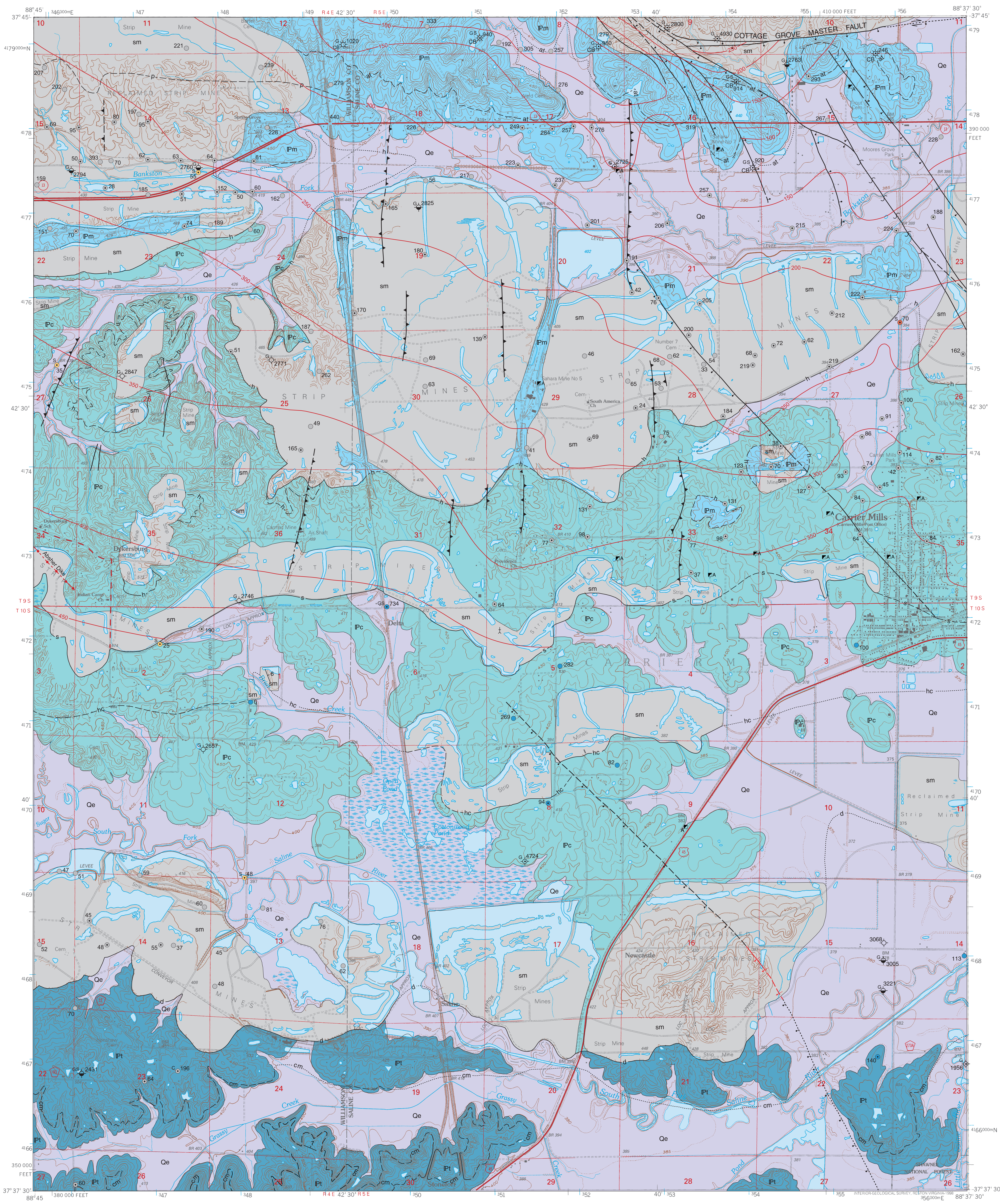
Illinois Department of Natural Resources
ILLINOIS STATE GEOLOGICAL SURVEY
William W. Shilts, Chief

# Bedrock Geology of Carrier Mills Quadrangle

## Williamson and Saline Counties, Illinois

W. John Nelson
2007

Illinois Geologic Quadrangle Map
IGQ Carrier Mills-BG




### EXPLANATION

| | | | | |
|---|---|---|---|---|
| | sm | Surface mines | | |
| Quaternary | Qe | Equality Formation | Pleistocene | |
| Pennsylvanian | Pm (at, p) | McLeansboro Group<br>at, Attila Shale Member<br>p, Piasa Limestone Member | Missourian | |
| Pennsylvanian | Pc (h, s, hc, d) | Carbondale Formation<br>h, Herrin Coal Member<br>s, Springfield Coal Member<br>hc, Houchin Creek Coal Member<br>d, Davis Coal Member | Desmoinesian | |
| Pennsylvanian | Pt (cm) | Tradewater Formation<br>cm, Carrier Mills Shale | Desmoinesian | |

### Symbols

40 Strike and dip of bedding, number signifies degree of dip

Abandoned drift mine

Abandoned shaft mine

Abandoned slope mine

### Drill Holes

from which subsurface data were obtained

Stratigraphic boring

Water well

Engineering boring

Coal boring

Dry hole

Dry hole - show of oil

Gas well

CB Coal bed methane hole

CSG 210 Labels indicate samples (S), geophysical log (G), or core (C). Numeric label indicates total depth of boring in feet. Dot indicates location accurate within 100 feet.

