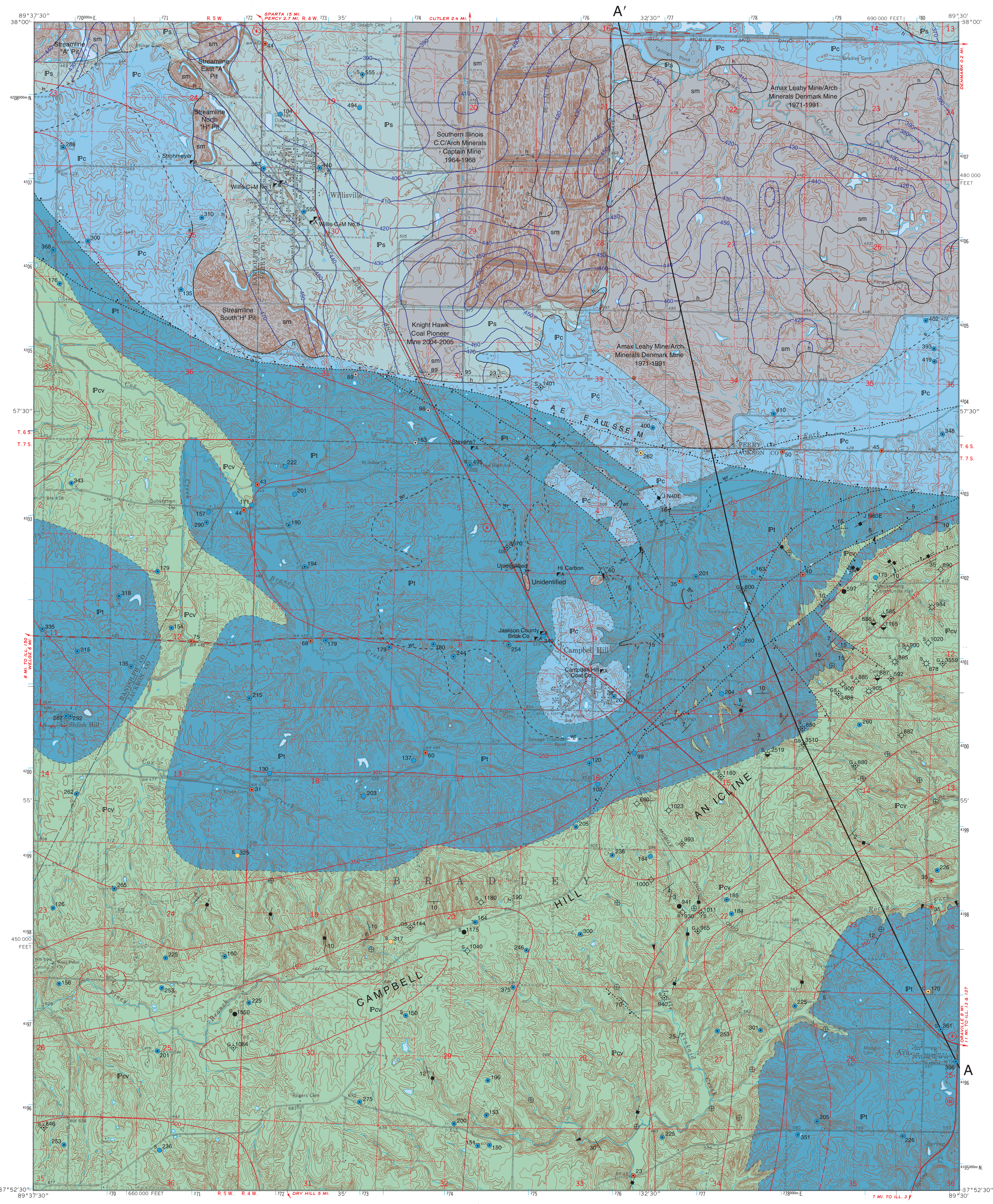
Bedrock Geology of Willisville Quadrangle

Jackson, Perry and Randolph Counties, Illinois

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

Illinois Preliminary Geologic Map
IPGM Willisville-BG

W. John Nelson
2005



EXPLANATION

	sm	Surface mine (coal)	
Quaternary	Q	Quaternary (cross section only)	Holocene and Pleistocene
Pennsylvanian	Ps	Shelburn Formation	Desmoinesian
	Unconformity		
	Pc	Carbondale Formation h, Herrin Coal Member s, Springfield Coal Member	Desmoinesian
	Unconformity		
	Pt	Tradewater Formation wr, Wise Ridge Coal Bed	Desmoinesian / Atokan?
	Pcv	Caseyville Formation	Morrowan

Symbols

- 20 — Strike and dip of bedding; number indicates degree of dip
- Horizontal bedding
- Vertical joints
- Multiple joints
- Outcrop of special note, where contact, map unit, or fault was well exposed at time of mapping
- A — Shaft mine (abandoned)
- A — Slope mine (abandoned)
- Drift mine (abandoned)

Drill Holes

from which subsurface data were obtained. Numbers indicate total depth of boring in feet.

