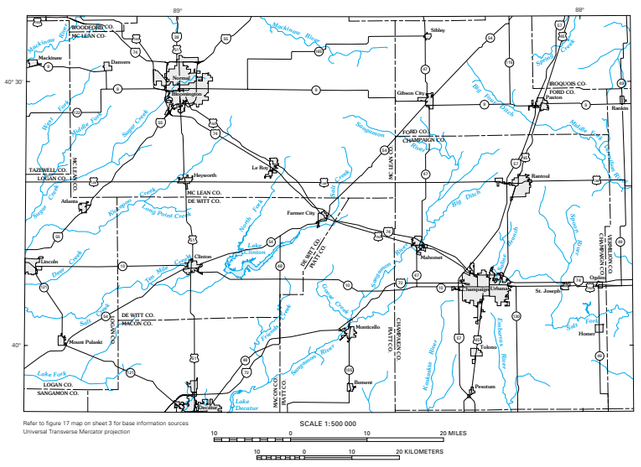
U.S. DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY

Figure 1.—Location of the map area, east-central Illinois.



Refer to figure 17 map on sheet 3 for base information sources
Universal Transverse Mercator projection

SCALE 1:500 000
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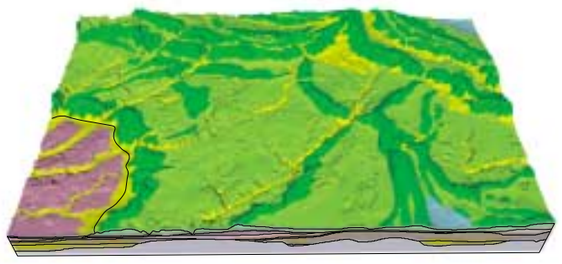
10 0 10 20 KILOMETERS

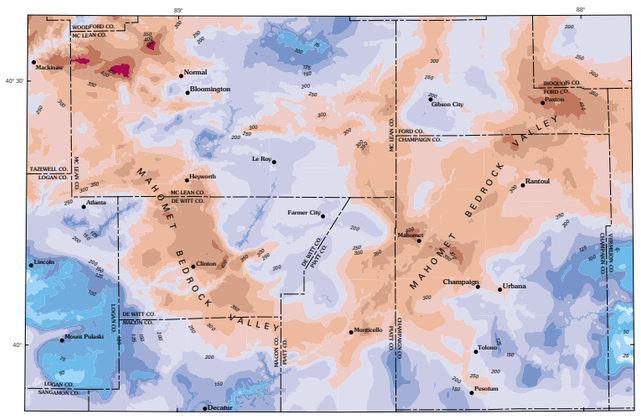
Figure 2.—Selected natural and cultural features in the map area.



EXPLANATION

- Cahokia Formation and Mason Group, Henry Formation—Recent, coarse- to fine-grained alluvial deposits and glacial outwash
- Mason Group, Equality Formation—Clay, silt, and sand deposits of glacial lakes
- Mason and Wedron Groups—Undifferentiated Mason and Wedron; predominantly diamictons (tills) of Wedron Group overlain and underlain by formations, members, and tongues of the Mason Group
- End moraine
- Ground moraine
- Upper Glasford Formation, Radnor Till Member—Mainly diamicton (till) with some associated deposits

Figure 3.—Perspective view, looking north, showing surficial geology and buried Quaternary units in the map area. Surficial geology is from Lineback (1979) and Stiff (1996); the latter is a digital version of the map by Hansel and Johnson (1996). Subsurface geology is from this study, and is shown in more detail on sheet 2; subsurface units are the same as those shown in figure 5. Bedrock interpolations in the southwestern part of the map area, the Upper Glasford Formation is covered in places by younger deposits, which for modeling purposes are assumed to be 15 ft thick (see discussion under "An internally consistent geologic model and set of maps," fourth paragraph). Black line shows the southwestern-most limit of Wedron Group deposits. Topography is from edited, digital versions of USGS 1:100,000-scale topographic maps. Image is vertically exaggerated approximately 30x.

