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HYDROGEOLOGY OF GLACIAL DEPOSITS OF THE MAHOMET BEDROCK VALLEY IN EAST-CENTRAL ILLINOIS


David A. Stephenson

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HYDROGEOLOGY OF GLACIAL DEPOSITS OF THE MAHOMET BEDROCK VALLEY IN EAST-CENTRAL ILLINOIS

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ABSTRACT

The Mahomet Bedrock Valley localizes highly permeable sand and gravel aquifers that are the only developed source of large ground-water supplies in east-central Illinois. These aquifers were studied by quantitative methods of geologic evaluation, and their three-dimensional configurations were determined.

Three hydrostratigraphic units are recognized within the drift. These units correlate with deposits of the Wisconsinan, Illinoian, and pre-Illinoian Stages of the Pleistocene Epoch. Pre-Illinoian sand and gravel strata occur within the drift filling the deepest portions of bedrock channels and constitute aquifers with a potential for increased ground-water development. These deposits are permeable, may exceed 150 feet in thickness, and appear to be present throughout a large percentage of the bedrock channels. Illinoian deposits contain a smaller proportion of permeable strata than pre-Illinoian deposits, but are presently the most widely utilized for small and moderate ground-water supplies. Wisconsinan deposits do not contain extensive permeable strata except for local occurrence of sand and gravel in depressions on the buried Sangamonian land surface.

Lithofacies maps were prepared for each 100-foot elevation interval to determine the three-dimensional distribution of aquifers within the drift. These maps illustrate one method of defining aquifer distribution in an economic and expedient manner and they afford the basis for extrapolating limited hydrologic data. Coefficients of transmissibility are estimated from specific-capacity data and are related to geologic units.

INTRODUCTION

The development of large ground-water supplies in east-central Illinois largely depends on the location of permeable sand and gravel strata within glacial drift and alluvial deposits of the region, particularly the permeable deposits within and adjacent to the buried Mahomet Bedrock Valley. The thick, permeable strata in this valley system are the only source of large ground-water supplies in east-central Illinois.

The Mahomet Bedrock Valley region (fig. 1) is covered by drift deposited by a succession of continental glaciers. The permeable strata within the drift are present in a complex depositional pattern. Alluvial deposits not directly associated with glacial processes also partially fill the present stream valleys.

Hydrogeologic conditions in the drift of the Mahomet Bedrock Valley region are evaluated in this report. Quantitative mapping techniques are tested as one method of describing the occurrence and distribution of the water-yielding deposits. Empirical relationships between subsurface geologic conditions and aquifer coefficients are determined to facilitate extrapolation of hydrologic data.

Previous Investigations

A number of investigations in east-central Illinois by the State Geological and Water Surveys have aided in the search for ground-water supplies. These earlier reports have been used as reference material or have been utilized indirectly in preparing this report.

Foster and Buhle (1951) utilized the results of electrical earth resistivity surveys, test drilling, and electric logging of borings near Champaign-Urbana to make a geological study of glacial-drift aquifers, and mapped untapped sources of ground water. Horberg (1945) first defined the buried Mahomet Bedrock Valley system and made a bedrock surface contour map of the system. He later (1950) related the bedrock surface of Illinois to physiography and Pleistocene glaciation to aid in the location of bedrock valleys and to determine general ground-water conditions throughout glaciated areas. Still later (1958) he studied the glacial deposits below the Wisconsin drift in northeastern and east-central Illinois. Selkegg and Kempton (1958) described the general ground-water conditions in east-central Illinois. Smith (1950) discussed aquifer characteristics in the three principal aquifers penetrated

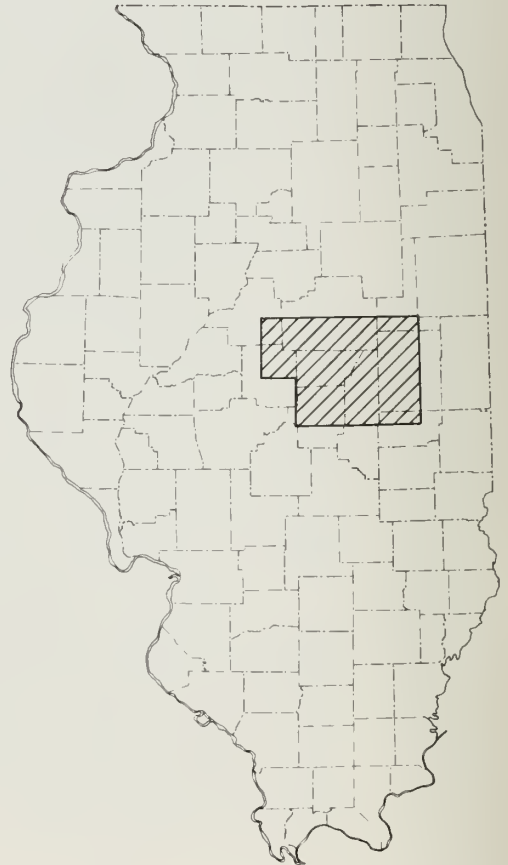


Figure 1 - Index map showing Mahomet Bedrock Valley region.

by wells in Champaign County, with specific reference to the area in and adjacent to Champaign-Urbana. Walton (1965) discussed ground-water recharge to the sand and gravel aquifers in the Champaign-Urbana region and in other areas of Illinois.

Acknowledgments

This report is adapted from a doctoral dissertation submitted to the Graduate College of the University of Illinois, under the direction of Professor R. N. Farvolden, Department of Geology. The research was carried on while the author was a member of the Illinois State Geological Survey. Members of the Ground-Water Geology and Geophysical Exploration Section and the Coal Section of the Geological Survey facilitated the project. Mr. Paul Heigold gave valuable assistance in IBM programming.

GEOGRAPHY

Location and Extent of Region

The Mahomet Bedrock Valley region comprises a reach of the buried Mahomet Bedrock Valley system approximately 100 miles long and areas adjacent to either side of the valley axis. This segment of the valley lies between the Havana Lowland on the west and the Kempton-Newark bedrock tributary valley on the east. The eastern boundary of the Havana Lowland near Armington (fig. 2) is near the confluence of the Ancient Mississippi channel and the Mahomet Valley.

The region has an area of approximately 3000 square miles, and includes all or portions of nine counties: Champaign, DeWitt, Douglas, Ford, Logan, Macon, McLean, Piatt, and Tazewell. The principal municipalities within the Mahomet Valley region are shown in figure 2.

Physiography and Drainage

The study area lies primarily within the Bloomington Ridged Plain of the Till Plain Section, Central Lowland Province (Leighton, Ekblaw, and Horberg, 1948, p. 18). The Bloomington Ridged Plain has wide stretches of relatively flat or gentle undulatory surfaces composed of ground moraine punctuated by a series of low, broad morainic ridges (fig. 3). The southern limit of this subsection, the Shelbyville Moraine, is the most prominent ridge, and is also the approximate boundary between Wisconsinan drift to the north and east and Illinoian drift that lies within the Springfield Plain.

The glacial deposits, possibly up to 400 feet thick, completely conceal the bedrock topography that is developed primarily on rocks of Pennsylvanian age. The nearest bedrock exposures are along the Sangamon River immediately southwest of the study area. Multiple drift sheets mask the irregularities of the bedrock surface and produce a plain of low relief.

The highest surface elevation in the region, about 900 feet above sea level, is on the crest of the Bloomington Moraine east of Bloomington, McLean County. The lowest elevation, about 540 feet above sea level, is in the southwest portion, where the Sangamon River leaves the area. Thus, the maximum total relief over

the Mahomet Bedrock Valley region is approximately 360 feet. The local relief ranges from 10 to 80 feet, except along valleys, where it reaches a maximum of 125 feet.

Many of the nearly flat areas of the ground moraine are artificially drained to improve agricultural conditions. Natural surface drainage is generally to the south and southwest. The largest surface drainage system is that of the Sangamon River and its tributaries. Other important streams include Salt Creek, Sugar Creek, Kickapoo Creek, and the Kaskaskia and Embarras River systems (fig. 2).

Climate

The majority of the climatological data were taken from records obtained at the Morrow Plots Station at the University of Illinois, Urbana (Changnon, 1959). These data are believed to be representative for the Mahomet Bedrock Valley region.

The climate of east-central Illinois is continental with warm summers and cold winters. During the coldest month, January, the mean temperature is 27.3° F. During the warmest month, July, the mean temperature is 75.5° F. The mean annual temperature is 52° F. Temperatures of ground water from wells in the drift av-

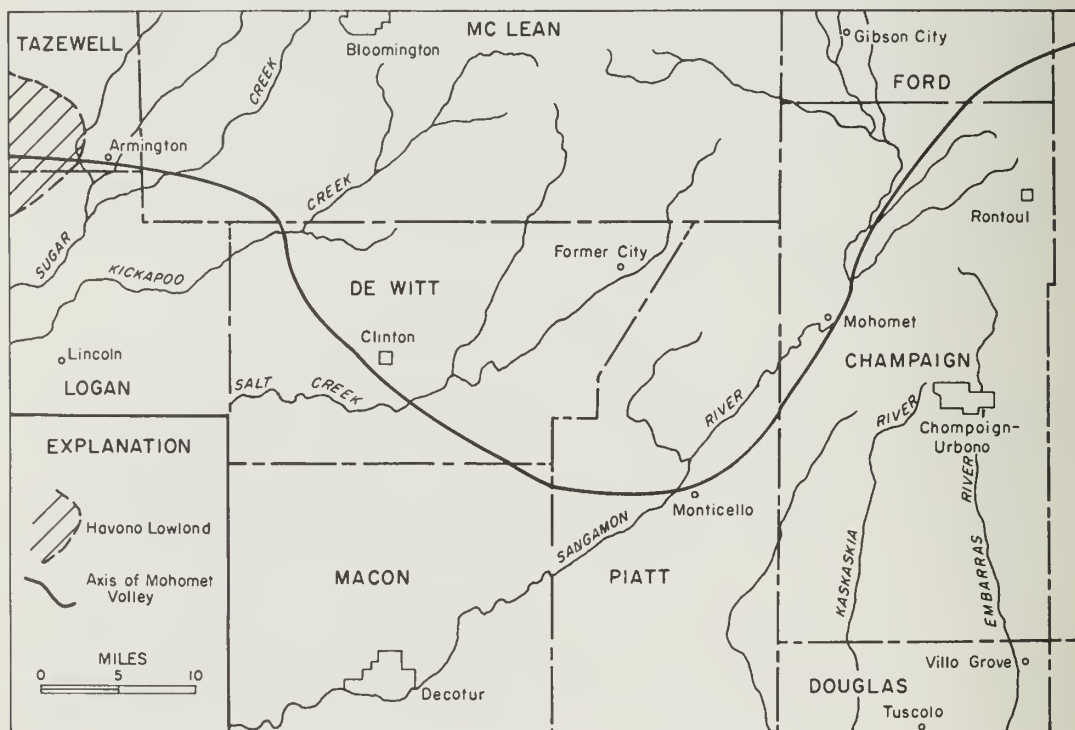


Figure 2 - Geographic map showing surface drainage, principal municipal areas, and the main axis of the Mahomet Valley.

erage 55° F. (Hanson, 1950). Figure 4 shows average monthly precipitation, mean temperature, and average pan evaporation within the region.

Average annual precipitation is 36.30 inches; it has never been less than 24 inches, and the highest amount recorded is 55.64 inches. Precipitation increases to over 38 inches toward the southern edge of the study area (Stout, 1960).

The growing season averages 181 days. The average date for the last killing frost is April 21; for the first killing frost, it is October 20.

The average annual evaporation measured in a U. S. Weather Bureau standard Class A pan is 41.77 inches, based on a ten-year period. Changnon (1959, p. 78) uses 0.7 as the Class A pan coefficient for the Morrow Plots Station, making the potential annual evaporation from the region approximately 29 inches.

Population, Economy, and Water Supplies

The population of the Mahomet Valley region, according to the 1960 census (U. S. Bureau of the Census, 1962), was approximately 355,000 persons. This was about 3.5 percent of the total state population, located within approximately 5.5 percent of the total state area. The largest centers of population—Bloomington, Champaign-Urbana, Decatur, Lincoln, and Rantoul—contained about 55 percent of the total or about 194,000 persons.

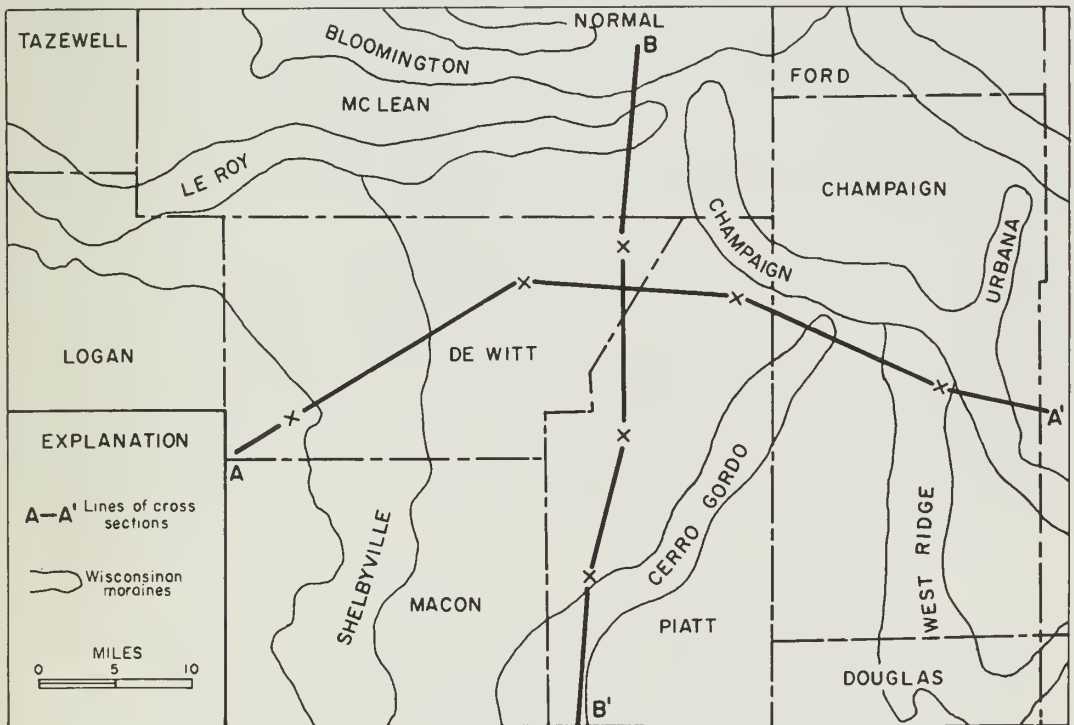


Figure 3 - Glacial geology map with lines of cross sections.