- Stratigraphic boring (ISGS)
- Water well
- Engineering boring
- Coal boring
- Oil well
- Dry hole
- Dry hole - show of oil
- Dry hole - show of oil and gas
- Gas well
- Other boring
- CSG — Boring with samples (S), geophysical log (G), or core (C); dot indicates location accurate within 100 feet

Line Symbols

dashed where inferred, dotted where concealed

- Contact
- Normal fault: bar and ball on downthrown side
- 440 — Elevation of top of Herrin Coal (top of Carbondale Formation), contour interval 10 feet
- 440 — Elevation of base of Kinkaid Limestone, contour interval 50 feet
- A—A′ — Line of cross section

Note: This is a subcrop map, showing bedrock surface with all Quaternary deposits removed. Geology shown as it was prior to surface mining.

Base map compiled by Illinois State Geological Survey from digital data provided by the United States Geological Survey. Topography by photogrammetric methods from aerial photographs taken 1965. Field checked 1968.

North American Datum of 1927 (NAD 27)
Projection: Transverse Mercator
10,000-foot ticks: Illinois State Plane Coordinate system, west 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
NATIONAL GEODETIC VERTICAL DATUM OF 1929

Released by the authority of the State of Illinois: 2005

Geology based on field work and well-log analysis by W.J. Nelson, 2004–2005.

Digital cartography by T. Goeppinger, Illinois State Geological Survey.

This Illinois Preliminary Geologic Map (IPGM) is a lightly edited product, subject to less scientific and cartographic review than our Illinois Geological Quadrangle (IGQ) series. It will not necessarily correspond to the format of IGQ series maps, or to those of other IPGM series maps. Whether or when this map will be upgraded depends on the resources and priorities of the ISGS.

ILLINOIS DEPARTMENT OF NATURAL RESOURCES

1905-2005 ISGS Illinois State Geological Survey

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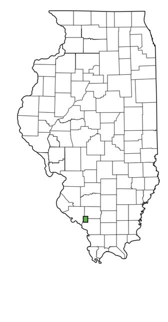
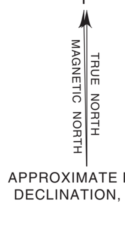


1	2	3
4		5
6	7	8

ADJOINING QUADRANGLES
1 Steeleville
2 Percy
3 Pinckneyville
4 Welge
5 Ava
6 Rockwood
7 Raddle
8 Oraville



APPROXIMATE MEAN DECLINATION, 2005

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

What this map shows and how it was made

This is a map of the bedrock formations in the Willisville Quadrangle. It depicts the rock layers as they would appear if all soil, glacial deposits, and other non-rock surficial materials were removed. These surficial materials (of Quaternary age) range in thickness from zero in places where bedrock is at the surface, to more than 140 feet. In large areas of the quadrangle, particularly the north and west, no rock is exposed at the surface.

Making this map required combining information from natural outcrops, man-made rock exposures in coal mines, and data from wells and boreholes. Rock outcrops are numerous in the east-central and southern parts of the quadrangle. With landowners' permission, I searched out and described rock exposures, found chiefly along streams. My observations were supplemented by those of previous ISGS geologists, dating back to the 1920s and catalogued in the Survey's library. Early notes provide information on rocks that are no longer visible due to landsliding and stream siltation, as well as those in areas I was unable to visit.

Survey files also contain notes made by geologists who visited active coal mines. The notes contain many observations on coal seams and enclosing strata along with faults and other disturbances to the strata. Included are notes I made during visits to the large Captain and Leahy surface mines, now abandoned and reclaimed.

The Survey also possesses logs of several hundred coal-test borings in the map area. Because most of these records are proprietary, they are not plotted on the map; but they were used - along with other information - to draw structure contours on the Herrin Coal in Perry County. Another source of coal structural data are maps of the abandoned underground mines at Willisville. More densely spaced, but proprietary coal-test brings encompass an area of several square miles north of Campbell Hill. These allowed very accurate mapping of coal outcrops and faults.

Water wells are a good source of geologic information throughout the quadrangle. The accuracy and detail of the drillers' logs are much higher than is generally the case in Illinois. Samples (rock chips or cuttings) from some are on file, and I examined them for additional control. Well locations provided by drillers are seldom precise, generally given only as a quarter-quarter-quarter of a section or 10-acre tract. Wherever possible, I ascertained well locations by field inspection and conversations with homeowners.

Test holes for oil and gas are another valuable source of information. These are concentrated in the old Ava-Campbell Hill oil and gas field in the east-central part of the map area. Holes drilled prior to the 1940s lack geophysical logs, but many have sample logs made by ISGS geologists. Locations of early holes are imprecise, e.g. SE 1/4 NE 1/4, in spite of elevations being stated to tenths of a foot, indicating that the wells were surveyed. Locations are impossible to verify because all wells have been plugged and abandoned with surface pipe removed. In some cases, the elevation and topographic maps allow educated guesses as to well locations. Wells drilled after 1940 are accurately located, and most have geophysical and/or sample logs.

Bridge borings made by the Illinois Department of Transportation generally penetrate a few feet into bedrock. Their logs provide information on Quaternary sediments, depth to bedrock, and the type of rock at the bedrock surface.

To assist drawing the bedrock geologic map, I first constructed a map showing elevation of the bedrock surface beneath Quaternary deposits. This map depicts ridges and stream valleys as they existed prior to glaciation, and enables better plotting of bedrock formation contacts in areas where there are concealed by glacial drift.