### Line Symbols

dashed where inferred, dotted where concealed

Contact

h Coal subcrop boundary

Normal fault: bar and ball on downthrown side

Fault, type unknown

Thrust fault, sawteeth on upthrown side

Thrust fault, upthrown side unknown

350 Elevation of top of Springfield Coal in feet; contour interval 50 feet

Strike-slip fault

Strike-slip fault, direction of slip unknown

Monocline

Igneous dike

**Note:** Well and boring records are on file at the ISGS Geological Records Unit and are available online at the ISGS Web site.

Note on faults: With the exception of the northwest-trending fault in the southern part of the map area, all faults shown are based on observations in underground mines and/or coal test drilling. Faults are shown where they intersect the Herrin or Springfield Coal and not where they intersect the bedrock surface. Although all faults are "concealed," they are shown with solid lines where accurately located and with dashed lines where approximately located, inferred, or projected through unmined areas.

Base map compiled by Illinois State Geological Survey from digital data provided by the United States Geological Survey. Topography compiled 1959. Planimetry derived from imagery taken 1993. Public Land Survey System and survey control current as of 1996.

North American Datum of 1927 (NAD 27)
Projection: Transverse Mercator
10,000-foot ticks: Illinois State Plane Coordinate system, east zone (Transverse Mercator)
1,000-meter ticks: Universal Transverse Mercator grid system, zone 16

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SCALE 1:24,000

1 1/2 0 1 MILE
1000 0 1000 2000 3000 4000 5000 6000 7000 FEET
1 .5 0 1 KILOMETER

BASE MAP CONTOUR INTERVAL 10 FEET
SUPPLEMENTARY CONTOUR INTERVAL 5 FEET
NATIONAL GEODETIC VERTICAL DATUM OF 1929

Released by the authority of the State of Illinois: 2007

Geology based on data analysis by W.J. Nelson, 2006.

Digital cartography by J. Domier, M. Widener, and M. Bentley, Illinois State Geological Survey.

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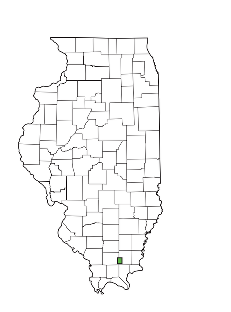
ILLINOIS
DEPARTMENT OF NATURAL RESOURCES

ISGS Illinois State Geological Survey

For more information contact:
Illinois State Geological Survey
615 East Peabody Drive
Champaign, Illinois 61820-6964
(217) 244-2414
http://www.isgs.uiuc.edu



| | | |
|---|---|---|
| 1 | 2 | 3 |
| 4 | | 5 |
| 6 | 7 | 8 |

ADJOINING QUADRANGLES
1 Pittsburg
2 Harco
3 Galatia
4 Crab Orchard
5 Harrisburg
6 Creal Springs
7 Stonefort
8 Eddyville


APPROXIMATE MEAN DECLINATION, 2007

ROAD CLASSIFICATION

Primary highway, hard surface

Secondary highway, hard surface

Light-duty road, hard or improved surface

Unimproved road

Interstate Route
U.S. Route
State Route

## Introduction

This map shows the bedrock geology of the Carrier Mills 7.5-minute Quadrangle. Surficial deposits are not shown, with the exception of the Equality Formation, which occupies level to very gently sloping bottom lands in large areas of the map. Omitted are the wind-blown silt (loess) that mantles all upland areas and the thin and patchy deposits of Illinoian glacial drift that occur mainly in the northern part of the quadrangle.

The primary sources of data used in making this map are drill-hole records and data from coal mines. Bedrock outcrops are small, scattered, and seldom informative. Among borehole records, those of coal test holes are most numerous and generally have accurate logs, albeit lacking in detail. Also valuable are sample logs and geophysical logs from holes drilled for oil, natural gas, and coalbed methane. Bridge borings of the Illinois Department of Transportation provide little information beyond depth to bedrock. Water wells (with one exception) have drillers' logs only; a few of these records are useful.

The Illinois State Geological Survey (ISGS) has nearly a complete collection of coal mine maps for this quadrangle (Myers and Obrad 2004). Maps of underground mines commonly depict faults and, in many cases, include surveyed elevation data on the coal seam that was mined. ISGS geologists (including the author) visited many of these mines over the years and made copious notes on geologic conditions. Such notes are available for public inspection in the ISGS Library.

## Structure

The Carrier Mills Quadrangle is situated along the southern margin of the Illinois Basin. Bedrock strata thus dip northward into the basin at an average rate of about 70 feet per mile, which equates to a gradient of 1.3% or less than 1° of dip. Structure contours on the map depict the elevation of the top of the Springfield Coal. Not enough data are available to enable construction of an accurate structure map on older rocks.

### Cottage Grove Fault System

Most faults in the map area belong to the Cottage Grove Fault System. This fracture system runs more than 70 miles west-northwest from Gallatin County on the east to Randolph County on the west. It is an intricate system, comprising a main or "master fault" that generally runs east-west, accompanied by a multitude of northwest-trending faults that form an en echelon pattern along the master fault. Some en echelon faults have been intruded by ultramafic igneous dikes, of which the Absher dike, at the western edge of the quadrangle, is an example. Seismic reflection profiles demonstrate that the Cottage Grove master fault is nearly vertical and extends into Precambrian crystalline basement (Duchek et al. 2004). The Cottage Grove is interpreted as a right-lateral, strike-slip fault system that was active primarily in Late Pennsylvanian and Early Permian time (Nelson and Krausse 1981).

