STATEMAP
Ridgway-BG

Bedrock Geology of the Ridgway Quadrangle

Gallatin and Saline Counties, Illinois

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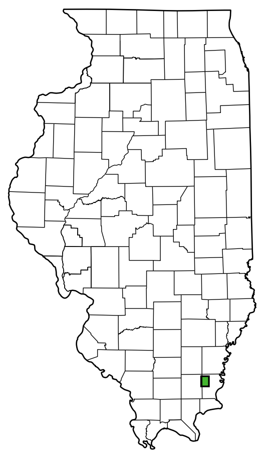
2017



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Introduction

This map portrays the distribution and structure of bedrock units and features as they would appear if all Quaternary sediments were removed. Quaternary deposits in the Ridgway quadrangle range in thickness from less than 10 feet to about 160 feet (Fig. M3 on map sheet 2). Bedrock is exposed in a few small areas along the North Fork Saline River in the central and southern parts of the map area. The geologic map therefore is based predominantly on subsurface information acquired from borehole records, underground mines, and geophysical surveys. Logs of nearly all of these wells and test holes are publically accessible at http://maps.isgs.illinois.edu/iloil/.

Sources of Information

Records of wells and borings, on file at the Illinois State Geological Survey, are the primary source of subsurface geologic information. Several hundred holes for oil and gas exploration have been drilled in the Ridgway quadrangle. Most of these have electric logs; many also have gamma-ray, neutron, and density logs; a few have sample studies made by geologists. Because of time constraints and the need to avoid excessive crowding of information, only selected well records (chiefly of the deeper holes having more modern logs) were used in the Omaha oil field in the northern part of the quadrangle.

Also used were logs from about 80 coal-test borings, many of which include continuous cores described by ISGS personnel. Although some coal records are available online, most exist only as paper records in the Geologic Records Unit and in the Coal Section at the ISGS. Two continuous cores drilled by the ISGS for stratigraphic control also are available. For determining depth to bedrock, logs of water wells and of bridge borings made by the Illinois Department of Transportation were used. Logs of these holes can be accessed at http://maps.isgs.illinois.edu/ILWATER/.

Limited information was obtained from outcrops and coal mines in the Ridgway quadrangle. We visited all accessible outcrops and also examined historic field notes (filed in ISGS Map Library) made by geologists who described rock exposures now covered or otherwise inaccessible. Survey geologists also made a few observations in mines within the study area, and some information can be gleaned from maps of those mines on file at the Survey. Myers and Chenoweth (2005) mapped coal mines in the Ridgway quadrangle at 1:24,000 scale.

Igneous Rocks

Many test holes and well borings in the Ridgway Quadrangle have penetrated intrusive igneous rocks. Core samples reveal ultramafic dark gray to green-gray inequigranular porphyritic rock. As revealed by petrographic studies, the phenocrysts comprise about 10 percent of the rock and are mainly olivine, pyroxenes, and phlogopite, set in an aphanitic matrix of calcite, mica, perovskite, Ti-magnetite, garnet, apatite, an altered lath-shaped mineral (possibly melilite pseudomorphs), hematite, and chlorite (Howard et al., 2016; Denny 2005, Sparlin and Lewis, 1994; English and Grogan, 1948). As Clegg and Bradbury (1956) observed, alteration of the primary minerals and lack of feldspars make these rocks difficult to classify. Currier (1920) classified igneous intrusive rocks in southern Illinois as lamprophyre. English and Grogan (1948) labeled these rocks as mica peridotite, whereas Sparlin and Lewis (1994) suggested that the igneous rocks were improperly classified as mica peridotite and should be classified as monticellite alnöite. Maria et al., (2016) suggested rocks of this province were similar to mela-aillikites or aillilites from Aillik Bay, Labrador. Fifarek (2001) suggested the ultramafic igneous activity in this region is related to extension of the North American Plate along the Reelfoot Rift accompanied by partial melting of the mantle during the Permian. Radiometric age determinations of igneous rocks in the region indicates they were emplaced during the Permian Period approximately 260-290 Ma (Zartman et al., 1967; Nelson and Lumm, 1984; Reynolds et al., 1997; Fifarek et al., 2001; Denny 2005; Morehead 2010) and are part of a regional event stretching from northern Saline County, Illinois to Caldwell County, Kentucky.

Igneous rocks in the Ridgway quadrangle occur in pipes or diatremes, tabular intrusive breccia dikes, tabular ultramafic dikes, and horizontal sills. The tops of the tabular dikes were observed in advancing surface mine cuts in the Wildcat Hills Cottage Grove Mine to be somewhat undulatory and express vertical relief along strike. Some dikes were observed intruding entirely through the Paleozoic section, while in other places the top of the dikes terminate below the ground surface. The mineralogy of these ultramafic rocks indicate they originated in the upper mantle. Therefore, the ultramafic rocks have ascended at least 25 km (15 miles) upward to reach their current position. Since these dikes have risen upward for over 25 km, the dikes should also extend for long distances in a horizontal direction.

Diatremes and intrusive breccias presumably are related to the volatile components of the ultramafic system. The volatile components separated from the magma, which created enough pressure to brecciate the overlying country rock and suspend brecciated sedimentary clasts within a fine-grained igneous matrix in vertical tabular and pipe-shaped geometries. The reason for the separation of the volatiles from the magma is uncertain, but it may be related to the composition of the magma. The amount of carbonate in some of the diatremes in this region led workers to suggest these rocks were genetically linked to a carbonatite system (Mariano A.N., 1987; Bradbury and Baxter, 1992; Wall and Mariano, 1996; Long et al., 2010; Denny et al., 2017). Conversely, separation of the volatiles from the magma could have taken place in response to rapid thermodynamic changes of the magma as the magma intruded into water-saturated strata creating a phreatomagmatic explosion (Brown, Emery, and Meyer, 1954). The diatremes represent high-pressure regions and some may be explosive vents. No volcanic extrusives have been documented in this area, but the texture in some of the diatremes indicates they probably were vented to the surface. Erosion of preexisting strata may account for the lack of preservation of the extrusive component suspected to have been present.

Ground-based magnetic surveys

These igneous rocks contain several percent magnetite and hence are strongly magnetic. Therefore, magnetometer surveys are a highly effective way to locate igneous rocks in southeastern Illinois. Sparlin and Lewis (1994), Hildenbrand and Ravat (1997), and Silverman et al., (2003) published results of magnetic surveys within the study area. We selected ten representative features visible on the aeromagnetic maps in the Ridgway Quadrangle and conducted ground-based magnetic surveys over the magnetic anomalies. We then modeled the features to estimate the size and composition of the igneous intrusions. Positionings of the dikes depicted on the geologic map were conditioned by these surveys. Details of these surveys can be obtained by contacting the authors.

