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ILLINOIS STATE GEOLOGICAL SURVEY
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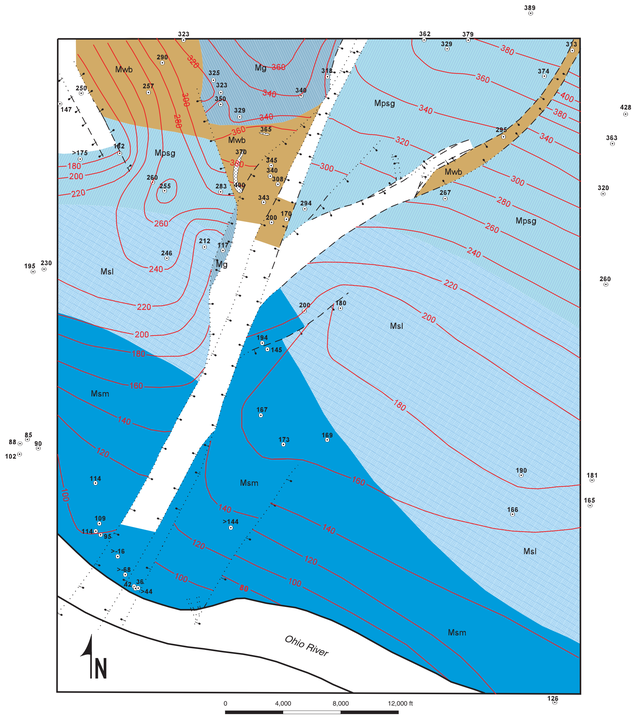
Illinois Geologic Quadrangle Map: IGQ Metropolis-SG, Sheet 2 of 2
2002

SURFICIAL GEOLOGY

Metropolis Quadrangle, Massac County, Illinois

W. John Nelson, John M. Masters, and Leon R. Follmer



Units

- Mg — Golconda Formation
- Mwb — West Baden Sandstone
- Mpsg — Paoli and Ste. Genevieve Limestones
- Msl — St. Louis Limestone
- Msm — Salem Limestone
- (blank) — Unknown, or no data

Data Type

- 186 — Control well, with elevation of bedrock surface in feet. The symbol ∘ signifies well did not reach bedrock at or below the specified elevation.
- 370 — Bedrock outcrop, with elevation in feet
- 180 — Contour line, elevation of top of bedrock in feet. Contour interval 20 feet.
- Fault that displaces bedrock surface, with ball and bar on downthrown side. Dashed where approximately located, dotted where inferred or projected.

Figure 1 Bedrock geology of the Metropolis Quadrangle.

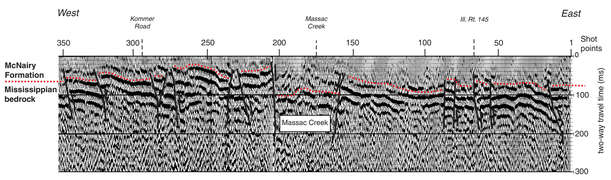


Figure 2 Interpreted seismic profile along Rosebud Road. The dark bands are "reflectors" that represent sediment and rock layers. They are much broken and tilted, indicating an intricate fracture zone associated with the Massac Creek Graben. Many more faults are evident on this seismic profile than can be mapped from outcrops and well data. Line of section is shown on geologic map, sheet 1. Note that the vertical scale is in the two-way travel time of seismic energy in milliseconds. This travel time scale is not linear and does not translate directly to distance.

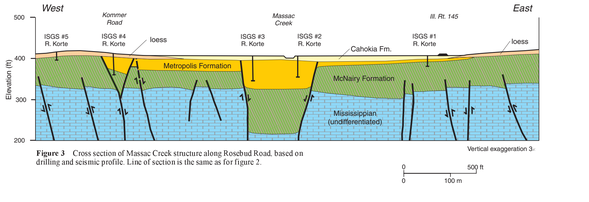


Figure 3 Cross section of Massac Creek structure along Rosebud Road, based on drilling and seismic profile. Line of section is the same as for figure 2.