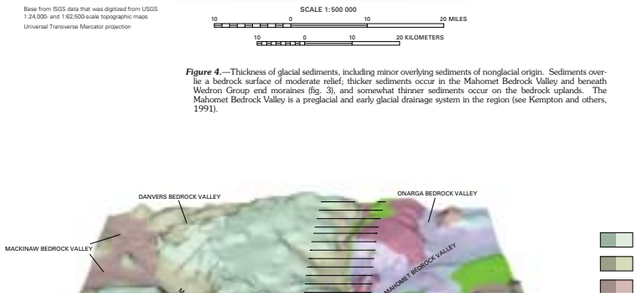


Base from ISGS data that was digitized from USGS 1:24,000- and 1:62,500-scale topographic maps
Universal Transverse Mercator projection

THICKNESS (feet)
For figures 4 and 8–10

450 400 350 300 250 200 150 125 100 75 50 25 10 0

Original measurements of stratigraphic-unit thicknesses were made in feet, so standard units are retained here. To convert to meters, multiply by 0.3048.



Base from ISGS data that was digitized from USGS 1:24,000- and 1:62,500-scale topographic maps
Universal Transverse Mercator projection

SCALE 1:500 000
10 0 10 20 MILES
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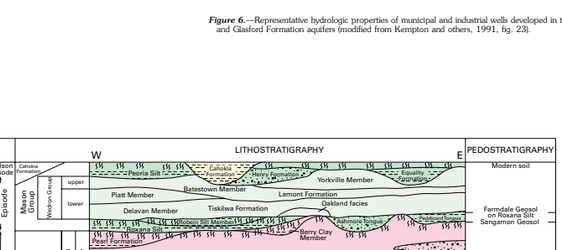
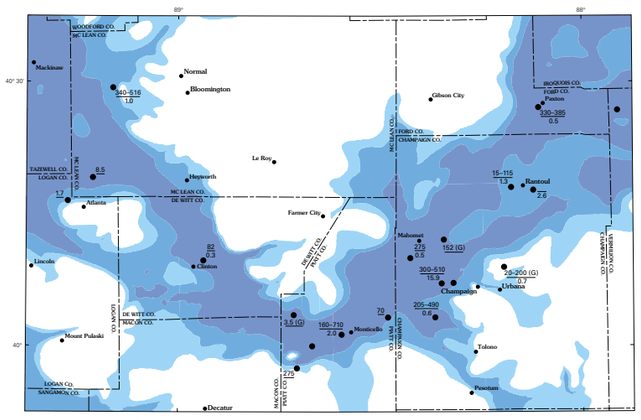
Figure 4.—Thickness of glacial sediments, including minor overlying sediments of nonglacial origin. Sediments overlie a bedrock surface of moderate relief; thicker sediments occur in the Mahomet Bedrock Valley and beneath Wedron Group end moraines (fig. 3), and somewhat thinner sediments occur on the bedrock uplands. The Mahomet Bedrock Valley is a preglacial and early glacial drainage system in the region (see Kempton and others, 1991).



BEDROCK MAP UNITS

- Mattoon and Bond Formations (Pennsylvanian)
- Modesto Formation (Pennsylvanian)
- Carbondale Formation (Pennsylvanian)
- Tradewater Formation (Pennsylvanian)
- Mississippian rocks
- Devonian rocks
- Sikurian rocks
- Approximate location of LaSalle Anticlinorium axis

Figure 5.—Perspective view, looking north, of the geology and topography of the bedrock surface in the map area. Bedrock geology is from Pius Weibel (Illinois State Geological Survey (ISGS), written commun., 1997). Bedrock topography is from this study. The axis of the LaSalle Anticlinorium, of late Paleozoic age, also is shown. To enhance topographic detail, the image is vertically exaggerated approximately 30x.



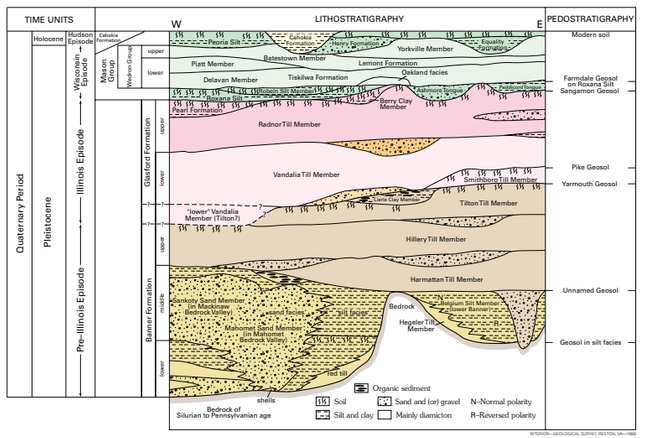
Base from ISGS data that was digitized from USGS 1:24,000- and 1:62,500-scale topographic maps
Universal Transverse Mercator projection

SCALE 1:500 000
10 0 10 20 MILES
10 0 10 20 KILOMETERS

THICKNESS of Mahomet Sand
- 0–50 ft
- 50–100 ft
- 100–200 ft

EXPLANATION
- Public or industrial water-supply well
- Transmissivity in thousands of gallons per day per foot
- 152 (G), 1.0 — Glasford Formation only; Pumpage (1982) in millions of gallons per day

Figure 6.—Representative hydrologic properties of municipal and industrial wells developed in the Mahomet Sand and Glasford Formation aquifers (modified from Kempton and others, 1991, fig. 23).