The economy of the region is based primarily upon agriculture. Many of the industrial developments that are concentrated in the large municipal areas are processing plants for agricultural products.

Of the total population, approximately 80 percent is located within areas that are served by municipal water systems; the remaining population is served by private or cooperative systems. As a comparison, within the entire state about 94 percent of the people are supplied by municipal water systems.

Although the Sangamon and Embarras Rivers provide large quantities of surface water, the majority of water supplies are from ground-water sources and are pumped from sand and gravel aquifers within glacial-drift deposits of the Mahomet Valley system and adjacent areas. With a few exceptions, such as the villages of Tuscola and Villa Grove, no major water supplies are obtained from bedrock in the area. Decatur and Bloomington are the only large municipalities that rely entirely on surface-water reservoirs for supply. Lincoln uses an infiltration gallery on Salt Creek, but supplements this supply with water from wells.

Nearly all the wells of the region are drilled by cable-tool, rotary, or reverse hydraulic methods. However, some wells are dug and yield small amounts

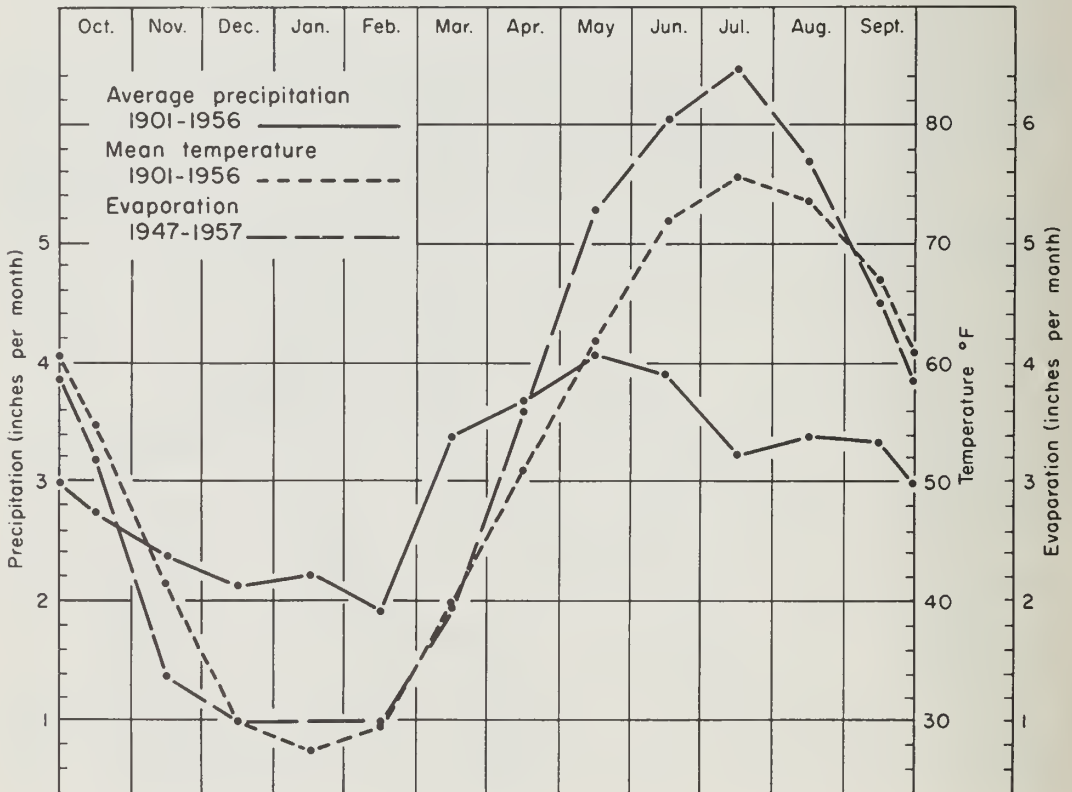


Figure 4 - Average monthly precipitation, mean temperature, and average pan evaporation at Morrow Plots station, University of Illinois, Urbana.

of ground water. Many such dug wells are unreliable due to faulty construction, lack of sufficient permeability of the shallow deposits, or insufficient depth. Many wells are finished in sands so fine grained that gravel or sand packing is required to avoid pumping fine sediment with the water.

SOURCES OF DATA

The largest source of geologic information used in this study is drillers' logs from water wells, water and oil test holes, and highway borings. Other sources include cable tool, rotary, and split-spoon samples from selected wells and test holes. Hydrologic information is from drillers' logs and from published reports of the Illinois State Water Survey.

Approximately 850 drillers' logs were selected as controls after examination of more than 2500 logs of borings available within the study area. Many of the selected borings penetrate the full thickness of glacial drift. Therefore, reports of these borings were also useful for determination of bedrock surface elevations. Several hundred additional control points for the bedrock surface were obtained from coal and oil test holes.

Information from each driller's log should include the following: description of the main rock types encountered, their thickness and depth; indications of which units are aquifers; description of the casing, including perforated or screened zones; static water level in the well after drilling is completed; and a report of a production test if any was made. In actuality, most logs have only a portion of the above information, and hydrologic data are frequently not included. Several examples of the geologic portion of typical drillers' logs are given in Appendix A, together with their interpretations.

Information from the drillers' logs has been supplemented by binocular examination of samples from control wells, which helps to eliminate personal bias in reporting and interpreting lithologies given on drillers' logs. To further standardize the interpretation of the logs and to facilitate the evaluation of questionable logs, a definite set of parameters based on sample-set examination was applied to drillers' terminology. The relationships between such terminology and geologic interpretations are given in table 1.

Several consistent patterns in drillers' terminology are readily observed by describing sample sets and comparing geologic descriptions to drillers' descriptions of the drift. Most "hardpan," "sand-gravel-clay," or "clay" of drillers' terminology is till; "clay" is occasionally a lacustrine deposit. Most breaks or weathering zones between till sheets are noted by drillers and are described as "driftwood," "green clay," or "peat."

TECHNIQUES OF QUANTITATIVE MAPPING AND ANALYSIS

The glacial drift deposits of the Mahomet Valley region were analyzed with quantitative techniques that were originally developed for use in the petroleum industry. Products of these techniques are maps that show areal variations in pre-selected parameters, such as center of gravity (center of mass) or spread of permeable deposits within a three-dimensional area. Vertical position, thickness, and distribution of sands and gravels can be obtained by proper interpretation of the maps.

Previous Work

Quantitative description of unconsolidated deposits has been applied recently to a few ground-water investigations. Meyboom (1960) used quantitative methods in a hydrogeologic study of a consolidated Cretaceous age sandstone in southern Alberta, Canada. Zones (1961) constructed a lithofacies map of the alluvial fill in Crescent Valley, Nevada, to indicate areas of favorable aquifer development. Bredehoeft (1963) utilized sand and clay ratio maps and gravel isolith maps for a hydrogeologic study of a portion of the lower Humboldt River Basin, Nevada, to illustrate aquifer distribution. Neither Zones nor Bredehoeft attempted to summarize in detail the vertical distribution of aquifers.

TABLE 1 - GEOLOGIC INTERPRETATION OF DRILLERS' TERMINOLOGY

Drillers' terminology	Geologic interpretation	
	Drift	Percent of sand and gravel*
Sand and gravel	Interbedded units of sand and gravel	100
Cemented gravel	All gravel, pebble-sized grains predominant	100
Gravel and clay	Pebbles and larger clastic material in matrix of clay, fine sand, silt; interbedded with lenses of sand, gravel (till)	0-25
Sand	All sand, predominantly medium grained or larger	100
Sandy clay	Similar to gravel and clay	0-25
Silty clay	No sand or gravel; negligible permeability	0
Clay	Negligible permeability; may be lacustrine	0
Hardpan	Usually till; negligible permeability	0-100
Organic zones, drift, soil, etc.	Usually fine alluvial silts; negligible permeability	0
Lacustrine	Negligible permeability	0

* In till sections described by drillers, up to 25 percent may be lenses of permeable clastics. Gravel is considered to have a median grain size of over 2 mm; sand is considered permeable for purposes of this study if the median grain size is between .25 mm and 2 mm.

The use of quantitative hydrogeologic evaluation of unconsolidated earth materials was demonstrated in a systems analysis of aquifers in Las Vegas Valley, Nevada, where geologic data were satisfactorily related to hydrologic data to facilitate construction of an electric analog model (Domenico, Stephenson, and Maxey, 1964). In this investigation, approximately 350 square miles within the central portion of the alluvial valley was studied to appraise the water resources and the geologic framework in which the ground water occurs. The valley is currently undergoing differential depletion of its water resources; the analog model of the aquifer systems is used as a water-management tool.

The geologic data for the Las Vegas study were derived basically from drillers' logs and from control-well sample cuttings. Hydrologic data were derived from aquifer performance tests. A time-transgressive, three-dimensional interval between 200 and 700 feet below the ground surface was used as the main mapping interval, as it contained the majority of the main water-producing zones. The vertical variability in position and thickness and the lithic percentage of permeable deposits within the mapping slice formed the basis of a presentation of geologic conditions necessary in the analog construction. Empirical relationships were established between subsurface geology and values of the coefficients of transmissibility and storage, the main aquifer characteristics. (The coefficient of transmissibility is the product of the coefficient of permeability, expressed in gallons a day per square foot of aquifer, and aquifer thickness, and is expressed in terms of gallons a day per linear foot of aquifer. The coefficient of storage is the volume of water released from or taken into storage within an aquifer per unit surface area of the aquifer per unit change in the component of head normal to that surface.) This relationship served as a basis for an extrapolation of hydrologic data from geologic data, which was significant because many geologic data were available, whereas hydrologic data were not. Relatively untested portions of aquifers within the area of geologic control were modeled, and pumping effects were recapitulated with a minimum of adjustment of model components.

Mapping Unit

A mapping unit is a three-dimensional slice of earth material with either physically recognizable or arbitrary boundaries. Two kinds of mapping units were used in this study. Surfaces of weathering and erosion (bedrock, Yarmouthian, and Sangamonian surfaces) were used to separate deposits for some purposes, and elevation planes were used to separate slices for quantitative mapping. In the latter case, materials in each even 100-foot slice between 300 and 800 feet of elevation were described. Materials in those portions of drill holes that neither end at nor begin at the limiting boundaries of a slice were considered to represent a full 100-foot slice, and the unpenetrated interval was considered devoid of the material being mapped.

Factors that influence the selection of a mapping slice include the amount of relief along the ground and bedrock surfaces and the position of the water table.

Map Types

All map types used in this study show three-dimensional aspects of stratigraphic variables and were selected because the variables have hydrologic significance.

Three paleosurface maps, which show the bedrock surface, the Yarmouthian interglacial surface, and the Sangamonian interglacial surface, were prepared. The bedrock surface map defines the base of the drift-aquifer systems. The Yarmouthian and Sangamonian surface maps define the boundaries of drift sheets.

The glacial-drift thickness map outlines areas of thick and thin drift, which generally are favorable and unfavorable, respectively, for ground-water development.

Lithofacies maps depict the composition of a stratigraphic unit. One variety is the percentage map, which shows the ratio of thickness of a selected lithologic type to the total thickness of the mapping interval (Forgotson, 1960, p. 86). Percentage data as used in this study were not contoured on separate maps but are included on vertical variability maps, described below. Such data have been useful because estimates of the coefficient of transmissibility could be made when the percentage of permeable clastics within a section, approximate average grain size, and permeability factors were known. From tests on alluvial aquifers of Pleistocene age in Nebraska, Keech and Dreeszen (1959) related permeability to sediment size (table 2). From data on permeability and percentage of aquifer material, estimates

TABLE 2 - COEFFICIENT OF PERMEABILITY RANGE
OF VARIOUS LITHOLOGIC TYPES¹

	Meinzer units ²
Clay and silt.	< 1 - 100
Sand, very fine, silty	100 - 300
Sand, fine to medium	300 - 400
Sand, medium	400 - 600
Sand, medium to coarse	600 - 800
Sand, coarse	800 - 900
Sand, very coarse.	900 - 1000
Sand and gravel.	1000 - 2000

¹ Adapted from Keech and Dreeszen, 1959, p. 38.

² Meinzer units = gallons a day per foot for water at 60° F. To convert to darcys, divide by 18.2.

of the coefficient of transmissibility (T) are made, using the relationship $T = Pm$, where P is coefficient of permeability and m is aquifer thickness.

Vertical variability maps depict the vertical position and arrangement of constituent rock types. Preparation of these maps requires data on the individual positions and thicknesses of selected rock types within the section being mapped. Such information is usually available on drillers' logs.

Vertical variability can be shown by a combination of center of gravity and standard deviation maps, which show relative vertical position of any selected lithologic type within a mapping section. In this study, the lithology of main interest is sand and/or gravel, the potential water-bearing material within the glacial drift.

Center of gravity maps give the position of the center of mass of sand and gravel strata, within the mapping slice, in feet from the top of the slice or feet

below the top, expressed as a percentage of the total thickness of the slice.

Standard deviation maps express the spread of the sand and gravel about the center of mass of these units. As with the center of gravity data, contouring the standard deviation data is a preliminary step toward a final vertical variability map. Adding or subtracting the standard deviation value to the center of gravity value gives the vertical range that is occupied by the majority of the cumulative thickness of sand and gravel lenses within the slice (Krumbein and Libby, 1957).

In this study, the center of gravity and standard deviation values were first superimposed to make one map, which was then subdivided to create a series of classes. These classes are illustrated by means of patterns on a map, called a vertical variability map. All points within the same pattern have approximately equal values for center of gravity and standard deviation. Therefore, the vertical distribution of sand or gravel within a class shown by a given pattern is the same.

The information obtained from analysis of a vertical variability map is applied to ground-water development by evaluating the relationships between geologic characteristics within the classes and data on aquifer characteristics. These relationships may then serve as a basis for modeling hydrologically or geologically untested portions of an area where one of these components is known. This procedure is necessary when producing analog models of a basin in order to model the entire basin.

Computation Method

IBM methodology provides a shortcut to computing the data required for the vertical variability maps. A program was written for the IBM 7094 facility on the University of Illinois campus and is given in Appendix B.

The method used for computing the center of gravity and standard deviation is illustrated in figure 5. The position (h) and thickness (t) of a sand or gravel unit is determined from a study of a lithologic log for each control point. The h is computed in feet below the upper limit of the mapping slice to the center of each sand or gravel unit.