Structure

Regional picture

The Willisville quadrangle is situated near the southwestern margin of the Illinois Basin. Across the Mississippi River in Missouri lies the Ozark Dome, a persistently high area that was uplifted repeatedly through geologic time while the Illinois Basin was warped downward. The Illinois Basin subsided intermittently throughout, as well as following the Pennsylvanian Period. In consequence, Pennsylvanian and older rock strata of Jackson, Perry, and Randolph Counties have been tilted gently toward the northeast. Faults and folds greatly modify regional dip in the Willisville Quadrangle.

One of southern Illinois' major fault zones, the Cottage Grove Fault System, crosses the Willisville Quadrangle. Willisville is near the known western end of the Cottage Grove, but the area farther west has not yet been mapped in detail. The Cottage Grove extends about 70 miles east-southeast from the Willisville Quadrangle, into western Gallatin County. It is a complicated structure having faults and folds of diverse orientations. The principal elements within the map area are:

- The main or master fault, having the largest displacements
- The Campbell Hill Anticline and associated faults
- Smaller faults having mostly northwest orientations

Master fault

The Cottage Grove master fault follows the Jackson-Perry county line in the eastern part of the map area, gradually bending to a west-northwest heading as it enters Randolph County. It appears to be a single fault in the central part of the map area, bifurcating toward east and west. As indicated on the map, the northern side is downthrown by 80 to 170 feet, displacement reaching a maximum near the point where S.R. 4 crosses the fault.

The master fault is entirely concealed by surficial materials. It tends to underlie valleys, especially on the east where Brushy Creek follows the northern branch. Drill-hole records are the only source of information within the quadrangle. Farther east the master fault is much better known from outcrops, exposures in surface and underground coal mines, and geophysical data (Nelson and Krausse 1981; Duchek et al. 2004). These data show that the fault is typically a high-angle reverse fault. There is also strong evidence of strike-slip, or horizontal displacement; rocks north of the fault having moved eastward relative to rocks south of the fault.

Campbell Hill Anticline

This upward fold of rock strata enters the east-central edge of the quadrangle and trends southwest, curving gradually to west-southwest. As shown by structure contour lines on the map, the anticline has 200 to 300 feet of relief. The crest is smoothly arched and both limbs have average dips of less than 2 degrees. The southern limb becomes nearly flat near the southwest corner of the map area.

The northwest flank of the anticline east of Campbell Hill is faulted. Most of the faults trend northeast, apparently merging with the master fault. These faults outline narrow upthrown wedges or slices of rock. Details are poorly known because of limited outcrops. The best fault exposure is along a small stream in the SW NW SE, Sec. 2, T7S, R4W. A ledge of brecciated Caseyville sandstone strikes N 55-60°E and dips vertically, indicating a vertical fault surface. Other faults, poorly exposed, also appear to dip vertically or nearly so. On the cross section I interpreted the zone as a high-angle reverse fault that branches into a keystone-shaped wedge near the surface. This arrangement, called a "positive flower structure", is characteristic of the Cottage Grove and other strike-slip fault systems (Duchek et al. 2004).

Northwest-trending faults

A group of relatively small northwest-trending faults is present north of Campbell Hill. They are mapped from densely spaced coal-test drilling; several faults are visible in outcrops. Displacements range from less than 20 feet to about 50 feet. Exposed faults dip steeply (70 to 80°) northeast and southwest, and appear to be normal faults. The best exposures are: stream bed at north edge of old strip mine near center of south line, Sec. 4; and stream bank, NW SE SE of Sec. 4, both in T7S, R4W. Another fault, trending nearly east-west, is visible in a gully just east of S.R. 4 on the border between Secs. 8 and 9. This fault has small offset.

Steeply tilted Caseyville sandstone was observed in a stream bed in the NW NE NE, Sec. 28, T7S, R4W. Bedding strikes N 50°W and dips 65 to 70° southwest. Such a steep dip is strong evidence for a northwest-trending fault nearby. This locality is south of the crest of the Campbell Hill Anticline.

Small northwest-trending faults, numbering in the hundreds, accompany the Cottage Grove master fault throughout its length. Their oblique, en echelon arrangement is strong evidence for strike-slip along the master fault (Nelson and Krausse 1981).

Structure in Perry County

Structure contours showing elevation of the top of the Herrin Coal are shown in Perry County. Lines are based on coal-test drill holes spaced an average of 660 feet (200 m) apart. The contour pattern is irregular, featuring odd-shaped and diversely oriented highs and lows. The only overall trend is a regional, very gentle basin-ward dip toward the northeast.

Inspection of well logs reveals that in many cases, the interval between the Springfield and Herrin coals increases in structural depressions. Thicknesses of the coal seams themselves do not change in any consistent fashion.

I observed a syncline in the active Leahy Mine in 1981. It ran north-south, having a gentle west limb and a steeper east one. The Herrin Coal rose about 50 feet on the east limb in a horizontal distance of 500 feet. This structure is reflected by the drilling data as illustrated by contours on the map.

The gentle, irregular folds in the Herrin Coal are more likely the product of depositional or compactional irregularities, than of tectonic deformation.

In 1981 I observed a shear zone within the Herrin Coal extending throughout the active pit of the Leahy Mine. Other ISGS geologists, Harold Gluskoter in 1972 and H.-F. Krausse in 1975, saw horizontal shear zones in the coal in other parts of this mine. I also saw sheared Herrin coal in the Captain Mine, north of the Leahy Mine (in the Percy quadrangle). Shearing takes the form of crushed or pulverized coal containing larger, rotated and slickensided coal fragments. The crushed zone occurs at various levels in the seam and ranges from a hairline to 0.7 feet thick. Such shearing is probably bedding-plane slippage induced by the Cottage Grove Fault System, south of the Leahy Mine. Similar shearing within coal is documented elsewhere along the fault system (Nelson and Krausse 1981).

