Department of Natural Resources
ILLINOIS STATE GEOLOGICAL SURVEY
Illinois Geologic Quadrangle Map: IGQ Alton SG
William W. Shilts, Chief
1999

SURFICIAL GEOLOGY MAP

Alton Quadrangle (Illinois portion), Madison County, Illinois

David A. Grimley

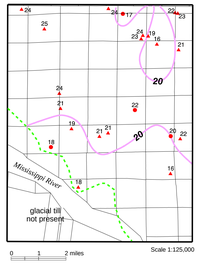


Figure 1 Clay content of Glasford Formation till. Shown are weight percentages of < .004 mm particles in the < 2 mm fraction of calcareous C and D horizon till from the Alton Quadrangle. All data are from the Glasford Formation, deposited during the Illinois Episode. Data are from hydrometer analyses. (Additional information on grain size data in Grimley 1999b)

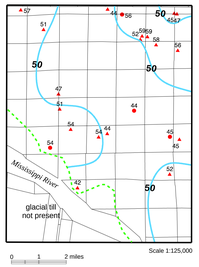


Figure 2 Percent illite in clay mineral fraction of Glasford Formation till. Samples are calcareous C or D horizon glacial till (Illinois Episode). Illite percentages were calculated from X-ray diffraction patterns from glycolated oriented slides of clay-size fractions. Samples were analysed by H. D. Glass. (Additional information on clay mineralogy in Grimley, 1999b)

Material Descriptions

Lithostratigraphic Units and Interpretations

QUATERNARY DEPOSITS

Human Episode
(postglacial; 0-10,000 years before present [B.P.])

Quarries, spoil piles, landfills, artificial levees, and major roadway fill; significant manmade forms of earth material or removed earth material.

Disturbed Ground — D

Stratified silt, sand, and gravel; up to 20 feet thick in West Fork, Wood River Valley; overlying older silt, clay, diamicton, or bedrock.

Cahokia Formation overlying Equality Formation or till or bedrock — Qc
This alluvium is silty where derived from loess, generally in the headwaters of creeks. Silty sand and sandy silt alluvium, derived from till and loess, occurs in most middle and lower reaches of creek valleys. Coarser sandy and sometimes gravelly alluvium occurs where bedrock is near-surface, such as in Hop and Youngblood Hollows, near the Mississippi River Valley bluffs. The Cahokia Formation normally overlies either Equality, Glasford, or Banner Formations or bedrock (see cross-sections).

Stratified clay, silt, and sand; approximately 15 to 50 feet thick; generally, the upper 5 to 30 feet is silt and clay and lower portions are more sandy; underlain by thick sand and gravel.

Cahokia Formation overlying Henry Formation — Qc/Qh
Postglacial Mississippi Valley alluvium is underlain by Henry Formation sand and gravel outwash. The total thickness of both units ranges from 40 to 120 feet.

Peat, muck, and marl; dominantly organic-rich silts; estimated thickness of 5 to 10 feet.

Grayslake Peat — Qgp
These organic deposits occur in one swampy depression in the headwater region of Rocky Fork Creek.

Pebbly silt, silt, and/or pebbly clay; yellow-brown to reddish-brown; 5 to 15 feet thick.

Peyton Formation — Qpy
Colluvium in the Alton Quadrangle is a relatively unsorted mixture of loess, residuum, and bedrock, deposited by mass wasting processes. This colluvium is mostly redeposited loess mixed with deeply eroded loess and contains small frag-ments of local rock. Peyton Formation is commonly found on steep sideslopes or footslopes, especially near Rocky Fork Creek, Youngblood and Hop Hollows. Some colluviation began during the glacial episodes, prior to or concurrent with loess deposition.

Wisconsin Episode
(about 10,000 - 75,000 Years B.P.)