Recommended citation

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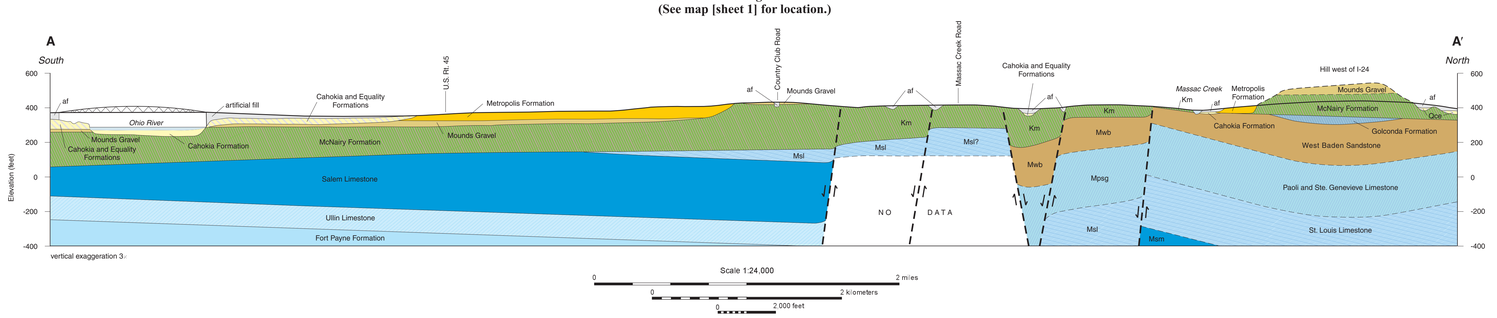
Cross Section along Interstate 24
(See map [sheet 1] for location.)



Geologic Structure

Regional Setting

The Metropolis Quadrangle is located near the northern end of the Mississippi Embayment, an extension of the Gulf Coastal Plain. The embayment was an arm of the Gulf of Mexico during the Cretaceous and early Tertiary Periods, and marine, coastal, and deltaic sediments were deposited there. These sediments thicken southward toward the gulf, as shown on the cross section that follows Interstate 24 (cross section A–A′). Within the Metropolis Quadrangle, embayment sediments include the Post Creek and McNairy Formations of late Cretaceous age. A few miles south of the map area in Kentucky, younger deposits of Tertiary age overlap the McNairy. These include the Paleocene Clayton and Porters Creek Formations and the Eocene Wilcox, Claiborne, and Jackson Formations (Finch 1966, 1967; Olive 1980). Some of these units originally extended further north across the map area but have been eroded. Small remnants of the Clayton and Porters Creek are preserved in downfaulted blocks within, and north of, the Metropolis Quadrangle. One such block is exposed in a gully along the Illinois Central Railroad, just north of the center of Sec. 11, T15S, R4E. Another such block was discovered in 1999 by drilling into the Massac Creek Graben about 0.5 mile north of the Metropolis Quadrangle.

Bedrock in the Metropolis Quadrangle is of Mississippian age and consists of limestone in the southern part and interbedded limestone, sandstone, and shale in the northern part of the quadrangle (fig. 1). Mississippian sandstone crops out in a small area along Massac Creek near the Interstate 24 bridge. In general, bedrock formations in Massac County dip toward the north or the northeast, into the Illinois Basin (centered in east-central Illinois), and away from the Pascola Arch (centered in the "boot heel" of Missouri).

Faults

Both bedrock and younger sediments of the map area are broken and offset by large faults that run northeast to north-northeast. These faults are part of the Fluorspar Area Fault Complex (FAFC), an intricate array of fractures that affects Hardin, Pope, and Massac Counties of Illinois and neighboring counties of Kentucky. The FAFC originated some 550 million years ago during the Cambrian Period and has been active repeatedly into and including the Quaternary Period. Although none is demonstrably active, faults in the Metropolis Quadrangle are the youngest known in Illinois. Moreover, these faults are in line with an active earthquake area, the New Madrid Seismic Zone, within 30 to 40 miles southwest of Metropolis. Earthquakes that struck the New Madrid area in 1811 and 1812 were among the most powerful ever experienced in North America.