DESCRIPTION OF UNITS

Cahokia Formation—Coarse- to fine-grained alluvial deposits; is the predominant fill in most of the smaller creek bottoms

Mason and Wedron Groups—Predominantly diamictons (tills) of the Wedron Group overlain and underlain by formations, members, and tongues of the Mason Group; only the Mason occurs in surface valley fills and beyond the Wedron margin. In the stratigraphic column, the Wedron is shown in lighter green and the Mason in darker green

Glasford Formation

Upper Glasford

Radnor Till Member—Mainly diamicton (till) and some associated deposits; includes the Roxana Silt and Robein Silt Member (Mason Group), which, along with the Berry Clay Member (Glasford Formation), provide subsurface marker horizon for the top of the Glasford

Basal Radnor sand and gravel

Lower Glasford

Vandalia and Smithboro Till Members— Mainly diamicton of Vandalia Till Member; the Smithboro occurs only locally at the base. Includes "lower Vandalia" diamicton (till), which may be a separate unit or correlated with the Tilton Till Member (upper Banner). The Robein Silt Member and Sangamon Geosol, including the Berry Clay Member, locally cap the Vandalia beyond the Radnor boundary

Basal Vandalia sand and gravel

Banner Formation

Upper Banner— Mainly diamictons and local sand and gravel of the Tilton, Hillery, and HarmattanTill Members; locally includes cap of the Lierle Clay Member and Yarmouth Geosol. Thin, patchy lower Banner deposits may occur on bedrock uplands, and are included

Middle and lower Banner—Mainly middle Banner sand and gravel of the Mahomet and Sankoty Sand Members, with associated silt (facustrine) facies. The lower Banner occurs locally as diamictons, silt, and sand and gravel, mainly in bedrock valleys in the northwestern part of the map area

Bedrock—Rocks of Pennsylvanian, Mississippian, Devonian, and Silurian age

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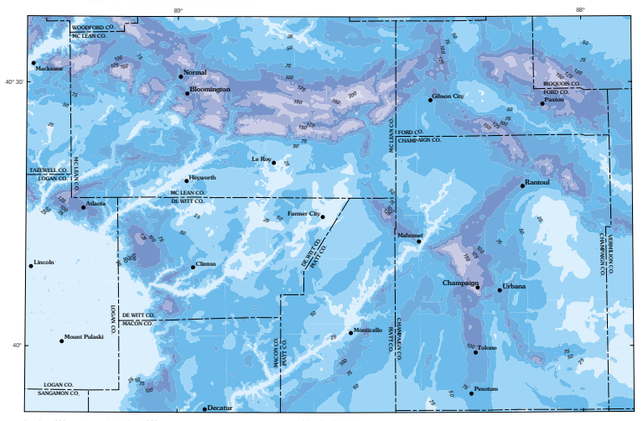
Figure 7.—Diagrammatic stratigraphic column of glaciogenic sediments in east-central Illinois. The Cahokia Formation was deposited mostly during the Hudson Episode. Geologic and stratigraphic names and intervals used in this figure are those accepted by the ISGS.

Prepared in cooperation with the
ILLINOIS STATE GEOLOGICAL SURVEY



Base from ISGS data that was digitized from USGS 1:24,000- and 1:62,500-scale topographic maps
Universal Transverse Mercator projection