Stratified to massive silty clay, silt and clay; often grey to yellow grey; estimated maximum thickness of 40 feet; overlain by younger sand and silt (alluvium) or by 3 to 5 feet of silt (loess)

Equality Formation — Qe
Slackwater lake deposits occur below about 475 feet elevation in broad sections of the West Fork Wood River and its major tributaries. Equality Formation is overlain by Cahokia Formation in valleys or by 3 to 5 feet of Peoria Silt (loess) on low terraces of Little Piasa Creek and West Fork Wood River

Sand and gravel; 50-90 feet thick underneath the broad Mississippi Valley in the southeast portion of the quadrangle, thinner towards valley edges; overlain by 15 to 50 feet of silts and sands.

Henry Formation (in cross-sections only) — Qh
Outwash deposited in the Mississippi River Valley, related to advances of upper midwestern glaciers that did not reach the study area, is overlain by 15 to 50 feet of postglacial alluvium (Cahokia Formation).

Massive silt to silt loam; loose, low density and soft; in uneroded areas, the upper two-thirds is yellow-brown to grey and lower one-third is pinkish-brown to grey-brown; total thickness of 15 to 50 feet; thickens in uneroded upland areas near the bluffs; underlain by clay and/or bedrock

Peoria and Roxana Silts (mapped as a separate unit where no till is present) — Qpr
Loess deposits (swindblown silt) are underlain by thin residuum and/or bedrock. Loess was derived primarily by deflation of sediment from the Mississippi-Missouri River Valleys. The upper yellow-brown to grey Peoria Silt is about twice as thick as the pinkish-brown to grey-brown Roxana Silt in uneroded areas. Total loess thickness contours (dashed lines on map) indicate maximum thickness in uneroded upland bluffs proximal to the Mississippi River Valley. The modern soil is contained in the upper 3 to 4 feet of Peoria Silt.

Illinois Episode
(about 200,000 - 130,000 years B.P.)

Pebbly loam diamicton containing some minor sand and silt beds; overlain by 5 to 45 feet of massive, soft silt. The upper 5 to 10 feet of the diamicton is more oxidized (yellow-brown), less compact, softer, sandier, and often contains interbeds of sorted sediment. The lower portion and typically major thickness of the diamicton is commonly unoxidized (grey to slightly greenish-blue), and is more uniform and dense. Local limestone, dolomite, and shale pebbles as well as spruce wood fragments are common in the unoxidized diamicton. Illite composes more than 50 % of clay minerals in the unoxidized till.

Fort Russell Member, Glasford Formation (overlain by 5 to 45 feet of loess) — Qpr/Qg
Till and ice marginal sediment are overlain by 5 to 45 feet of Roxana and Peoria Silts. The upper 4 to 7 feet of the Glasford Formation contains the solum of the Sangamon Geosol. The upper 5 to 10 feet of Glasford Formation is generally melt-out till and the lower and thicker portion is denser, subglacial till. The till lithology indicates the sediment was primarily derived from Paleozoic shales and carbonates with a large amount of local input. Bedrock striations indicate ice advance from the northeast.

Pebbly loam diamicton within about 5 feet of ground surface with < 5 feet of overlying silt. Otherwise the description is same as above.

Fort Russell Member, Glasford Formation (< 5 feet of loess cover) — Qg
Till within about 5 feet of ground surface with <5 feet of a loess or weathered loess cover. Otherwise same as above. The thick loess cover was largely eroded during either its deposition in the Wisconsin Episode or during postglacial times along steep ravines.

Pre-Illinois Episode
(deposition between about 500,000 and 450,000 years B.P ?)

Clay loam to silty clay diamicton, brown to brown-grey, often with orange stained fractures; underlain by bedrock and overlain by any number of younger units. This unit is up to 10 feet thick where observed, but could thicken into bedrock valleys. The diamicton contains more expandable clay minerals in the clay fraction than Illinois Episode tills (McKay, 1979). This unit occurs primarily in subsurface, but is exposed in bedrock lows, such as at outcrops 12f (Sec. 6, T6N, R10W) and 15f (Sec. 28, T6N, R10W).

