STATEMAP
Cave-in-Rock-BG

Bedrock Geology of Cave-in-Rock Quadrangle

Hardin County, Illinois, and Crittenden County, Kentucky

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Introduction

The Cave-in-Rock Quadrangle occupies the area between 37˚ 22' 30" and 37˚ 30' 00" N latitude and 88˚ 07' 30" and 88˚ 15' W longitude. It is situated in the northeastern portion of the Illinois-Kentucky Fluorite District (IKFD), a region with valuable economic minerals and a complex history of faulting (fig. 1). Although very rare in continental interiors, late Permian igneous dikes and sills in the region are quite common.

Aside from the igneous intrusions, the bedrock is composed of middle and upper Mississippian sedimentary rocks, which are dissected by faults with displacements ranging from a few feet to hundreds of feet. The limestones in the lower part of the section cover about two-thirds of the central and western portion of the quadrangle, forming gently rolling hills. The Salem and lower part of the St. Louis Limestones are exposed in and near the Ohio River bluff and in smaller actively eroding streams. Sinkholes are developed in the upper St. Louis and lower Ste. Genevieve Limestones, forming a karst landscape.

The Aux Vases through Bethel units consist of alternating beds of limestone, sandstone, and shale, predominantly dipping 0.5˚ to 8˚ northeast. The more resistant sandstones form dip slopes that stand out in the topography, and the limestones and shales are more easily eroded and form more gentle slopes between sandstone ledges.

The area is sparsely populated, and its major industries consist of fluorspar mines and limestone quarries, with farming being a minor component of the economy.

The quality and quantity of rock exposures range from excellent to non-existent, with the best exposures being in quarries and steep bluffs, and the poorest exposures being in wide valleys and in the sinkhole plain. Drill holes from the several companies that mine fluorspar and limestone were helpful in understanding the stratigraphy of the area.

Stratigraphy

Rock units present in the quadrangle are middle and upper Mississippian (Valmeyerean and Chesterian) sedimentary rocks, late Permian igneous intrusions, and Quaternary deposits. Fluorite, calcite, barite, sphalerite, and galena are present along faults and fractures.

Many workers have studied the rock units in the area (Ulrich 1905, Weller 1927, Baxter et al. 1963, Willman et al. 1975, Trace and Amos 1984). Our stratigraphic terminology and descriptions of units are presented in the geologic column on sheet 2 of the map. The nomenclature and mapping units used in this study closely match those used in adjacent quadrangle maps (Denny et al. 2011, 2013). A brief description of mapping units follows.

The Salem, St. Louis, and Ste. Genevieve Limestones were deposited in the shallow and broad sea of the Illinois Basin. Lithologic changes were gradual near the basin's depocenter, which lies near Hardin County. Thick transition zones (60 to 90 feet) occur between the Salem, St. Louis, and Ste. Genevieve Limestones.

The Aux Vases Sandstone was called the "Rosiclare Sandstone Member" (a term used in the mining industry) and was included in the Ste. Genevieve Limestone in the Kentucky portion of the Cave-in-Rock Quadrangle (Trace 1974). Although it is thin in the map area, it is mapped as a separate formation (Mav).

The Renault Limestone, Yankeetown Formation, and Downeys Bluff Limestone are each relatively thin, and so they have been mapped together as a unit that is about 100 feet thick (Mdyr). This combined mapping unit is poorly exposed in most places; outcrops seem to occur in places where the Bethel Sandstone forms a prominent bluff. It should be noted that the name "Renault Formation" of Trace (1974) and Weller et al. (1952) referred to the interval containing the units that we call Downeys Bluff Limestone, Yankeetown Formation, and the Shetlerville Member of our Renault Limestone. Trace included the Levias Limestone Member in the Ste. Genevieve because of a sharp contact between the Shetlerville and Levias Members. There is disagreement as to whether the contact is conformable or unconformable; Baxter (1963) stated that the contact is unconformable, but Trace and Amos (1984) suggest that in many places, it appears to be conformable. Our Renault Limestone includes the Shetlerville and Levias Limestone Members.

