U.S. GEOLOGICAL SURVEY GEOLOGIC INVESTIGATIONS SERIES MAP I-2669

Three-Dimensional Geologic Maps of Quaternary Sediments in East-Central Illinois

By **David R. Soller, Susan D. Price, John P. Kempton,** ***and*** **Richard C. Berg**

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 Estabrook 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 Koteff (USGS).

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, fig. 17), which were drawn by hand as the regional model of geologic history was developed.

Although only 177 boreholes constituted the key stratigraphic control, many more well data were used in preparation of these maps. These secondary data were helpful in refining the location of contour lines. For some stratigraphic surfaces, these secondary data were numerous; for example, 1355 boreholes were used in the construction of the bedrock-surface elevation map.

Methodology

Because of the thick sequence of geologic materials in the region, and the paucity of exposures, subsurface information was a critical part of the geologic mapping project. Subsurface information formed the basis for most geologic maps of the region and for the evolution of concepts of the geologic history of the Mahomet Bedrock Valley system and the origin of the sediment cover that incrementally buried it (for example, Horberg, 1953; Kempton and others, 1991; Herzog and others, 1995; and Larson and others, 1997). It was a primary goal of our study to build upon the findings of prior investigations, using newly refined stratigraphic data to produce updated, revised maps that could be used for various computer-aided applications such as ground-water modeling.

Another goal was to produce these maps using digital methods because, increasingly, counties, planning agencies, and other entities are using geographic information systems (GIS) to support decisionmaking and planning. These entities need digital geologic map information and specific information or interpretations derived from geologic maps. This derived information, combined with related scientific and socioeconomic data, can help support reasoned decisions. Commonly, this information is compiled and analyzed using GIS technology because of the large size and complexity of many map databases and the need to readily update and revise maps as new interpretations and data become available. Because computer-based mapping of deposits in three dimensions is not yet a common, well-established practice, we developed GIS-based methods to integrate point data (key stratigraphic control) and areal data (geologic mapping) in three dimensions. These methods are only briefly described here and in Soller and others (1998).

Maps constructed using GIS techniques are in some ways easier to produce than conventional, hand-drawn maps. For example, map revision and generation of color proofs is done more quickly in a GIS. For other needs, however, conventional mapping can be easier and less time consuming. For example, consider an area having thin, discontinuous units. While creating a hand-drawn set of maps showing elevation of the top of each unit, the geologist will attempt to ensure, visually, that a unit's elevation contour lines do not conflict with those of overlying and underlying units (so that, for example, the elevation of a lower unit does not surpass an upper unit). In so doing, the geologist produces an internally consistent, three-dimensional geologic model and set of maps for a region.

With GIS techniques, maps are produced that are similar in appearance to hand-drawn maps; to the eye, each elevation map may appear to not conflict with the elevation maps of other stratigraphic units. However, to develop a truly internally-consistent set of maps, the maps are processed into a raster (gridded) format, as described below. Then, conflicts in elevation between horizons (and larger conflicts across several horizons) are easy to detect. Correcting those conflicts is not, however, a trivial undertaking. A significant effort was spent to develop a set of maps which adhered to our models for glaciofluvial deposition and erosional history.

Based on our experience, and considering the time needed to generate this model and set of maps, we advise that before a mapping project is begun, the planned and potential uses of the map products be carefully evaluated. Providing an internally consistent, three-dimensional model is essential if there is an analytical use planned, such as development of a ground-water flow model. However, if adequate high-quality data are not available, these maps should not be developed, but more conventional, vector-based methods for preparing maps of each surface should be used to provide a general, visual depiction of the geologic framework.

Creating a vector map

Figures 13-16 (sheet 2) present for each of five primary Quaternary stratigraphic units and two minor sand layers a block diagram (three-dimensional perspective view) showing topography of the upper surface, an elevation map of the upper surface, and a thickness map. A block diagram and an elevation map of the bedrock surface are also shown. Our mapping of each stratigraphic unit was an iterative process that, through re-examination of stratigraphic data and maps, gradually refined our understanding of the vertical and lateral distribution of each unit. To map a unit, we first plotted the stratigraphic control data, then prepared a hand-contoured map based on the data and on an understanding of the regional distribution of the materials and geologic history (for example, the middle Banner Formation had a glaciofluvial origin and was confined to bedrock valleys). The map was then scanned and a vector map of the linework was created.