A segment of the Cottage Grove master fault crosses the northeastern corner of the map area. The structure is best described as a sharp faulted flexure with overall displacement down to the south. Individual faults have small throws, ranging from less than an inch to about 12 feet. I had an opportunity to examine the master fault zone in the Sahara No. 20 Mine in 1979. The coal was intensely fractured and dropped about 40 feet in elevation in a distance of 100 feet. The largest fault had 6 to 8 feet of throw and bore two sets of striations, one vertical and the other nearly horizontal. The vertical set appeared to be younger.

Many northwest-trending faults were encountered in underground mines. The largest recorded throw is 27 feet on a fault near the air shaft of Peabody No. 44. This was a normal fault dipping 45° southwest. Another normal fault at Mine 44 had 5 feet of throw and a dip of 60°. Most of the faults that appear on mine maps have displacements of less than 5 feet. In many cases, the downthrown side or direction of dip changes along the strike of a fault. Such changes in dip and throw are characteristic of oblique-slip faults.

Faults examined in the Sahara No. 22 Mine (NW 1/4 Sec. 23, T9S, R5E) showed an intricate combination of normal, thrust, and bedding-plane shear (figs. 1 and 2). There were multiple sets of oblique striations and multiple episodes of movement. In one place, the fault had a wide zone of pulverized coal and rock but no vertical offset. Evidently the major movement was strike-slip.

A northwest-striking fault in the southeastern part of the quadrangle was exposed in the Will Scarlet (Secs. 15 and 16, T10S, R5E) surface mine where it took the form of a sharp, fractured monocline with the Dekoven Coal locally pulverized. Small fault surfaces bore vertical striations. Total throw was only 10 feet, but the fault extends for several miles, offsetting the outcrop of the Houchin Creek Coal on the northwest and Tradewater strata near the southeastern corner of the map.

### Absher Dike

An igneous dike known as the Absher dike was uncovered in the Delta mine at the western edge of the map in Sec. 34, T9S, R4E. There were two parallel dikes visible in the mine 1.5 to 17 feet wide and about 50 feet apart, running N 40°W and dipping vertically. The rock was mica peridotite, an ultramafic rock composed of olivine, pyroxene, biotite, pyrite, and calcite. The Springfield Coal was altered to a coke-like substance along the dike margins (Clegg 1955). This dike is one of many similar intrusive bodies associated with the Cottage Grove Fault System in southeastern Illinois (Clegg and Bradbury 1956, Nelson and Krausse 1981, Nelson and Lumm 1987).

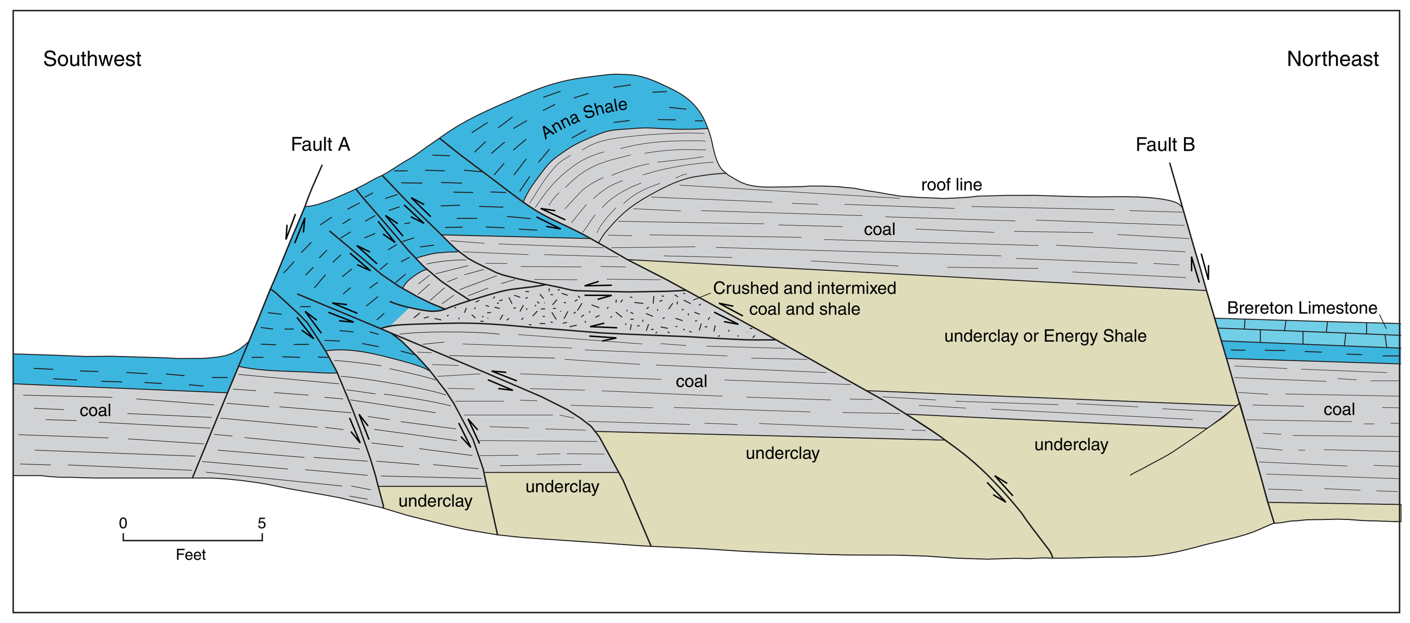



**Figure 1** Sketch of fault zone observed underground in 1982 in the Sahara No. 22 Mine in Sec. 22, T9S, R5E. Two large normal faults (A and B) outline a horst that strikes N 30° W. Within the horst is a multitude of reverse, thrust, and bedding-plane faults, some accompanied by thick zones of contorted and pulverized coal. Cross-cutting relationships indicate multiple episodes of movement. Also notice that the Anna Shale is much thicker within the horst than on its northeast margin, implying a component of strike-slip. Many small faults and structures were omitted. Sketch by author.