The Bethel Sandstone, Ridenhower Formation, and Cypress Sandstone are mapped as a single unit that is about 200 feet thick in the map area (Mcrb). The Ridenhower Formation was not positively identified in the Illinois portion of the map area, possibly because the Cypress locally cuts down into the Bethel. This unit of combined sandstone layers is a bluff former with well-developed topographic expression along the northern rim of the quadrangle, composing Barker Bluff, and continuing as a dip slope to the northeastern corner of the quadrangle. Within the Commodore Fault System, the Renault, Yankeetown, Downeys Bluff, Bethel, Ridenhower, and Cypress were combined (Mcr) in places where stratigraphic relations were unclear.

The Golconda Formation was formerly at "Group" rank (Baxter 1963, Willman et al. 1975) and was reduced to "Formation" rank by Nelson et al. (2002). We have adopted the classification and terminology of Nelson et al. (2002) and split the Golconda Formation into three members, although it should be noted that Trace (1974) did not split the Golconda Formation into members.

There is excellent agreement among many studies (e.g. Weller 1927, Baxter 1963, Trace 1974, Denny et al. 2013)

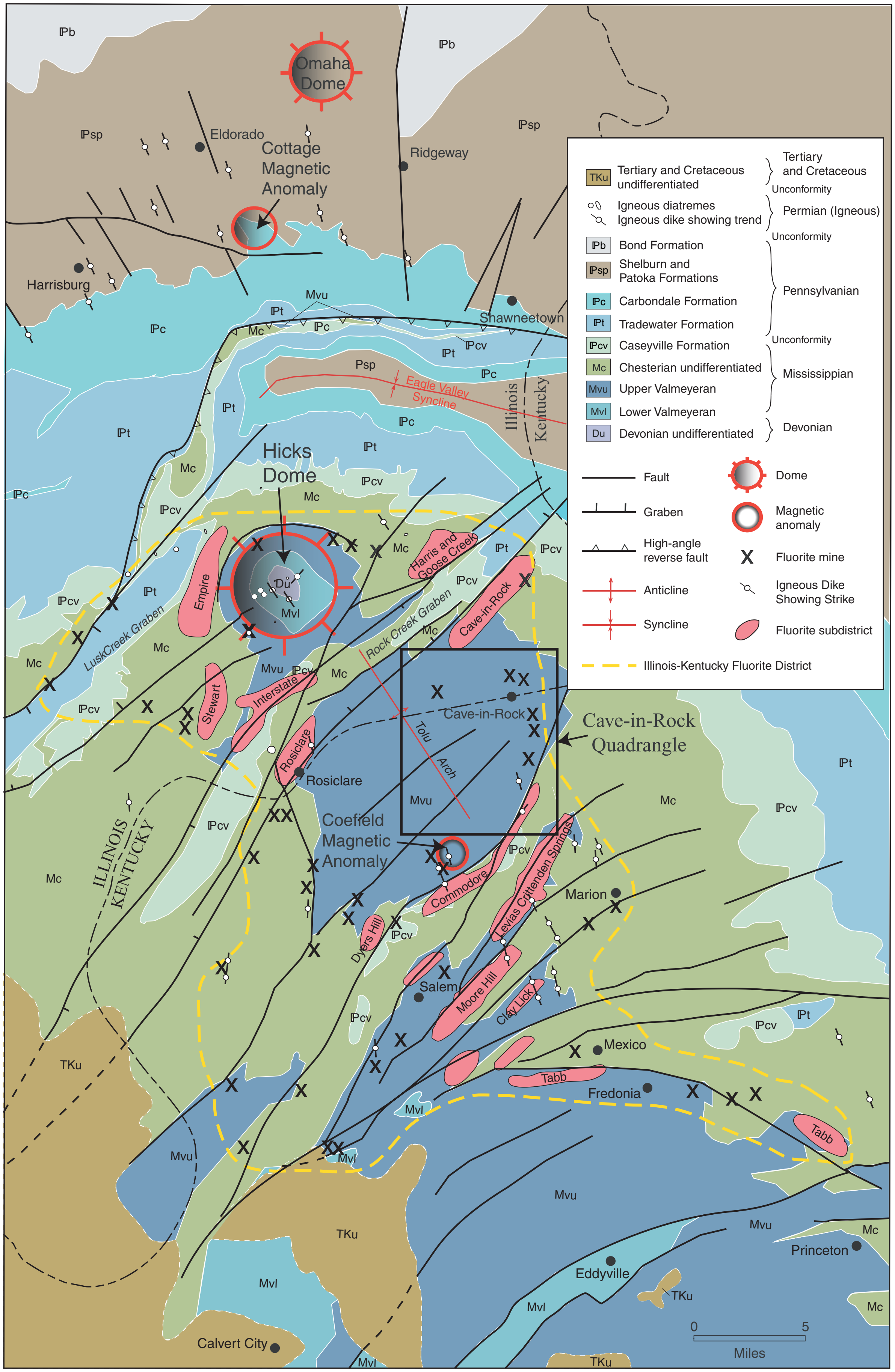

Figure 1 General geology of the Illinois-Kentucky Fluorite District and the location of the Cave in Rock 7.5-minute Quadrangle. Adapted from Denny et al. (2008)

regarding the definitions of the Hardinsburg Sandstone, Glen Dean Limestone, and Tar Springs Sandstone formations. Each of these units is mappable at the 1:24,000 scale. The Waltersburg Sandstone and Vienna Limestone are each too thin to map separately, so they have been combined to form a single mappable unit (e.g. Trace 1974). The Menard Limestone and Palestine Sandstone can each be mapped as separate units.

Structural Geology