Massac Creek Graben A fault zone here named the Massac Creek Graben extends south-southeast across the quadrangle, passing beneath the city of Metropolis. Northeast of the map area, the Massac Creek Graben is continuous with the Hobbs Creek Fault Zone, which continues as far as Hardin County (Baxter et al. 1967, Weibel et al. 1991, Nelson 1996). The graben probably extends southwest into Kentucky, although it has not been mapped there. The graben is a zone of narrow downfaulted blocks that are bounded by nearly vertical fault planes. The actual fracture pattern probably is much more complex than presented on the map, which shows only faults that can be identified from drill hole data.

A seismic reflection profile (fig. 2) across the graben following Rosebud Road, at the northern edge of the Metropolis Quadrangle, indicates more than a dozen faults in a zone 3,500 feet wide. An interpretive cross section along Rosebud Road (fig. 3) is based on the seismic profile and five shallow Illinois State Geological Survey (ISGS) boreholes along the same traverse.

The Massac Creek Graben displaces Mississippian bedrock formations, as shown on the bedrock geologic map (fig. 1). Faulting is indicated by abrupt changes in elevation of the bedrock surface and by different formations juxtaposed between adjacent wells. The municipal water wells for the city of Metropolis penetrated the graben, encountering large crevices in the bedrock, of which some are open and others are filled with sand, gravel, and chert rubble.

The Massac Creek Graben displaced units as young as the Metropolis Formation (early to middle Pleistocene). Test drilling by the ISGS indicates that the Metropolis Formation is downthrown at least 100 feet near the north end of the quadrangle. A deep test hole drilled in 2000 about 0.5 mile north of the Metropolis Quadrangle indicated that the Mounds Gravel is downthrown 500 feet in the graben and that the Owl Creek Formation (uppermost Cretaceous) and the Clayton Formation and Porters Creek Clay (both Paleocene; early Tertiary) are present beneath the Mounds. Elsewhere in Massac County, these units were eroded prior to deposition of the Mounds Gravel. Clearly, the Massac Creek structure underwent multiple episodes of movement, continuing through the Tertiary Period and well into the Quaternary. No faults, however, displace the Equality Formation (Wisconsinan or late Pleistocene) or the Cahokia Formation (Holocene). Therefore, the Massac Creek Graben appears to have been inactive for at least 75,000 years.

Barnes Creek Fault Zone The Barnes Creek Fault Zone enters the northeastern corner of the Metropolis Quadrangle, veers toward the southwest, and merges with the Massac Creek Graben. Northeast of the map area, this fault zone has been mapped for 25 miles across parts of Massac, Pope, and Hardin Counties (Baxter et al. 1967, Nelson et al. 1999, Nelson, unpublished). Within the map area, the fault zone is known from exposures along Barnes Creek and from numerous test holes drilled by the ISGS along the creek. A seismic reflection profile (Koffi et al. 1997) further substantiates the fault zone as displacing the Mississippian bedrock and younger units.

A detailed map and cross section (figs. 4 and 5) depict the structure along Barnes Creek. Streambank outcrops show that the Barnes Creek Fault Zone consists of high-angle normal faults and a few high-angle reverse faults. Most faults strike northeast, but a few trend north to north-northwest. Faults typically occur in pairs, outlining narrow grabens in which the Metropolis Formation is downdropped against the McNairy Formation, offsets typically being several tens of feet. In one case, a borehole (BC-7) shows the Metropolis Formation is downthrown a minimum of 95 feet. A few faults having less than 5 feet of displacement appear to offset the Sangamon Geosol, a Pleistocene buried soil that is 75,000 to 125,000 years old. None of the faults affects the Cahokia Formation, which is less than 10,000 years old. Thus, most movement in the Barnes Creek Fault Zone took place more than 125,000 years ago, and no movement has occurred during the last 10,000 years (Nelson et al. 1997, 1999).