Also seen in the Leahy Mine was a group of small reverse or thrust faults trending approximately N 30°W. Some dipped northeast although the larger ones dipped southwest, having the southwest sides upthrown. Throw varied from less than an inch to about 2 feet.

Clastic dikes were fairly common in the Springfield Coal. Dikes were vertical or inclined and generally a few inches wide. The filling was either sandy clay or hard, fine-grained, pyritic sandstone. Because no sandstone overlies the Springfield Coal in this area, the sand must have come from below. Such sandstone dikes might be earthquake-induced liquefaction structures or sand blows that developed before the peat was lithified.

Economic Geology

Coal

Coal mining has been an important industry in the Willisville area for more than a century. The Willis Coal and Mining Co. No. 1, a shaft mine in the Herrin Coal at Willisville, opened in 1896 and operated until 1924. The adjacent Willis Coal and Mining Co. No 8 mine operated from 1903 to 1937 under four different owners. Between 1936 and 1950, the Southwestern Illinois Coal Company's Streamline mine strip-mined Herrin and Springfield coal from several pits west of Willisville. Southwestern opened its Captain surface mine east of Willisville in 1964 and removed Herrin and Springfield Coal from nearly three square miles of ground by 1968. The Captain Mine shifted its operations north of the Willisville quadrangle after 1968 and worked until 1984, leading the state in coal production for a number of years. The AMAX Coal Co. Leahy Mine, later Arch Minerals Denmark Mine, removed Herrin and Springfield Coals from 6½ square miles east of the Captain Mine between 1971 and 1991. Currently, Knight Hawk Coal's Pioneer Mine is stripping Herrin Coal about two miles southeast of Willisville. This is the only active mine in the map area.

The Wise Ridge Coal was extracted in several small underground and surface mines near Campbell Hill between the 1920s (and possibly earlier) and the early 1960s. Information on most of these mines is sketchy. The largest operation probably was the Campbell Hill Brick Company, later named Jackson County Brick Co., which was active from 1925 to 1953. Claystone underlying the coal was used to manufacture bricks; the coal served as fuel for the kilns.

Smith (1958) mapped strippable coal resources of an area that includes the Willisville Quadrangle. Since publication of that report, the Herrin Coal has been almost entirely mined out within the map area. The Springfield Coal has been extensively removed also, although a sizeable tract remains between the Streamline Mine on the west and Captain Mine on the east. This coal could be mined underground; however, abandoned underground workings of the Willis Coal & Mining Co. cover much of the area. These workings in the Herrin Coal, 15 to 35 feet above the Springfield, undoubtedly are filled with water and/or gas. In Jackson County, the Wise Ridge Coal is 3 to 4 ½ feet thick and underlies several square miles. The Mt. Rorah Coal is 1 to 3 ½ feet thick and lies only 5 to 7 feet below the Wise Ridge in the same area. Much of this coal lies under less than 50 feet of overburden, making it accessible to strip mining. Smith (1958) estimated more than 11 million tons of resources in the Wise Ridge Coal alone. Negative factors include probable high ash and sulfur content of both seams, along with markedly variable thickness and presence of many faults. Since the 1950s, several coal companies have leased and thoroughly drilled this tract without opening mines.

The Murphysboro Coal is 5 feet thick or more and is currently being mined within 4 miles east of the Willisville Quadrangle. However, this seam is less than 1 foot thick in most of the Willisville Quadrangle. Water-well logs suggest the Murphysboro may be 3 feet or thicker north of the Cottage Grove master fault in the eastern part of the map area. Here it lies several hundred feet below the surface, accessible only to underground mining. More drilling is required to assess its potential for mining.

A coal seam less than 1 foot to about 4 feet thick is widely present near the base of the Tradewater Formation. Shaw and Savage (1912) and Smith (1958) incorrectly identified the seam as Murphysboro. Small underground mines south of Ava worked the basal Tradewater coal during the early 20[th] century. Field notes and drilling records indicate that coal thicker than 3 feet is highly localized. This seam probably has negligible potential for development.

Oil and Gas

The Ava-Campbell Hill oil and gas field was developed along the crest of the Campbell Hill Anticline, east and southeast of Campbell Hill, during the early 20[th] century. According to Root (1928), drilling before and during 1916 showed presence of oil and gas; one household used natural gas piped from a well. The Mid-Egypt Oil and Gas Company commenced systematic drilling in 1918. Incomplete records (ISGS open files) indicate that approximately 20 wells were completed as oil producers and 27 as gas producers. As of midsummer 1925, Root estimated cumulative oil production of 20,000 to 25,000 barrels and daily gas production of 450,000 to 500,000 cubic feet. By this time, the field was already in decline. The last of the original wells was capped in 1943, but new test holes continue to be drilled in the area.

The lion's share of oil and gas output came from the sandstone of the Cypress Formation (Chesterian; Mississippian). Where productive, the sandstone was 25 to 40 feet thick and lay 750 to 900 feet below the surface (Root, 1928). Small amounts of oil were produced from deeper sandstone lenses in the Paint Creek, Aux Vases, and Yankeetown Formations. A considerable amount of gas was obtained from the Tar Springs Formation (Chesterian) at depths of 515 to 560 feet.