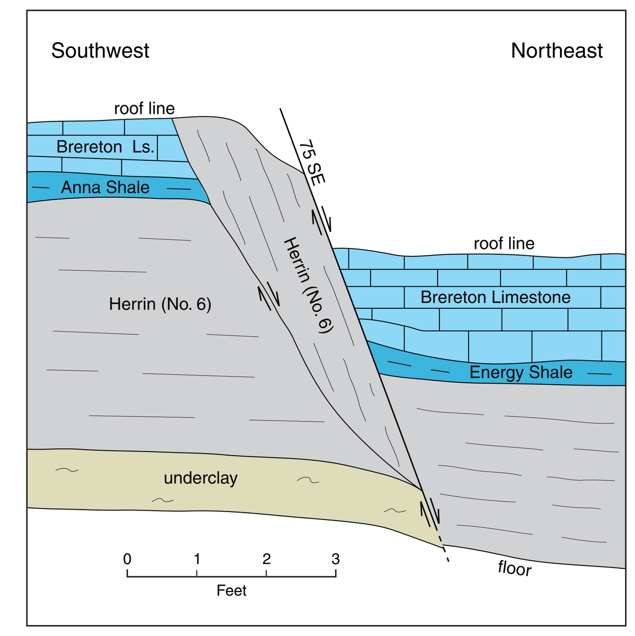



**Figure 2** Sketch of fault in another part of the Sahara No. 22 mine; this is Fault B of figure 1. At first glance it appears to be a normal fault, but the slice of crushed, contorted coal along the fault is thrust upward relative to the coal on either side. Also, notice that the coal is overlain by Energy Shale northeast of the fault, but Anna Shale on the southwest. Such juxtaposition of different rock units virtually demands strike-slip. This is a simplified illustration. Sketch by D.K. Lumm.

### Small Thrust Faults

Surface and underground coal mines in the Carrier Mills Quadrangle encountered a number of small thrust faults that trend north-south. ISGS geologists have observed several of these faults; other faults were reported by coal company officials and marked on mine maps. Although the largest recorded displacement is about 5 feet, these faults were disruptive to mining by creating bad roof and wet conditions. Faults dip at low angles (less than 45°) and commonly merge with bedding planes in the coal or roof. Some dip east; others dip west. Commonly, single faults marked on mine maps prove to be intricate zones of small east- and west-dipping thrusts.

These small thrusts, encountered elsewhere in southern Illinois and western Kentucky, appear unrelated to the Cottage Grove Fault System. As Nelson and Bauer (1987) hypothesized, they are aligned with the present-day tectonic stress field and may be of geologically recent origin.

## Economic Geology

### Coal

Coal mining has been an important industry in the area for nearly a century. Although no mines are currently active, plenty of minable coal remains. Comprehensive maps and accounts of past mining are available (Myers and Obrad 2004).

Essentially all strippable Herrin Coal was removed in two large mines, the AMAX Coal Co. Delta Mine and Sahara Coal Co. Mine 6. Two underground mines, Sahara No. 7 and No. 22, together removed Herrin Coal beneath about 430 acres. Herrin Coal available for underground mining remains under 5 or 6 square miles in the quadrangle. These reserves are somewhat hemmed in by past mining, and faults will be encountered in the northeastern corner of the area. The largest unbroken tract of Herrin that is likely free of faults is in Secs. 7 and 18, T9S, R5E. Given its normal roof of black shale and limestone, the Herrin is expected to have a high (3 to 5%) sulfur content.

The Springfield Coal is largely mined out, except in the northwestern part of the quadrangle, where underground reserves remain. These reserves are tightly hemmed in by past mining, but are probably free of large faults. The Springfield Coal, where overlain by gray Dykersburg Shale 20 feet or thicker, has a relatively low (less than 2%) sulfur content.

The Houchin Creek Coal was surface-mined by Peabody Coal Company in Secs. 4 through 8, T9S, R5E and in the much smaller D.D. Thomas Mine in Sec. 1, T9S, R4E. The coal varies from a little less than 2 feet to 2.5 feet thick and has a high sulfur content. Strippable Houchin Creek under thin overburden probably remains west of the Thomas Mine.

The Survant Coal ranges from 1 to 3 feet thick and is split into two seams separated by shale and claystone. The Davenport shaft mine in Sec. 9, T10S, R5E, may have extracted this coal in 1908–1910. Although Myers and Obrad (2004) reported the Davis Coal was mined, the shallow depth (60 feet) points to the Survant.

The Colchester Coal is generally too thin to be worth mining in Saline County, although Peabody Coal Company reportedly allowed employees to mine this seam for their own use when it was exposed during overburden removal at the Will Scarlet Mine.