Other Faults Three faults that trend north-northwest are mapped in the northwestern part of the quadrangle. The easternmost of these, which lies just west of and parallel to Interstate 24, is based on well records that indicate West Baden Sandstone is downthrown on the northeast opposite upthrown Paoli and Ste. Genevieve Limestones on the southwest (see fig. 1). However, the top of the bedrock (or base of the Cretaceous) is displaced about 100 feet down to the southwest, suggesting that the fault underwent two episodes of movement. In the earlier movement, the northeast side was downthrown; in the second episode, the southwest side was downthrown during or after late Cretaceous time.

The other two northwest-trending faults outline a horst (upthrown block) roughly 0.25 mile wide. The eastern fault is inferred from exposures in the Illinois Central railroad cut south of Round Knob village, where McNairy and Metropolis Formations are tilted and offset, indicating activity as young as Pleistocene. The western fault is mapped solely on the basis of water-well records.

Faults in the bank of the Ohio River at Fort Massac, on the east side of Metropolis, were described by Kolata et al. (1981). These faults have been covered with concrete and riprap and are no longer visible. According to Kolata et al. (1981), the easternmost fault was a normal fault that juxtaposed Mounds Gravel on the southeast, downthrown side against McNairy Formation on the northwest. The displacement was estimated to be about 50 feet. Four additional faults west of the first ran north-south and displaced only the McNairy Formation. Most likely, the faults observed by Kolata et al. (1981) are associated with the Barnes Creek and Massac Creek structures, however, a non-tectonic origin cannot be ruled out.

Groundwater

Drilled wells supply water for the cities of Metropolis and Brookport and for many rural homes and farms in the map area. These wells tap aquifers in Mississippian bedrock, the McNairy Formation, the Mounds Gravel, and, to a small extent, the Metropolis Formation. Groundwater is highly dependent on geologic conditions, which vary considerably throughout the quadrangle.

Bedrock

Bedrock aquifers supply the Metropolis city wells. Specifically, these wells are completed either in the rubble zone of weathered chert fragments (resembling gravel) that rest on the bedrock or in crevices and fissures within the limestone. The Massac Creek Graben, a fault zone that passes beneath Metropolis, greatly fractured the limestone, enhancing the movement of groundwater. The limestone contains large cavities; some are open, and others are filled with sand and gravel. Fred M. Luth, who drilled Metropolis well no. 1 in 1925, reported in a letter that the top of rock was encountered at 229 feet, but the casing sank under its own weight, following the drill to a depth of 290 feet, where solid rock finally was encountered.

Metropolis was served until recently by four wells, nos. 1, 2, 3, and 4, drilled between 1925 and 1955. Well nos. 1, 2, and 3 are located at the city water plant at First and Catherine Streets; well no. 4 is located two blocks northwest of the water plant. Weller (1975) reported that, in 1972, the average daily pumpage from these four wells was 1,481,450 gallons per day. This rate is equivalent to an average continuous output of about 250 gallons per minute from each of the four wells. Well no. 5, in the northwestern part of the city, was completed in 1955. This well yielded 280 to 305 gallons of water per minute on a pumping test. Because its water has high mineral, iron, and hydrogen sulfide content, well no. 5 is maintained for emergency use only. Well no. 6 was drilled in 1999, and no data are available on yield or water quality.

Large industrial wells are completed in the limestone bedrock adjacent to the Metropolis Quadrangle in the Joppa Quadrangle on the west and in the Paducah, Kentucky, area to the south. Water yields from these wells are highly variable. One well at the Cook Coal Terminal west of Metropolis was judged as being capable of a sustained yield of 2,000 gallons per minute, but another test hole on the same property was dry and abandoned. As at Metropolis, water-bearing zones are chiefly the chert rubble on top of bedrock and open or sand-filled voids in the limestone. Davis et al. (1973) reported that, in Kentucky, water from the rubble zone is soft to moderately hard, whereas water from crevices in the rock is moderately to very hard. They also stated that water derived from bedrock commonly contains a high enough iron content to require special treatment for most uses.