SCALE 1:500 000
10 0 10 20 MILES
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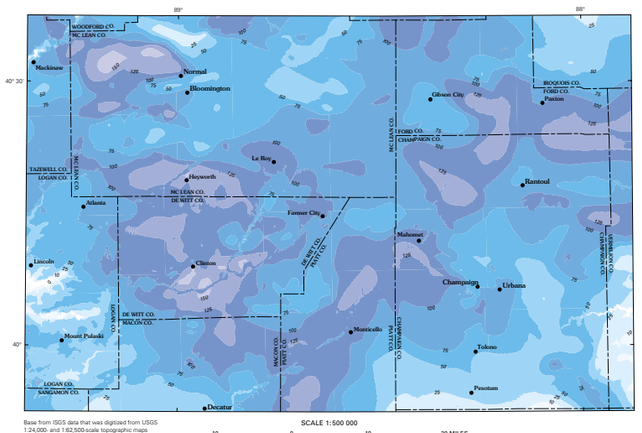
Figure 8.—Thickness of the Wedron and Mason Groups (Wisconsin Episode); includes minor thickness of the Cahokia Formation (Wisconsin and Hudson Episodes) as alluvial fill in the valleys and the Peoria Silt as loess on the uplands. Arcuate bands of thicker sediment correspond to end moraines (see fig. 3), where glacial ice stagnated. Sinuous areas of thin sediment correspond to modern river valleys, where the Wedron and Mason Group deposits have been eroded (for example, the valleys of the Sangamon River and Salt Creek). The southwestern part of the map area lies beyond the limit of Wedron Group deposits. There, only thin, discontinuous Cahokia Formation and Mason Group deposits occur, mostly as alluvium, outwash, and loess; to permit them and the underlying units to be mapped efficiently by computer, a uniform thickness of 15 ft was assumed (see discussion under "An internally consistent geologic model and set of maps," fourth paragraph).



Base from ISGS data that was digitized from USGS 1:24,000- and 1:62,500-scale topographic maps
Universal Transverse Mercator projection

SCALE 1:500 000
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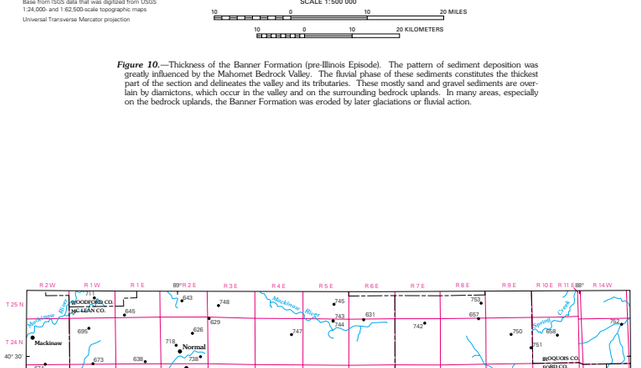
Figure 9.—Thickness of the Glasford Formation (Illinois Episode). The pattern of sediment deposition was affected by the Mahomet Bedrock Valley, which had been partly filled by older sediment. Areas of thicker sediment mostly correspond to this ancient valley. Sinuous areas of thinner sediment correspond to modern river valleys, where the Glasford Formation has been partly or completely eroded (for example, the valleys of the Sangamon River and Salt Creek).



Base from ISGS data that was digitized from USGS 1:24,000- and 1:62,500-scale topographic maps
Universal Transverse Mercator projection

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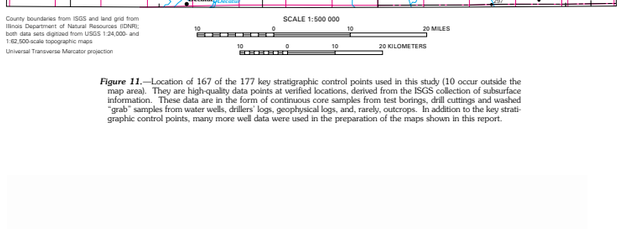
Figure 10.—Thickness of the Banner Formation (pre-Illinois Episode). The pattern of sediment deposition was greatly influenced by the Mahomet Bedrock Valley. The fluvial phase of these sediments constitutes the thickest part of the section and delineates the valley and its tributaries. These mostly sand and gravel sediments are overlain by diamictons, which occur in the valley and on the surrounding bedrock uplands. In many areas, especially on the bedrock uplands, the Banner Formation was eroded by later glaciations or fluvial action.



County boundaries from ISGS and land grid from Illinois Department of Natural Resources (IDNR); both data sets digitized from USGS 1:24,000- and 1:62,500-scale topographic maps
Universal Transverse Mercator projection

SCALE 1:500 000
10 0 10 20 MILES
10 0 10 20 KILOMETERS

Figure 11.—Location of 167 of the 177 key stratigraphic control points used in this study (10 occur outside the map area). They are high-quality data points at verified locations, derived from the ISGS collection of subsurface information. These data are in the form of continuous core samples from test borings, drill cuttings and washed "grab" samples from water wells, drillers' logs, geophysical logs, and, rarely, outcrops. In addition to the key stratigraphic control points, many more well data were used in the preparation of the maps shown in this report.