Omphghent Member, Banner Formation (in cross-sections only) — Qbo
This unit is mainly till that is preserved in bedrock depressions and valleys where the Illinois Episode glacial advance was unable to completely erode the till. The Banner Formation is difficult to delineate in this quadrangle because evidence of Yarmouth Geosol development is rarely found separating it from the Glasford Formation. Omphghent till occurs at outcrops 12f and 15f below Glasford Formation and Cahokia Formation, respectively.

PENNSYLVANIAN AND MISSISSIPPIAN BEDROCK [R]

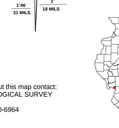
Near-surface limestone, dolomite, shale, siltstone, or coal; in some cases bedrock may be at depths slightly greater than 5 feet; includes some talus-covered bedrock slopes at the bluffs of the Mississippi Valley; (for more information, see Devera, *Bedrock Geology Map of the Alton Quadrangle*, in progress).

Pennsylvanian and Mississippian Bedrock — R
Bedrock exposures or bedrock within about 5 feet of land surface.
Bedrock is predominantly Mississippian limestone in southwestern parts of the quadrangle and Pennsylvanian shales, siltstone, coal and carbonate rock in central and northeastern portions of the quadrangle. Mississippian rocks dip gently (< two degrees) to the east. Pennsylvanian rocks unconformably overlie Mississippian rocks, also dip gently, and thicken to the east and northeast.

Water Bodies

Acknowledgments
Discussions in the field with E. D. McKay, J.A. Devera and B.F. Denny aided considerably with this mapping project. H.D. Glass studied the clay mineralogy of till samples. Areas of near-surface bedrock were modified based upon additional field observations by J.A. Devera and B.F. Denny. J. Schoen aided greatly with digitization and computerization of the geologic units. C.C. Abert and T. McTighe helped considerably with producing the digital topographical base map (from USGS digital line graphics) and P.K. Carrillo designed the final layout. Thanks also to J.M. Masters for his comments on the sand and gravel resources in the area. Henry Bush, a local water well driller, was also very generous with his time, and discussions with him were extremely useful for correlation of his many well log descriptions to our new data. This project was funded by the STATEMAP quadrangle mapping program, a cooperative agreement between the State of Illinois and the U.S. Geological Survey (contract no. 1434-HQ-97-AG-01483).

Base map compiled at the Illinois State Geological Survey (ISGS) from digital data (1994) provided by the U.S. Geological Survey and the ISGS 1927 North American Datum



ADJOINING 7.5-MINUTE QUADRANGLES

Data Point Type

ALT-1*	stratigraphic test holes
1f*	outcrops examined
FN1*	ISGS field note descriptions
25776*	water wells and engineering borings (county numbers indicated)
	more reliable border
	less reliable border
	loess contours (indicates typical thickness of loess deposits on undissected upland areas; includes Peoria and Roxana Silts; loess does not occur over areas mapped as Cahokia Formation); contour interval 10 feet
	striation directions (arrow points in direction of ice advance)

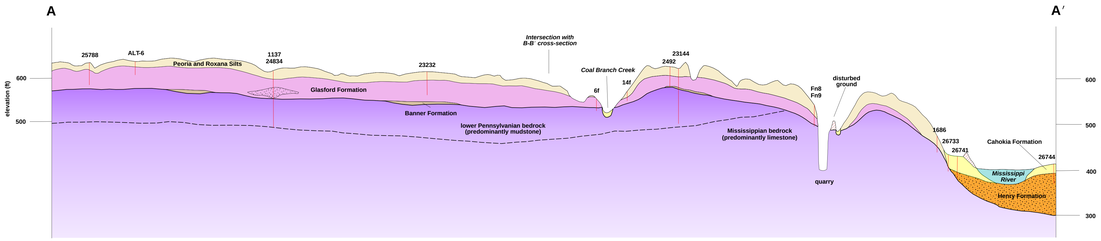
For further information about this map contact:
ILLINOIS STATE GEOLOGICAL SURVEY
615 East Peabody
Champaign Illinois 61820-6964