The magnetic surveys were conducted with a Geometrics G-858 cesium vapor magnetometer with integrated GPS. This allowed us to obtain rapid, high-density, high-precision magnetic data for these sites. The anomalies were 100 to 400 m in width and 30 to 800 nT in intensity. In general, the ground-based work corroborated the aeromagnetic surveys. As expected, the measured anomalies were larger than the aeromagnetic surveys, but they were encountered in the same location and with the same patterns. The anomalies were modeled individually, but in general, the magnetic susceptibilities that optimized the models were in the range of 0.04 to 0.08 SI, consistent with values measured on cores obtained from the region (Sparlin and Lewis, 1994; Hildenbrand and Ravat, 1997; this study). As noted by Hildenbrand and Ravat (1997) the linear features appear to be only a few meters wide and extend upwards to within a few to 10's of meters of the ground surface, possibly silling into Pennsylvanian coals. Deeper sills, such as those in the Omaha Dome region, are not evident in the ground surveys or the high-resolution aeromagnetic maps. The magnetic anomaly measured by Sparlin and Lewis (1994) had similar magnetic intensity (135 nT) but had a diameter of about 10 km.

Igneous Rock in the Stella Robinson Core

We acquired about 19 feet of drill core from CountryMark Oil Company's Stella Robinson #4 oil test (4-T8S,R8E; API# 120592571400). This core was donated by CountryMark to the University of Southern Indiana (USI) for scientific research purposes. USI loaned the core to the ISGS to allow research on the igneous sill and the sill's lower contact with sedimentary rock. The lower portion of the igneous sill incorporates fragments of metamorphosed sandstone from the Mississippian Aux Vases Formation. The Ste. Genevieve Limestone immediately below the sill has been metamorphosed to a low-grade marble that contains andradite garnet and metasomatic wollastonite (Howard et al., 2016). A white to translucent

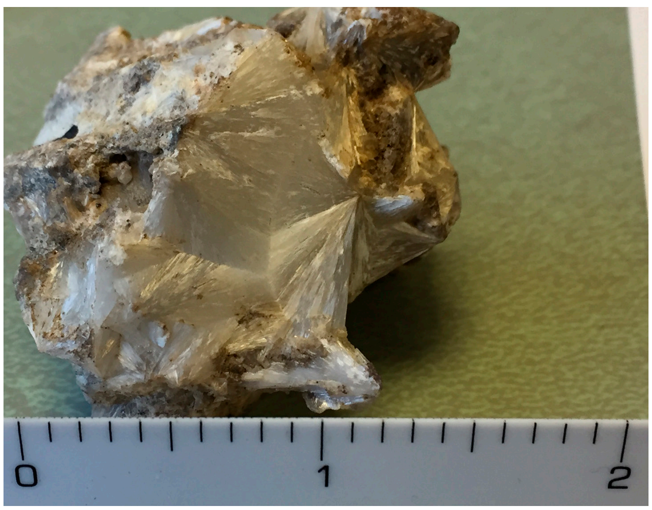

Fig 1. White radiating mineral forming a nearly vertical vein in the Stella Robinson #4 core. Scale in inches

radiating mineral (Fig. 1 and Appendix 2) cross cuts the core near the top. Energy Dispersive X-Ray Fluorescence (EDXRF) analysis of major oxide and trace elements (Appendix 1) of the vein was inconclusive. The calcium oxide content of the unknown mineral is higher than the theoretical composition of most any known single mineral species. The small amount of Na_2O, Al_2O_3, and Fe_2O_3 may indicate a calcium silicate mineral such as a calcium-zeolite is present but without further tests, the mineral cannot be positively identified. Further investigation of the sample detected another light gray to white fine-grained mineral on the surface of the acicular mineral. This mineral effervesced when cold 10% HCL was applied. Therefore, based on visual examination and the results of the EDXRF analysis, we surmise that the unknown white vein is composed of a calcium silicate mineral (wollastonite? or Ca-zeolite?) along with calcium carbonate (calcite). Additional work is ongoing to identify the Ca-silicate mineral species clearly.

Several $\delta^{13}C$ and $\delta^{18}O$ analyses of the Stella Robinson core for were conducted at the ISGS. The analyses were conducted using a Kiel III automated carbonate preparation device coupled to a Finnigan MAT 252 isotope ratio mass spectrometer (IRMS). The system digests carbonate material with 100% phosphoric acid for 10 minutes at 70°C and then purifies the CO_2 product, which is then passed to the IRMS for mass 44, 45, 46 measurement alternately with that of a calibrated reference CO_2 gas. The isotopic composition of light elements are reported as delta (δ) values in parts per thousand (denoted as ‰ or spelled out as per mil). δ values are calculated by the following equation: [‰ = (Rsample / Rstandard – 1) 1000] where R is the ratio of the heavy to light isotope (e.g. ^{13}C / ^{12}C) in the sample or the standard. Therefore, a positive δ value means that the sample contains more of the heavy isotope than the standard, while a negative δ value means that the sample contains less of the heavy isotope than the standard.

Whole rock samples were taken every 6 inches by micro-drill from the core in both the igneous ultramafic sill and the sedimentary rock intervals. The $\delta^{18}O$ values of the ultramafic sill range from 17.32 to 23.84 ($\delta^{18}O_{VSMOW}$) and the $\delta^{13}C$ values ranged from -8.49 to 3.95 ($\delta^{13}C_{VPDB}$). The $\delta^{18}O$ values of the sedimentary rocks range from 16.98 to 23.84 ($\delta^{18}O_{VSMOW}$) and the $\delta^{13}C$ values ranged from -10.97 to -0.48 ($\delta^{13}C_{VPDB}$). Gregory and Taylor (1981) calculated the $\delta^{18}O$ values of mid ocean ridge basalts (MORB) in an ophiolite section ($\delta^{18}O$ = 5.7). Taylor et al., (1967) also calculated primary igneous carbonate values, which are plotted on Figure 3. Eiler (2001) suggested that upper level mantle rocks should have a $\delta^{18}O$ value between 5 and 6, and that subsequent water-rock interactions or hydrothermal circulation will enrich the rocks