Nearly all strippable Davis and Dekoven Coals were removed in Peabody's Will Scarlet Mine (this mine was originally owned by Stonefort Coal Company, whose owner, a Mr. Sherwood, named all his mines after Robin Hood characters). The only underground mining of record comprises small slope and drift mines near the outcrop of the coal. Thus, the Davis and Dekoven seams show potential for underground mining north of Will Scarlet. The Davis Coal is generally the thicker of the two, averaging about 3.5 feet and reaching 4.2 feet thick. Davis Coal of similar thickness currently is being mined underground in Kentucky. Jacobson (1993) mapped resources and described the geology and mining conditions of Dekoven and Davis Coals in Saline County.

The Mt. Rorah Coal has been mined in small open pits and shallow drift mines, including one in the SE 1/4 of Sec. 24, T10S, R4E. The Mt. Rorah reaches 3 feet thick but more commonly is less than 2 feet thick and may be split by shale. The Murphysboro Coal attains 5 feet thick in some drill holes, but is highly lenticular in this area. Under present economic conditions, the Mt. Rorah and Murphysboro seams are better targets for coal-bed methane extraction than for mining.

### Coal Bed Methane

Five coal bed methane wells recently have been drilled in the northern part of the Carrier Mills Quadrangle, and more are operating in neighboring quadrangles. These wells represent the first commercial extraction of coalbed methane in Illinois. Complete details are rather sketchy. Most wells were drilled into the middle part of the Tradewater Formation (below Delwood coal zone) but completed only through 50-foot intervals encompassing either Dekoven and Davis or Mt. Rorah and Murphysboro Coals. These wells were completed by setting casing, perforating the casing, hydrofracturing, and treating with acid. Water must be pumped continually to stimulate gas flow. One well was drilled into an abandoned mine in the Springfield Coal to tap accumulated mine gas.

The five coal bed methane wells within the map area all were drilled into or close to faults, which was undoubtedly intentional, because faults should provide extensive pathways for gas flow.

Among Illinois counties, Saline County has long been known for gassy coal mines, probably due to several factors, including higher rank coal, igneous activity, and prevalence of faulting. Vertical faults can tap gas from multiple coal seams. Considering all coal seams from Danville through Delwood, the net coal thickness in the quadrangle is 30 to 35 feet. Extracting methane provides a dual benefit, producing a resource and removing gas to benefit future underground mines. Coal bed methane extraction in Saline County is poised for growth.

### Oil and Gas

Two wells in the northern part of the quadrangle (Sec. 9, T9S, R5E) encountered natural gas in the Tar Springs Formation (Mississippian; formation not shown). One of these wells was shut in and apparently never produced; the other produced for 4 years and then was abandoned. A number of other oil and gas test holes have been drilled in the quadrangle. Several of these encountered shows of oil, but none advanced production. The two deepest tests were Brehm No. 1 Ozment in Sec. 9, T9S, R5E (4,930 feet) and C. & F. Parker No. 1 Fee in Sec. 8, T10S, R5E. Both reached Middle Devonian carbonate rocks and have been plugged and abandoned.

Producing oil fields occur in several neighboring quadrangles, but their outputs are small. Carrier Mills lies along the southern limit of historic oil production in Illinois. It is likely that hydrocarbons that originally were present largely escaped up-dip to the outcrop in the Shawnee Hills south of the area or escaped vertically via fault zones.

## References


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 J.C. Bradbury, 1956, Igneous intrusive rocks in Illinois and their economic significance: Illinois State Geological Survey, Report of Investigations 197, 19 p., 1 plate.

Denny, F.B., R.J. Jacobson, and W.J. Nelson, 2007, Bedrock geology of Harrisburg Quadrangle, Saline County, Illinois: Illinois State Geological Survey, Illinois Preliminary Geologic Quadrangle Map, IPGM Harrisburg-BG, 2 sheets, 1:24000, 11-page report.

Duchek, A.B., J.H. McBride, W.J. Nelson, and H.E. Leetaru, 2004, The Cottage Grove Fault System (Illinois Basin): Late Paleozoic transpression along a Precambrian crustal boundary: Geological Society of America Bulletin, v. 116, no. 11/12, p. 1465–1484.

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., 5 plates.

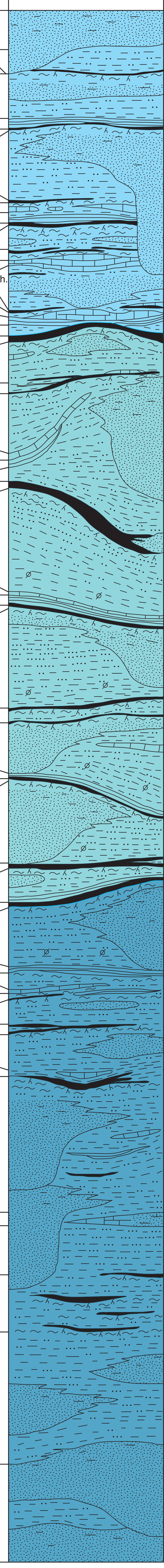
Myers, A.R., and J.M. Obrad, 2004, Directory of coal mines in Illinois, 7.5-minute quadrangle series, Carrier Mills Quadrangle, Saline and Williamson Counties: 71 p., 3 maps, 1:24,000.

Nelson, W.J., and R.A. Bauer, 1987, Thrust faults in southern Illinois Basin—Result of contemporary stress?: Geological Society of America Bulletin, v. 98, no. 3, p. 302-307.