Converting to raster format

A vector map generally is a faithful rendition of a hand-drawn contour map. For example, each vector, or line, on an elevation map of the upper surface of the middle Banner Formation has an elevation value (for example, the 475- or 500-foot elevation contour). Areas between contour lines possess a range of elevation (for example, between 475 and 500 ft), and the elevation at any location on the map (other than on a contour line itself) cannot be more precisely defined. Although such values may be inferred by interpolation, they are not explicitly defined. A raster map, however, depicts information at each of many regularly spaced grid cells. It contains more information than a vector map, because it also provides an estimated or interpolated value between data points and contour lines. Computer-generated cross-sections, three-dimensional visualizations, and many modeling routines (for example, for ground-water flow) require raster data.

Data on the vector map were processed to a raster format. Although useful for analysis, raster maps can appear somewhat different from vector maps, because they tend to show the map information with a blocky or jagged appearance rather than the smoothly drawn boundaries to which we are accustomed. For example, refer to the northeast corner of figure 15B (sheet 2), specifically the areas classified as 25-50 and 50-75 ft thick. There, a jagged contact is displayed because each raster data point, which varies by as little as one foot from its neighbor, has been assigned to an elevation category. This has been done purely to aid in visual comprehension--the continuous data on a raster map are force-fit into an interval classification, which is more appropriate to vector maps. Jagged contacts, while they may appear to signify errors or inconsistencies on our maps, actually connote very small changes in elevation (for example, values on either side of the jagged 50-foot contour in the northeast corner of figure 15B vary by only a foot or so). In contrast, values on either side of that contour on a vector map may only be inferred to differ by somewhat less than the contour interval, here 50 ft.

For presentation, we considered creating a smoothed, vector version of each raster map. However, the time and expense involved, and, more important, our desire to emphasize the analytic uses of digital geologic maps, led us to retain the raster maps in this report. To aid visual aesthetics, we chose a small raster grid size (100 meters), thereby minimizing the characteristic blockiness of raster maps. If only the key stratigraphic control data were considered in the gridding, this grid size would be inappropriately small. However, for each stratigraphic unit a general interpretation of depositional and erosional history was developed (a conceptual geologic process model), providing a basis for assumptions about each unit's three-dimensional distribution. Our grid size was selected to maintain the traditional, vector-like appearance of the maps while creating a digital map product that could be adapted to more analytical purposes. For an application such as ground-water modeling, the grid cells may be aggregated to provide a spatial framework more realistic to the needs of that application.

An internally consistent geologic model and set of maps

After each elevation map was rasterized, it was compared to the stratigraphic control data and to the elevation maps of stratigraphic units above and below it. This was the first stage of an iterative process of re-evaluating stratigraphic interpretations in the database and refining the maps. In many cases, interpreting the stratigraphy was difficult because units of distinctly different ages and different depths looked the same. For example, in test borings that sample multiple diamictons, upper Banner Formation diamictons can be misidentified as lower Glasford Formation due to their similar appearance, especially if intervening soils are not present. If the elevation of a stratigraphic unit at a particular point was anomalously higher than appropriate, based on the regional geologic map trend, it was re-examined for a potentially better fit with an overlying map unit. In some cases, the lithologic characteristics of the sample were inconclusive and the stratigraphic interval was assigned to the younger age, whereas in other cases the stratigraphy was found to be correct and diagnostic of the lower unit. In the latter case, a shortcoming of the regional mapping is indicated: the anomalously high data point was correct and represented some local relief that was not mappable at our scale. Those map data were retained, and the resulting local "spike" in the map surface indicates a need to gather more information for that area. This situation occurs near the southeast corner of the map area shown in figures 13D and E (sheet 2); there, a small topographic high corresponds to a key stratigraphic control point. Only with extraordinary efforts to collect significantly more data could the fine detail around the data point be mapped.

Discontinuous units are particularly difficult to map because gridding algorithms compute cell values by interpolation methods. [We used the Arc/Info Topogrid algorithm; for these data, we found that other algorithms supplied in Arc/Info and in other software provided results less appropriate to our needs.] No algorithm can produce a realistic map where data are absent across areas of relatively high relief. Consider, for example, the middle Banner Formation, which is confined to valleys separated by expanses of upland. A gridding algorithm must compute a value for every cell, including those far removed from data points, and each cell's value depends in some measure on adjacent cells. Unrealistic cell values that greatly departed from values on the vector map were corrected by 1) increasing the density of the elevation data on the vector map (especially in topographically flat areas and near large changes in slope gradients), 2) re-gridding the map, and 3) removing upland-area data from the raster map (because, as noted above, the middle Banner Formation does not occur on the uplands). This method is useful for units whose depositional pattern is predictable. For the basal sands of the Glasford Formation (sheet 2, fig. 16), data are sparse and the unit's distribution is not so predictable. There, we gridded the unit thickness data and computed the elevation of the upper surface by adding unit thickness to the elevation of the underlying unit.

