413, 41 p. and map, 1:24,000.

Brown, J. S., Emery, J. A., and Meyer, P. A., Jr., 1954, Explosion pipe in test well on Hicks Dome, Hardin County, Illinois: Economic. Geology, volume 49, no. 8, p. 891-902.

Butts C., 1917, The Mississippian formations of Western Kentucky: Kentucky Geological Survey, 97 p.

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

Fifarek, R.H., Denny, F.B., Snee, L.W., and Miggins, D.P., 2001, Permian igneous activity in southeastern Illinois and Western Kentucky: implications for tectonism and economic resources: Geological Society of America Abstracts with Programs, v. 33, no. 6, p. A-420.

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

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

Heyl, A.V., Landis, G.P., and Zartman, R.E., 1974, Isotopic Evidence for the Origin of Mississippi Valley-Type Mineral Deposits: A Review: Economic Geology; October 1974; v. 69; no. 6; p. 992-1006.

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

Nelson, W.J., Denny, F.B., Devera, J.A., Follmer, L.R., Masters, J.M., 1997, Tertiary and Quaternary Tectonic Faulting in Southernmost Illinois: Engineering Geology 46, no. 3 4, p. 235 258.

Osterling, W.A., 1952, Geologic and economic significance of the Hutson zinc mine, Salem, Kentucky; its relation to the Illinois-Kentucky fluorspar district: Economic Geology; May 1952; v. 47; no. 3; p. 316-338

Trace, R.D., Amos, D.H., 1984. Stratigraphy and structure of the western Kentucky fluorspar district, United States Geological Survey Professional Paper 1151-D, 41 pp.

Weibel, C.P., W.J. Nelson, and J.A. Devera, 1991, Geologic map of the Waltersburg Quadrangle, Pope County, Illinois: Illinois State Geological Survey, Illinois Geologic Quadrangle Map, IGQ-8, 1:24,000.

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

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

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

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

Zartman, R.E., Brock, MR., Heyl, A.V., and Thomas, H.H., 1967, K-R and Rb-Sr ages of some alkalic intrusive rocks from Central and Eastern United States: American Journal of Science, v. 265, p. 848-870.