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

Nelson, W.J., and D.K. Lumm, 1987, Structural geology of southeastern Illinois and vicinity: Illinois State Geological Survey, Circular 538, 70 p., 2 plates.


| SYSTEM | SERIES | FORMATION | MEMBER | THICKNESS (FEET) | UNIT |
|---|---|---|---|---|---|
| PENNSYLVANIAN | MISSOURIAN | McLeansboro Group undivided (210 max.) | Trivoli Sandstone | 40 max. | A |
| | | | Lake Creek Coal | 0–0.4 | B |
| | | | | 30–35 | C |
| | | | Attila Shale | 3–7 | D |
| | | | Pond Creek Coal | 0.3–1.7 | E |
| | | | | 45–55 | F |
| | DESMOINESIAN | | De Graff Coal | 0–1 | G |
| | | | Piasa Limestone | 2–5 | H |
| | | | | 6–11 | I |
| | | | Danville Coal | 1.0–2.5 | J |
| | | | | 10–15 | K |
| | | | Allenby Coal | 0–0.8 | L |
| | | | Bankston Fork Ls. | 3–10 | M |
| | | | Anvil Rock Ss./Lawson Sh. | 30–47 | N |
| | | | Conant Ls., Jamestown Coal | 0–1, 0–1 | O |
| | | | Brereton Limestone | 0–8 | P |
| | | | Anna Shale | 0–5 | Q |
| | | | Energy Shale | 0–9 | R |
| | | Carbondale (325–375) | Herrin Coal | 4.5–7.0 | S |
| | | | | 20–40 | T |
| | | | | 0.5–2.0 | U |
| | | | Briar Hill Coal | 10–50 | V |
| | | | St. David Limestone | 0–5 | W |
| | | | Turner Mine Shale | 0–3 | X |
| | | | Dykersburg Shale | 7–80 | Y |
| | | | Springfield Coal | 2–10 | Z |
| | | | | 40–75 | AA |
| | | | Hanover Limestone | 0.5–1.5 | BB |
| | | | Excello Shale | 4–6 | CC |
| | | | Houchin Creek coal | 1.8–2.2 | DD |
| | | | | 45–70 | EE |
| | | | Survant Coal | 1–3 coal 7–12 shale | FF |
| | | | | 35–70 | GG |
| | | | Mecca Quarry Shale | 3–4 | HH |
| | | | Colchester Coal | 0.5–1.5 | II |
| | | | Palzo Sandstone | 25–55 | JJ |
| | | | | 2.0–3.5 | KK |
| | | | | 6–30 | LL |
| | | | Dekoven Coal | 2.0–3.5 | MM |
| | | | | 3.2–4.2 | NN |
| | | Tradewater (450 plus) | Davis Coal | 30–60 | OO |
| | | | Carrier Mills Shale | 2.5–5.0 | PP |
| | | | | 5–15 | QQ |
| | | | Stonefort Limestone | 0–2 | RR |
| | | | Wise Ridge Coal | 0–1 | SS |
| | | | | 15–25 | TT |
| | | | Mt. Rorah Coal | 1–3 | UU |
| | | | | 30–40 | VV |
| | | | Murphysboro Coal | 0–5 | WW |
| | | | | 80–100 | XX |
| | | | Mitchellsville Ls. | 0–10 | YY |
| | | | | 30–50 | ZZ |
| | | | Delwood coal zone | zone 20–50 coal 2–6 | A3 |
| | | | | 70–90 | B3 |
| | ATOKAN | | Murray Bluff Sandstone | 60 + | C3 |



**A Trivoli Sandstone** Light to medium gray, fine- to medium-grained, micaceous litharenite, carbonaceous, shaly laminae common. Caps hills at northern edge of quadrangle. Lower contact erosional. As much as 15 feet of gray, silty shale intervenes between sandstone and Lake Creek Coal.

**B Lake Creek Coal** Bright-banded to dull and shaly, thin but widely persistent.

**C Unnamed interval** Greenish gray, rooted claystone directly underlies coal, grading downward to sandstone, which in turn grades downward to gray siltstone, medium gray silty shale, and dark gray clay shale at the base.

**D Attila Shale** Black, hard, thinly fissile.

**E Pond Creek Coal** Bright-banded, thin but widely persistent.

**F Unnamed interval** Rooted claystone directly underlies coal. Remainder of interval comprises gray shale, siltstone, and fine-grained sandstone. These strata commonly coarsen upward, but in one borehole they fill a channel that is incised below the Bankston Fork Limestone.

**G De Graff Coal** Bright-banded to dull and shaly, overlooked on most drillers' logs. A few feet of gray shale or mudstone separate the De Graff from the Piasa Limestone.

**H Piasa Limestone** Logs describe it as buff to light gray and "finely crystalline." In nearby areas, it is lime mudstone to packstone with brachiopods, echinoderm fragments, and fusulinids.

**I Unnamed interval** Green and gray mottled clay-shale at the top grades downward to fissile shale that is dark gray, becoming black near the base.

**J Danville Coal** Bright-banded.

**K Unnamed interval** Rooted claystone underlies Danville Coal and grades downward to gray shale and siltstone. Lenticular sandstone occurs in lower part of interval.

**L Allenby Coal** Either a single layer of bright-banded coal or two to three stringers of impure coal or carbonaceous shale, separated and underlain by mudstone.

**M Bankston Fork Limestone** Light gray to buff, sublithographic to very finely granular, with scattered fossils that include echinoderm fragments, brachiopods, and fusulinids. Inclusions of green clay are common. Bedding may be nodular to massive; thin interbeds of shale or claystone are present. The type locality, along Bankston Creek in NW NE NW of Sec. 19, T9S, R5E, has been obliterated by surface mining.