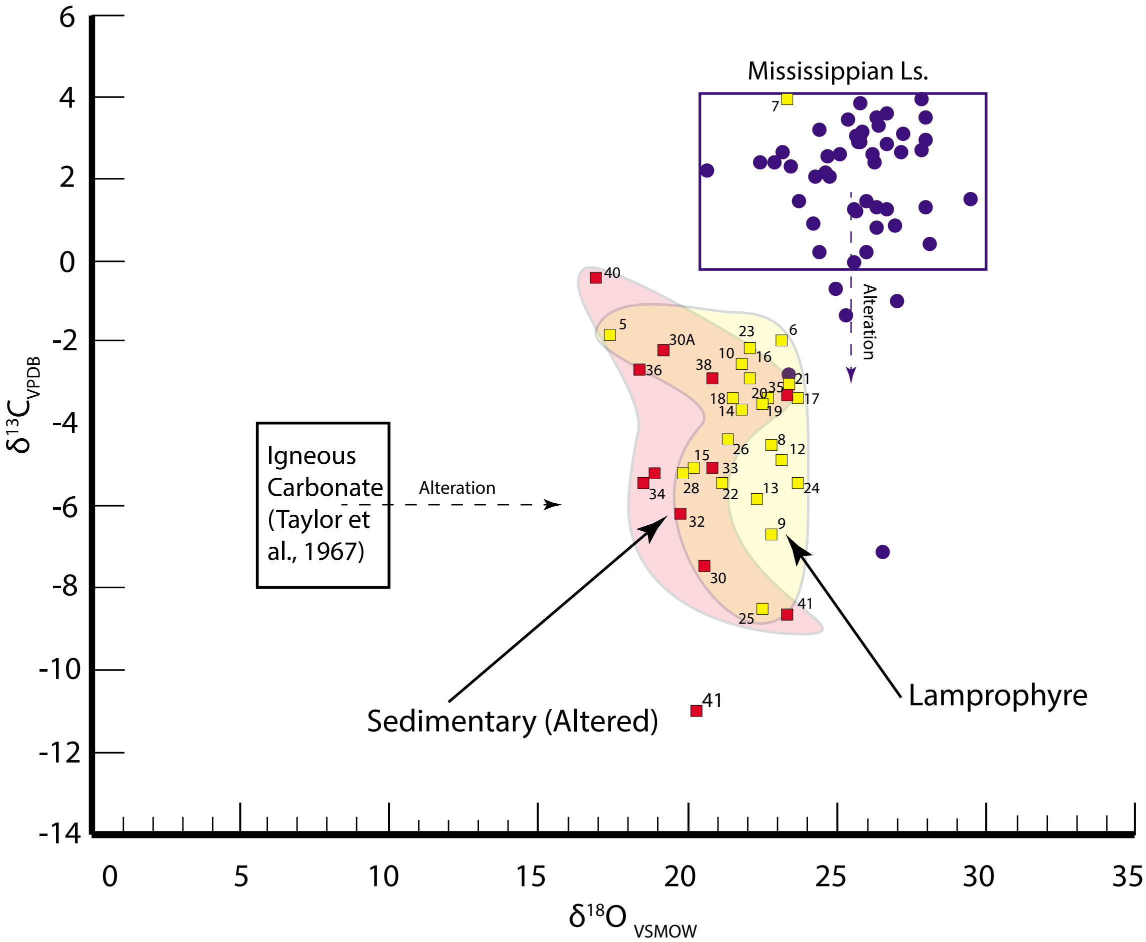

Fig. 2 Plot of $\delta^{8}O$ versus $\delta^{3}C$ from the Stella Robinson core. The blue circles are Mississippian Age limestone values from southern Illinois (Denny unpublished). The yellow squares are the ultramafic lamprophyre values, and the red squares are the Mississippian sedimentary values, both from the Stella Robinson core. Sample numbers are depicted on Appendix. 2 and higher than 26 are sedimentary rock samples while less than 26 are ultramafic igneous samples. The igneous carbonate box is from Taylor et al., 1967.

in ^{18}O. The high $\delta^{18}O$ values observed in the carbonate the matrix of the ultramafic igneous rock in the Stella Robinson core indicate these rocks have been altered. The suite of minerals (metasomatic garnet, serpentine, calcite) observed in the ultramafic rocks of this region also confirms that alteration has occurred. It is likely that the exchange of fluids between the sedimentary rock and igneous intrusion has taken place. Additional alteration through hydrothermal activity is also likely. We analyzed the entire length of the Stella Robinson core, but it is unfortunate that more limestone at the base was not recovered by the drilling, as no correlation with distance away from the base of the sill is observable in the stable isotope data we collected.

Omaha Dome

Oil was discovered in the northern part of the Ridgway quadrangle at Omaha Dome in 1940, trapped in the Mississippian Palestine Formation. Subsequent oil tests revealed the presence of a substantial oil deposit trapped in a nearly circular dome 3 to 4 miles in diameter. Many of the wells also encountered intrusive bodies of mica peridotite, leading English and Grogan (1948) to attribute the domal structure to "upward thrusting accompanying the rise of an igneous intrusion". Because no well at this time had penetrated major igneous bodies, their idea remained hypothetical until 1972, when the Alva Davis #1 Luther Rister well near the apex of the dome was deepened to 5,320 feet in Middle Devonian limestone. The Rister well penetrated igneous rocks having a cumulative thickness of more than 300 feet and showed that Middle Devonian strata, below the intrusive bodies, are not involved in the uplift (Cluff et al., 1981, p. 57).

Since 2011, eighteen new wells on Omaha dome have been drilled to depths of 3,900 feet or more, including a second Middle Devonian test 5,400 feet deep. Nearly all of these holes penetrated an igneous body 100 to 260 feet thick in the Mississippian St. Louis and Salem Limestone. This intrusion alone is sufficient to account for the 200 feet of structural closure we mapped on the Pennsylvanian Springfield Coal. Multiple igneous bodies have been drilled in younger Mississippian and Pennsylvanian beds, in addition to 110 feet of igneous rock drilled by the Luther Rister well in the Upper Devonian New Albany Shale. The fact that many of these intrusions occur at the same stratigraphic level in multiple wells demonstrates that they are sills. Although the big intrusion in the St. Louis and Salem is basically a sill, it is partly discordant to bedding (see cross section).

Other igneous intrusions

A swarm of igneous dikes striking slightly west of north crosses the Ridgway quadrangle. These dikes are part of a system previously mapped in the adjacent Harrisburg (Denny et al., 2007), Galatia (Nelson and Denny, 2015a), Harco (Nelson and Denny, 2015b) and Eldorado (Nelson and Denny, 2016) quadrangles (Fig. 3). Earlier authors who mapped and described these intrusions include Clegg (1955), Clegg and Bradbury (1956), and Nelson and Krausse (1981). Dikes mapped in the Ridgway quadrangle are based on three sources of information (1) the final (2013) map of the Willow Lake underground coal mine, (2) boreholes that penetrated igneous rock or contact metamorphism, and (3) airborne magnetometer surveys.