The Cave-in-Rock Quadrangle lies within the Fluorspar Area fault complex, which extends from Illinois into western Kentucky (Trace and Amos 1984, Nelson 1995). Four major sub-parallel NE-trending fault systems cross the map area: the Peters Creek fault zone, the Lola (Dyer Hill) fault system, the Commodore fault system, and the Levias-Crittenden Springs fault system. The Griffith Bluff Graben is the downdropped block between the Commodore and Levias-Crittenden Springs fault system. The Tolu Arch is a NE-trending regional uplift that is offset by the NE-trending faults.

Peters Creek Fault Zone

The Peters Creek fault zone trends northeast and lies almost entirely in Illinois, although a branch of the fault may reach into Kentucky (Nelson 1995, p. 97). It is a high angle normal fault and is downthrown about 600 feet on the northwest side in the adjacent Saline Mines Quadrangle (Denny et al. 2013). The portion that lies in this quadrangle is a miniature graben of the Cypress Sandstone, Ridenhower Formation, and Bethel Sandstone. The faults are poorly exposed, although faulting was inferred from steeply dipping beds and silicified sandstone with secondary quartz overgrowths.

Lola (Dyer Hill) Fault System

The Lola fault system is named for the adjacent Lola Quadrangle and consists of two parallel NE-striking faults that are spaced about one mile apart. These faults originate in the Smithland Quadrangle (15 miles to the southwest) and are called the Dyer Hill fault system there. Fluorite, iron, and barite mineralization is associated with the Lola fault system (Anderson and Sparks 2012). The northwestern fault is a scissor fault on the southwest side of Caney Creek, its displacement is about 40 feet down to the northwest, and on the northeast side of Caney Creek, it is downdropped about 40 feet to the southeast. The southeastern fault is downthrown 40 feet to the southeast.