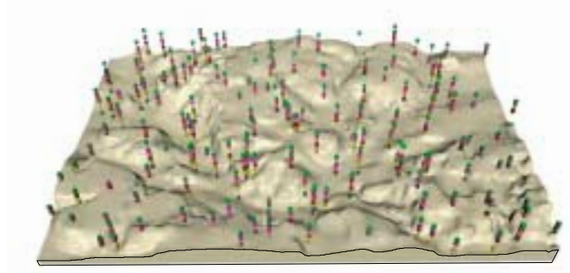


Figure 12.—Perspective view of the map area showing distribution of 167 *key* stratigraphic control points relative to the bedrock topographic surface. Viewpoint is from the south. Each control point is represented by a linked, vertical sequence of colored cubes. The top of each cube represents the top of a stratigraphic unit, as follows: green, land surface; magenta, upper Glasford Formation; pink, lower Glasford Formation; orange, Glasford Formation sands; brown, upper Banner Formation; yellow, middle Banner Formation; and black, bedrock. Cube thickness does not imply unit thickness. To show topographic detail, the image is vertically exaggerated approximately 30x.

DISCUSSION

INTRODUCTION

This geologic mapping project was conducted cooperatively by the Illinois State Geological Survey (ISGS) and the U.S. Geological Survey (USGS) to map the Quaternary deposits in east-central Illinois (figs. 1 and 2). This area provides an excellent geologic setting to develop and test new techniques for mapping Quaternary deposits in three dimensions (that is, mapping the thickness and distribution of geologic materials both at the land surface and in the subsurface), because it has diverse Quaternary geology and thick, regional sand and gravel aquifers within a buried bedrock valley system, the Mahomet Bedrock Valley (figs. 3–5). Decades ago, this valley commonly had been considered part of the Teays River system, a proposed westward-flowing drainage system formed during preglacial and glacial times, which was thought to extend across Illinois, Indiana, and Ohio, to West Virginia. Modern evidence, however, suggests the Mahomet Bedrock Valley is a local drainage system in western Indiana and eastern Illinois that formed during early glaciations through alteration of the preglacial drainage patterns (Melhorn and Kempton, 1991).

The total glacial drift succession is locally thicker than 500 ft in the Mahomet Bedrock Valley, whereas the bedrock uplands are covered by 50 to 300 ft of glacial sediments (fig. 4). Glacial deposits overlie Paleozoic bedrock ranging in age from Silurian to Pennsylvanian. Transmissivity and water quality vary among the bedrock units. Through leakage upward into the Mahomet Sand aquifer, the bedrock units have some effect on its water quality, and should be considered in the modeling and management of ground-water resources (Panno and others, 1994). Figure 5 prominently shows the Mahomet Bedrock Valley incised into the bedrock surface; it also shows the axis of the LaSalle Anticlinorium near the center of the map area. Across this major north-south-trending structure, the Mahomet Bedrock Valley changes course; the upvalley part (to the east) is oriented northeast-southwest whereas the downvalley part (to the west) is oriented southeast-northwest. The map area also contains some of the oldest glacial sediments identified in the region, including a complex sequence of diamictons and sands and gravels associated with multiple glaciations and buried soils associated with interglaciations. A diamicton is a mixture of clay, silt, sand, gravel, and boulders that, if of glacial origin, is commonly referred to as till, although most of the diamictons in the map area are interpreted as till, we use diamicton, the more general descriptor.[1] However, the term "till" is retained where it is part of the stratigraphic name of a unit.

In past studies, various surface and subsurface mapping techniques have been applied to all or parts of the map area. These include an ISGS statewide stack-unit map (Berg and Kempton, 1988), which shows the succession of geologic materials in their order of occurrence to a depth of 50 ft, and a small-scale (1:1,000,000) USGS map of thickness and character of Quaternary deposits (Soller, 1993, 1998). Detailed geographic information system (GIS) techniques (Berg and Abert, 1994, and McLean and others, 1997) have also been developed for the region. This part of east-central Illinois provides an excellent opportunity to test and develop new concepts and procedures for portraying geologic materials in three dimensions, for possible use in future state and national mapping programs.