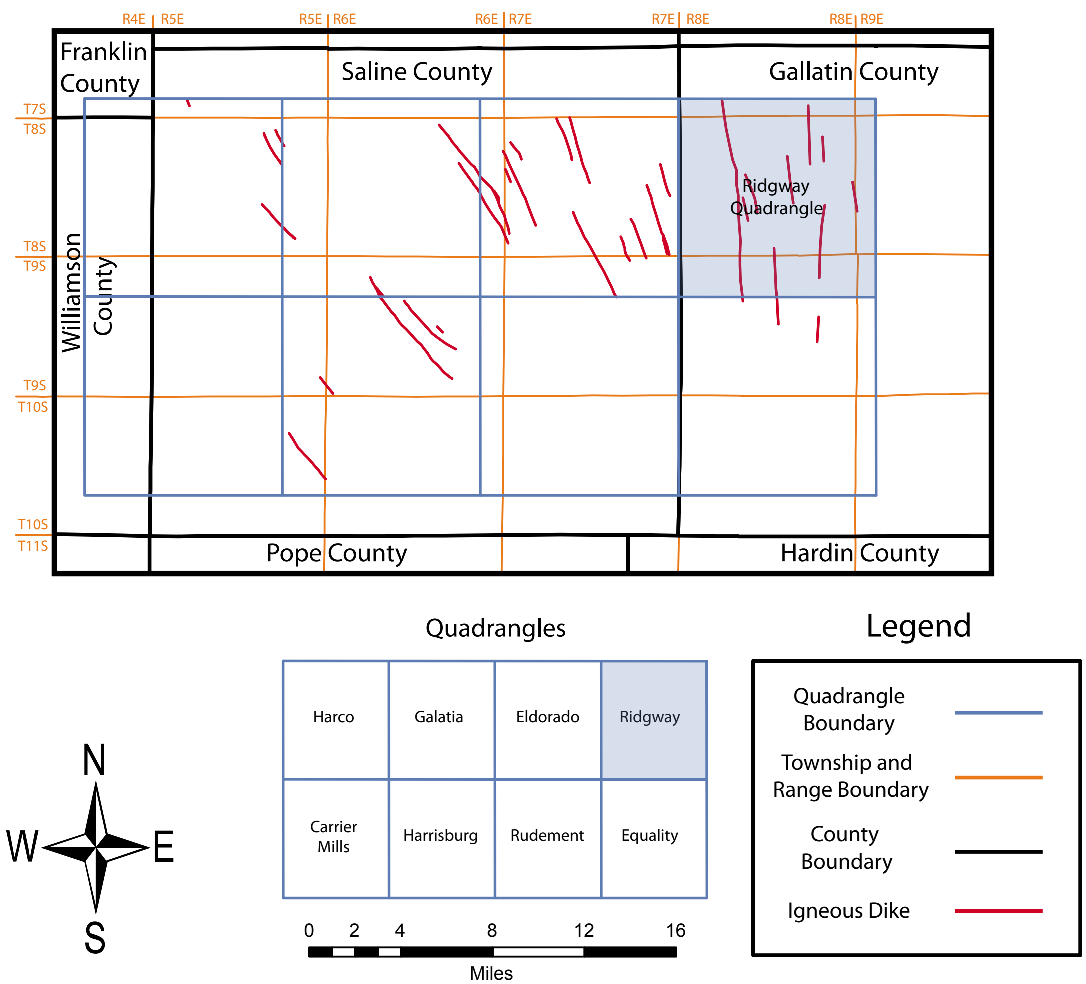

Fig. 3. Location of igneous dikes in the immediate project area.

The Willow Lake Mine encountered several dikes penetrating the Springfield Coal. A dike in the west-central part of Secs. 17 and 20 is more than 5,000 feet long and varies in width from 6 to 20 feet. As explained below, the Exchange Oil #1 Opal Evans oil-test hole drilled through the same intrusion, but the dike is weakly expressed on magnetometer surveys. A smaller parallel dike is about 1,000 feet west of the Opal Evans dike. The small dike is approximately 1 foot wide and 1,200 feet long, terminating within mine workings at both ends.

About 1,500 feet east of the Opal Evans intrusion, another dike can be traced nearly 6 miles to the southern border of the Ridgway quadrangle. The Willow Lake mine workings butted into this dike in several places, but did not cross it. Closely-spaced coal-test drilling in T9S, R8E further delineates the intrusion. This dike is not continuous; two offset segments overlap near the northeast corner of Sec. 32, T8S, R8E. A strongly defined linear magnetic high coincides with this intrusion.

Other dikes have been encountered during random or dedicated drilling by coal operators. A high-resolution aeromagnetic survey acquired by Peabody Energy Company and covering most of the Ridgway quadrangle was very useful to map the extension of igneous dikes on the Ridgway quadrangle Map. Narrow, linear, north-trending magnetic highs on these maps can be confidently interpreted as dikes and have been plotted on the geologic map. Also evident are intense roughly circular magnetic highs that coincide with known sills at Omaha dome and the smaller Cottage dome in the Eldorado quadrangle (Nelson and Denny, 2016). Another notable intense, circular magnetic high lies about 1 mile south of Ridgway on the eastern (downthrown) side of the Ridgway fault (Fig. 4). No drilling records are available in the vicinity of this magnetic high. The Ridgway feature and numerous smaller magnetic highs probably represent intrusions that are yet to be verified.

Six oil-test holes in Secs. 23 and 24, T8S, R8E (about one mile northwest of Ridgway) encountered igneous rock 15 to 40 feet thick in the upper part of the Mississippian Cypress Formation at a depth of approximately 2,450 feet. Because the six adjacent wells found intrusive rock at virtually the same stratigraphic horizon, the body is interpreted as a sill having minimum dimensions of 3,500 feet east to west and 3,000 feet north to south. Neither a structural high nor a definite magnetic anomaly is associated.

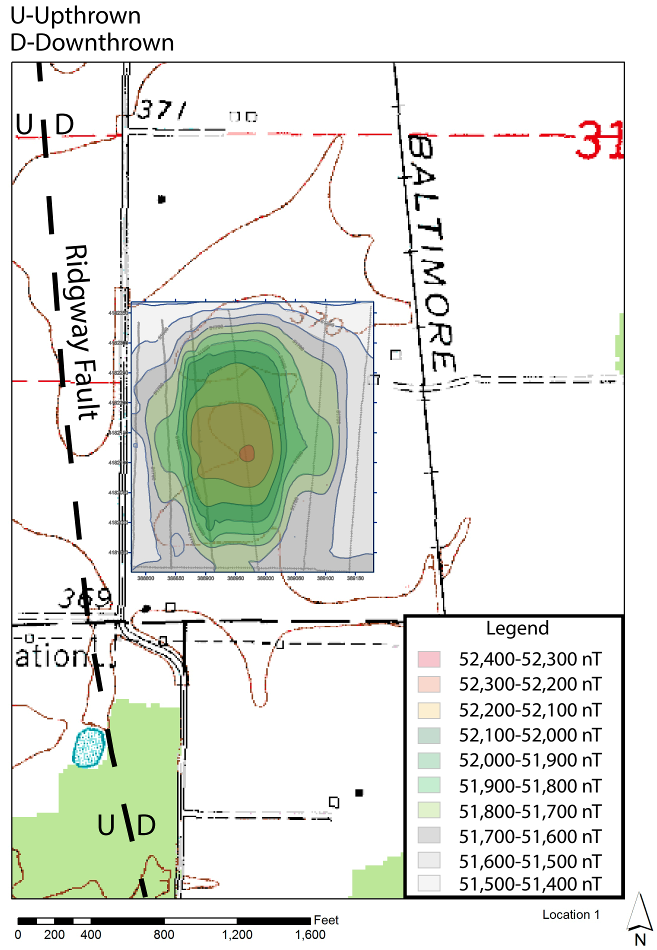

Fig. 4 Circular magnetic anomaly south of Ridgway (SW 1/4 of section 31-T8S-R9E). Units are nanoTesla (nT)

Closely spaced test drilling by Peabody Coal Company delineated a dike in the western part of Sec. 4, T9S, R8E. This dike is less than 50 feet wide and follows a linear course of N10°W at the level of the Herrin Coal. No detailed description or samples of the intrusive rock are available. Drilling on either side of the dike indicates that the coal is not displaced vertically across the intrusion.