Comparison of maps for each layer revealed potential inconsistencies such as areas where an older, lower unit was mapped at a higher elevation than the unit above. For example, the initial raster map of the upper Banner Formation was computed without considering the topography of underlying units. Comparison of bedrock and upper- Banner elevation maps revealed the control that bedrock topography imposes on the distribution of upper Banner deposits. Revision of contour lines and re-gridding produced a map showing the correct spatial relation--progressive thinning and then absence of upper Banner Formation, from the valley to the bedrock uplands. Refinement of the map of each stratigraphic unit proceeded in this fashion until an internally consistent stack of maps was created.

Internal consistency between the elevation map of the Wedron and Mason Groups and the elevation map of the upper Glasford Formation (sheet 2, figs. 14E and F) was difficult to achieve, especially in the southwestern part of the map area at the limit of Wisconsin ice, where thick Wedron Group end-morainal deposits abut an area underlain by outwash, alluvium, and loess of the Mason Group and Cahokia Formation (sheet 2, fig. 15E). There, Mason Group deposits and Cahokia Formation are in places thick, thin, or absent; all overlie upper Glasford Formation deposits, which are in places exposed. Considering the thin, discontinuous nature of the overlying deposits in that area, the upper Glasford Formation reasonably could be mapped at the land surface. However, joining the complex land-surface topography with the far more generalized contours of the buried upper Glasford Formation surface to the north and east, under the Wedron Group end moraine, and then integrating that composite surface with the map of the overlying unit (Wedron and Mason Groups) did not give satisfactory results. The fine topographic detail southwest of the end moraine could not readily be meshed with the coarser, less detailed contour data on the upper Glasford surface under the end moraine. Attempts to mesh the contours were unsuccessful, resulting in abrupt topographic breaks across the toe of the end moraine. These breaks could be corrected, mostly through editing of individual cells or pixels. It was decided not to do so, because of the time and effort needed and because the corrections would produce a map that could not readily be updated or revised during development of the integrated geologic model and set of maps. Also, future revisions to the map by the process described above (that is, revisions to the vector map and re-gridding) could not be made if the raster map were extensively edited. Therefore, the following assumption was applied to the map information, prior to rasterization: the topographic break beneath the end moraine was resolved by assuming a minimum 15-foot thickness for surface deposits of the Wedron and Mason Groups and Cahokia Formation across the study area. Southwest of the end moraine, this effectively lowered the top of the Glasford Formation by 15 ft, removing the topographic break and permitting a smooth integration of the Wedron and Mason Group map with the upper Glasford Formation map across the area. This assumption also affects areas where modern streams have incised Glasford Formation and older deposits; there, the top of the older deposits in these valleys has been effectively lowered by 15 ft, producing a minimum 15-foot thickness of Cahokia Formation alluvium in the riverbeds. The presence of Cahokia Formation alluvium is reasonable and is generally supported by field observations. However, as a consequence of the assumed minimum 15-foot thickness, thin surficial deposits also are shown along valley margins where they may not actually occur (see fig. 17 on sheet 3); there, modern erosion has in places exposed upper Glasford Formation and older deposits.

Both data quality and certainty of interpretation varied significantly for each stratigraphic unit. We used the most certain of the units as the starting point to develop the set of maps, relying on them to constrain the mapping of less well-understood units. The top of the Mason and Wedron Groups, which corresponds to the land surface, was an obvious starting point. Among the buried units, we had the most confidence in maps of the bedrock surface and the top of the middle Banner Formation, for two reasons. First, the Mahomet Sand Aquifer and the bedrock surface were easy for drillers and geologists to identify, relative to the gray-brown diamicton-dominated stratigraphy in the remainder of the section. Second, the fluvial processes that controlled bedrock erosion and deposition of the middle Banner Formation are relatively well understood; fluvial processes leave a relatively predictable pattern of deposits constrained within a network of valleys.