In order to depict the nature of the lithology at any given point, as well as the position of selected units, it is necessary to incorporate a sand-clay ratio or a lithic percentage as a supplement to the vertical variability pattern (Forgotson, 1960). In this study, percentage data are plotted with the vertical variability pattern to depict the relative percentage of permeable material in the working slice and to show horizontal changes in distribution of permeable materials. The need for this supplement is demonstrated by considering that a thick sand or gravel unit lying in the middle of a section will have the same relative center of gravity (50 percent) and the same spread (0 percent) as a thin sand or gravel unit lying in the middle of the section. The percentage figure shows whether the unit is thick or thin.

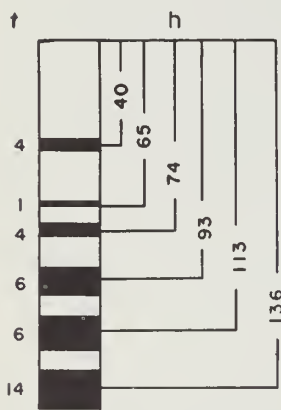
GENERAL GEOLOGY

Bedrock and Paleosurface Geology and Topography

The unconsolidated sediments of the Mahomet Bedrock Valley region are underlain by relatively impermeable bedrock. Permeable sediments in bedrock

channels are the only aquifers capable of yielding large supplies of ground water. Aquifers within the drift on the bedrock uplands yield only small to moderate supplies.

The youngest bedrock formations in the region are of Pennsylvanian age, of the McLeansboro Group, and consist of impermeable shale, with some thin, discontinuous lenses of sandstone and limestone. The Pennsylvanian strata occur



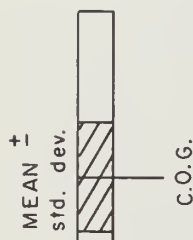
Sond number	Distance from top (h)	Thickness in feet (t)	ht	h ² t
1	40	4	160	6400
2	65	1	65	4225
3	74	4	296	21904
4	93	6	558	51894
5	113	6	678	76614
6	136	14	1904	258944
Sums :		35	3661	419981

(A) (B) (C)

TOTAL THICKNESS
L = 143

$$\text{Center of gravity: } B/A = \frac{3661}{35} = 104.6 \text{ ft. below top}$$

$$\text{Relative center of gravity} = \frac{\text{C.O.G.}}{L} \times 100 = 100 \times \frac{104.6}{143} = 73.1\% \text{ of thickness, below top}$$



$$\text{Approximate variance} = \frac{c - (B^2/A)}{A} = 1058$$

$$\text{Approximate standard deviation} = \sqrt{\text{o.v.}} = 32.5 \text{ ft. added and subtracted from the C.O.G.}$$

Relative standard deviation =

$$\text{op. std. dev.} \times 100 = \frac{32.5}{143} \times 100 = 23\%$$

Figure 5 - Method of computing center of gravity and standard deviation. Modified from Krumbein and Libby (1957, p. 201). A driller's log from the NW¹/₄ SW¹/₄ sec. 36, T. 16 N., R. 5 E., Platt County, has been used.

directly below the drift except in portions of Ford, Champaign, and Douglas counties, where older bedrock formations underlie the drift along the LaSalle Anticlinal Belt.

The bedrock surface map (fig. 6) used in this study is a compilation of all data currently available from the following sources: the area north of the Mahomet Valley is modified from Heigold, McGinnis, and Howard (1964); the remaining portion is based on information in the files of the Illinois State Geological Survey, including water and oil test holes and completed wells, coal test holes, seismic records, plus published information. In the portion south of the Mahomet Valley, all of the control wells and test holes used reached bedrock. The majority of these were oil or coal tests, however, and do not include information on the lithology of the drift deposits. The locations and distribution of control points are shown in figure 6.

The positions of several of the major tributary valleys depart somewhat from an earlier interpretation by Horberg (1950). Additional data accumulated since 1950 form the basis for making these changes.

The coarse texture of many portions of the bedrock map suggests that only large valleys are identifiable from existing data. Another factor contributing to a coarse texture is the 50-foot contour interval. The tributaries in most instances are probably not as straight nor as wide as indicated.

Relief on the bedrock surface is 200 to 300 feet. The surface is a product of preglacial, glacial, and interglacial erosion of strata primarily of Pennsylvanian age. The majority of the bedrock channels were eroded prior to glaciation of the region. Several valleys, however, were possibly formed or altered during the Pleistocene epoch.

The upland bedrock surface is developed primarily on relatively weak shale that had weathered and eroded to form a subdued topography. The bedrock highs exerted an influence on subsequent depositional patterns; portions of glacial moraines occur above these highs. Small percentages of permeable materials occur in the drift deposited over the bedrock uplands; hence these sites are not geologically favorable for occurrence of large ground-water supplies.

The major feature of the bedrock map is the Mahomet Valley, which takes its name from the village of Mahomet located over the deepest part of the channel in Champaign County (fig. 6). The bottom elevation of the valley averages 350 feet, placing it 200 to 300 feet below adjoining uplands. In contrast, most of the tributaries to this main bedrock valley are 100 to 150 feet in depth.

The gradient of the Mahomet Valley averages approximately 0.25 to 0.3 feet per mile between Paxton, in Ford County, and Armington, in Tazewell County, a distance of approximately 100 miles. For comparison, the gradient of the Sangamon River in the area is about 1.9 feet per mile.

Paleosurface maps of the Yarmouthian and Sangamonian weathered zones were constructed for comparison with the bedrock surface map to illustrate how surface topography changed during the filling of bedrock channels. The map of the Yarmouthian zone (fig. 7), contoured on the basis of about 125 control points from sample studies and drillers' logs, shows the major valley trends of the bedrock still in evidence, with the exception of the Middletown Valley, which traverses southern Macon County, as seen in figure 6. Between 25 and 200 feet of pre-Illinoian drift were deposited in the Mahomet Valley region prior to formation of this surface.

Illinoian glaciation greatly disrupted drainage in the Mahomet Valley system. Figure 8, based on data from 465 control points, shows the surface at the end of

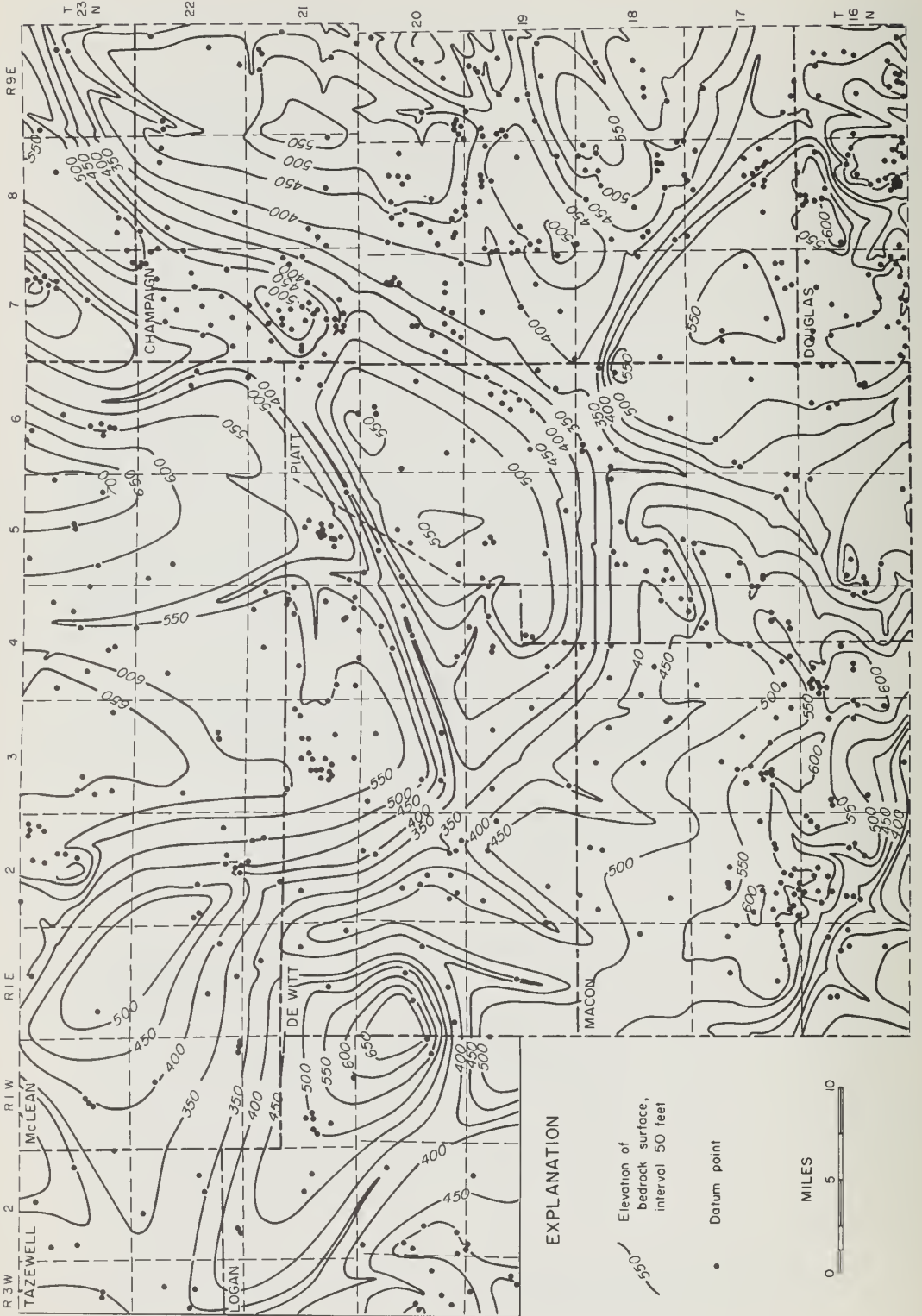


Figure 6 - Configuration of the bedrock surface. The main channel is the Mahomet Valley.

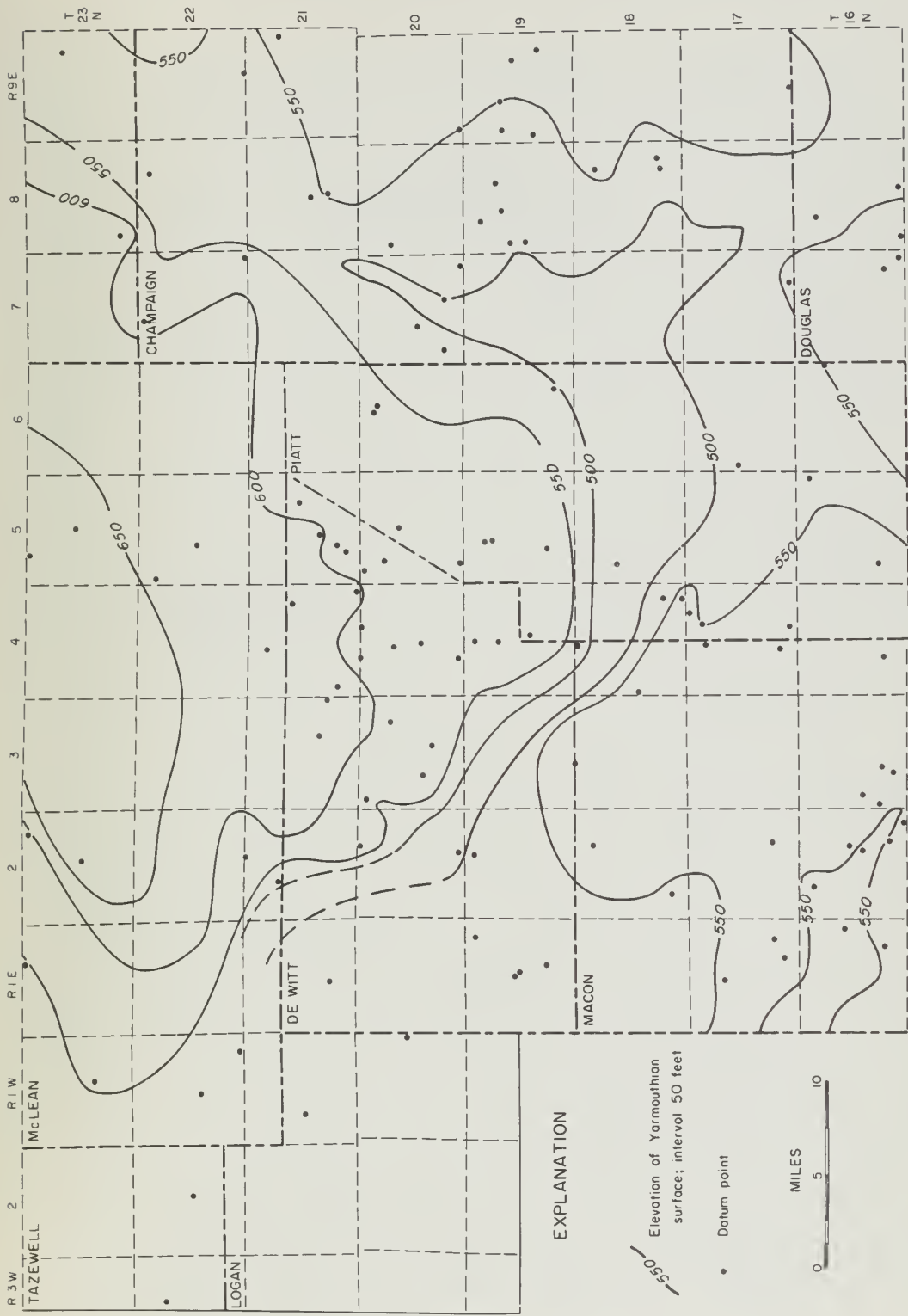


Figure 7 - Configuration of the top of the Yarmouthian weathered zone.