Commodore Fault System

The Commodore fault system trends northeast and is downthrown a maximum of 800 feet at the southern edge of the quadrangle. The fault system contains many small fault slivers, and in places, rock units within faulted blocks cannot be confidently assigned to a formation. Fault surfaces are rarely exposed but are the most well preserved in the sandstone outcrops. Along the fault system, lamprophyre dikes and sills are present in core holes, and fluorite mineralization is common.

Levias-Crittenden Springs Fault System and Griffith Bluff Graben

The southeastern corner of the quadrangle contains the northeastern portion of the Levias-Crittenden Springs fault system. Several sub-parallel faults offset Ste. Genevieve through Bethel units, and displacement totals about 200 feet, with the northwest side downthrown. Mica-peridotite dikes and fluorite, galena, sphalerite are present along the fault in this quadrangle and in the adjacent Salem and Repton quadrangles (Anderson and Sparks 2012). The Griffith Bluff Graben is the downdropped block between the Commodore and Levias-Crittenden Springs fault systems. It is composed of Chesterian units that dip about 2˚ SW. The Hardinsburg and Palestine Sandstone form erosion-resistant caps on the southwestward-dipping cuestas.

Tolu Arch

The Tolu Arch is a broad, subtle elongated dome whose structural high is near the town of Tolu, Kentucky. It brings Salem Limestone to the surface at Tower Rock, Illinois. The long axis of the structure trends about N40˚W and dies out near Hicks Dome in Illinois (Nelson 1995). Cross sections indicate that beds dip 0.5˚ northeast at Tower Rock, and attain a maximum dip of 2˚ near Illinois Route 146. The Tolu Arch extends southeastward into Kentucky, but it is difficult to trace where it is intersected by the NE-trending fault systems. NE-trending lamprophyre dikes are numerous along the arch (Anderson and Sparks 2012). The process that formed the arch may be related to the Permian igneous intrusions.

Economic Minerals

Limestone aggregate, sand and gravel, and fluorite occur in this quadrangle. Large resources of limestone are favorably located for barge transportation on the Ohio River. The Salem Limestone through Downeys Bluff Limestone interval contains largely limestone and dolostone, which are suitable for a wide variety of purposes, including concrete aggregate, agricultural lime, rock dust, and crushed stone for surfacing secondary roads. Several quarries are present in the Illinois portion of this quadrangle.

Illinois Kentucky Fluorite District (IKFD)

The Cave-in-Rock quadrangle lies within the Illinois Kentucky Fluorite District (IKFD). The IKFD encompasses over 2,600 square kilometers in southeastern Illinois and western Kentucky and has been a productive mineral district for over 175 years. Several limestone quarries are present in the Mississippian units. The IKFD was formerly the leading source of fluorite in the United States and produced significant quantities of lead, zinc, and other commodities. Economic mineralization in the IKFD is dominantly composed of fluorite, with 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 within open space along faults and fractures, and (3) residual deposits derived from veins or beds. Mine-run ore commonly contains 30 to 40% fluorite, as much as 2 to 3% zinc, and galena. Some deposits contained small values of silver in galena, along with recoverable cadmium and germanium in the sphalerite (Trace and Amos 1984). Several mines have been in operation in this quadrangle and are listed below.

Illinois Fluorspar Mines

Alco and Palmer Mines
According to Larry Gustin, a local resident of the area, the Alco surface mine (Sec. 16, T12S, R9E; 1,100 NL, 200 WL) was active approximately 50 years ago and was operated by Alco Lead Company. The primary mineral extracted was galena, but a small quantity of fluorite was also recovered. The principal pit is approximately 30 feet deep and trends for approximately 500 feet in a N45°W direction. Northeasterly fractures in the sidewall of the pit are lined with calcite and a small amount of purple fluorite. The gravel and residuum in the pit is very cherty and moderately high in iron oxides. The mine was probably along a small northwesterly trending fracture in the St. Louis Limestone. Mineralization was likely open space filling, although some evidence of replacement style mineralization was observed. Larry Gustin reported that several small pits are scattered around the main pit in this area. Weller et al. (1952) reported that this mine was also called the Patrick Mine and that mainly galena, cerussite, smithsonite, and anglesite were recovered in a chert and clay rich residuum. The early mines in this area were small shafts and drifts; these were later exhumed by the larger pits using power shovels and small draglines. The Alco mine tried to recover the small sand size fraction of the cerussite by means of a floatation mill, which ultimately proved unsuccessful (Weller et al. 1952). A small operation known as the Palmer Mine (Sec. 17, T12S, R9E; 1,500 NL, 2,300 EL), operated by Alco Lead Company, produced minor amounts of cerussite with fluorspar being notably absent (Weller et al. 1952).