Many residential wells in the northern part of the Metropolis Quadrangle are finished in bedrock aquifers. Information from the drillers' logs is so sketchy that few conclusions can be drawn regarding the geology. The Ste. Genevieve and Paoli Limestones, the West Baden Sandstone, and—surprisingly—the Golconda Formation (interbedded shale and limestone) all supply domestic wells in the area. Most of these wells yield 5 to 25 gallons of water per minute, but several have substantially greater yield. Most productive is the Aremsman irrigation well (Sec. 18, T15S, R5E), which produces 650 gallons per minute from the West Baden Sandstone at a depth of 400 to 550 feet. Significantly, this well is located within the Massac Creek Graben. Several other high-producing bedrock wells in the northern part of the map area are completed either in fractured rock in fault zones or in rubble zones resting on top of limestone bedrock.

To summarize, large-capacity bedrock wells in the map area generally tap aquifers in the rubble zone on top of bedrock, or voids and crevices within the limestone. The likelihood of finding large water-bearing fissures in the rock is greatest along the fault zones, particularly the Massac Creek Graben. Water from bedrock is apt to be hard and may require treatment to reduce the iron content.

McNairy Formation

The McNairy Formation contains lenses of water-bearing sand that supply many domestic wells. Three of the four municipal wells at Brookport (just outside the southeast corner of the map area) were completed in sand near the base of the McNairy. The water-bearing sand is fine- to coarse-grained and consists of nearly pure quartz sand that is loose to weakly consolidated. According to Weller (1975) and ISGS data, production from the three McNairy wells at Brookport ranges from 75 to 300 gallons per minute. Other McNairy wells in the Metropolis Quadrangle have much smaller yields. Water from the McNairy Formation generally is hard and contains enough iron to require treatment for most uses (Hansen 1966, Davis et al. 1973, Weller 1975).

The McNairy Formation in Illinois is not a predictable target for water-well drillers. The formation consists of clay and silt, which do not yield water, interbedded with sand, which yields small to moderate amounts of water in most cases. The sand bodies are lenticular and, at best, can be correlated for short distances. A densely drilled area around the Paducah gaseous diffusion plant in Kentucky illustrates the lens-like nature of the sands. Dozens of deep wells, most having detailed logs, were drilled on the plant grounds. They show that individual sand bodies in the McNairy are a few hundred to a few thousand feet across. A fence diagram of the McNairy at the Shawnee Steam Plant, across the river from Metropolis, also illustrates the lack of continuity of sand bodies (Finch 1967).

Mounds Gravel

The Mounds Gravel is the principal aquifer for domestic wells in the southern part of the quadrangle, within the area of "low Mounds" marked on the geologic map. In most of this area, the gravel is 10 to 40 feet thick and lies within 50 feet of the surface. The aquifer is generally capable of supplying domestic wells having a 6-inch casing and a production capability of 10 to 30 gallons of water per minute. Locally, however, the gravel in the southern area is thin, missing, or lacks permeability because of a clay matrix, and water wells must be drilled into deeper formations.

Hansen (1966), Lambert (1967), and Davis et al. (1973) reported that the Mounds Gravel is the primary aquifer in the area of Kentucky immediately south and southeast of Metropolis. They stated that the Mounds may yield as much as 1,000 gallons per minute in Kentucky. The water tends to be hard (120 to 300 ppm of dissolved solids), but has lower iron content than does water from other sources.

In the northern part of the Metropolis Quadrangle, the Mounds Gravel lies at a higher elevation and is found as isolated deposits on the tops of hills. These gravel deposits are too small to serve as a reliable source of well water.