The Exchange Oil #1 Opal Evans test hole drilled about 5 miles WNW of Ridgway (NE NE NW, Sec. 21, T8S, R8E) penetrated approximately 700 feet of igneous rock and contact-metamorphosed sedimentary rock, including 450 feet in the lower part of the Pennsylvanian and 160 feet in the Mississippian Kinkaid through Palestine Formations. No significant structural high is present and the sedimentary section is not expanded, so the intrusions must crosscut sedimentary layering. The Leathers #10 Opal Evans oil test hole, 660 feet west of the Exchange oil test hole, reached a depth of 2,235 feet without encountering igneous rock. As outlined above, the Willow Lake underground mine encountered a large igneous dike in the Springfield Coal close to the Opal Evans hole. A small, nearly circular magnetic high coincides with location of the Exchange oil test on the Peabody magnetic map. The Opal Evans well may have drilled vertically down a dike or possibly, into a nearly vertical plug or diatreme.

Another hole that drilled vertically down a discordant intrusion is Quinn Energy No. 1 Ramsey, near Elba in NW¼ SW¼, Sec. 16, T8S, R8E (county number 24892). The density-neutron log indicates several intervals of igneous rock and/or contact-metamorphosed rock within the Pennsylvanian. The thickest zones are at 1240-1295 and 1335-1580 feet depth in the lower Tradewater and Caseyville Formations. Combined with several smaller intrusions, total thickness of igneous and altered rock is approximately 330 feet. As in the Opal Evans well, no structural high is present and the section is not expanded, proving that the intrusion is discordant. Moreover, the Ramsey borehole lies along a strong NNW-striking linear magnetic high mapped as a dike.

Geologic Structure

Geologic structure is shown on the map by means of contour lines indicating elevation of the top of the Springfield Coal Member, the unit for which the most abundant and reliable data are available. Faults and igneous bodies that approach the bedrock surface are also shown. An east-west cross section across the northern part of the map area displays the structure at depth, as revealed by data from deep wells.

The Ridgway quadrangle is situated in the southern part of the Illinois basin. Pennsylvanian and older strata regionally dip toward the deepest part of the basin, nearly 100 miles north in east-central Illinois. Modifying this regional picture are the nearly circular uplift known as Omaha dome and a zone of faults running northward near the east edge of the map area.

Ridgway Fault

A large north-striking fault displaces bedrock strata near the eastern edge of the Ridgway quadrangle. Because this fracture passes beneath the town of Ridgway, it may be called the Ridgway fault, and it marks the western margin of a larger array of faults called the Wabash Valley fault zone (Bristol, 1975; Bristol and Treworgy, 1979). Traced northward, the Ridgway fault is one of a series of aligned crustal breaks named the Albion-Ridgway fault zone.

Like other elements of the Wabash Valley fault system, the Ridgway fault is a high-angle normal fault. Six wells that penetrated the fault plane demonstrate this fact; their logs indicate 160 to 405 feet of missing section. Three wells in the NE¼ of Sec. 24, T8S, R8E crossed the fault in the lower part of the Pennsylvanian around 1,000 feet depth. A fourth well farther east, the Dunn oil test in Sec. 19, T8S, R9E, encountered the fault in Mississippian Golconda and Cypress Formations at a depth of 2,900 feet. Geometric construction indicates average dip of the fault plane is approximately 65 degrees. Maximum throw is approximately 450 feet down to the east and occurs close to the above-mentioned wells. Displacement decreases south and north from this point, being about 150 feet near the southern edge of the quadrangle and perhaps 200 feet at the northeastern corner, where the fault seems to split into two planes.

As shown by structure contours, a narrow north-trending syncline parallels the eastern (down-