**N Anvil Rock Sandstone and Lawson Shale** These members are lateral facies equivalents. Shale is medium to dark gray and commonly interlaminated with light gray siltstone and sandstone. Planar and ripple lamination are common. Sandstone is light gray, fine-grained litharenite with abundant mica, carbonaceous debris, and interstitial clay. The interval may coarsen upward from shale at the base to sandstone at the top, or fine upward from shale at the top to sandstone at the base, having an erosional lower contact. Thin layers of shaly coal and carbonaceous shale containing abundant *Cordaites* (land plants) occur locally near the top of the interval.

**O Conant Limestone and Jamestown Coal** The Conant is dark gray, argillaceous lime mudstone to fossiliferous wackestone that is thin and lenticular, grading laterally to calcareous shale. The coal varies from bright-banded to dull and shaly; it is more widespread than the limestone. Rooted claystone as thick as several feet may separate the Jamestown from the Brereton Limestone.

**P Brereton Limestone** Limestone is medium-dark to dark gray, argillaceous lime mudstone to wackestone with fusulinids and brachiopods. The rock commonly exhibits nodular or hummocky layering separated by thin partings of dark gray shale. This unit is strongly lenticular.

**Q Anna Shale** The shale is black, hard, and brittle, highly fissile, pyritic, and phosphatic. Septarian limestone and dolomite concretions up to several feet in diameter are numerous. Locally there is a thin basal layer of shaly limestone or fossil shell debris. Fossils are not reported within the map area, but elsewhere in Illinois the Anna contains conodonts, fish remains, and inarticulate brachiopods. The unit is lenticular, and the lower contact sharp.

**R Energy Shale** This shale is medium to dark gray, well-laminated but not highly fissile, slightly silty, and sideritic. Fossils are not reported. The Energy Shale occurs as small lenses between Anna Shale and Herrin Coal and, in places, fills "rolls" developed within the uppermost layers of the Herrin.

**S Herrin Coal** Bright-banded, pyritic, contains several persistent claystone partings, of which the "blue band," 0.7 to 2.0 feet above the base, is most conspicuous. Large masses of coal balls were encountered in the Sahara No. 6 surface mine. These were composed of brown limestone that replaced the peat before it was coalified. In places the entire thickness of the seam was 90% limestone across areas as large as 100 feet in diameter.

**T Unnamed interval** Directly beneath the Herrin Coal is claystone that is olive-gray to greenish gray, heavily slickensided and rooted. Limestone and siderite nodules are common in the lower part. The claystone grades downward to siltstone, which in turn may grade to either shale or sandstone. Locally a thin layer of shaly limestone lies directly on the Briar Hill Coal.

**U Briar Hill Coal** A single seam or as many as 4 thin stringers of impure coal and carbonaceous, fissile shale that contains abundant fossil plants. Coal stringers are separated by and overlie claystone through intervals as thick as 10 feet.

**V Unnamed interval** Includes claystone beneath the Briar Hill Coal and a variable succession of shale and sandstone. No details are available.

**W St. David Limestone** Medium to dark gray, argillaceous lime mudstone to wackestone; fossils include pectenoid pelecypods.

**X Turner Mine Shale** Black, hard, thinly fissile, pyritic, and phosphatic. Absent where Dykersburg Shale is thick.

**Y Dykersburg Shale** Medium to dark gray, well laminated; generally coarsens upward. The upper part contains numerous laminae and thin interbeds of light gray siltstone and sandstone ("zebra rock") and exhibits planar, ripple, and slumped lamination. Highly rhythmic or "varved" lamination is common. The lower part changes to a darker gray, slightly silty shale or clay-shale containing siderite nodules. Plant fossils are abundant in the lower Dykersburg. They include fossil tree stumps rooted in the top of the Springfield Coal and flat-lying logs as large as 5 feet wide and 50 feet long.

**Z Springfield Coal** Bright-banded, generally low in sulphur, lacks persistent claystone partings. In underground mines the coal bed undulates strongly, forming "hills" and "valleys" with as much as 40 feet of local relief. Also common are large "rolls" or erosional channels where the upper layers of coal are replaced by siltstone. Large areas of coal too thin to mine and/or split with clastic partings was encountered in mines near Carrier Mills. Areas seem to define a sinuous, channel-like feature that trends northeast to southwest. This feature may be an offshoot of the main Galatia channel, which completely removes the Springfield Coal a few miles east of the map area (Denny et al. 2007).

**AA Unnamed interval** At the top is claystone that is greenish-gray to olive-gray, rooted, and slickensided. The claystone is underlain locally by limestone, and elsewhere by siltstone to fine-grained sandstone that grades downward to dark gray, sideritic clay shale.

**BB Hanover Limestone** Dark gray, shaly, nodular to massive.

**CC Excello Shale** Black, hard, highly fissile, well-jointed, contains small calcite and apatite bands and nodules and large septarian limestone concretions. Conodonts are present and pyritized shell "hash" occurs at the base.

**DD Houchin Creek Coal** Bright-banded; contains numerous pyrite lenses and laminae.

**EE Unnamed interval** Claystone at the top is greenish gray, rooted, and slickensided. The lower part contains small carbonate nodules and irregular fractures lined with calcite and siderite. The claystone grades downward to sandstone that is light gray and very fine to fine-grained, interlaminated with shale and siltstone and locally burrowed. The sandstone in turn grades downward to siltstone, silty shale, and dark gray clay-shale that contains siderite nodules, pyrite "trails" (after plants?), fish scales, and small pelecypods and brachiopods.