(217)244-2414

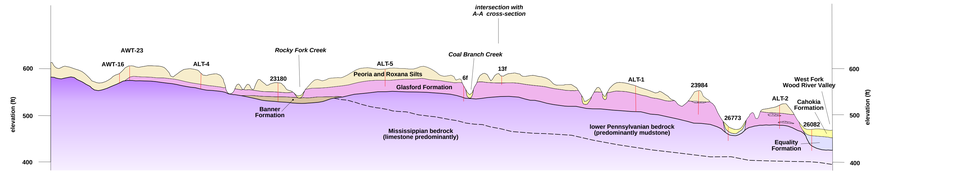
http://www.isgs.uiuc.edu

Released by the authority of the State of Illinois: 1999

Cross-Section A-A′



Cross-Section B-B′



Quaternary Geology

This area is near the margin of pre-Illinois and Illinois Episode ice advances, both of which originated from the east to northeast (Willman and Frye 1970, McKay 1979), but which thinned to their terminus several miles to the west of the Alton area (Grimley 1999a). During the Wisconsin Episode, glacial ice terminated more than 60 miles to the northeast of this quadrangle; however, thick fluvial (outwash), lacustrine (lake sediment), and eolian (loess) deposits are associated with Wisconsin Episode glaciation in the Upper Mississippi River drainage basin.

Pre-Illinois Episode deposits are scarce in this area, but scattered occurrences of an old till unit indicate an early advance of glacial ice from the east-northeast. The Omphghent Member of the Banner Formation (McKay 1979) is preserved primarily in bedrock lowlands and depressions, where erosion of earlier Quaternary deposits by Illinois Episode ice was limited. Omphghent till, a brown to grey silty clay loam diamicton with frequent local bedrock clasts, has only been found at thicknesses of less than 10 feet and stripped of the Yarmouth Geosol solum (a well developed interglacial soil). However, oxidation or jointing related to a stripped Yarmouth Geosol are often present below unaltered Fort Russell till (Illinois Episode). Bedrock, thin residuum and weathered silt underlies Omphghent till. The till has a clay content ranging from 25% to 35 % (< 4 mm clay) and an illite content ranging from 33% to 45 % of total clay minerals. Omphghent till is generally finer grained (more clay and less sand) and less illitic than Fort Russell till. Higher clay content and more smectite in Omphghent till is perhaps due to incorporation of old Quaternary paleosols and residual bedrock soils, as this would have been the first ice advance across an unglaciated terrain in southwestern Illinois.

The main Illinois Episode unit in this quadrangle is the Fort Russell Member of the Glasford Formation (McKay, 1979). This unit is a uniform, grey to grey-green, dolomitic, illitic, pebbly loam diamicton, which oxidizes yellow-brown. Carbonate pebbles in the till are common as are clasts of Pennsylvanian shale and spruce wood within unaltered portions of the till unit. Some sandy stratified sediments are also included in the upper portion of the Fort Russell Member. The Fort Russell Member is as much as 60 feet thick, but thins to the southwest because Mississippian limestone bedrock highs probably diverted or limited the covering of thinning glacial ice. Furthermore, after the Mississippi River's base level dropped from its glacial aggradational high, fluvial and colluvial erosion cut deeply into sediments near the bluffs. The Fort Russell Member often contains the Sangamon Geosol (the last interglacial soil) preserved in its upper 4 to 7 feet, where weathering and strong soil development have caused clay increases, increased soil structure, carbonate leaching, and sometimes color mottling of red-brown to green-grey. The Fort Russell Member and Sangamon Geosol are overlain by Wisconsin Episode loess, except where creeks have eroded through the silts during the Hudson Episode. A typical exposure of the Fort Russell Member, containing the Sangamon Geosol and overlain by loess, can be viewed at Lohr Quarry (site 12f) in the northwestern part of the quadrangle (see photo).