There is practically no information on completion techniques, production from individual wells, or physical characteristics of reservoir rocks. The early wells presumably were drilled with cable tools. Some wells were shot with nitroglycerine. No cores were taken; cuttings from some have been described by geologists and are on file at the ISGS samples library. Few wells drilled before 1940 were accurately located (or if they were, their locations were not made public).

The Ava-Campbell Hill field contained at least 8 separate pools. They are arrayed along the crest of the anticline like beads on a string. Dry holes are commonly up-structure from producers, indicating reservoirs are compartmentalized by pinch-outs or permeability barriers. Production figures cited by Root (1928) indicate that even in its heyday, this field was marginally economic. Wasteful drilling practices (many wells drilled practically on top of one another) and primitive completion techniques must have cut deeply into oil recovery.

Deeper prospects have been thoroughly tested and found lacking. Five holes penetrated the Kimmswick (Trenton) Limestone, the oldest formation that has ever produced oil in Illinois. The Stanolind #1 Leiner in Sec. 20, T7S, R4W, reached the St. Peter Sandstone at total depth of 4,144 feet. Several Trenton tests were drilled on good structural highs with modern equipment and evaluated with modern geophysical logs. None of these holes encountered economic quantities of oil or gas.

William Nuxoll's #1 Luehr in Sec. 25, T7S, R5W, was recently (2001) completed as a marginal oil producer. The Luehr well recovered 2 barrels of oil per day from a stray sandstone in the Paint Creek Formation (Chesterian) at a depth of 950 feet. The Luehr well is several miles west of the old Ava-Campbell Hill field, but still on the Campbell Hill Anticline. Nuxoll drilled a second well higher structurally on the anticline, but that well was dry.

Ground Water

Drilled wells are the primary source of water for homes, farms, businesses, and communities in the Willisville quadrangle. Although some shallow domestic wells are completed in glacial drift, most wells, including the Ava, Campbell Hill, and Willisville municipal wells, tap aquifers in bedrock.

The majority of wells produce from sandstone in the Caseyville Formation. Output of 10 to 30 gpm (gallons per minute) from a 6-inch well is normal. Eight-inch wells typically produce 50 to 100 gpm. In Perry County, several 4½ - to 6-inch wells are producing 50 to 60 gpm from the Caseyville. Higher flow in Perry County partially compensates for the fact that wells here have to be drilled as deep as 500 feet to reach the Caseyville.

In the southern and western parts of the map area, many water wells are finished in the Degonia Sandstone of Chesterian (Mississippian) age, below the Caseyville. Water volume from the Degonia is comparable to that from the Caseyville; in most cases 10 to 40 gpm.

Several homeowners told me that their wells, completed in the Caseyville Formation, yielded poor-tasting water or water with high iron or mineral content. Two or three reported that their wells, when deepened from the Caseyville to the Degonia, produced better tasting water. A couple of geologic factors may be relevant. One is that sandstones of the Caseyville, as seen on the outcrop and in well samples, often contain more iron oxide that the Degonia Sandstone. Another factor is that the Caseyville Formation comes to the surface and receives its water recharge along the Campbell Hill Anticline. The fact that many homes (with septic systems) and farms with livestock are in the recharge area, creates the potential for ground water contamination in the Caseyville Formation. The Degonia Sandstone, in contrast, crops out only to the south of the Willisville Quadrangle. The Degonia recharge area thus lies largely in the Shawnee National Forest, an area with few homes and farms.

Clay

Clay was formerly mined underground by the Campbell Hill/Jackson County Brick Company, and used to make bricks. The clay that was mined lay directly beneath the Wise Ridge Coal, which also was taken for use as fuel to fire the kilns. Mine and kilns operated from 1925 to 1953. During this same time period, coal and clay were mined together at many places in Illinois to support brick and ceramic industries. Due to changing trends in the construction business, the demand for locally produced bricks declined and these local producers went out of business. The old brick works, at the junction of S.R. 4 and Brick Plant Road, now lie in ruins. Should the market return for Illinois clay, the Campbell Hill area has abundant resources. Claystone beds beneath the Wise Ridge and Mt. Rorah Coals together range from 8 to 13 feet thick, and as in the past, the coal is available as fuel. Both could be mined from shallow open pits at many sites near Campbell Hill.

Acknowledgments

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The views and conclusions contained in this document are those of the authors and should not be interpreted as necessarily representing the official policies, either expressed or implied, of the U.S. Government.