This study was conducted in a ground-water-rich area of the State, where delineation of sand and gravel aquifers is essential to better understand resource potentials, to resolve conflicts over ground-water use, to support planning for ground-water protection strategies, and to support regional economic growth. Previous studies by Horberg (1945, 1953), and Kempton and others (1991) increased our understanding of the Quaternary deposits. However, since then, available subsurface data have improved, models of regional geologic history have been refined, and the public's need for more precise information has increased. Consequently, existing maps have become outdated. New maps can supply societal benefits not realized by pre-existing ones [for example, see Bernknopf and others (1993) and Soller and Bernknopf (1994)]. A significantly updated database of subsurface information and newly developed methods that incorporate digital mapping techniques have allowed us to provide updated maps based on an improved understanding of the regional geology.

This report comprises three sheets. Figures 1–12 are shown on sheet 1, figures 13–16 are on sheet 2, and figures 17–19 are on sheet 3.

ACKNOWLEDGMENTS

These maps are the product of a cooperative project supported by the ISGS and the USGS. We thank Bill Shilts (ISGS Chief and State Geologist) and John Pallister (Program Coordinator, USGS National Cooperative Geologic Mapping Program) for fostering the cooperative environment needed to conduct the project. We particularly wish to thank Mary Mushrush (ISGS) for many weeks of work in helping to develop the database for the mapping. We also thank Pius Weibel (ISGS) for providing the map of bedrock geology, and James Estaborook and Paul Mathieux (both USGS) for their skillful and timely work on map editing and graphic design. The quality of the maps and text were improved by thoughtful reviews provided by Ardith Hansel, Robert Krumm, and Don McKay (all ISGS), and Carl Kotelly (USGS).

Local school students visiting USGS drill rig at the Gifford site in Champaign County. ISGS geologists are explaining sediment cores from stratigraphic test hole and discussing area's geologic history and resources. The Gifford site is shown in figure 11 (locality 774, section 1, T. 21 N., R. 10 E.).

REGIONAL GROUND-WATER RESOURCES

Ground water within sand and gravel of the buried Mahomet Bedrock Valley aquifer system has been estimated by the Illinois State Water Survey (Visocky and Schicht, 1969) to be able to provide about 445 million gallons per day (mgd) to large municipalities, industry, and private residences. Figure 6 shows representative data from water-well records. Even during the drought of 1988, however, only about 85 mgd were used, which was the maximum yearly usage (Illinois State Water Plan Task Force [ISWPTF], 1997). Therefore, the resource potential of the aquifer system is quite large.

The Mahomet Sand, which fills the deepest parts of the bedrock valley, is the thickest and most widespread aquifer in the system. In addition, overlying the Mahomet Sand are sand and gravel units intercalated with fine-grained sediment. Where the Mahomet Sand is absent, these aquifers are important sources of water for farmsteads, communities, and industries. They also hold water for gradual recharge into the underlying Mahomet Sand Aquifer (ISWPTF, 1997).

The Mahomet Bedrock Valley was defined first by Leland Horberg in 1945. Since then, the bedrock valley and its sand and gravel aquifers have been the subject of considerable interest by scientists, planners, State and local regulatory agencies, the agricultural and industrial community, and the general public. The ISWPTF (1997) reported that increased water use and recent droughts have caused concern about long-term use of the region's aquifers. They noted that the drought of 1988 significantly affected surface-water reservoirs that supply water for the cities of Decatur, Danville, and Bloomington (fig. 1). Potential additional development of the Mahomet Sand Aquifer to supplement these surface water supplies could amount to about 20 to 30 mgd. Of concern is the continued growth in the Champaign-Urbana area (whose wells are the largest system tapping the aquifers) and dependence on the aquifers as the primary supply to many smaller communities. Other users of the ground-water supply have increased in number and in demand and are expected to continue to increase. The number of irrigation systems has expanded and there have been increased industrial activities such as the production of ethanol, which requires large volumes of water.

Because resource development is expected to increase, many communities have sought to control ground-water resource development near their wells and well fields, and local water authorities have been established. However, as the ISWPTF (1997) states, "The desire to unduly or unfairly restrict or control ground-water resource development generally stems from a lack of information about the resources or from a fear of becoming economically disadvantaged due to unknown adverse impacts . . . . Consequently, timely appraisal of these ground-water resources is important so that their development and use will enhance the region while minimizing unnecessary conflicts and preventing degradation of the resource." The maps provided on these sheets are intended to help decisionmakers address this issue.