We therefore began our modeling from the top (land surface) and the bottom (bedrock surface and top of middle Banner Formation) of the depositional sequence, and worked toward the middle, where interpretations of spatial patterns of buried diamictons and associated sand and gravel are most difficult. For example, the boundary between the upper Banner Formation and lower Glasford Formation was particularly problematic because multiple diamictons commonly occur with scant evidence of paleosols separating them or without the presence of a complete section. Our map of a stratigraphic unit was vastly improved by comparing it to vertically adjacent, well-defined units.

With a complete set of elevation maps generated, maps of unit thickness were then computed, by calculating the difference in elevation between the top of the unit and the top of the underlying unit. Because these thickness maps are derived from two raster elevation maps, they reflect characteristics of each parent map. Consequently, when displayed as interval rather than continuous data, they tend to show more of the characteristic jagged appearance of raster maps than do the elevation maps. As discussed above, these are not mapping errors.

VISUALIZING THE DEPOSITS IN THREE DIMENSIONS

Geologists have traditionally used cross sections and fence diagrams to visualize geologic units in three dimensions. Portraying the three-dimensional nature of geologic materials in as much detail as possible is essential to an improved understanding of geologic maps and geologic processes responsible for the distribution of deposits. This information is needed both during the iterative process of mapping and for the public's comprehension of map information. The three-dimensional visualization products we provide here were developed in EarthVision software, from two-dimensional grids of each stratigraphic horizon created in Arc/Info. They include block diagram perspective views of each stratigraphic horizon (sheet 2, figs. 13 and 16C and F) and the fence diagram and horizontal "slices" on sheet 3 (figs. 18 and 19).

Traditional methods of showing changes in subsurface-unit geometry along a vertical plane (cross sections; see fig. 17 on sheet 3) and providing a three-dimensional perspective of these planar views (fence diagrams; see fig. 18 on sheet 3) are useful for illustrating the configuration of the Mahomet Bedrock Valley and progressive valley infilling. Cross sections may be selected to emphasize a particular feature, such as unit thickness along the length of the Mahomet Bedrock Valley at its thalweg, or deepest point (see cross-section J-J' on sheet 3).

Computer software provides the opportunity to easily manipulate data in order to quickly view and evaluate subsurface deposits as maps are iteratively being developed. Software also allows the geologist to view and evaluate the deposits from more perspectives than would be efficient using traditional cartographic methods. For example, figure 19 on sheet 3 shows the pattern of units that would be seen along a horizontal plane at a given elevation if overlying deposits were removed. Starting with the lowest plane, this series of images shows the gradual infilling of the Mahomet Bedrock Valley, and may suggest the persistence of this feature throughout the section. When displayed on the computer as an animation, this series of maps provides a new, dynamic visualization of the distribution of deposits through time. Computer-based, three-dimensional visualization offers a significant new opportunity for a more complete understanding of subsurface glaciogenic sediments, both to the geologist and to other map users.

REFERENCES CITED

Berg, R.C., and Kempton, J.P., 1988, Stack-unit mapping of geologic materials in Illinois to a depth of 15 meters: Illinois State Geological Survey Circular 542, 23 p., map scale 1:250,000.

Berg, R.C., and Abert, C.C., 1994, Large-scale aquifer sensitivity model: Environmental Geology, International Journal of Geosciences, v. 24, no. 1, p. 34-42.

Bernknopf, R.L., Brookshire, D.S., Soller, D.R., McKee, M.J., Sutter, J.F., Matti, J.C., and Campbell, R.H., 1993, Societal value of geologic maps: U.S. Geological Survey Circular 1111, 53 p.

Hansel, A.K., and Johnson, W.M., 1996, Wedron and Mason Groups: Lithostratigraphic reclassification of deposits of the Wisconsin Episode, Lake Michigan Lobe area: Illinois State Geological Survey Bulletin 104, 116 p.

Herzog, B.L., Wilson, S.D., Larson, D.R., Smith, E.C., Larson, T.H., and Greenslate, M.L., 1995, Hydrogeology and groundwater availability in southwest McLean and southeast Tazewell counties; Part 1: Aquifer characterization: Illinois State Geological Survey and Illinois State Water Survey Cooperative Groundwater Report 17, 70 p.

Horberg, Leland, 1945, A major buried valley in east-central Illinois and its regional relationships: Illinois State Geological Survey Report of Investigations 106, 11p.

------1953, Pleistocene deposits below the Wisconsin drift in northeastern Illinois: Illinois State Geological

Survey Report of Investigations 165, 61 p.

Illinois State Water Plan Task Force, 1997, The Mahomet Bedrock Valley Aquifer System, knowledge needs for a vital resource: University of Illinois at Urbana-Champaign, Water Resources Center Special Report 21, 49 p.