Tower Rock Mine
(Sec. 17, T12S, R9E; 1,400 EL, 400 SL) The Tower Rock Mine was also known as the Iron Hill Mine and was operated by Jones and Ginn (Weller et al. 1952). The mine was located along a N35°E trending fault with minor displacement. Fluorite was noted as small narrow veins associated with a silicified limestone host rock. Both replacement and open space filling were noted within the host rock of the Salem and St. Louis Formations. The mineralization along this northeasterly trending feature was explored in a series of small pits and shafts for approximately 1,000 feet distance. While most of these workings were shallow, Weller et al. (1952) reported that some of the shafts extended as deep as 130 feet.

Hill Mine
(Sec. 11, T12S, R9E; location approximate) The Hill Mine is located north of Cave-in-Rock along the west side of Illinois Highway 1. It was mined by Bryan and Wallace along a N55°-60°E-trending fault zone. The average width of the vein was about 2 feet and the shafts were between 12 to 60 feet deep. The mineralization was fluorite with moderate amounts of barite along two working levels within the Ste. Genevieve Limestone (Weller et al. 1952). Production was minimal, but the mines extended along the northeasterly trending fault for a distance of about 700 feet.

Winn, Underwood and Frayser Mines
(Sec. 13, T12S, R9E) The Winn, Underwood and Frayser Mines are located just northeast of Cave-in-Rock. These mines are located along a northeasterly trending fault with minor displacement. Most of the shafts were less than 45 feet deep, but the Frayser shaft was considerably deeper, extending 110 feet below the surface (Weller et al. 1952). The ore was gravel spar, which is a result of weathering of fluorspar within the Ste. Genevieve Limestone. The total production of fluorite from these mines was small.

Kentucky Fluorspar Mines

Mico and Spring Mines
The Mico Mine is located in Kentucky on the southwest side of State Highway 91, about 3,500 feet southeast of the intersection of State Highway 135 and 91. The mine was active in the late 1950s and was adjacent to the Spring Mine. Local residents reported that a shaft at least 80 feet deep was present at the Spring Mine. The ore was rich in barite, with accompanying fluorite and sparse galena. The ore was mined along the northeast extension of the Coefield fault, between the Lola and Commodore fault systems. Bill Frazer, a local resident, indicates the trend of the vein was N35°E and the width of mineralization was nearly 200 feet. Information provided by Frazer indicates the Mico Mining and Milling Company proposed an earthen dam near the Spring Mine site to be used as a settling pond for the proposed mill. No additional historical information could be obtained concerning this mine, but a surface pit is present at the intersection of State Highway 91 and Aunt Jane Tabernacle Road. Cobbles of fluorite and barite that were scattered along the rim of the pit were collected for analysis. Along strike of the fault, about 3,000 feet to the northeast, another surface pit was dug. Little information concerning this pit was available, but local residents stated that it was dug by the same company that operated the Mico Mine. The Mico Mining and Milling Company also explored a few surface prospects for barite along the Lola Fault on the southeast side of Hurricane Church Road. Anderson and Sparks (2012) apply the name "Moore prospects" to these prospect pits. Little evidence of these surface prospects could be found during our field mapping this year.