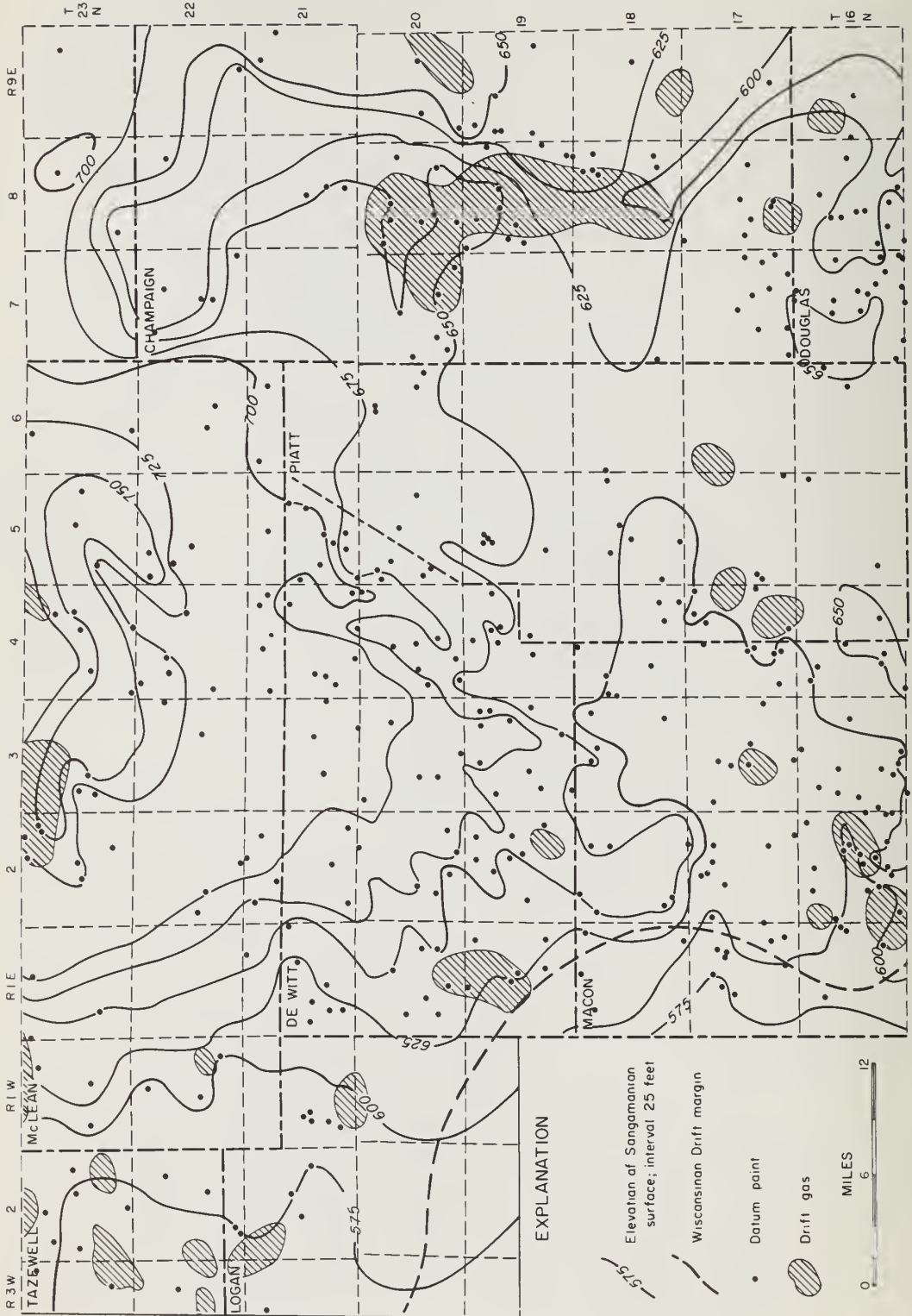


Figure 8 - Configuration of the top of the Sangamonian weathered zone. Shaded areas are known drift gas occurrences (after Meents, 1960, p. 3), most of which are associated with the Sangamonian surface.

the Sangamonian, prior to the initiation of Wisconsinan glaciation. A break was recorded on drillers' logs or seen in sample studies for each control point. At the close of Sangamonian time, the Mahomet Valley was no longer a prominent drainageway. Only the low areas remained through Champaign County that suggested prior drainage patterns. Ancestral outlines of the present north-south drainage patterns were being established. Between 50 and 225 feet of Illinoian drift were deposited within the Mahomet Valley region.

Widespread occurrence of Sangamonian deposits and weathered zones shows that the Wisconsinan ice advances did not greatly disrupt the deposits beneath the Sangamonian surface.

The cross sections (fig. 9) suggest that surface highs and lows parallel the bedrock highs and lows to varying degrees. In places, bedrock valleys underlie present-day uplands and have no surface expression, although elsewhere similar valleys have been partially re-excavated and influence the position of modern streams. Portions of deposits in the bedrock valleys have undergone greater consolidation than deposits over the bedrock uplands; this causes a surficial sag, which influences the position of modern streams.

A correlation coefficient analysis was made to test the degree that the bedrock surface parallels more recent land surfaces. It was concluded that analysis of present topography cannot be used to predict bedrock surface configuration in east-central Illinois. Present topography may, however, be a clue in helping to interpret configuration of buried land surfaces, if such surfaces are not deeply buried, and assuming these surfaces are correctly identified.

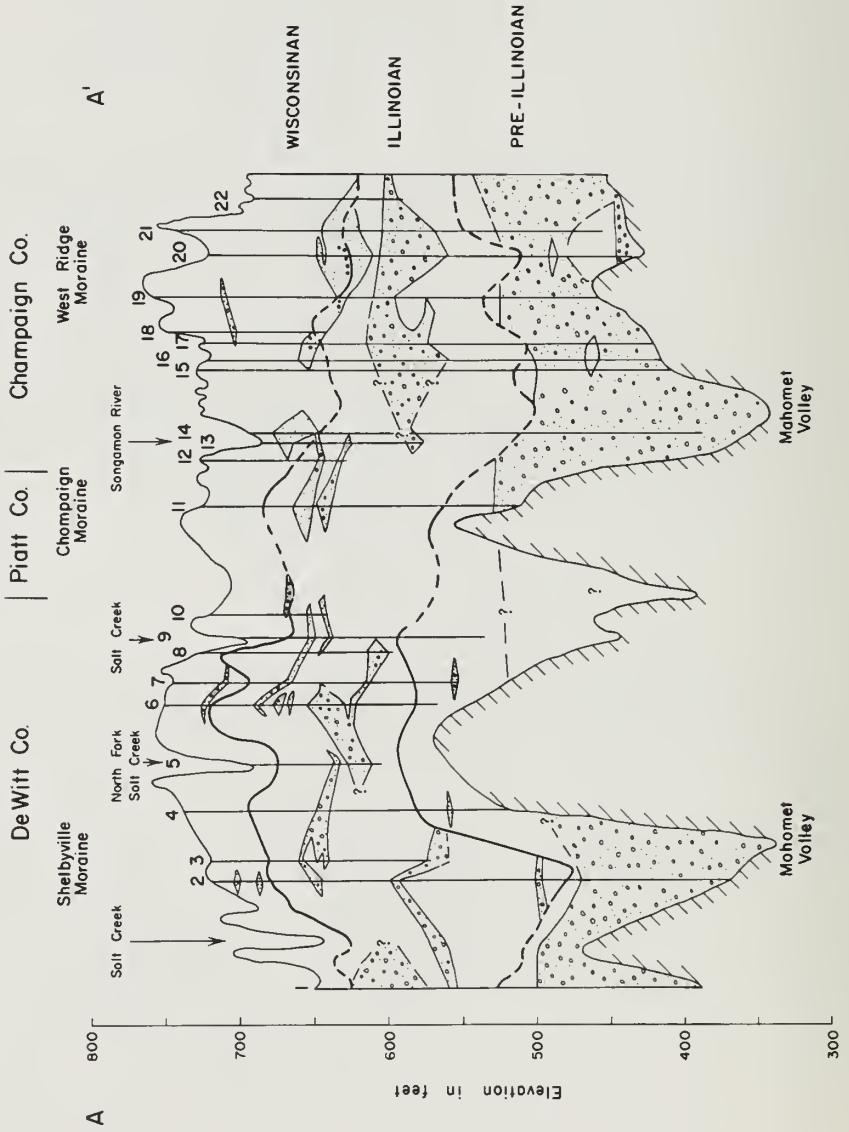
Glacial Drift

Lithology and Hydrologic Properties

Unconsolidated deposits of Pleistocene and Recent ages overlie the eroded bedrock surface in all of the study area and reach a maximum thickness of over 400 feet in some portions of bedrock channels. These surficial materials represent a complex series of glacial and post-glacial events (Horberg, 1950, 1953). Basal sands and gravels deposited in deep bedrock channels give evidence of a source area to the north and east. Glacial ice did advance into east-central Illinois during Kansan, Illinoian, and Wisconsinan time (table 3). Evidence of a Nebraskan ice advance into eastern Illinois is speculative.

The Mahomet drainage system was blocked by the end of the Illinoian Stage, during which the maximum development of glaciation in Illinois occurred. Wisconsinan ice progressed to the limit indicated by the Shelbyville Moraine. A series of roughly parallel morainic ridges was built north of the Shelbyville Moraine as the Wisconsinan glacier melted and readvanced. Illinoian and older drifts are preserved beneath the Wisconsinan drift but are generally known only from subsurface records.

The Pleistocene classification of the Illinois State Geological Survey (table 3) is based on radiocarbon dates in part and on detailed stratigraphic and geomorphic studies. As stated by Morrison and Frye (1965), identification of glacial stages and substages in the subsurface is frequently made by use of interglacial geosols, the Sangamon, Yarmouth, and Afton Soils. A geosol is a fundamental soil-stratigraphic unit (Morrison and Frye, 1965, p. 7). Major geosols develop on glacial deposits during an interglacial stage; weaker geosols are used to differentiate glacial substages.



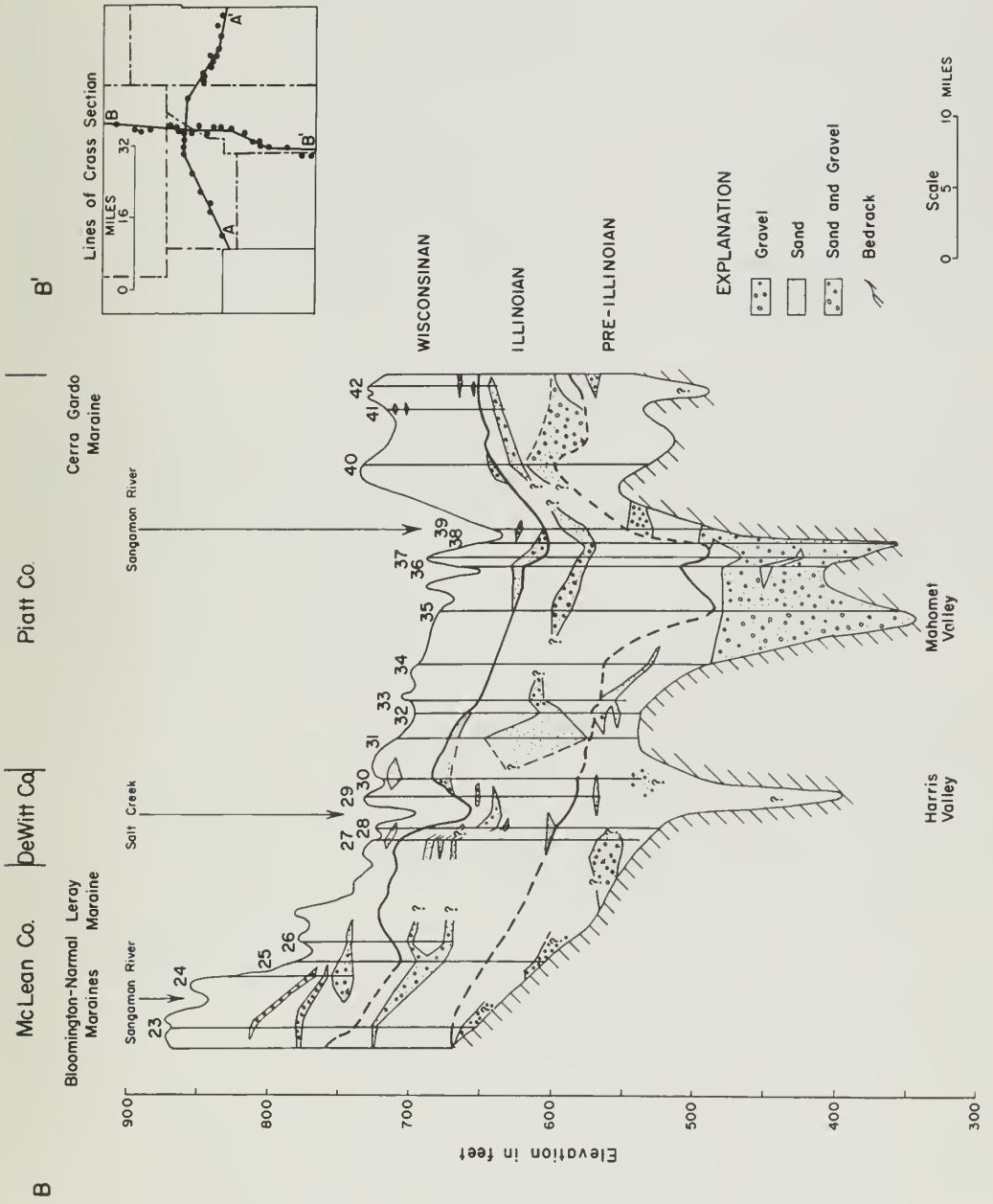


Figure 9 - Cross sections of the glacial drift.

Standard practice has been to assign the major interglacial stage names to the major soil horizons encountered in a test hole. In some areas, therefore, till-like materials have been identified tentatively as Nebraskan, as these materials occur below the third buried major soil zone encountered in drill holes in the area. However, the practice of assigning each soil horizon the status of a major geosol can lead to misinterpretations. Local differences in climate or topography can lead to relatively strong soil development even though the regional soil development is weak.

Many of the logs of test holes and wells that penetrate the drift record some evidence of weathering breaks that are used to subdivide the various glacial episodes. The most prevalent break is represented by peat-organic silt and/or a greenish gray colluvial sequence of the Farmdalian Substage or Sangamonian Stage, or both. It is possible that no lower Wisconsinan glacial deposits are present within the area and that the Altonian time was characterized by a period of nondeposi-

TABLE 3 - PLEISTOCENE CLASSIFICATION¹

Time-stratigraphic subdivision	Radiocarbon dates before present
Recent Stage	
Wisconsinan Stage	5,000
Valderan Substage	
Twocreekan Substage (interstadial)	11,000
Woodfordian Substage	12,500
Farmdalian Substage (interstadial)	22,000
Altonian Substage	28,000
Sangamonian Stage (interglacial)	inferred limit 50,000 - 70,000
Illinoian Stage (glacial)	
Yarmouthian Stage (interglacial)	
Kansan Stage (glacial)	
Aftonian Stage (interglacial)	
Nebraskan Stage (glacial)	
Early Pleistocene or late Pliocene	

¹ Modified in part from Frye and Willman, 1960, p. 2-3.

tion and by colluviation; in this case, the persistent peat-colluvial break represents the time interval from Sangamonian through Farmdalian time. For this study, the top of this break was considered the top of the Sangamonian surface; thus it marks the division between Wisconsinan and underlying Illinoian deposits.