Kempton, J.P., 1990, Key stratigraphic control (Quaternary): SSC area: Illinois State Geological Survey Open-file Series 1990-10, 42 p.

Kempton, J.P., Johnson, W.H., Cartwright, K., and Heigold, P.C., 1991, Mahomet Bedrock Valley in east-central Illinois: topography, glacial drift stratigraphy, and hydrogeology, *in* Melhorn, W.N., and Kempton, J.P., eds., Geology and hydrogeology of the Teays-Mahomet Bedrock Valley system: Geological Society of America Special Paper 258, p. 91-124.

Kempton, J.P., and Visocky, A.P., 1992, Regional groundwater resources in western McLean and eastern Tazewell counties with emphasis on the Mahomet Bedrock Valley: Illinois State Geological Survey and Illinois State Water Survey Cooperative Groundwater Report 13, 41 p.

Larson, D.R., Kempton, J.P., and Meyer, S., 1997, Geologic, geophysical, and hydrologic investigations for a supplemental municipal groundwater supply, Danville, Illinois: Illinois State Geological Survey and Illinois State Water Survey Cooperative Groundwater Report 18, 62 p.

Lineback, J.A., 1979, Quaternary deposits of Illinois: Champaign, Ill., Illinois State Geological Survey, scale 1:500,000.

McLean, L.R., Kelly, M.D., and Riggs, M.H., 1997, Thickness of Quaternary deposits in McLean County, Illinois: Illinois State Geological Survey Open-File Series 1997-1E, map scale 1:100,000.

Melhorn, W.N., and Kempton, J.P., 1991, The Teays System; A summary, *in* Melhorn, W.N., and Kempton, J.P., eds., Geology and hydrogeology of the Teays-Mahomet Bedrock Valley system: Geological Society of America Special Paper 258, p. 125-128.

Miller, B.B., Reed, Philip, Mirecki, J.E., and McCoy, W.D., 1992, Fossil molluscs from pre-Illinoian sediments of the buried Mahomet Valley, central Illinois: Current Research in the Pleistocene, v. 9, p. 117-118.

Panno, S.V., Hackley, K.C., Cartwright, K., and Liu, C.L., 1994, Hydrochemistry of the Mahomet Bedrock Valley Aquifer, east-central Illinois: indicators of recharge and ground-water flow: Ground Water, v. 32, no. 4, p. 591-604.

Soller D.R., 1993, Preliminary map showing the thickness and character of Quaternary sediments in the glaciated United States east of the Rocky Mountains: U.S. Geological Survey Open-File Report 93-543, map scale 1:3,500,000.

------1998, Map showing the thickness and character of Quaternary sediments in the glaciated United States east of the Rocky Mountains: Northern Great Lakes States and Central Mississippi Valley States, the Great Lakes, and southern Ontario (80°31' to 93° West Longitude): U.S. Geological Survey Miscellaneous Investigations Series Map I-1970-B, scale 1:1,000,000.

Soller, D.R., and Bernknopf, R.L., 1994, Geologic information and land use decisions: Geotimes, v. 39, no. 4, p. 12-14.

Stiff, B.J., 1996, Quaternary deposits of Illinois, 1996: Champaign, Ill., Illinois State Geological Survey GIS database "quat96", version 1.0, scale 1:500,000.

Visocky, A.P., and Schicht, R.J., 1969, Ground-water resources of the buried Mahomet Bedrock Valley: Illinois State Water Survey Report of Investigation 62, 52 p.

Willman, H.B., and Frye, J.C., 1970, Pleistocene stratigraphy of Illinois: Illinois State Geological Survey Bulletin 94, 204 p., map scale 1:500,000.

Wilson, S.D., Kempton, J.P., and Lott, R.B., 1994, The Sankoty-Mahomet aquifer in the confluence area of the Mackinaw and Mahomet Bedrock Valleys, central Illinois: A reassessment of aquifer characteristics: Illinois State Geological Survey and Illinois State Water Survey Cooperative Groundwater Report 16, 64 p.

[1]Geologic and stratigraphic names and intervals used in this report are those accepted by the Illinois State Geological Survey.

Back to I-2669

U.S. Geological Survey, U.S. Department of the Interior
This page is <URL: http://pubs.usgs.gov/i-maps/i-2669/readme.html>
Maintained by the Eastern Publications Group
Contact: Dave Soller
Last Modified 02.29.00