**FF Survant Coal** Two benches of coal are separated by claystone, shale, and siltstone. The upper coal bench is generally bright-banded, whereas the lower commonly grades downward to laminated black shale that contains *Cordaites* and other plant remains along with root traces, fish remains, coprolites, and *Lingula*. The upper coal bench generally has an underclay, whereas the lower bench may lack an underclay.

**GG Unnamed interval** Considerable lateral variation. In some places, there is a single upward-fining succession having claystone at the top grading downward to siltstone and sandstone that has an erosional lower contact. Elsewhere are two upward-coarsening sequences, the upper about 20 feet thick and the lower 15 to 50 feet thick. Shale at the base of the lower sequence contains brachiopods, gastropods, echinoderm fragments, and marine fossils. Between the two sequences is a bed of marine limestone up to 4 feet thick. This dark gray wackestone is burrowed and contains abundant brachiopods, gastropods, and echinoderm fragments. It is very argillaceous and intergrades with calcareous shale.

**HH Mecca Quarry Shale** Black, hard, highly fissile, pyritic, contains small apatite nodules.

**II Colchester Coal** Upper part is normally bright-banded; where the coal is thick, the lower part commonly grades to interlaminated coal and carbonaceous shale.

**JJ Unnamed interval** At the top is claystone that is greenish gray to olive-gray, heavily rooted, and slickensided. The claystone commonly grades downward through silty shale and siltstone to sandstone (Palzo Sandstone Member) that is fine- to coarse-grained, ripple-laminated to cross-bedded, and has an erosional contact marked by basal conglomerate of shale, siderite, and coal pebbles. Elsewhere the interval coarsens upward from dark gray, sideritic clay shale at the base through silty shale and siltstone to fine sandstone.

**KK Dekoven Coal** Bright-banded, moderately pyritic, no persistent clastic partings.

**LL Unnamed interval** Rooted claystone underlies the Dekoven Coal. Below this is lenticular sandstone and gray silty shale and siltstone.

**MM Unnamed black shale** The upper part is moderately fissile and contains a variety of brachiopods, gastropods, pelecypods, echinoderm fragments, and burrows. This grades to the lower portion that is hard and highly fissile, containing conodonts, *Orbiculoidea*, and *Lingula*.

**NN Davis Coal** Bright-banded, moderately pyritic, no persistent clastic partings.

**OO Unnamed interval** Claystone beneath the Davis is greenish to brownish gray, slickensided, and rooted. Downward it grades to shale that contains root traces and irregular siderite masses. This in turn grades downward through gray silty shale and siltstone to sandstone that is very fine- to medium-grained micaceous litharenite having abundant interstitial clay. The sandstone is cross-bedded to massive in the lower part and has an erosional contact marked by basal conglomerate of rounded siderite pebbles and coal stringers.

**PP Carrier Mills Shale** Black, hard, highly fissile, well-jointed; contains large septarian limestone concretions. Fossils include the pelecypod *Aviculopecten*. Locally the shale grades to thin, canneloid coal at the base. The lower contact is sharp.

**QQ Claystone** Olive-gray to greenish gray, massive and slickensided; roots not clearly evident. Small limestone nodules are common. One or more coal stringers or carbonaceous shale horizons are present.

**RR Stonefort Limestone** Medium gray lime mudstone to wackestone is argillaceous and nodular to massive. Fossils include echinoderm fragments, ostracods, and *Spirorbis*.

**SS Wise Ridge Coal** Bright-banded to dull and shaly, discontinuous. In some drill holes, lies shale that yields high gamma-ray readings is at about the position of the coal.

**TT Unnamed interval** Generally rooted claystone is at the top, underlain by sandstone that grades downward to siltstone and shale.

**UU Mt. Rorah Coal** Bright-banded, pyritic; commonly split into two coal benches separated by claystone up to several feet thick.

**VV Unnamed interval** Generally rooted claystone is at the top, underlain by sandstone that grades downward to siltstone and shale. Lower 5 to 10 feet is dark gray to black, thinly laminated, carbonaceous shale that contains plentiful plant fossils. In some boreholes, limestone occurs at or just above the Murphysboro Coal.

**WW Murphysboro Coal** Bright-banded to dull and shaly, commonly split with shale (such as the overlying unit). This seam is strongly lenticular.

**XX Unnamed interval** Widely variable lithology. In some holes, this interval is almost entirely sandstone, comprising at least two stacked channel-fill sequences. In other holes, the interval is mostly gray shale and siltstone but may include thin, lenticular coal, black shale, and limestone.

**YY Mitchellsville Limestone** Light gray to buff; contains brachiopods and echinoderm fragments, sandy and silty; grades laterally to calcareous sandstone.

**ZZ Unnamed interval** Mostly gray shale and siltstone, with lenticular sandstone. In most boreholes this interval coarsens upward.

**A3 Delwood coal zone** Bright-banded to dull and shaly. As many as four coal beds, each a few inches to at least 3 feet thick, occur within the interval. They are separated by claystone, shale, and siltstone.

**B3 Unnamed interval** Mostly gray shale and siltstone, with lenticular sandstone.

**C3 Murray Bluff Sandstone** Light gray to brown, iron-rich, very fine to coarse, typically a sublitharenite with less mica and carbonaceous debris than found in younger sandstone.