Several lesser breaks are recognized within the Wisconsinan deposits above the Sangamon Soil. Below the Sangamon Soil, several weathering breaks are recognized, the most persistent of which is called the Yarmouth Soil.

Glacial drift of the Mahomet Valley region can be divided into three lithologic units (fig. 9) that are approximately equal to the presently accepted pre-Illinoian, Illinoian, and Wisconsinan stratigraphic units. This nomenclature is based on identification of geosols and nonglacial deposits, such as peat, in the subsurface and is designed to reflect hydrostratigraphic subdivisions rather than to reflect a stricter time-stratigraphic nomenclature. Hydrostratigraphic units are defined by Maxey (1964, p. 126) as "bodies of rock with considerable lateral extent that comprise a geologic framework for a reasonably distinct hydrologic system." The three hydrostratigraphic units used here have different properties in relation to the occurrence and movement of ground water.

Studies of drill-cutting samples from various water wells show the general character of the materials in the three recognized operational units. The Wisconsinan deposits generally are fine-grained sediments and are a poor source of ground water, except for shallow and local occurrences of sand and gravel deposits. Illinoian deposits contain rather widespread lenses of sand and gravel intercalated in the glacial drift, and are the most widely utilized for small and moderate ground-water supplies. Pre-Illinoian deposits occur in a basal position and within the drift, filling the deepest portions of bedrock channels. Permeable strata within this hydrostratigraphic unit constitute a source of large ground-water supplies.

Sand and gravel constitute the bulk of the pre-Illinoian deposits. They include Kansan and possible Nebraskan deposits, occupy a basal position in the drift, and are closely associated with bedrock channels. The pre-Illinoian deposits occur as drift, outwash, valley trains, and reworked coarse till, concentrated by periodic discharge of glacial meltwater down the bedrock channels. Horberg (1953, p. 12) referred to these deposits as the Mahomet Sand and considered them approximately equivalent to the Sankoty Sand of the Peoria region. The Sankoty Sand (Horberg, 1950, p. 51-52) is present in the Havana Lowland area (fig. 2) and northward within bedrock channels; it is overlain by Illinoian and older drifts. The Mahomet and Sankoty Sands actually contain both sand and gravel and are found in the main bedrock channels.

The top of the Mahomet and Sankoty Sand is approximately 450 to 500 feet above sea level. These sands are the oldest unconsolidated deposits within the drift, with the possible exception of till (?) and/or lacustrine deposits in the bottom of several bedrock channels. Such fine materials are sometimes reported by drillers as occurring just above bedrock and actually may signify only the presence of weathered bedrock. The Sankoty Sand is considered to be derived from weathering products of sandstones and crystalline rocks in Wisconsin and Minnesota, carried south through drainageways into the Havana Lowland. The Mahomet Sand, however, is different mineralogically and had a provenance within glacial terranes. Heavy and relatively unstable minerals characterize the Mahomet Sand. An analysis by Manos (1961) shows abundant garnet, with hornblende, epidote, and small amounts of pyroxene, an assemblage that is typical of Pleistocene tills.

The sample study log of a test hole in central Piatt County shows the character of the pre-Illinoian deposits.

City of Decatur well no. 3, NW $\frac{1}{4}$ NE $\frac{1}{4}$ NE $\frac{1}{4}$ sec. 17, T. 18 N., R. 5 E., Willow Branch Township, Piatt County. Elevation: 680 feet. Drilled by Layne-Western Drilling Co., 1954. Sample set no. 24148, described by D. A. Stephenson.

	<u>Depth to base (feet)</u>	<u>Elevation (feet)</u>
Pleistocene Series		
Wisconsinan Stage		
Silt, sandy, mottled dark gray and yellow-gray; till and loess	10	670
Silt, sandy, gray, calcareous, becoming gravelly to the bottom, till	27	653
Silt, sandy, gravelly, pinkish gray-brown, cal- careous, till	52	628
Sangamonian Stage		
Silt, sandy, clayey, green-gray, calcareous, colluvium	62	618
Illinoian Stage		
Silt, sandy, gravelly, predominantly gray, zones of organic silt, calcareous, till and/or collu- vium	125	555
Silt, sandy, pinkish brown-gray, calcareous, becoming gravelly silt at 180 feet, till	200	480
Pre-Illinoian Stage		
Gravel, sandy, silty, subrounded to rounded, some organic silt and wood, outwash, proba- bly top of Mahomet Sand, not clean	295	385
Sand and Gravel, quartzose sand, medium to coarse grained, clean, Mahomet Sand	315	365
Silt, sandy, clayey, gray, slightly calcareous, till or lacustrine, or weathered bedrock	318	362
Pennsylvanian Series		
Shale		

Permeable materials within the Illinoian deposits are both lenticular and sheetlike and may be found in a basal position or within the section. The Illinoian drift is composed of till with considerable amounts of sand and gravel interspersed, locally becoming thick. Permeable materials are more abundant in Illinoian deposits than in Wisconsinan deposits, but less abundant than in pre-Illinoian deposits.

The sample study logs of two wells described below illustrate sequences of Illinoian deposits and show the variable position of sand and gravel deposits within the Illinoian.

L. Mueller well, SE $\frac{1}{4}$ SW $\frac{1}{4}$ SW $\frac{1}{4}$ sec. 26, T. 16 N., R. 2 E., South Wheatland Township, Macon County. Elevation: 675 feet. Drilled by Woolen, 1943. Sample set no. 9544, described by L. Horberg.

	<u>Depth to base (feet)</u>	<u>Elevation (feet)</u>
Pleistocene Series		
Wisconsinan Stage		
Silt, leached, oxidized, till	20	655
Silt, gray, pink tint, calcareous, till	50	625
Sangamonian Stage		
Silt, dark brown, humus	55	620
Illinoian Stage		
Silt, gray-green, leached, oxidized, colluvium	65	610
Silt, light gray, calcareous, till	85	590
Sand, medium grained	90	585
Gravel, $\frac{1}{2}$ -inch diameter, clean above, dirty below	100	575
Yarmouthian Stage		
Silt, brown, calcareous, sandy	105	570
Silt, same as above, and granular gravel	110	565
Sand and Gravel, brown, slightly calcareous	115	560
Silt, brown, few sand grains, calcareous, loess- like	120	555
Kansan Stage		
Silt, similar to above, sandy and gravelly	145	530
Silt, gravelly, greenish brown, calcareous, till	170	505
Gravel, yellow, oxidized, sandy	175	500

Village of Kenney well, SE $\frac{1}{4}$ NE $\frac{1}{4}$ SE $\frac{1}{4}$ sec. 16,
T. 19 N., R. 1 E., Tunbridge Township, DeWitt
County. Elevation: 650 feet. Drilled by Mash-
burn, 1956. Sample set no. 27080, described by
J. Hackett.

	<u>Depth to base (feet)</u>	<u>Elevation (feet)</u>
Pleistocene Series		
Wisconsinan Stage		
Silt, noncalcareous, loess	9	641
Sand, fine to coarse grained, silty	15	635
Sand, medium to coarse grained, silty	20	630
Sand, coarse grained, fine gravel, some wood	25	625
Illinoian Stage		
Sand, fine to coarse grained, fine gravel, very silty, organic	40	610
Sand, fine to coarse grained	60	590
Gravel, sandy	70	580
Sand, fine to coarse grained	75	575
Silt, sandy, gravelly, brown-gray, calcareous, till	90	560
Sand, medium to coarse grained	95	555
Silt, sandy, gravelly, brown-gray, till	120	530

	<u>Depth to base (feet)</u>	<u>Elevation (feet)</u>
Illinoian Stage (cont.)		
Silt, gravelly, brown-gray to light brown, calcareous, till	125	525
Kansan Stage		
Silt, gravelly, light brown, mixed with soil, till	130	520
Silt, gravelly, light brown to dark gray, calcareous, till	150	500
Gravel, fine grained	175	475
Sand, fine to coarse grained, clean from 250 feet	262	388
Pennsylvanian Series		
Limestone		

Hydrologic conditions in the Illinoian deposits are more varied than in the pre-Illinoian deposits, as relatively impermeable till units are interbedded with permeable sands and gravels. Water is often of poor quality where it occurs in association with drift gas generated in the Sangamon Soil. Meents (1960, p. 3) outlines areas of known drift gas occurrence in east-central Illinois. These occurrences, shaded on figure 8, are associated primarily with the Sangamonian weathered zone in this area.

As many as four separate glacial advances may be represented by the Wisconsinan deposits. The ridges considered to be the terminal moraines of these advances are shown in figure 2, with the southernmost, the Shelbyville Moraine, being the oldest. Moraines frequently appear to overlie bedrock ridges, and therefore their prominence is not entirely due to glacial deposition. Furthermore, deposits of a given ice advance appear sometimes to continue over and beyond a moraine-like ridge, with thickness remaining essentially unchanged; thus, portions of morainic ridges may not necessarily be terminal positions of advancing glaciers.

Drillers' logs usually do not distinguish the separate Wisconsinan drift sheets but list them as "blue clay" due to the freshness of their appearance in contrast to underlying Illinoian deposits. Sample studies sometimes permit differentiation of the drifts.

In Piatt County, the following sequence appears within the "blue clay," from the Sangamon Soil upward: (1) a brown-gray till with a pink or red cast that may be Shelbyville; (2) one or more gray tills that may be Cerro Gordo and possibly Champaign; (3) loess up to 10 to 15 feet thick.

The Wisconsinan deposits are regionally the most barren of sand and gravel lenses. A sample study of cuttings from a well in Piatt County shows a typical Wisconsinan sequence.

S. L. Rogers well, NE $\frac{1}{4}$ NW $\frac{1}{4}$ SW $\frac{1}{4}$ sec. 22, T. 19 N., R. 4 E., Goose Creek Township, Piatt County. Elevation: 700 feet. Drilled by Woolen, 1943. Sample set no. 9384, described by D. A. Stephenson.

	<u>Depth to base (feet)</u>	<u>Elevation (feet)</u>
Pleistocene Series		
Wisconsinan Stage		
Silt, yellow-brown, oxidized, sandy, loess	15	685

	<u>Depth to base (feet)</u>	<u>Elevation (feet)</u>
Wisconsinan Stage (cont.)		
Silt, sandy, gray, some gravel, till (Cerro Gordo?)	25	675
Silt, sandy, red-gray-brown to dark gray, some wood, non- to slightly calcareous, till (Shelbyville?)	53	647
Illinoian Stage		
Silt, brown, organic, bog	70	630
Sand, gravelly, outwash	75	625
Silt, sandy, gray-brown, gravelly, clayey, till	80	620
Gravel and silty gravel, sorted gravel over coarse till	90	610
Gravel, sand, and silt, gray, till	105	595
Sand, silty, and silt, sandy, gray-brown, till	125	575
Gravel	130	570
Silt, sandy, gray-brown, till	140	560
Kansan (?) Stage		
Silt, gray-brown, probably bog	145	555
Silt, sandy, brown-gray, till	155	545
Silt, sandy, yellow-brown to brown	170	530
Pennsylvanian Series		
Limestone		

Loess deposits of variable thickness cover the entire region. On uneroded topography they range between 50 and 150 inches thick (Smith, 1942). They are not important sources of ground water, except for a few dug wells where sand lenses are present within the loess. In some areas, Recent alluvium and colluvium directly overlie the drift, and southwest of the study area these deposits may locally overlie bedrock. Recent deposits occur mainly in floodplains and at the bases of steep slopes. In this study, both loess deposits and Recent materials are treated as part of the drift sequence.

Thickness and Distribution

The drift thickness map (fig. 10) shows the average thickness to be approximately 200 feet, with a minimum value of less than 50 feet and a maximum value of over 400 feet. Thicker deposits generally are associated with bedrock valleys or with morainic ridges. Maximum thickness occurs where the Champaign and Bloomington Moraines cross the deepest part of the Mahomet Valley. Sand and gravel deposits also are usually thickest where the drift is thickest. The thinnest drift deposits occur where ground moraine overlies bedrock uplands or where recent degradation has partially or completely removed the drift.

The drift thickness map can be of some use as an exploration tool, as it reflects the bedrock channel pattern to a degree, and greater thicknesses of water-bearing sands and gravels occur most frequently in bedrock channels.

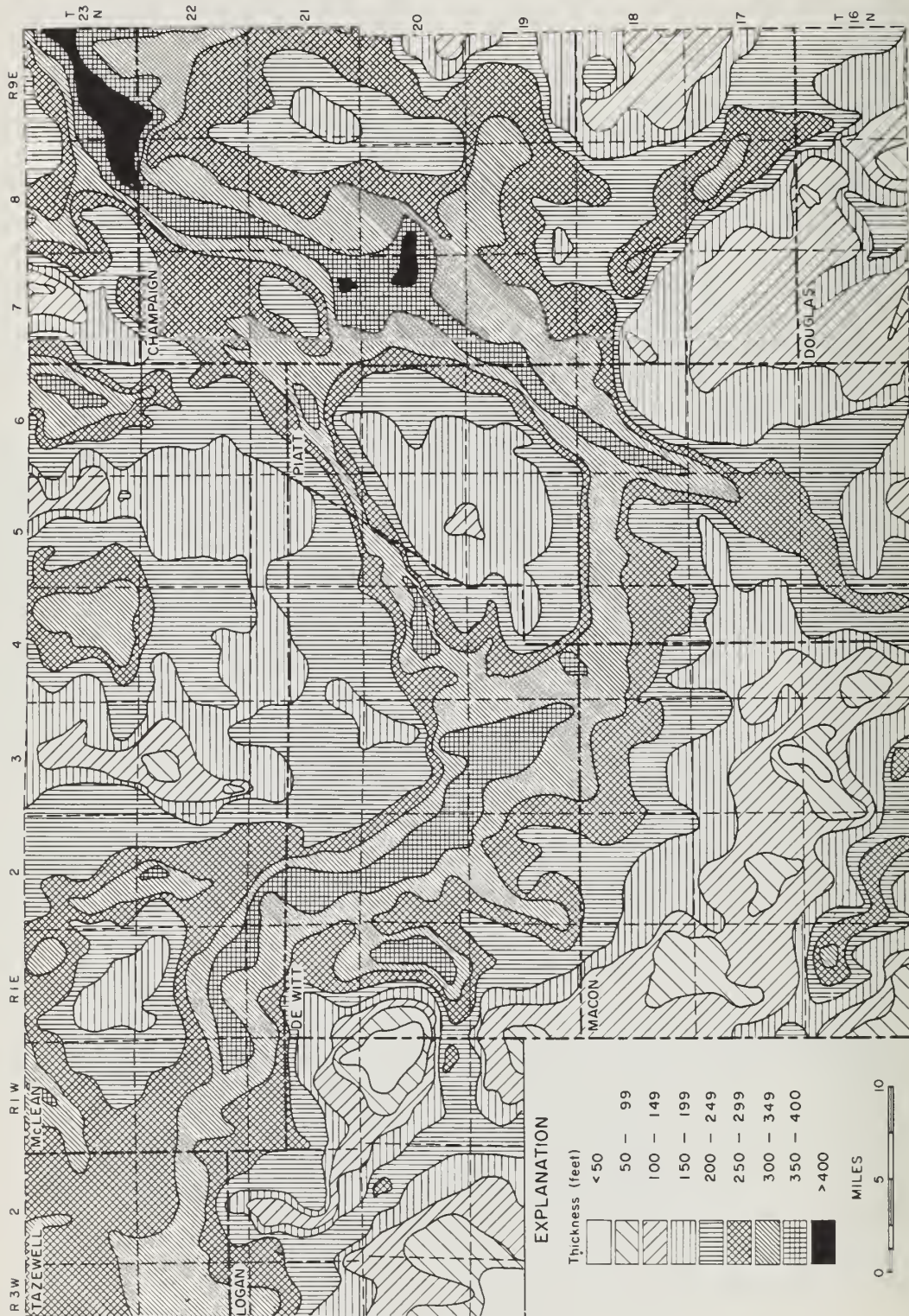


Figure 10 - Drift thickness map.