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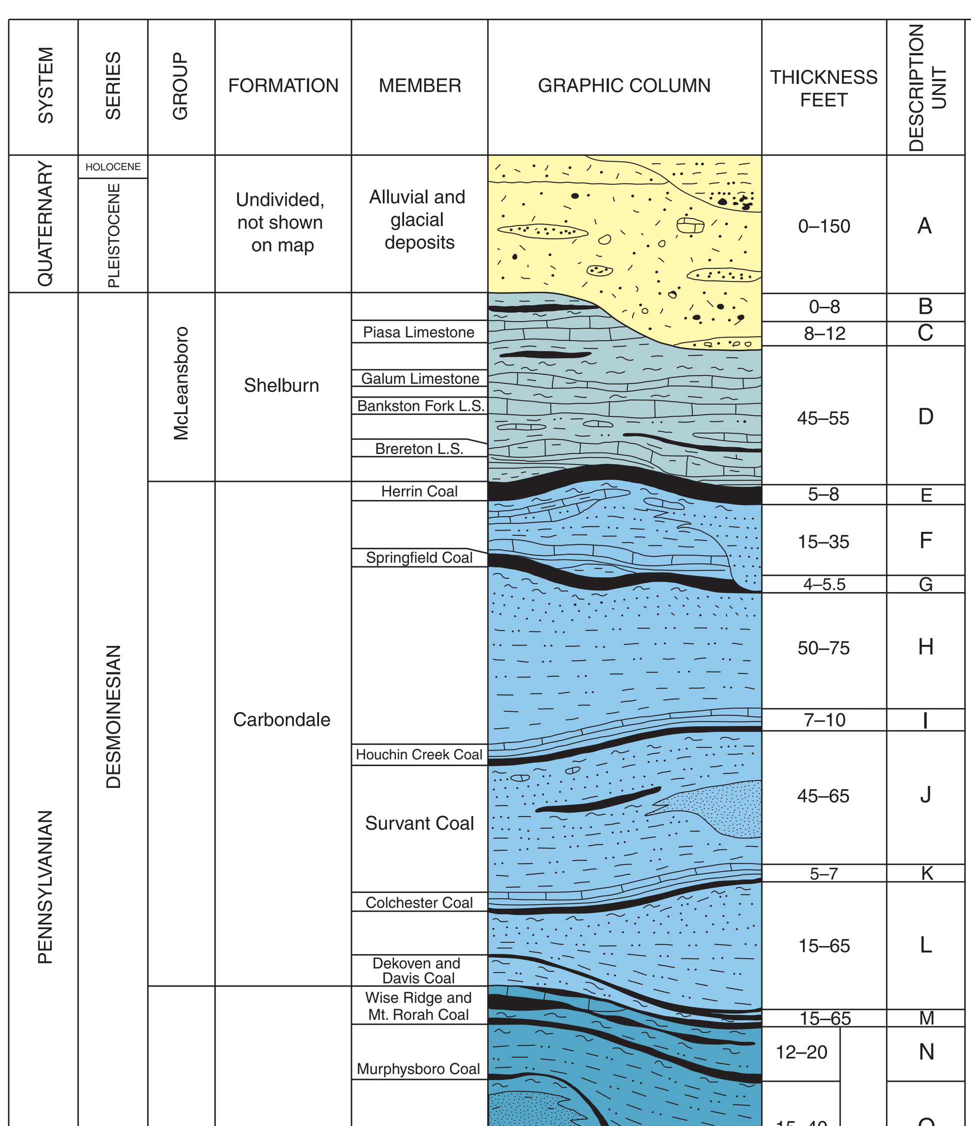

A Quaternary deposits Not shown on bedrock geologic map. The principal deposits are alluvium, loess, and glacial drift. Alluvium comprises deposits on flood plains of modern streams and ranges from a few feet to about 30 feet thick. Alluvium is largely silt and sand that is more or less stratified and contains varying amounts of gravel and rock fragments. Loess is silt that mantles all upland areas and commonly is 5 to 15 feet thick. The silt varies in color from yellowish gray to yellowish and reddish brown. It has a moderate clay content and lacks layering except that represented by soil horizons. Loess was deposited by the wind during the Wisconsinan Age (about 10,000 to 75,000 years ago). Glacial drift in the study area is dominantly massive silt and silty clay that contains a few percent of scattered sand, gravel, and rocks. The color is dark bluish to olive gray when fresh, changing to yellowish brown in weathered deposits. The erratic rocks range from cobbles to boulders more than ten feet across and represent sandstone, limestone, granite, and a host of other rock types. Lenses of stratified sand and gravel occur in the drift and supply water to domestic wells. Ranging from a few feet to 140 feet thick, drift is present throughout the study area, except where eroded along streams and steep hillsides. It was deposited by glaciers that overrode the area during the Illinoian Age, which ended about 125,000 years ago.

B Shale, coal, and claystone About 5 feet of gray shale overlies 1 foot of coal and 2 feet of underclay or claystone, as recorded in water wells in Secs. 18 and 19, T6S, R4W.

C Piasa Limestone Light gray, buff or cream-colored limestone that weathers yellowish orange. It is dolomitic lime mudstone to wackestone with crinoid stems, brachiopods, fusulinids, and other marine fossils.

D Limestone, shale, mudstone, and thin coal In descending order, gray shale and mudstone 7 to 17 feet thick is at the top. One well log records a 2-foot coal seam, the Danville Coal, near the top of this interval. Galum Limestone is about 2 to 5 feet thick; logs lack detail. Bell et al. (1931), who named the Galum from exposures a few miles north of map area, described it as yellow, earthy, nodular limestone, the upper part of which appears weathered and grades into claystone with limestone nodules. Below Galum Limestone is 5 to 7 feet of dark greenish gray mudstone to weakly laminated shale. Bankston Fork Limestone is 3 to 6 feet thick and similar in lithology to the Piasa Limestone. Below the Bankston Fork is 10 to 15 feet of gray to black, silty, calcareous shale that contains thin interbeds, lenses, and concretions of argillaceous limestone. The Jamestown Coal Member, less than 0.5 foot of shaly coal or carbonaceous shale, lies within this interval. The Brereton Limestone is 2 to 7 feet thick, generally dark gray, argillaceous lime mudstone to wackestone with fusulinids, brachiopods, and other marine fossils. Bedding can be massive to nodular or hummocky. Below the Brereton is the black, fissile, hard, highly organic, phosphatic Anna Shale Member, 0 to 6 feet thick. Large spheroidal limestone concretions are common; fossils include fish scales. The Energy Shale at the base of the interval is gray, weakly laminated, slickensided shale or mudstone that contains mytiloid and pectenoid pelecypods. Less than 6 feet thick, the Energy occurs as small lenses and fills erosional "rolls" in the upper part of the Herrin Coal.