QUATERNARY STRATIGRAPHY

Figure 7 depicts the relations and current classification of sediments deposited by glacial, periglacial, and fluvial activity in east-central Illinois. The figure is based on this study and on studies by Larson and others (1997), Hansel and Johnson (1996), Herzog and others (1995), Wilson and others (1994), Kempton and Visocky (1992), and Kempton and others (1991). Stratigraphically from top to bottom, these sediments are grouped into three major units whose distribution and thickness are portrayed in figures 8, 9, and 10, respectively. Figure 8 shows the interfingering Mason and Wedron Groups and overlying Cahokia Formation alluvium (Wisconsin and Hudson Episodes); figure 9 shows the Glasford Formation (Illinois Episode); and figure 10 shows the Banner Formation (pre-Illinois Episode). The lower two units are separated into two and three subunits, respectively. The distribution and thickness of the lower and middle Banner Formation subunits are significantly influenced by the configuration of the Mahomet Bedrock Valley system, which generally trends east-west across the map area, and the Mackinaw Bedrock Valley in the northwestern part of the map area. These bedrock valleys and their tributaries are shown in figure 5. Ages of these sedimentary bundles are not precisely known, but are constrained by the following general estimates: Hudson Episode—less than 12,000 years before present (yBP); Wisconsin Episode—75,000 to 12,000 yBP; Illinois Episode—180,000 to 125,000 yBP; and pre-Illinois Episode—more than 500,000 and mostly less than 730,000 yBP. Soils referred to as the Sangamon Geosol and the Yarmouth Geosol formed during interglacial episodes between the Wisconsin and Illinois glacial episodes and the Illinois and pre-Illinois glacial episodes, respectively. The units discussed in this paragraph are also shown in maps on sheets 2 and 3.

In the map area, the Wedron Group is composed of two formations, the Lemont and the Tiskilwa, each composed predominantly of diamicton; two members are recognized in each formation. The Mason Group is composed of water-laid and windblown sediments subdivided into formations, members, and tongues, which occur as deposits both at the land surface and intertonguing with or underlying the Wedron Group units. Within the Mason Group, the Peoria Silt (loess) is the most widespread surface unit; it caps much of the map area but is thickest west of the Wedron boundary in the southwestern part of the map area. The Morton Tongue of the Peoria Silt locally underlies the Wedron Group diamicton. The Henry Formation occurs predominantly in the principal river valleys, commonly beneath modern alluvium, as ribbons of sand and gravel outwash; the Ashmore Tongue of the Henry Formation locally occurs below the Wedron Group diamicton. The Roxana Silt (loess) is the predominant subsurface unit within the Mason Group. It is most easily recognized and identifiable in the subsurface by water-well drilling contractors as well as by geologists) by presence of the Robein Silt Member, a dark-brown to black organic-rich silt (a part of the Farmdale Geosol, whose radiocarbon ages range between 20,000 and 25,000 yBP). The Roxana Silt represents the youngest part of the ice-free interval after deposition of the Glasford Formation. The youngest of the three sedimentary bundles includes the Cahokia Formation, composed of alluvial deposits which fill the river and creek bottoms.

The Glasford Formation as defined for this study includes four recognized members: the Berry Clay Member (an accretion-gley included as part of the Sangamon Geosol), the Radnor Till Member, the Vandalia Till Member, and the Smithboro Till Member. Locally significant sand and gravel commonly occur between the Radnor and Vandalia diamictons and at the base of the Vandalia diamicton. For purposes of this report, the thin, discontinuous Berry Clay Member and overlying Robein Silt Member and Roxana Silt have been grouped with the Radnor Till Member as upper Glasford Formation. Although included in the upper Glasford Formation, the basal sand and gravel also is mapped separately. The lower Glasford Formation includes the Vandalia Till Member, present in most of the map area, the Smithboro Till Member, recognized only locally, and the "lower" Vandalia Member, which currently is assigned to the Glasford Formation but which may be a separate unit or correlated with the Tilton Till Member of the Banner Formation. Beyond the Radnor diamicton boundary in the southeast corner of the map area, the Berry Clay Member, Robein Silt Member, and Roxana Silt are included with the lower Glasford Formation map unit. The basal sand and gravel of the Vandalia Till Member is included in the map unit but also is shown separately.