GROUND-WATER GEOLOGY

Interpretation and Use of Hydrogeologic Maps

Distribution of sand and gravel deposits within the glacial drift of the Mahomet Valley region are shown by quantitative maps (figs. 11-15). Maps were constructed for five separate 100-foot intervals within the glacial drift by utilizing the data and methods previously described. Maps were not constructed for the hydrostratigraphic units, as elevation slices are more practical in field applications. They do not rely on an interpretation of geosols or paleosurfaces, which, as mentioned, can be misleading.

The mapping units chosen were the intervals between the elevations of 700 to 799 feet (fig. 11), 600 to 699 feet (fig. 12), 500 to 599 feet (fig. 13), 400 to 499 feet (fig. 14), and 300 to 399 feet (fig. 15). The maps illustrate vertical variability patterns for the sands and gravels within each of the elevation slices. The patterns are based on a combination of center of gravity and standard deviation contour maps that are derived from statistical analyses of available subsurface data.

The vertical variability maps show whether a test hole in a given area will encounter favorable lithologic conditions for a ground-water supply and at what relative position within an elevation slice these conditions exist. They also show where nonpermeable deposits will be encountered and at what elevation bedrock will be encountered. These maps, therefore, may be of use to well drillers, consulting engineers, and land owners in reducing the amount of exploration sometimes required to locate suitable aquifers in the drift.

Permeable materials within each elevation slice, shown in figures 11 through 15, were placed in one of four possible classes (fig. 16), based on differences in vertical position and distribution (center of gravity and standard deviation). Each class has distinct characteristics of vertical distribution and position of permeable materials different from the other three classes in a slice. By referring to figure 16, one can see that possible occurrences include high or low position for the main concentration of sand or gravel with either small or wide distribution about the position of concentration. The center of gravity is divided into high and low position based on a 0- to 50-foot interval (high center) and a 50- to 100-foot interval (low center). The standard deviation is divided into small or wide spread based on values that are 0 to 10 feet (small) and 10 to 50 feet (wide) either side of the center of gravity.

Information on vertical distribution and position is supplemented on each map by values of the percentage of permeable materials, given at each control point. The percentage information shows the relative amount of sand and gravel within a given elevation slice. As each slice is 100 feet thick, the percentage number is also the total thickness of permeable material at each point.

The percentage numbers vary in each slice and in each class within a slice. It has been illustrated earlier that Wisconsinan deposits do not contain as many water-bearing strata as older Pleistocene deposits; it follows that the higher elevation slices have the lowest percentage averages and that percentage of permeable material increases with depth.

Description for the vertical variability classes, lettered from A to D, are given in table 4. Characteristics and descriptions of each class are similar for each slice, varying primarily in percentage (total thickness) values.

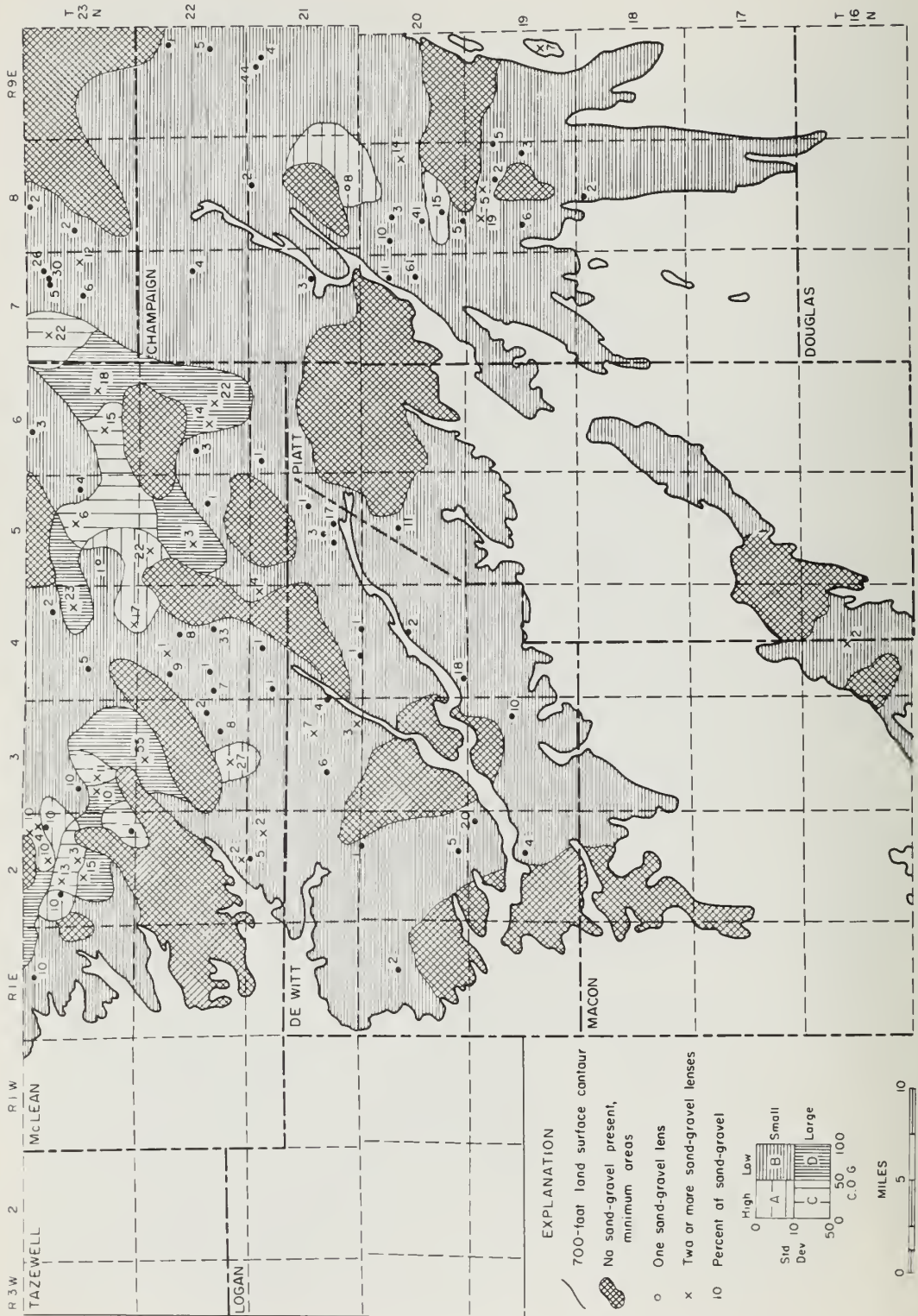


Figure 11 - Vertical variability pattern map of the 700- to 799-foot elevation interval.

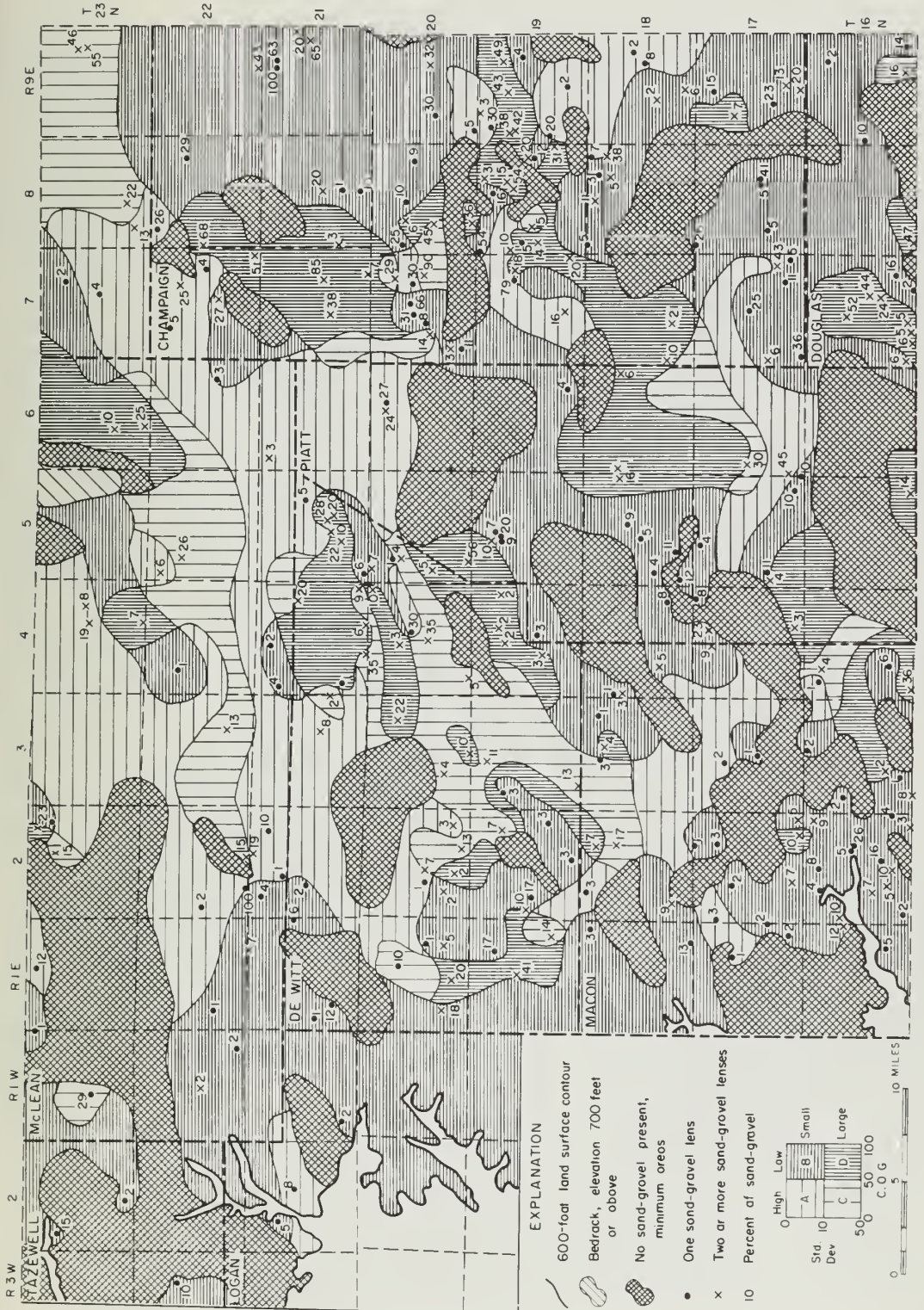


Figure 12 - Vertical variability pattern map of the 600- to 699-foot elevation interval.

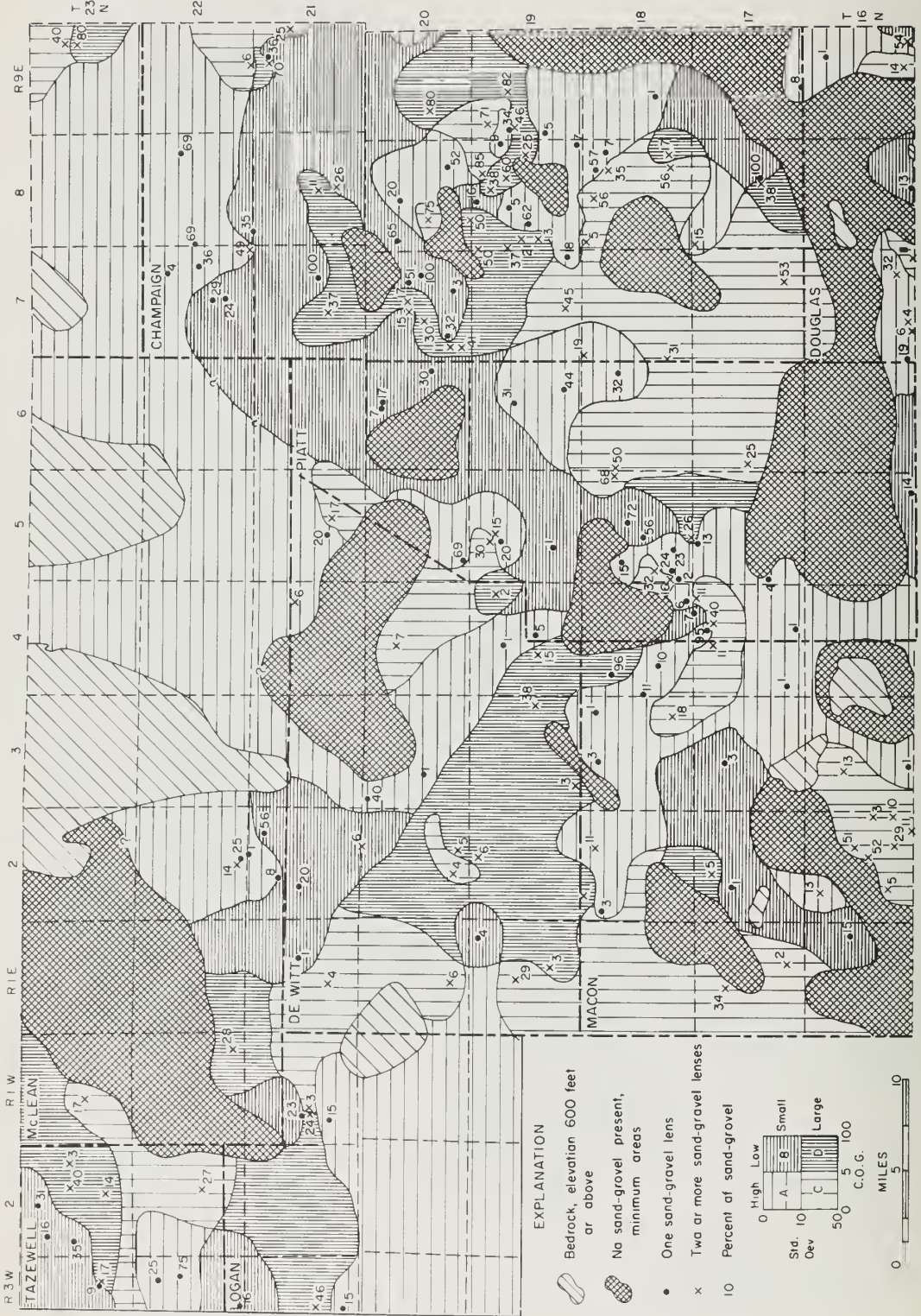


Figure 13 - Vertical variability pattern map of the 500- to 599-foot elevation interval.