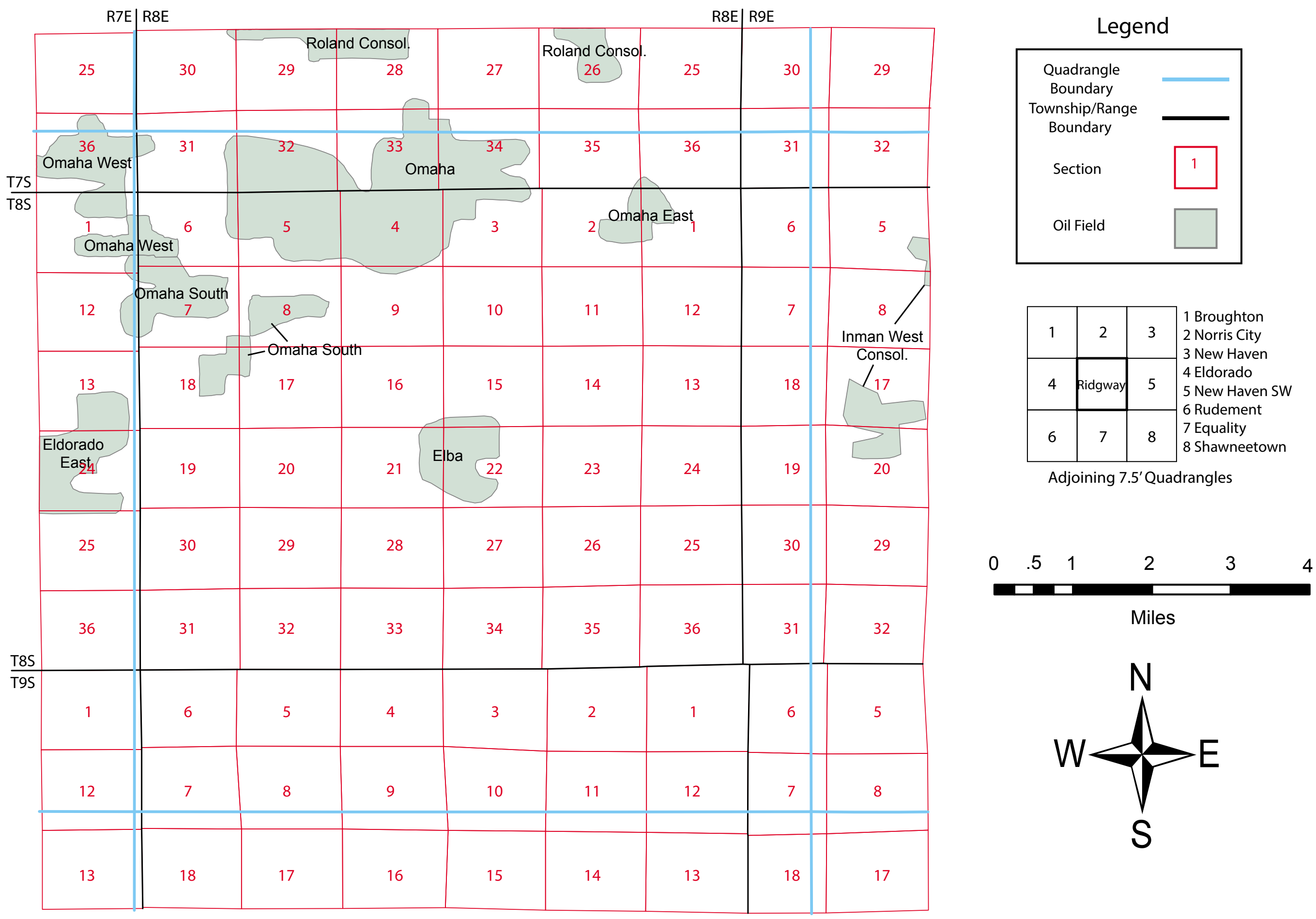

Fig. 5 Oil fields in the Ridgway area.

thrown) side of the Ridgway fault. West of the fault strata dip east or northeast, toward the fault, except in the middle portion where the throw is greatest. These folds should not be attributed to frictional "drag" because exposures of Wabash Valley faults in underground coal mines reveal little or no drag. Possibly, the folds developed during an early stage of deformation in which the strata gradually flexed until the fault propagated upward from below.

Economic Geology

Oil and Gas

Approximately 10 million barrels of oil and a small amount of natural gas have been produced within the confines of the Ridgway quadrangle. The lion's share has come from the Omaha oil field, which is situated atop the Omaha dome structure in the northern part of the map area. Smaller output has been achieved from several satellite fields, namely Omaha East, Omaha South, Omaha West, and Elba (Fig. 5).

Omaha oil field. Although coal structure mapping by Cady (1919), based on meager data, showed a structural high in the general area of Omaha, the area did not attract industry attention until 1938, when Carter Oil Company drilled a series of shallow structure test holes in northern Gallatin County (the ISGS lacks logs of these borings.) Drilled in early 1940, the first test hole on Omaha dome was dry, but later that same year the Carter Oil #1 York test in SE-SE-SW, Sec. 33, T7S, R8E, became the first commercial producer in the Omaha field. As of 1948, the field hosted 20 pumping wells through an area of 480 acres mostly in Sec. 4, T8S, R8E. These wells tapped petroleum from sandstone reservoirs in the Upper Mississippian Palestine and Tar Springs Formations, which lie at depths of about 1,700 and 1,900 feet, respectively, at the crest of the dome. Deeper tests had been drilled to the St. Louis Limestone at about 2,800 feet, penetrating formations that yield copious amounts of oil elsewhere in the basin; but at Omaha these units either lacked porosity or had been flushed of oil (English and Grogan, 1948). Published accounts of subsequent development of the Omaha oil field are not available, so information must be gleaned from ISGS records on a well-by-well basis. Discovery of oil in sandstone of the Aux Vases Formation in 1958 touched off a second round of development. Oolitic limestone and sandstone in the slightly deeper Ste. Genevieve Limestone (depth 2,700-2,800 feet) also proved to be productive, as did sandstone in the Hardinsburg, Cypress, Sample, and Bethel ("Paint Creek" and "Benoist") Formations, all shallower than the Aux Vases. Many wells were completed in two or more formations, achieving initial production as high as 400 barrels of oil per day. A third round of development began in late 2011, with most wells being carried to the Salem Limestone at depths of 3,900 to 4,000 feet. Returns from the Salem were disappointing, most wells being completed in the Aux Vases or shallower formations. As for the Countrymark #14 Kuder Devonian test (SE-SW-SE, Sec. 33, T87S, R8E), shows of gas and immobile oil were encountered, but not in commercial quantities.

With approximately 10 square miles of closure, Omaha dome is among the larger structural traps in the Illinois basin. Many fields of smaller area have far exceeded Omaha's 8,217,285 barrels (Bryan Huff, ISGS, written communication, 2017). The Salem oil field, the most productive field in the Illinois basin, has less than twice the enclosed area of Omaha, but has yielded nearly 50 times more oil. Large areas inside structural closure at Omaha Dome, including most of the northern third of the dome, have only dry holes. Surrounded by producing wells and drilled at the apex of Omaha dome, the Luther Rister well (SW-SW-NW, Sec. 4, T8S, R8E) was dry.

Multiple factors might account for lack of production within a proven structural trap. All of the Mississippian sandstone and permeable limestone bodies that serve as reservoirs are lenticular. However, we suspect that the same igneous activity that created the trap also "cooked" or drove out large quantities of hydrocarbons. Uplift undoubtedly fractured overlying rock layers, facilitating escape of oil and gas. In addition small quantities of fugitive oil may have taken refuge in satellite fields, such as Elba, Omaha East, and Omaha South.

Omaha East field. Centered about 3 miles east of the apex of Omaha dome (Fig. 5), the Omaha East oil field contained 10 producing wells, all of which have been plugged. The discovery well was completed in 1946, but the second producer did not come in until late 1957. Eight of the ten commercial wells produced from Ste. Genevieve Limestone at depths of 2,850 to 2,900 feet. The other two tapped oil from the shallower Cypress Formation, a sandstone reservoir. The structure is a nearly uniform eastward dip, so trapping must be stratigraphic. The final well was capped in 1988, leaving total cumulative production of the field at 65,050 barrels (Bryan Huff, ISGS, written communication, 2017).

Omaha South field. As defined, the Omaha South oil field (Fig.) comprises several geologically unrelated oil pools that are close together geographically. One well in the SW¼ of Sec. 8, T8S, R8E produced oil between 1951 and 1955 from the Spar Mountain Sandstone Member of the Ste. Genevieve Limestone (Mississippian) at a depth of 2,867 feet. Two other wells in Section 8 were completed in 1969 in the slightly shallower Aux Vases Sandstone. One of the two was later converted to water injection, sustaining the producing well until 2011. Southwest of the Mississippian producers in the NE¼ of Sec. 18, eight wells were completed during the early 1980s in Pennsylvanian sandstone reservoirs at depths of 550 to 700 feet. The sandstone units lie in the lower Carbondale and upper Tradewater Formations. Given virtually flat structure, trapping presumably is stratigraphic. Five of the eight Pennsylvanian wells are still pumping, or at least have not been officially plugged. Total output from the Omaha South field is 188,835 barrels (Bryan Huff, ISGS, written communication, 2017).