E Herrin Coal Bright banded coal contains several thin layers of dark gray claystone, the most persistent being the "blue band" found 0.5 to 1.5 foot above the bottom. Fusain laminae are common; pyrite occurs as lenses, nodules, laminae, and cleat facings. Calcite and kaolinite also line cleat surfaces. Seam ranges from 5 to 8 feet thick but is 5.5 to 6.5 feet in most places. The Herrin Coal is largely mined out within the map area.

F Shale, limestone, sandstone, and claystone Directly beneath Herrin Coal is rooted, slickensided olive-gray to dark gray claystone 2 to 5 feet thick. Next is limestone 0 to 10 feet thick: light to medium gray, ranging from argillaceous lime mudstone to skeletal grainstone, massive to nodular, commonly silty to finely sandy. Marine indicators include common brachiopods, crinoid fragments, and glauconite. The upper part of the limestone is brecciated and bears root traces. In places the limestone grades to claystone containing irregular carbonate nodules. Next downward is an interval of shale, siltstone and sandstone that commonly coarsens upward and displays planar, wavy, and flaser lamination. Locally channels are developed that scour down to, or even through the Springfield Coal. The St. David Limestone, 2 to 5 feet thick, is medium to dark gray, argillaceous lime mudstone to packstone that commonly contains brachiopods. It can be either a single bed or two layers of nearly equal thickness separated by a shale parting. The Turner Mine Shale is 1.5 to 5 feet thick and rests directly on the Springfield Coal in most places. This is a black, hard, highly fissile, highly organic shale that contains large spheroidal limestone concretions. A few lenses of gray, weakly laminated Dykersburg Shale occur between the Springfield and Turner Mine Members.

G Springfield Coal Bright banded, lacks clastic partings but has fusain laminae along with laminae, lenses, and cleat-facings of pyrite. Clastic dikes filled with sandstone or sandy mudstone are common. Except in the area surrounding Willisville, the Springfield Coal has been removed by strip mining.

H Claystone, sandstone, siltstone, and shale Directly beneath the Springfield Coal is olive-gray, massive, slickensided and rooted claystone 3 to 6 feet thick. This grades downward to gray siltstone or fine, shaly sandstone10 to 20 feet thick. The sandstone in turn grades downward through siltstone and silty shale to dark gray clay-shale that contains many siderite nodules. Near the base the shale contains pyrite "trails" (after plants?) and pectenoid pelecypods.

I Limestone, shale, and coal The Hanover Limestone Member is 1 to 2 feet of dark gray, dolomitic lime mudstone that is dense, massive, and contains scattered shell fragments. The Excello Shale Member, 4 to 6 feet thick, is black, fissile, hard, highly organic shale that is pyritic and contains large spheroidal limestone concretions. The Houchin Creek Coal is less than 2 to about 3 feet thick and is a bright-banded coal without clastic layers. Together, the Hanover, Excello, and Houchin Creek produce a characteristic double-spike signature on resistivity logs.

J Claystone, sandstone, siltstone, shale, and local coal Beneath the Houchin Creek is rooted claystone several feet thick, having carbonate nodules and slickensides. This passes downward to siltstone or fine-grained, shaly sandstone, which commonly grades in turn downward back to siltstone and shale. The Survant Coal Member is locally present near the middle of the interval; it is 1 foot or thinner and rests on rooted claystone. A cored test hole showed sandstone below the Survant, having an erosional lower contact and basal conglomerate of siderite and shale clasts. Fossil plants occur in the lower part of the interval. At the base the shale becomes calcareous and fossiliferous, grading into underlying limestone.

K Limestone, shale, and coal The Oak Grove Limestone, 1.5 to 2.0 feet thick, is dark gray, argillaceous lime mudstone to wackestone that contains brachiopods, pelecypods, gastropods, and crinoid fragments. The Mecca Quarry Shale Member is a black and highly organic shale, similar to the Anna, Turner Mine, and Excello Shales. All of these units produce extra-high or "hot" readings on gamma-ray logs. The Colchester Coal is a bright-banded seam about 0.5 to 1.5 feet thick.

L Claystone, sandstone, siltstone, and shale Rooted claystone 3 to 5 feet thick underlies the Colchester. This grades downward to siltstone or shaly sandstone that may contain lenses of impure limestone. The sandstone in turn grades downward through siltstone to dark gray silty shale or clay shale.

M Dekoven and Davis Coals The interval consists of two to three coal layers, each a few inches to about 2 feet thick; separated by claystone, shale, and siltstone. In Perry County the entire interval is as thin as 5 feet and comprises coal layers separated by thin, rooted claystone layers. Near Campbell Hill the Dekoven and Davis are separated by as much as 12 feet of clastic strata, grading from rooted claystone at the top through sandstone and siltstone to shale at the base.