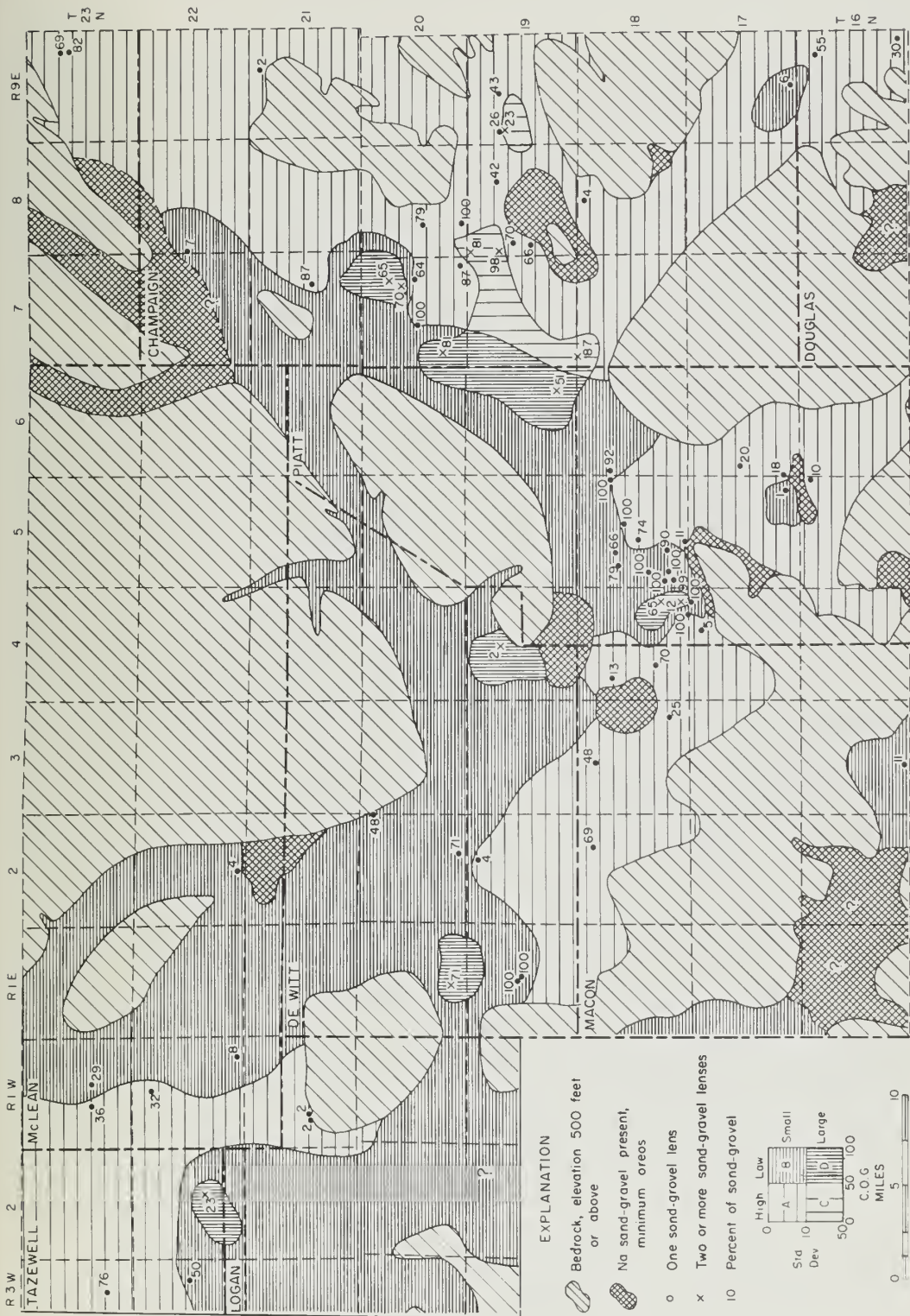


Figure 14 - Vertical variability pattern map of the 400- to 499-foot elevation interval.

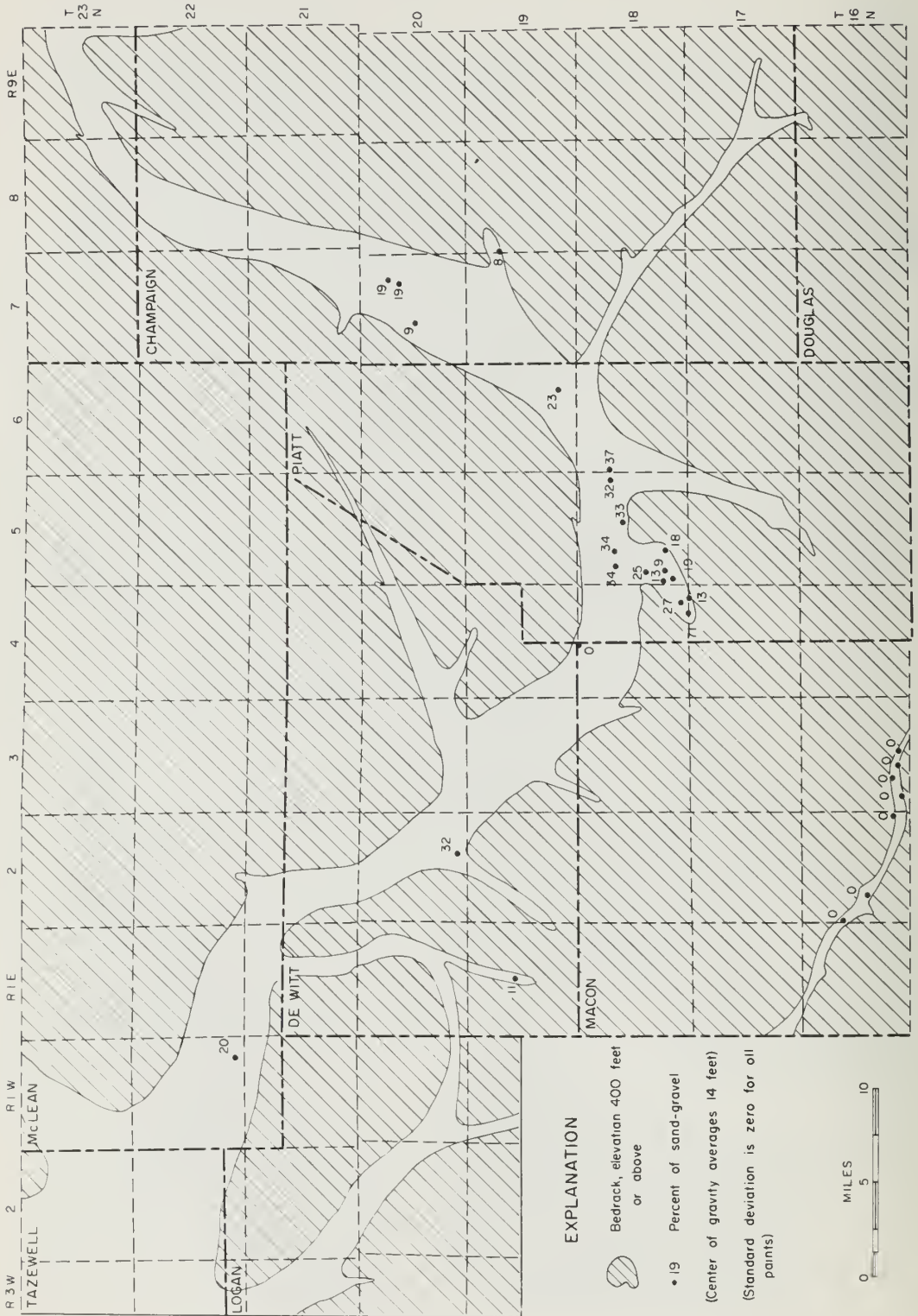


Figure 15 - Vertical variability pattern map of the 300- to 399-foot elevation interval.

Other features on the maps include the number of district sand and gravel units at each control point, the boundaries of areas where no sand or gravel deposits are present within a given slice, bedrock contours, and ground-surface contours. If two or more sand or gravel lenses are present, the lenses are separated by intervals of material of low permeability; thus, the standard deviation is usually large.

The contours outlining areas where no sand or gravel occur are probably minimal boundaries. The implication is that some of the areas shown as containing sand or gravel may in fact contain none. The density of data controls the accuracy here. However, sand or gravel units, when present, have the characteristics of the class in which they occur.

Distribution of Aquifers

The heterogeneous distribution of aquifers within drift makes their location somewhat unpredictable. However, quantitative methods of mapping permit conditions relating to aquifer occurrence to be categorized by areas.

In a study of a similar complex geologic environment, that of alluvial fans in a present-day semi-arid zone that was affected by major Pleistocene climatic changes, Bredehoeft and Farvolden (1964) determined that aquifer distribution could be predicted from lithofacies analyses of alluvial fan environments in the lower Humboldt River Basin, Nevada. The study concluded that many of the clastics composing the best aquifers were derived from alluvial fans and reworked and redeposited. The original deposits within the fans generally were not good aquifers.

A similar phenomenon occurred in the Mahomet Valley region. The drift served as a source for coarse clastics that were subsequently reworked and redeposited as fluvial or glaciofluvial sediments, free of large amounts of fine-grained materials. The bedrock topography and subsequent surface topographic patterns were controls on the depositional environments of these clastics. Pluvial conditions during interglacial stages and fluvial conditions associated with glaciation resulted in sculpturing of the various paleosurfaces and concentration of clastic deposits in depression areas. Many sand and gravel units are located in depressions that are related to either bedrock, Yarmouthian, or Sangamonian surfaces. Greatest thicknesses of sand and gravel occur where these depressions mark the juncture of tributary systems.

Many of the sand and gravel units have a preferred orientation, with elongation in a north-south direction, parallel to direction of ice movement and to regional slopes. Locally, the elongation is parallel to east-west drainage patterns that filled major bedrock channels, especially for the basal deposits of the pre-

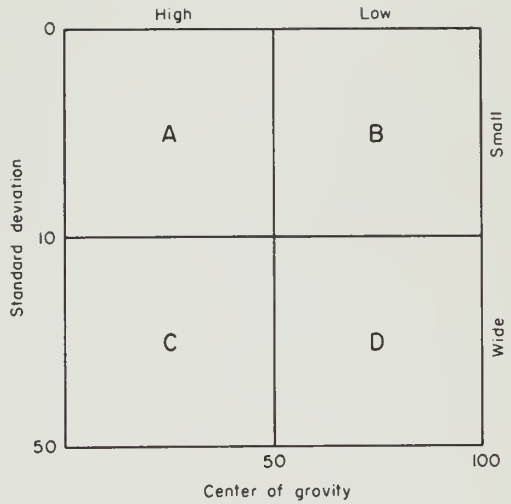


Figure 16 - Parameters of vertical variability classes in each elevation slice.

TABLE 4 - DESCRIPTION OF VERTICAL VARIABILITY CLASSES FOR THE MAHOMET VALLEY REGION*

Class	Characteristics	Description
A	<p>Center of gravity high, 0 to 50 feet below the top of the slice. Standard deviation (spread) small, 0 to 10 feet either side of the center of gravity (the majority of points with small spread have a standard deviation value of zero, which indicates that only one unit is present, the thickness of which is given by the percentage values). Percentage of permeable materials is variable, but the average is 24 percent for all control points in this class.</p>	<p>The main sand and gravel development occurs in the upper portion of the section and generally consists of one or a few lenses interbedded with small quantities of material of low permeability. (In reference to the ground surface, the center of gravity is between 0 and 50 feet below the top elevation of each slice.) Over two-thirds of the permeable materials are accounted for in the range of the standard deviation either side of the center of gravity. Average percentage values for each elevation slice are as follows: 700 to 799 feet, 17 percent; 600 to 699 feet, 15 percent; 500 to 599 feet, 20 percent; 400 to 499 feet, 35 percent; 300 to 399 feet, 24 percent. The decrease in percentage for the latter slice is a result of the method used in calculating percentages and indicates that the bedrock surface occurs within the interval.</p>
B	<p>Center of gravity low, 50 to 100 feet below the top of the slice. Standard deviation small, 0 to 10 feet either side of the center of gravity. Percentage of permeable materials averages 16 percent for all control points, but varies in each slice.</p>	<p>The main sand and gravel development is in the lower portion of the interval and consists of one or a few lenses interbedded with small quantities of relatively impermeable material. The majority of sand and gravel lenses occur within 0 to 10 feet either side of the center of gravity. Lenses are thicker when percentage values increase. The average percentage values for each slice are as follows: 700 to 799 feet, 9 percent; 600 to 699 feet, 13 percent; 500 to 599 feet, 24 percent; 400 to 499 feet, 38 percent. No Class B is defined in the 300- to 399-foot slice.</p>
C	<p>Center of gravity high, 0 to 50 feet below the top of the slice. Standard deviation large, 10 to 50 feet either side of the center of gravity. Percentage of permeable materials averages 28 percent for all control points, but is variable, generally increasing with depth.</p>	<p>The main development of permeable materials occurs in the upper portions of the interval with a spread of 10 to 50 feet either side of the center of gravity. Low percentage values in this class coupled with the large spread indicate there are thin lenses of sand and gravel with large quantities of material of negligible permeability interspersed. Average percentage values per slice are as follows: 700 to 799 feet, 12 percent; 600 to 699 feet, 22 percent; 500 to 599 feet, 24 percent; 400 to 499 feet, 44 percent. No Class C is defined in the 300- to 399-foot elevation slice.</p>
D	<p>Center of gravity low, 50 to 100 feet below the top of the slice. Standard deviation large, 10 to 50 feet either side of the center of gravity. Percentage of permeable materials averages 40 percent for all control points, but varies for each slice.</p>	<p>Where high percentage values occur coupled with large spread, relatively thick sequences of sand and gravel are indicated, primarily in a low position as the main development is toward the bottom of the slice. The spread is 10 to 50 feet either side of the center of gravity. Where low percentage values occur coupled with large spread, relatively thin lenses interspersed with large quantities of silt and clay are indicated. Average percentage values per slice are as follows: 700 to 799 feet, 21 percent; 600 to 699 feet, 23 percent; 500 to 599 feet, 29 percent; 400 to 499 feet, 50 percent. No Class D was defined for the lower slice, 300 to 399 feet.</p>

* See figures 11-15.