Omaha West field. Lying mostly west of the Ridgway quadrangle, the Omaha West field sprawls west and southwest of the apex of Omaha dome and encompasses wells producing from two or more disconnected oil deposits. Within the map area, production dates from 1953 from wells completed to the Mississippian Cypress Formation at depths of 2,500 to 2,550 feet. Most of the Cypress wells have been plugged. A second round of development during the mid 1980s established production from the Aux Vases Formation at 2,875 to 2,900 feet depth. Several of the Aux Vases wells came in at more than 100 barrels per day and are still pumping. As in the other Omaha satellite fields, structure does not appear to be a factor in oil trapping. Wells within the Ridgway quadrangle probably account for less than half of the 2.1 million barrels produced from the Omaha West field.

Elba field. The Elba oil field comprises 15 present and former producing oil wells clustered about 3 miles south of the highest part of Omaha dome. Most of these were completed during the mid to late 1950s in sandstone reservoirs of the Bethel and Aux Vases Formations and oolitic limestone in the Ste. Genevieve Limestone. All pay zones are Mississippian age and lie at depths of 2,650 to 2,850 feet. Although several of these wells initially pumped more than 100 barrels per day, all were plugged within a few years of completion. A second round of drilling in the early 1980s established renewed production from the same formation. These wells have been longer lived than those of the 1950s, likely as a result of better completion procedures. Cumulative output of the Elba field is listed at 105,215 barrels (Bryan Huff, ISGS, written communication, 2017).

Coal

Two large coal mines have operated in the Ridgway quadrangle. The Willow Lake Mine of Big Ridge, Inc. began extracting the Springfield Coal underground in 2002 and completed operations in November 2012. Their workings underlie more than 10 square miles in the southwestern and west-central parts of the map area. Myers and Chenoweth (2005) mapped outlines of underground mines in the Ridgway quadrangle at 1:24,000 scale. Still active is the Cottage Grove surface mine of Peabody Midwest Mining, which opened in the year 2000. The Herrin Coal is the primary economic target, but the Baker and Danville Coals also have been mined. Approximately 4 square miles in the southwest corner of the quadrangle have been worked out (Myers and Chenoweth, 2005).

Assuming the coal industry in Illinois remains viable, extensive reserves remain in the Ridgway quadrangle. The Herrin and Springfield Coals are both consistently 4 to 5 feet thick, and the deeper Dekoven and Davis Coals, which have never been mined within the quadrangle, are 3 to 5 feet thick across wide areas (Jacobson, 1993). About the only area that needs to be ruled out for coal extraction is the Omaha dome area, which has been densely drilled for oil and gas and many wells are still pumping. The Ridgway fault is an obvious geologic obstacle, as are igneous dikes and sills, but near-surface dikes and sills can be accurately located through magnetic surveys.

Wells used on cross section (west to east):

1. Pinbridge Corp. #1 Wollard, 1650’ NL, 2310’ WL, 7-8S-8E, county # 24382, drilled 1983. Gamma ray/density log.
2. Pinbridge Corp. #2 Mosby, 990’ NL, 2310’ EL, 7-8S-8E, county # 1965, drilled 1984. Electric log.
3. Nation Oil & Duncan #1 Adamson, 2310’ SL, 1650’ WL, 5-8S-8E, county # 2559, drilled 1961. Electric log.
4. Alva Davis #2 Luther Rister, 2310’ NL, 330’ WL, Sec., 4, T8S, R8E, county # 151, drilled 1941. Electric log and partial sample study.
5. Countrymark Energy #6 Stella Rister, 1024’ NL, 1783’ WL, 4-8S-8E, county # 25746, drilled 2015. Electric and gamma ray/density logs.
6. Countrymark Energy #14 Kuder, 330’ SL, 1650’ EL, 33-7S-8E, county # 25757, drilled 2015. Electric and gamma ray/density logs and detailed sample study.
7. George Trust #4 McDaniel, 330’ NL, 330’ WL, 3-8S-8E, county # 2339, drilled 1958. Electric

log.

8. Countrymark Energy #6 Utley, 990' NL, 2310' WL, 3-8S-8E, county # 25718, drilled 2014. Electric and gamma ray/density logs.
9. Heflin Oil #1 Brockschmidt, 990' SL, 330' WL, 1-8S-8E, county # 24390, drilled 1985. Electric and gamma ray/density logs.
10. Exchange Oil #1 Huelsing, 1650' NL, 330' WL, 7-8S-9E, county # 165, drilled 1940. Electric log.
11. Bankston Creek Land Trust #3 Bradley, 990' SL, 990' EL, 6-8S-9E, county # 25557, drilled 2012. Electric and gamma ray/density logs.

Acknowledgements

The authors wish to thank all of the landowners who gave permission and access to their property. We also thank CountryMark Oil Company and the University of Southern Indiana for allowing acess to an igneous rock core. Digital cartography was completed by Jennifer Carrell. The research was funded in part by the U.S. Geological Survey (USGS) National Coperative Geologic Mapping Program under USGS STATEMAP award number G16AC00296. The views and conclusions cotained 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

Bradbury, J.C. and J.W. Baxter, 1992, Intrusive breccias at Hicks Dome: Illinois State Geological Survey, Circular 550, 23 p.

Bristol, H.M., 1975, Structural geology and oil production of northern Gallatin County and southernmost White County, Illinois: Illinois State Geological Survey, Illinois Petroleum 105, 20 p.

Bristol, H.M. and Treworgy, J.D., 1979, the Wabash Valley fault system in southeastern Illinois: Illinois State Geological Survey, Circular 509, 19 p.

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

Cady, G.H., 1919, Coal resources of District V (Saline and Gallatin Counties): Illinois State Geological Survey, Cooperative Mining Series Bulletin 19, 134 p. and 9 plates.

Clegg, K.E., 1955, Metamorphism of coal by peridotite dikes in southern Illinois: Illinois State Geological Survey, Report of Investigations 178, 18 p.

Clegg, K.E. and Bradbury, J.C., 1956, Igneous intrusive rocks in Illinois and their economic significance: Illinois State Geological Survey, Report of Investigations 197, 19 p.

Cluff, R.M., Reinbold, M.L., and Lineback, J.A., The New Albany Shale Group of Illinois: Illinois State Geological Survey, Circular 518, 83 p. and 4 plates.

Currier, L. W., 1920, Igneous Rocks in Weller et al., 1920, The geology of Hardin County, Illinois: Illinois State Geological Survey, Bulletin 41, pp. 237-244.

Denny, F.B., 2005, The Cottage Grove Dike and mafic igneous Intrusions in southeastern Illinois and their relation to regional tectonics and economic resources, M.S. Geology Thesis, Southern Illinois University at Carbondale, 6 tbls, 28 figs., 83 p.

Denny, F.B., Jacobson, R.J., and Nelson, W.J., 2007, Bedrock geology of Harrisburg quadrangle, Saline County, Illinois: Illinois State Geological Survey, Illinois Preliminary Geologic Map IPGM Harrisburg-BG, 2 sheets, scale 1:24,000 and 11-page pamphlet.