At some localities (e.g., 16f, 17f), up to 15 feet of Petersburg Silt (Illinois Episode loess or lake deposit) underlies Fort Russell till. This silt unit occurs primarily in bedrock valleys or tributaries where slackwater lake sediments, perhaps backed up from the Mississippi River Valley, were deposited and sometimes mixed with washed-in loess. Where ice incorporation of Petersburg Silt would have been considerable (mainly within 2 miles of the Mississippi Valley), the texture of Fort Russell till is silty, having < 20 % clay (fig. 1). Clay contents (% < .004mm in the < 2 mm fraction) of calcareous Fort Russell till range from 16% to 24 % in the Alton Quad-rangle based on data from 21 localities.

Hairpin erosion marks occur on the limestone bedrock at this site, at the base of Illinois Episode till. Striations occur alongside and within these features. Two directions of ice advance are indicated: N55 E followed by N40 E (right to left in photo). This directional change probably occurred during the Illinois Episode. Alternatively, the N55 E direction may be reminiscent of a pre-Illinois Episode ice advance. [Photo by David A. Grimley, 1997]

The surficial deposits at Lohr Quarry (site 12f in SE. Sec. 5, T6N, R10W). Here, about 11 feet of windblown silt (Peoria and Roxana Silts) overlies Fort Russell Member till as well as some sorted sediments, deposited during the Illinois Episode. The Sangamon Geosol (last interglacial soil) is strongly developed in the upper few feet of Fort Russell Member till, sand and silts. Patchy pre-Illinois Episode till occurs in a bedrock low in the northern portion of the quarry. [Photo by David A. Grimley, 1996]

A view of the severe flooding on Front Street which occured in downtown Alton, during the summer of 1993. Sand bagging efforts provided only limited help for the downtown area because water flowed underneath this barrier via the sewer system to the Broadway Street area. This flood rose to an elevation of 440 feet, higher than any other flood in modern history. Floods during the last glacial episode rose to about 495 feet elevation, depositing slackwater lacustrine sediment (Equality Formation in cross-section B-BN) and clay beds within the loess at sites FN4 and FN5 (Leighton and Willman, 1949) [Photo by Joel M. Dexter, 1993]

Some low-clay tills are meltout till in the upper portion of Fort Russell Member. Often, lower portions of basal till are most clayey when the underlying bedrock is shale. Thus, there are vertical as well as lateral variations in texture. Illite content ranges from 44% to 59 % in the clay mineral fraction of calcareous Fort Russell till (fig. 2). Oxidized samples of Fort Russell till have experienced noticeable weathering of chlorite to vermiculite in many samples, which causes illite values to increase slightly in altered tills (H.D. Glass, personal communication).

Loess deposits, derived from the Mississippi River Valley, are up to 50 feet thick in uneroded near-bluff upland areas, but thin to about 15 feet in northeastern portions of the quadrangle, as most silt settled out close to its deflation area. Thickness contours for Wisconsin Episode loess, which includes both Peoria and Roxana Silts, are indicated on the surficial geology map. In the late 19th century, mammalian fossil fragments such as deer were found in loess deposits near the Alton bluffs (Leighton 1921). Occasionally, clay or fine sand beds, resulting from high level Mississippi River aggradation and flooding, have been noted within Peoria Silt at the 495 foot elevation (Leighton and Willman 1949).

Concurrent with loess deposition, up to 90 feet of Wisconsin Episode sand and gravel outwash (Henry Formation) was deposited in the broad Mississippi Valley. This coarse-grained, valley-train sediment grades into silty lacustrine sediment (Equality Formation), which was deposited in slackwater lakes and is preserved in some of the wide tributary valleys to the Mississippi Valley. Henry Formation sand and gravel in the Mississippi Valley is overlain by 20-30 feet of post-glacial sand, silt and clay (Cahokia Formation).