The Banner Formation contains three distinct subunits: an upper unit consisting principally of diamictons, a middle unit composed principally of coarse- to fine-textured water-laid sediments, and a lower unit composed of interbedded diamictons and coarse- to fine-textured water-laid sediments. The upper Banner Formation contains three named diamicton members, the Tilton, Hillery, and Harmattan, and a locally occurring uppermost member, the Lierle Clay, which is an accretion-gley facies of the Yarmouth Geosol developed in the uppermost Banner Formation unit. All of these units may be present over the bedrock valley or uplands. Of the three diamicton members, the Hillery Till Member is the most widespread and easily recognized unit in samples and in well-drillers' logs (because of its distinctive reddish color) throughout the map area. The Harmattan Till Member may intertongue with the upper part of the middle Banner Formation sand and gravel just to the east of the map area. On the uplands, lower Banner Formation deposits are described in well logs in various places, but their distribution is apparently patchy and they are not easily separated; therefore, for this report, lower Banner deposits on the uplands are included in the upper Banner Formation.

The middle and lower Banner Formation units are restricted mainly to the bedrock valleys and compose most of the fill in these valleys. The middle Banner Formation consists of the Mahomet Sand Member in the Mahomet Bedrock Valley and its equivalent, the Sankoty Sand Member in the Mackinaw Bedrock Valley. It is composed mainly of outwash sand and gravel within the main bedrock valleys, but intertongues with a silt facies in the tributary valleys, and grades upward into fine-textured lacustrine silts, and locally organic-rich alluvial silt, in some areas of the main bedrock valleys. These silts were deposited in temporary lakes created by ice or sediment dams. The approximate delineation between the fluvial and lacustrine facies of the Mahomet Sand Member is shown in figures 14B and 15A (sheet 2). In most of the Mahomet Bedrock Valley, the middle Banner Formation composes the entire fill of the valley and rests on Pennsylvanian or older bedrock units; in some of the tributaries, its silt facies overlies older deposits of the lower Banner Formation. Lower Banner Formation deposits are described in well logs and samples in various places in the Mahomet Bedrock Valley, but their distribution is patchy and they are not easily separated; therefore, for this report, lower Banner deposits in the Mahomet Bedrock Valley are included in the middle Banner Formation.

The most extensive deposits of the lower Banner Formation are found in the western confluence area of the Mahomet and Mackinaw Bedrock Valleys. In this region, recent studies and drilling (for example, Herzog and others, 1995) have shown extensive areas containing interbedded diamictons, coarse-textured sand and gravel, and fine-textured lacustrine sand, silt and clay beds. Although these deposits appear to be highly variable in distribution, thickness and composition, it is possible with more data they will become more predictable, and mappable. To the east of the map area on the bedrock uplands, local remnants of older sediments are present and correlated mainly with the lower Banner Formation. These deposits include the Belgium Silt Member, which records a remanent magnetism with reversed polarity (Kempton and others, 1991). This information, along with amino-acid racemization determinations (Miller and others, 1992) made on shells collected from a gravelly clay resting on bedrock and directly below the Mahomet Sand Member close to the deepest part of the Mahomet Bedrock Valley, suggests that the age of these oldest deposits is more than 730,000 yBP.

MAPPING THE DEPOSITS

Stratigraphic Database

Over many years, an extensive ISGS collection of records from wells and borings has been used to interpret age relations and lithology for geologic mapping and groundwater studies in cooperation with local, State, and Federal partners. A cornerstone of our current effort was identifying a set of "key stratigraphic control points" (Kempton, 1990) from the ISGS collection of subsurface data. This collection was supplemented by data from six test holes drilled for this project, including the Gifford site shown in the photographs. From these control points, we built a stratigraphic database. We identified 177 such borehole records, which, if they were evenly spaced, would average about 1.5 per township. These data served as principal control for constructing maps of each stratigraphic unit. Figures 11 and 12 show the locations of the control points. Only 167 control points are shown in figures 11 and 12 because 10 points are located outside the map area.

These high-quality data points have been described in detail by ISGS geologists, and their locations have been field verified. The information is in the form of continuous core samples from test borings, drill cuttings and washed "grab" samples from water wells, geophysical logs, and, rarely, outcrops. Some drillers' logs having detailed descriptions were used in a few areas of sparse data. Samples provide an understanding of the geology at a given site, and are commonly compared to data in nearby well logs to develop interpretations of the distribution of any particular geologic surface, both areally and at depth. When integrated with geologic surfaces above and below, these data served as principal control while we constructed a map of each stratigraphic unit. These data also were used to develop the interpretive cross sections (sheet 3