Sullenger Mine

The Sullenger Mine is composed of three prospect pits located along a small northerly trending fault bifurcating from the Lola fault. The prospects are located about 3,000 feet east of Irma, Kentucky. No further historical information could be obtained concerning these prospects.

Beard Mines

The Beard Mines are a series of prospect pits located along the Commodore fault zone, on the east side of Hurricane Creek. There were several pits observed at this location, and fluorite was readily collected. The pits are small circular depressions not much deeper than a few feet, and the pits are aligned in a northeasterly direction. Southwest of the Beard Mines, along the Commodore fault zone, several prospect pits and shafts have been developed. Little historical information could be obtained concerning the following mines and prospects: Patmore-Stalion prospect, Craighead-Coates (Old Glory) area, Frazer Prospect, Slick Frazer (Owl Hollow) shaft and the Bellman Mine.

Memphis (North) Prospects

The Memphis (North) prospects are a cluster of exploration pits located along the Levias-Crittenden Springs fault system in the extreme southeast corner of the map. In this area, Anderson and Sparks (2012) only plotted the Memphis (North) prospects, although several prospect areas are located along this fault system. The cluster of prospect areas is known as the Memphis prospect area.

Iron Ore Mines

Iron Ore has been mined in the Kentucky portion of this quadrangle. The ore occurs in small pods along the top of weathered limestone units. Over 1,200 tons of iron ore have been smelted from the Hurricane Furnace in Kentucky. A second iron ore furnace called the Deer Creek Furnace also operated in this area. The Hurricane and Deer Creek Furnaces operated from about 1850 to 1860. No commercial production has occurred in the Illinois portion of this quadrangle.

Oil and Gas

Ten oil and gas wells have been drilled in Kentucky within the quadrangle. Gas was produced from the Devonian New Albany Shale in one well about one-half mile northeast of Tolu, Kentucky. All other holes were dry and abandoned.

Igneous Activity

Igneous activity has been detected in outcrops and in drill holes in the Cave-in-Rock Quadrangle. These rocks have been primarily observed in the Kentucky portion of this quadrangle and have been described as ultramafic lamprophyres and mica peridotites (Koeing 1956). These rocks have been identified in drill holes along the Commodore fault system (i.e. Little Hurricane Lamprophyre, interpreted as sills) and have been found as dikes in outcrops on the Kentucky side of the Cave-in-Rock Ferry landing and at the Hurricane and Cyclone Hill Lamprophyres. Samples from the Cyclone Hill Lamprophyre were collected for geochemical and petrographic analysis. Geochemical analysis of the Cyclone Hill dike was performed at ALS Chemex (appendix 1). These rocks contain low values of SiO2 and are highly altered, which make modal classification difficult. The texture is inequigranular with altered rounded-to-anhedral phenocrysts, most of which are less than 10 millimeters in diameter. The phenocrysts are completely altered to calcite, serpentine, and chlorite. The fine-grained matrix is composed of laths of biotite and calcite and abundant mafic iron oxides. The geochemical analysis identified approximately 3.8% TiO2, indicating that some of the mafic iron oxides could be iron-titanium oxide. Veins of calcite cross cut the igneous rock and carry small amounts of quartz and very small amounts of fluorite. Fluorine identified through whole rock geochemical analysis of the Cyclone Hill Lamprophyre was less than 0.2%, although rare earth element (REE) values are elevated. Microprobe analysis is being conducted to measure REE concentrations, and compositional analysis of primary minerals is being performed to aid in classifying this ultramafic rock. Similar types of rocks in Illinois have recently been classified as alnöite (Denny 2005) and aillikite (Maria and King 2012) but without additional analysis, the term ultramafic lamprophyre is the most appropriate term for this igneous occurrence.

Acknowledgments

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Appendix 1 Geochemical analysis of 2 samples from the Cyclone Hill Lamprophyre.