Material Resources and Environmental Hazards

Karst (sinkhole and cavern development) Karst topography is evident at the surface, especially along the bluffs from the Alton area and westward, where limestone bedrock is generally within 25 feet of land surface. Sinkholes are also occasionally present near the western edge of this quadrangle. In these areas, where thin loess and residuum overlies pure limestone such as the Salem or St. Louis Formations, sinkhole and underground cavern development is most prevalent (Panno et al. 1997). Underground drainage in karstic areas near the Alton area can be rapid (> 0.5 miles/day) and commonly follows joint sets in the N60°E and N45°W directions toward the Mississippi River Valley (Lamar 1928). Bedrock aquifers underlying karstic regions are thus highly susceptible to contamination because groundwater recharge flows quickly into cavernous bedrock and is not filtered through soil, clay or slowly permeable bedrock (Panno et al. 1997, Panno and Weibel 1998). Karstic regions also pose a hazard to building structures because of the danger of sinkhole collapse and widening.

Groundwater Groundwater supplies on the uplands are from either fractured carbonate bedrock or upper Glasford Formation. Where karst topography is evident, bedrock is generally cavernous and these bedrock aquifers are highly susceptible to contamination through conduit flow (Panno et al. 1997). When these aquifers are overlain by thick till, lake sediment or shale, the water quality is much better protected. Well water on rural upland farms is often drawn from loose, sandy deposits in the upper portion of the Fort Russell till, where water collects below the permeable loess and above the dense, clayey basal till. Yields from these wells are low and are mainly suitable only for household water supplies. Lower portions of Fort Russell till are uniform and quite impervious to groundwater flow; thus, this unit is often drilled into as a natural collection area for groundwater utilized in household wells.

Henry Formation sand and gravel and Cahokia Formation sand in the Mississippi River floodplain comprises the most significant Quaternary aquifer in the bottomlands of this quadrangle. Yields from this aquifer are good; however, the potential for contamination is high because of the relatively thin covering of silt and clay (approximately 5-30 feet).

Sand and Gravel Sand and gravel deposits (but primarily sand), which lie predominantly below the water table, are a potential source for construction materials. As much as 90 feet of sand and gravel occur in the Mississippi River Valley (see cross-section A-A′). Dredging for sand in the Mississippi River is currently in operation (Bluff City Minerals) in the channel northwest of Alton. The sands are primarily siphoned from the upper 15 feet of channel sediment and are used for asphalt and mortar. Gravel content is low, somewhat limiting the use of these sediments by the construction industry (Goldman 1994). As indicated by well logs in the floodplain, usable river sands may be buried by as much as 30 feet of silt and clay.

Mass Wasting Erosion, undercutting and slumping of thick loess deposits at bluff edges are a potential hazard (Killey et al. 1985). Slumps in this area commonly occur when water collects at the base of relatively permeable loess, on top of the clayey Sangamon Geosol or Glasford Formation. Higher pore water pressures in these perched water tables increases the likelihood of slumping or failure along steep slopes. Natural slumps in glacial materials have been noted along many cut-banks, such as along the West Fork Wood River at SE, SW, Sec. 5, T5N, R9W (Killey et al. 1985) and also at site 17f, (Sec. 32, T6N, R9W).

Soil Erosion Steep slopes along ravines and along the bluffs are subject to severe soil erosion due to the nature of loessal soils. Areas mapped as Peoria and Roxana Silt and Peyton Formation have loose, windblown, near-surface silt deposits that are soft and weakly cohesive, and thus have a low shear resistance. These loess deposits (and redeposited loess) are easily eroded by running water during heavy rainfalls. Runoff during rain storms can quickly erode into and enlarge rills and gullies, thereby accelerating the process of erosion, as water is channeled into the growing drainage system.