Other Units

Gravel lenses in the Metropolis Formation supply a few domestic wells, but yields from this unit are marginal. Of greater concern, Hansen (1966) and Lambert (1967) reported that, in Kentucky, water from the Metropolis is hard and has a high iron and nitrate content. Surface runoff from farm fields is the likely source of nitrates in water from shallow wells. Hansen (1966) and Lambert (1967) stated that water having a nitrate content of 45 ppm or higher may induce the potentially fatal "blue baby disease," methemoglobinemia, and should not be used in infant formulas. The Mounds Gravel, which directly underlies the Metropolis Formation in most areas, can supply much larger quantities of water, and nitrate pollution generally is not a problem.

Other Quaternary units, including loess, Cahokia Formation, and Equality Formation, are not aquifers in the map area.

Mineral Resources

Sand and Gravel

A dredge is currently extracting sand from the bed of the Ohio River a short distance upstream from Metropolis. Dredging is an efficient way to recover river sand, which can be screened and dried to be sold for a variety of uses.

The Mounds Gravel has been taken from numerous small pits in Massac County and used for surfacing county roads and private lanes. The demand for road gravel is not great enough to support sustained operations, so these pits operate intermittently. Among pits in the Metropolis Quadrangle, one on the east side of Fourmile Creek and another on the east side of Sevenmile Creek were in operation during the 1990s. These pits are in the low Mounds Gravel, which occurs at shallow depth throughout the southern part of the quadrangle. In the northern part of the map area, the Mounds Gravel is at higher elevation and limited to the tops of hills. Several small gravel pits formerly operated among these hills.

A small gravel pit was active during the 1980s on the east side of Sevenmile Creek in the northwest quarter of Sec. 2, T16S, R5E. J.M. Masters visited this pit while it was active and found it to be working a gravel deposit in the Henry Formation. Similar deposits of Henry gravel have been quarried east of the Metropolis Quadrangle in Illinois and also south of the Ohio River in Kentucky. These gravel beds are interpreted as bars and beach ridges that formed along the shoreline of glacial Lake Paducah. These take the form of low, linear, or arcuate ridges near the mouths of tributaries to the Ohio River at or slightly above the 350-foot topographic contour (Finch et al. 1964). Gravel from the Henry Formation is similar in character and uses to gravel from the Mounds.

During the 1920s, the Western Indiana Gravel Company set up a dredge on the floodplain of Massac Creek north of Metropolis (northeast quarter of the northeast quarter, Sec. 36, T15S, R4E) and mined gravel from the bed of the creek. Because the gravel was cemented by iron oxide, it had to be blasted with explosives before being screened and washed. Sand and gravel of several different sizes then were dried, loaded into railroad cars, and marketed for a variety of uses (Lamar 1929). The pit is currently flooded, and the gravel that was mined is not visible. Whether this gravel was the Mounds Gravel or a younger, Quaternary age gravel, possibly of the Henry Formation, is not known.

Clay

Three clay pits operated in the McNairy Formation during the early twentieth century near the village of Round Knob in the northwest corner of the quadrangle. Lamar (1948) reported that clay from these pits was shipped to Metropolis and Paducah, where it was used to make pottery and stoneware. We located the clay pits during mapping, but the clay is almost entirely covered by slope wash. Lamar visited the pits when the exposures were fresher and collected samples of clay for analysis. He indicated that the clay varied in character, but most of it was silty to sandy and contained laminae or thin beds of sand. Lamar characterized the clay as possibly being suitable for making several kinds of brick and tile. Because of the diminished demand for clay products, no clay from the McNairy Formation has been mined in Illinois for more than 50 years. Clay deposits of the McNairy, like sand in the same formation, are lenticular and vary in character. Extensive drilling and testing probably would be needed to define a deposit worthy of mining.

The absorbent clay that is being mined near Olmsted in Pulaski County, west of the map area, is from the Porters Creek Formation, a unit that does not occur in significant quantity in Massac County.