Element	Method	Units	Cyclone Hill 1	Cyclone Hill 2
F (%)	LMF-ICP-MS	%	0.18	0.17
Ba (ppm)	LMF-ICP-MS	ppm	852	785
Ce (ppm)	LMF-ICP-MS	ppm	154.5	166.5
Cr (ppm)	LMF-ICP-MS	ppm	690	760
Cs (ppm)	LMF-ICP-MS	ppm	1.92	1.67
Dy (ppm)	LMF-ICP-MS	ppm	4.42	4.6
Er (ppm)	LMF-ICP-MS	ppm	1.52	1.57
Eu (ppm)	LMF-ICP-MS	ppm	3	3.22
Ga (ppm)	LMF-ICP-MS	ppm	13.6	13.5
Gd (ppm)	LMF-ICP-MS	ppm	7.78	8.17
Hf (ppm)	LMF-ICP-MS	ppm	5.8	5.4
Ho (ppm)	LMF-ICP-MS	ppm	0.69	0.71
La (ppm)	LMF-ICP-MS	ppm	77.2	83
Lu (ppm)	LMF-ICP-MS	ppm	0.12	0.12
Nb (ppm)	LMF-ICP-MS	ppm	122.5	126
Nd (ppm)	LMF-ICP-MS	ppm	63	68.3
Pr (ppm)	LMF-ICP-MS	ppm	17.65	19.1
Rb (ppm)	LMF-ICP-MS	ppm	57.7	54.6
Sm (ppm)	LMF-ICP-MS	ppm	11.1	11.75
Sn (ppm)	LMF-ICP-MS	ppm	2	2
Sr (ppm)	LMF-ICP-MS	ppm	881	760
Ta (ppm)	LMF-ICP-MS	ppm	7.7	8.3
Tb (ppm)	LMF-ICP-MS	ppm	0.95	0.99
Th (ppm)	LMF-ICP-MS	ppm	9.22	9.97
Tl (ppm)	LMF-ICP-MS	ppm	<0.5	<0.5
Tm (ppm)	LMF-ICP-MS	ppm	0.2	0.17
U (ppm)	LMF-ICP-MS	ppm	2.46	2.34
V (ppm)	LMF-ICP-MS	ppm	303	297
W (ppm)	LMF-ICP-MS	ppm	1	1
Y (ppm)	LMF-ICP-MS	ppm	17.2	16.8
Yb (ppm)	LMF-ICP-MS	ppm	0.99	0.96
Zr (ppm)	LMF-ICP-MS	ppm	250	226
SiO_2 (%)	LMTF-ICP-AES	%	30.4	29.8
Al_2O_3 (%)	LMTF-ICP-AES	%	5.45	5.03
Fe_2O_3 (%)	LMTF-ICP-AES	%	12.4	12.6
CaO (%)	LMTF-ICP-AES	%	12.35	11.55
MgO (%)	LMTF-ICP-AES	%	16.65	16.9
Na_2O (%)	LMTF-ICP-AES	%	0.59	0.41
K_2O (%)	LMTF-ICP-AES	%	1.18	1.11
Cr_2O_3 (%)	LMTF-ICP-AES	%	0.09	0.09
TiO_2 (%)	LMTF-ICP-AES	%	3.8	3.9
MnO (%)	LMTF-ICP-AES	%	0.19	0.18
P_2O_5 (%)	LMTF-ICP-AES	%	0.75	0.7
SrO (%)	LMTF-ICP-AES	%	0.1	0.09
BaO (%)	LMTF-ICP-AES	%	0.09	0.08
LOI (%)		%	16	16.2
Total (%)		%	100.04	98.64

The symbol (<) indicates less than detection limit. LOI is loss on ignition calculated from thermal decomposition through a gravimetric method. Trace elements determined by lithium metaborate fusion - Induced coupled plasma - mass spectrometry (LMF-ICP-MS). Major oxides by lithium metaborate/lithium tetraborate fusion – induced coupled plasma – atomic emission spectrometry (LMTF-ICP-AES).