Flooding Severe flooding, in the Alton area occurs periodically. During the flood of 1993 (Chrzastowski et al. 1994), the Illinois-Mississippi River rose to almost the 440 foot elevation, severely inundating a portion of downtown Alton. The downtown commercial district was susceptible to flooding because it is in a tributary valley to the Mississippi Valley. When water level in the Mississippi River rose above its banks to its maximum height in August 1993 (see photo), floodwaters backed up and inundated tributary valleys (such as downtown Alton) that were not impeded by levees or dikes. The high levee from Clark Bridge and eastward was able to withstand floodwaters east of downtown Alton. However, the city's water treatment plant was endangered because it was located adjacent to the Mississippi River and in its floodplain. The water treatment plant is now being moved to higher ground on uplands a couple of miles west of Alton.

Mapping Techniques

This surficial geologic map is based in part upon soil series parent materials compiled from the Jersey and Madison County soil surveys (Fehrenbacher and Downey 1966, Goddard and Sabata 1982), but was considerably modified based upon field observations and drilling operations, performed as part of this STATEMAP project. Well log data, Illinois Department of Transportation records, and other engineering boring data, on file at the Illinois State Geological Survey, were used to further aid in mapping, and especially in drafting the two cross-sections. A list of data points is available from the ISGS (Grimley, 1999b).

References

Chrzastowski. M.J., M.M. Killey, R.A. Bauer, P.B. DuMontelle, A.L. Erdmann, B.L. Herzog, J.M. Masters, and L.R. Smith, 1994, "The great flood of 1993; geological perspectives on the flooding along the Mississippi River and its tributaries in Illinois", Illinois Geological Survey Special Report #2, Champaign.

Fehrenbacher, J.B. and C.B. Downey, 1966, "Soil Survey: Jersey County, Illinois", University of Illinois Agricultural Experiment Station and United States Dept. of Agriculture.

Goddard, T.M. and L.R. Sabata, , 1982, "Soil Survey: Madison County, Illinois", University of Illinois Agricultural Experiment Station and United States Dept. of Agriculture.

Goldman, H.B., 1994, "Sand and gravel", *in* Industrial Minerals and Rocks 6th Edition (ed. Donald D. Carr), Society for Mining, Metallurgy, and Explor-ation , Inc., Littleton, Colorado.

Grimley, D.A., 1999a, "Surficial Geology Map, Grafton Quadrangle IL-MO", Illinois State Geological Survey IGQ Grafton - SG, 1 sheet.

Grimley, D.A., 1999b, "Key Boring, Outcrop, and Well-Log Descriptions for the Surficial Geology Map of the Alton 7.5' Quadrangle", Unpublished Manuscript (#3), Illinois State Geological Survey.

Killey, M.M., J.K. Hines, and P.B. DuMontelle, 1985,"Landslide Inventory of Illinois": Illinois State Geological Survey Circular 534, 27 p.

Lamar, J.E., 1928, "Karst topography and sanitary engineering at Alton, Illinois": Transactions of the Illinois Academy of Science, v.20, p.261-264.

Leighton, M.M., 1921," The Pleistocene Succession Near Alton, Illinois, and the Age of the Mammalian Fossil Fauna", Journal of Geology, v.29, p.505-514.

Leighton, M.M. and H.B. Willman, 1949, "Late Cenzoic geology of the Mississippi Valley. Itinerary", 2nd Biennial Surface Geologists Field Conference, Illinois State Geological Survey, 86p.

McKay, E. D., 1979, "Stratigraphy of Wisconsinan and older loesses in southwestern Illinois", *in* Geology of Western Illinois, 43rd Annual Tri-State Geological Field Conference, Illinois State Geological Survey, Guidebook 14, p. 37-67.

Panno, S. V., and Weibel, C. P., 1998, "Karst landscapes of Illinois: Dissolving Bedrock and Collapsing Soil": Illinois State Geological Survey Geobit 6, 4 p.

Panno, S, V., Krapac, I. G., Weibel, C. P., and J. D. Bade, 1997, "Groundwater Contamination in Karst Terrain of Southwestern Illinois": Illinois State Geological Survey, Environmental Geology 151, 43 p.

Willman, H.B. and J.C. Frye, 1970, "Pleistocene Stratigraphy of Illinois", Illinois Geological Survey Bulletin 94, 204 p.