Denny, F.B, R.N. Guillemette, J. Mulvaney-Norris, R. Cahill, R.H. Fifarek, J.T. Freiburg, and W.H. Anderson, 2017, Geochemical and Petrographic Analysis of the Sparks Hill Diatreme and its relationship to the Illinois-Kentucky Fluorspar District: Illinois State Geological Survey, Prairie Research Institute, Circular 588, in press.

Eiler J. M, 2001, Oxygen Isotope Variations of Basaltic Lavas and Upper Mantle Rocks, Reviews in mineralogy and geochemistry, vol. 43, no. 1, 319-364.

English, R.M. and Grogan, R.M., 1948, Omaha pool and mica-peridotite intrusives, Gallatin County, Illinois: American Association of Petroleum Geologists, Structure of Typical American Oil Fields, vol. 3, p. 189-212; reprinted as Illinois State Geological Survey, Report of Investigations 130.

Fifarek, R.H., F.B. Denny, L.W. Snee, and D.P. Miggins, 2001, Permian igneous activity in southeastern Illinois and Western Kentucky: Implications for tectonism and economic resources; Geological Society of America, 33(6): A 420.

Hildenbrand, T.G. and Ravat, D., 1997, Geophysical setting of the Wabash Valley fault system: Seismological Research Letters, v. 68, no. 4, p. 567-585.

Hopkins, M.E., 1958, Geology and petrology of the Anvil Rock Sandstone of southern Illinois: Illinois State Geological Survey, Circular 256, 49 p. and 2 plates.

Howard K.F, A.H. Maria, J.A. Dipietro, and W.J. Cashel-Cordo, 2016, Petrography and geochemistry of igneous and metamorphic core samples from the Omaha Dome in southern Illinois, GSA Abs. with Prog., vol. 48, no. 5.

Jacobson, R.J., 1993, Coal resources of the Dekoven and Davis Members (Carbondale Formation) in Gallatin and Saline Counties, southeastern Illinois: Illinois State Geological Survey, Circular 551, 41 p.

Long, K.R., B.S. Van Gosen, N.K. Foley, and D. Cordier, 2010, The principal rare earth elements deposits of the United States—A summary of domestic deposits and a global perspective: U.S. Geological Survey Scientific Investigations Report 2010–5220, 96 p.

Maria, A.H., Dipietro, J.A., and Howard, K.F., 2016, Geochemistry and Sr-Nd isotopoic compositions of Permian ultramafic lamprophyres in southern Illinois, Geological Society of America Abstracts with Programs. Vol. 48, No. 7.

Mariano A.N., 1987, Analytical report on 4 regolith samples and 4 pieces of drill core from Hicks Dome, Hardin County, Illinois: Confidential report to John Lee Carroll, 24 p.

Morehead A.H., 2013, Igneous intrusions at Hicks Dome, southern Illinois, and their relationship to fluorine-base metal-rare earth element mineralization: M.S. Geology Thesis, Southern Illinois University at Carbondale, 17 tbls., 23 figs., 226 p

Myers, A.R. and Chenoweth, C., 2005, Directory of coal mines in Illinois, 7.5-minute quadrangle series, Ridgway quadrangle, Gallatin and Saline Counties: Illinois State Geological Survey, 2 sheets, scale 1:24,000, and 13-page directory.

Nelson, W.J. and Denny, F.B., 2015a, Bedrock geology of Galatia quadrangle, Saline County, Illinois: Illinois State Geological Survey, STATEMAP Galatia-BG, 2 sheets, scale 1:24,000 and 4-page pamphlet.

Nelson, W.J. and Denny, F.B., 2015b, Bedrock geology of Harco quadrangle, Saline, Williamson, and Franklin Counties, Illinois: Illinois State Geological Survey, STATEMAP Harco-BG, 2 sheets, scale 1:24,000 and 4-page pamphlet.

Nelson, W.J. and Denny, F.B., 2016, Bedrock geology of Eldorado quadrangle, Saline County, Illinois: Illinois State Geological Survey, STATEMAP Eldorado-BG, 2 sheets, scale 1:24,000 and 4-page pamphlet.

Nelson, W.J. and Krausse, H.F., 1981, The Cottage Grove fault system in southern Illinois: Illinois State Geological Survey, Circular 522, 65 p. and 1 plate.

Nelson, W.J., and D.K. Lumm, 1984, Structural geology of southeastern Illinois and vicinity: Illinois State Geological Survey, ISGS Contract Grant Report 1984-2, 127 p.

Reynolds, R.L., Goldhaber, M.B., and Snee, L.W., 1997, Paleomagnetic and 40Ar/39Ar from the Grant Intrusive Breccia and comparison to the Permian Downeys Bluff Sill-Evidence for Permian igneous activity at Hicks Dome, Southern Illinois Basin: U.S. Geological Survey, Bulletin 2094-G, 16 p.

Silverman, Marc, Andre J. M. Pugin, Timothy H. Larson, and Robert J. Finley, 2003. Aeromagnetic and surface seismic surveys for dike detection in Illinois coal seams, Saline County, Illinois: Illinois Clean Coal Institute Final Technical Report 02-1/US-2, 21 p.

Sparlin, M.A. and Lewis, R.D., 1994, Interpretation of the magnetic anomaly over the Omaha oil field, Gallatin County, Illinois: Geophysics, v. 59, no. 7, p. 1092-1099.

Taylor S. R. and S.M. McLennan, 1985, The Continental Crust: Its Composition and Evolution Blackwell Scientific Publication, Oxford. 312 p.

Wall F. and A.N. Mariano, 1996, Rare earth minerals in carbonatites: a discussion centered on the Kangankunde Carbonatite, Malawi, in Rare Earth Minerals, edited by A.P. Jones, F. Wall, and C.T. Williams: Chapman and Hall, London p. 193-225.

Zartman, R.E., Brock, M.R., 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

Appendix 1. **EDXRF (major oxide) average of several analyses of an unknown white vein.**

Sample	Na_2O	MgO	Al_2O_3	SiO_2	P_2O_5	SO_3	K_2O	CaO	TiO_2	MnO	Fe_2O_3	Total
41A	3.85	0.68	1.07	17.63	0.03	0.17	0.09	74.10	0.33	0.09	1.26	99.19

All values mass %

EDXRF (trace element) average of several analyses of an unknown white vein.

Sample	Cl	V	Cr	Ni	Cu	Zn	Ga	As	Se	Br	Rb	Sr	Y
41A	784	ND	ND	<11.0	14.1	621	<6.3	13.3	<1.2	3.7	ND	1,901	ND

	Nb	Mo	Ag	Cd	In	Sb	Cs	Ba	La	Ce	Pb	Th	U
	ND	ND	ND	ND	ND	ND	ND	4,073	ND	ND	277	ND	ND

All values mg/kg or ppm, Values between the detection limit and quantitation limit are reported as "less than values", ND = No detection.

Appendix 2. Graphic column of the Stella Robison core from depths of 2,596 feet to 2,615 feet, along with the results of Oxygen and Carbon isotopic analyses and magnetic susceptibility measurements.