Oil and Gas

Two test holes for oil and gas are known to have been drilled in the Metropolis Quadrangle, near Sevenmile Creek in the southeastern part of the area. The Marshall Drilling Company no. 1 McGhee well was drilled from February 1939 through July 1940 in the northeast quarter of the northeast quarter of the northeast quarter of Sec. 3, T16S, R5E, to a total depth of 2,335 feet. In 1956, the Edwards Henners No. 1 Fred Molter hole was drilled to a depth of 1,099 feet in the northwest quarter of the northwest quarter of the southwest quarter of Sec. 35, T15S, R5E. Both holes were plugged and abandoned, although the McGhee well encountered a show of oil at 1,004 to 1,012 feet in the Fort Payne Formation (Mississippian). Sample logs for both holes are on file at the ISGS. The log for the McGhee well ends at 1,012 feet, below which depth no samples were taken. According to the scout ticket, the "Hardin sandstone" was encountered at 2,124 feet, and the top of Devonian limestone at 2,335 feet. Samples from the Molter well were logged from 215 to 1,090 feet, and the log indicates the bottom of the hole was in the Fort Payne Formation.

The outlook for oil or gas in the Metropolis area is not favorable. The nearest producing wells are in Saline and Williamson Counties, Illinois, more than 30 miles north of the Metropolis Quadrangle. The Upper Mississippian formations that yield most of the petroleum produced in Illinois are either eroded or close to the bedrock surface in the map area. Deeper formations might be productive, but no direct information is available. Chief among these are the Devonian limestone, Silurian dolomite, and the Kimmswick (Trenton) Limestone of Ordovician age. The Trenton is the oldest formation that has produced oil in Illinois. The northeastern part of the Metropolis area severely fractured the bedrock to great depth. These faults, active repeatedly through a long period of geologic history, provide many avenues for oil and gas to escape to the surface.

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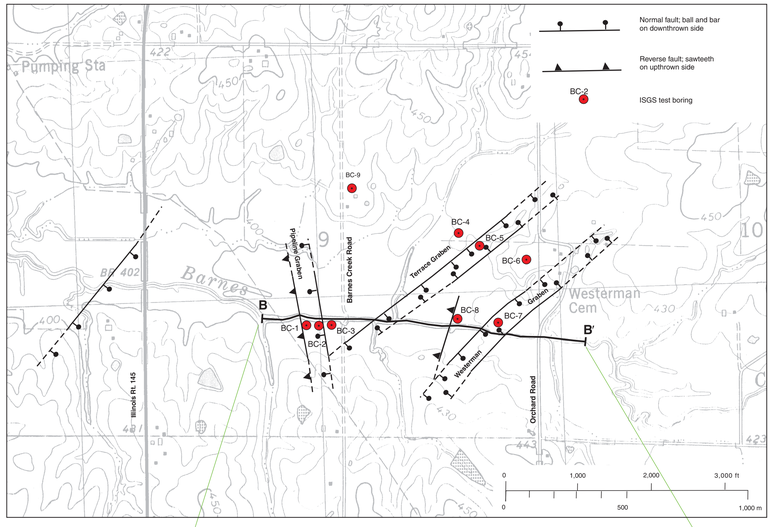

Figure 4 Enlarged map of the fault zone along Barnes Creek, Sec. 9, T15S, R5E.

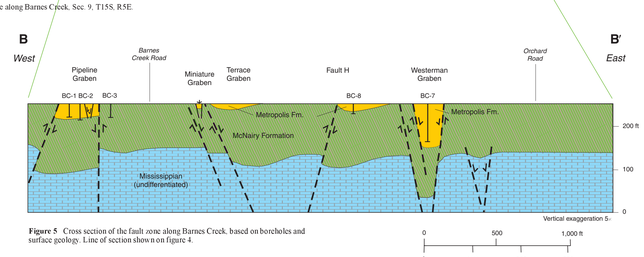

Figure 5 Cross section of the fault zone along Barnes Creek, based on boreholes and surface geology. Line of section shown on figure 4.