N Wise Ridge and Mt. Rorah Coals Beneath the Davis Coal is 1 to 10 feet of rooted claystone, silty mudstone, and siltstone. Next is the lenticular Seahorne Limestone Member, which is correlative with the Stonefort Limestone of southern Illinois. The limestone is gray, weathering yellowish orange, lime mudstone to wackestone that contains crinoid stems, gastropods, brachiopods, and fusulinids. It is nodular to massive, and in places exhibits conglomeratic texture. Thin black, fissile shale may underlie the limestone. Next is the Wise Ridge Coal, previously called Campbell Hill or Seahorne Coal and mined in small surface and underground operations near Campbell Hill. Here the coal is as thick as 5 feet, but elsewhere in the map area (as elsewhere in Illinois) the seam rarely exceeds 1 foot thick. Rooted claystone 5 to 7 feet thick underlies the Wise Ridge and formerly was used for making bricks. A cored test hole in Perry County showed the claystone to have green and red mottling, a distinctive feature of this particular interval in southern Illinois. The Mt. Rorah Coal, 1 to 3.5 feet thick, is bright-banded coal that has a persistent band of hard claystone about 1.3 feet above the base. The entire interval thickens northward.

O Claystone, shale, and siltstone Rooted claystone 3 to 6 feet thick underlies the Mt. Rorah. This grades downward to shale that commonly has alternating bands of light and dark gray, the latter being very carbonaceous. Coal stringers, fossil plants, and weakly developed soil horizons are common. The shale becomes darker and more fissile downward, grading in places to a black, fissile, highly organic shale similar to Anna and Turner Mine Shales. The Murphysboro Coal is thin or absent in the Jackson County portion of the quadrangle but thickens to as much as 7 feet near the northeast corner of the map area. Thicker coal appears to correlate with a thicker interval between Murphysboro and Mt. Rorah Coals, suggesting greater subsidence during deposition.

P Shale, mudstone, siltstone, sandstone, and coal The lower Tradewater Formation contains a variety of lenticular rock units difficult to trace laterally. Approximately half is shale, siltstone, and mudstone, medium to dark gray, massive to laminated, micaceous and carbonaceous. The other half is sandstone that is mostly gray, weathering brown, very fine to medium-grained, lithic arenite to sublitharenite with plentiful mica and interstitial clay. This sandstone contains much siderite and iron oxide and commonly weathers rusty on the outcrop. Near the base is strongly hematitic and limonitic sandstone that contains scattered coarse sand and quartz granules. A widespread layer of shaly coal or carbonaceous shale containing well-preserved fossil plants is at the base of the Tradewater. Coal is generally less than 1 foot thick, but reportedly reached 4 feet thick where it was mined near the southeast corner of the map area. Shaw and Savage (1912) incorrectly identified this coal as the Murphysboro; the coal outcrop as they mapped it cannot be verified due to glacial cover and lack of drilling. Lower contact appears to be sharp and in some places erosional.

Q Sandstone, siltstone, shale, conglomerate, and thin coal Sandstone is prevalent and is white to light gray, very fine to coarse quartz arenite (95% or greater quartz sand). This rock weathers yellowish gray to orange and contrasts with the impure, micaceous sandstone of the Tradewater; although Caseyville sandstone can be thoroughly permeated with iron oxide. Well rounded quartz granules and small pebbles(to about 1 inch) are common but not universally present. Siltstone and shale are medium to very dark gray, finely micaceous and well laminated. Shale commonly contains laminae of light gray, very fine sandstone. Conglomerate, which occurs as lenses, consists of quartz pebbles along with (in some cases) pebbles of chert, quartzite, sandstone, ironstone, and other rock types, all in a matrix of sandstone. Coal seams in the Caseyville are thin (1 foot or less), localized, and commonly shaly. The Caseyville is thinnest in the western part of the map area, where it rests on the Kinkaid Limestone. Eastward the Caseyville thickens markedly and fills valleys scoured deeply into Mississippian rocks.

R Limestone and minor shale Limestone is gray to brown, somewhat argillaceous and cherty, wackestone to packstone containing echinoderm fragments and other fossils. Gray to greenish-gray shale 3 to 5 feet thick is at the base of the unit.

S Limestone Light to medium-dark gray and brownish gray, largely wackestone to packstone. Some sample studies indicate light gray, oolitic and crinoidal grainstone in the upper part.

T Sandstone, shale, and siltstone At the top is generally about 10 feet of greenish gray shale or claystone that locally shows reddish mottling. This grades downward through siltstone to the sandstone that comprises the bulk of the unit. Sandstone is white to light gray, very fine to fine-grained quartz arenite, containing occasional partings of dark gray shale. Interbeds of gray silty shale and siltstone occur in the lower part of the Degonia in some wells.

U Limestone, dolomite, shale, and sandstone Upper part is mostly shale, with thin interbeds of limestone and dolomite. Shale is greenish to olive-gray clay shale that is calcareous and thinly fissile. Dolomite is light brown and sublithographic. Lower part of Ford Station is limestone commonly 10 to 15 feet thick. Tygett Member is sandstone, light gray, very fine to fine quartz arenite with laminae and interbeds of dark gray shale, commonly grading downward to silty shale.