Illinoian Stage(s). This directional property may be an important factor in determining hydrologic boundaries.

The 700- to 799-foot slice (fig. 11) is composed entirely of Wisconsinan and Illinoian deposits. The thickest aquifers generally are in Classes C (high center, wide spread) and D (low center, wide spread) of figure 16. Classes B (low center, small spread) and D include segments of the Sangamon Soil zone; sand and gravel deposits frequently are associated with low-lying portions of this zone. Many of the clastic deposits are lenses within the till, rather than deposits in sags. The A (high center, small spread) and C classes occur primarily on the upland areas of McLean and Champaign Counties, and generally are within the margins of topographic highs associated with terminal moraines. High percentages of permeable material are associated with areas of outwash extending south and west from the Champaign Moraine.

The 600- to 699-foot slice (fig. 12) is composed primarily of Illinoian deposits, although Wisconsinan deposits are present in the eastern portion of the area. The Sangamonian, Yarmouthian, and bedrock surfaces all influenced depositional patterns of this slice to a degree. The best aquifers are likely to occur in Class D. High percentages of sand and gravel, such as in Champaign County, are concentrated along low sags on the Yarmouthian surface and on the Sangamonian surface. Additional high percentage values are associated with places on the Yarmouthian surface where tributary valleys join. In most cases, lowest percentages of permeable material are associated with the highest upland surfaces.

The 500- to 599-foot slice (fig. 13) contains few Wisconsinan deposits, but is composed predominantly of Illinoian and pre-Illinoian deposits. At present, there are more water wells completed in this slice than in any of the other slices. The greatest thicknesses of permeable materials occur in Class D, although Classes B and C also contain thick permeable lenses. Much of the Yarmouth Soil is within this slice, and its configuration controlled deposition of clastics in much of the A and C classes. Erosion during Yarmouthian time removed some thick gravel lenses; this is illustrated in the area of well number 39 of cross section B-B', figure 9. Clastic depositional patterns in the B and D classes were influenced by the configuration of the bedrock surface, and many high percentage values occur in areas above bedrock valleys. Generally, in this slice, high center of gravity of permeable material occurs over high upland surfaces.

The 400- to 499-foot slice (fig. 14) is composed essentially of pre-Illinoian deposits. Depositional patterns of material in this slice were controlled largely by the configuration of the bedrock surface. The slice includes much fluvial material considered to be Mahomet Sand. Percentages of permeable materials are high—up to 100 percent—in areas such as T. 18 N., R. 5 E. Class B contains the best aquifers, as all clastics are one continuous unit in that class and, therefore, have zero spread. Percentage values decrease in Class A, corresponding to a decrease in the thickness of sand and gravel. Generally, D classes occur at the confluence of bedrock channel tributaries coincident with high percentage values, where clastics have been concentrated. The lack of permeable deposits in the valley in T. 16 N., R. 1-3 E., indicates it was not a through-drainageway to the extent the Mahomet Valley was.

Deposits in the 300- to 399-foot slice (fig. 15) fall only in Class A and are composed of pre-Illinoian sediments. The center of gravity of permeable materials is high, averaging only 14 feet below the top of the slice. Generally, the total interval above bedrock in this slice is continuous sand or gravel; the percentage figures, where present, indicate the amount of permeable material, in feet,

above the bedrock. Grain sizes of the sand and gravel are in the range of medium- to very coarse-grained sand and fine- to medium-grained gravel (standard Wentworth scale limits).

The nature of deposits in the Harris Valley, in northern Piatt County, is uncertain, and recent exploratory drilling has raised the question as to whether a valley actually exists. Geophysical evidence shows the existence of a valley (L. D. McGinnis, 1965, personal communication), and data from oil test holes determined the presence and location of a valley, though no lithologic logs are available for it. However, results of exploratory drilling for a water supply in an area south of Farmer City indicate that bedrock elevations may be at least 140 feet higher than indicated for the Harris Valley. The bedrock ridge that trends north-south through R. 5 E., T. 20 and 21 N. (fig. 6), may be continuous.

General Hydrology

Ground water in the Mahomet Valley region is derived from precipitation and underflow into the area through bedrock and bedrock valleys. Also, some of the intermittent streams, or upland reaches of streams, act as line sources of ground water and are considered influent streams. Perennial streams act as drains on the ground-water system along most of their reaches, with a ground-water gradient toward the stream. Locally, the natural direction of ground-water movement is reversed by pumpage of wells near streams.

Two types of glacial drift have previously been discussed: unstratified drift, or till, and stratified drift. The till was deposited directly by ice and consists of a heterogeneous mixture of clay, silt, sand, and gravel. Generally, these tills have a matrix of silt or clayey silt and have low permeabilities, except for fracture permeability in moderately indurated tills. At most places, till is sufficiently impermeable that it forms an aquitard between productive aquifers. Dug wells in till may yield a few gallons of water per minute but commonly rely upon storage capacity to be economically useful. Norris (1962) gathered evidence that vertical permeability in tills is reasonably uniform over fairly large distances. He concludes that permeability values of till can be extrapolated regionally and applied with reasonable confidence in estimating recharge rates of ground water through till. Permeability values for the till commonly exceed 0.01 gpd/sq ft.

Stratified sediments may occur above, below, or as lenses interbedded within a till, or as relatively continuous deposits in bedrock channels or depressions. The most widespread stratified deposits are outwash sands and gravels in the bedrock channels or in channels of formerly weathered zones. Water generally occurs in stratified deposits under semiconfined or confined conditions. Therefore, such water-yielding deposits are considered to represent an artesian condition and the water level rises above the level of first encounter. Walton (1965, p. 33) gives the recharge rates for glacial sand and gravel aquifers as ranging between 115,000 to 500,000 gpd/sq mi. The lower rate is for an area where the sand and gravel aquifer is overlain by thick glacial drift consisting largely of till. Where sand and gravel deposits are present from the surface to bedrock, recharge rates commonly exceed 300,000 gpd/sq mi (over 6 inches of rainfall).

The aquifers are enclosed by relatively impermeable material (aquitards), usually the silty till described above, or, in the case of the basal clastics, the Pennsylvanian shale forms the bottom aquitard. The aquitards are saturated if they occur below the water table but yield little water during short time intervals. Re-

charge to the sand and gravel units occurs as vertical leakage through the aquitards. Rate of this leakage is controlled by vertical permeabilities, the thickness of confining beds, and head differences.

Drift aquifers vary in their capacity to transmit and yield water. Reported yields of wells penetrating the pre-Illinoian deposits range from 5 gallons per minute (gpm) to 3000 gpm, Illinoian deposits from 3 gpm to 885 gpm, and Wisconsinan deposits from 3 gpm to 510 gpm.

Relation of Permeability to Geologic Conditions

The most common hydrologic information available from drillers' logs are pumping and nonpumping water levels, rate of discharge of water from a pumping well, and length of well-development tests. A specific capacity (Q/s) can be calculated for each well or test hole with this information. Specific capacity is defined as the yield of the well per foot of drawdown for a stated pumping period and rate. It is expressed in gallons per minute per foot of drawdown (gpm/ft). The higher the value of Q/s , the more productive is the aquifer in which a given well is bottomed.

A theoretical relationship between specific capacity and the coefficient of transmissibility (T) exists that permits one factor to be determined if the other is known. If specific capacity is known, T can be found. Then, using thickness information for aquifers, which also is obtained from drillers' logs, a coefficient of permeability (P) can be calculated from a general equation: $P = T/m$.

Assuming a well discharging at a constant rate in a homogeneous, isotropic, nonleaky artesian aquifer infinite in areal extent, the theoretical specific capacity is related to the coefficient of transmissibility in the following manner (equation modified from Walton, 1962, p. 12):

$$Q/s = T / \left[264 \log_{10} (Tt / 1.87 r_w^2 S) - 65.5 \right]$$

where

- Q = pumping rate, in gallons per minute
- s = drawdown of the well, in feet, which equals the nonpumping water level minus the pumping water level
- T = coefficient of transmissibility, in gallons a day per foot of aquifer
- t = pumping period in days
- r_w = effective well radius, in feet
- S = storage coefficient
- Q/s = specific capacity, in gallons per minute per foot of drawdown.

This equation also requires that the well penetrates and is uncased through the total saturated thickness of the aquifer, that well loss is negligible, and that the effective radius of the well has not been extended beyond the casing radius by drilling and well-development operations. Errors that result when these conditions

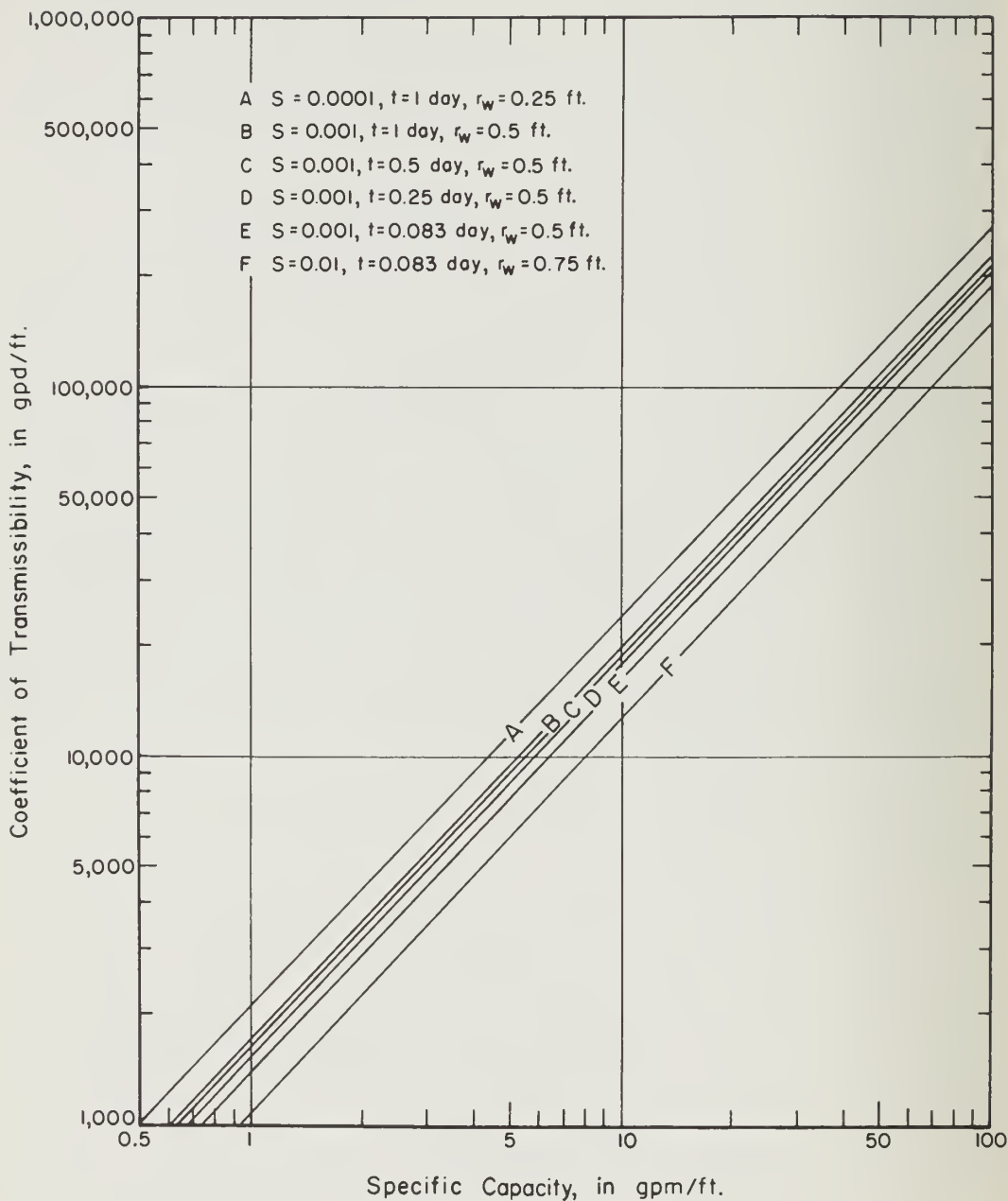


Figure 17 - Theoretical relationship between specific capacity and the coefficient of transmissibility. Several lines are drawn representing variations of values of r_w^2/t and of the storage coefficient.

TABLE 5 - HYDRAULIC PROPERTIES OF HYDROSTRATIGRAPHIC UNITS

Unit	Specific capacity Q/s (gpm/ft)	Transmissivity T (gpd/ft)	Thickness m (ft)	Permeability P (gpd/ft ²)
Wisconsinan	0.1 to 27.0	— 54,000	1 to 20	— 2,700
Illinoian	0.1 to 57.0	120 to 110,000	4 to 32	30 to 3,440
Pre-Illinoian	0.2 to 146.0	— 700,000	3 to 10	— 70,000

are violated are partly compensatory; however, the conditions usually adversely affect specific capacity, and actually the coefficient of transmissibility is greater than that computed from specific capacity data.

The specific capacity data available include considerable range in pumping period, radius, and discharge from the well. Therefore, graphs were prepared for relating specific capacity and transmissibility in several possible combinations of these factors. An estimate of the storage coefficient of 0.001 was substituted into the equation. This value is indicative of semiconfined conditions that probably best fit the actual situation. Figure 17 shows the limiting range of best fit lines by using the following data: pumping periods of 2, 6, 12, and 24 hours; radii of 3, 6, and 9 inches; and S values of 0.01 to 0.0001. To construct figure 17, assumed values of transmissibility of 10,000 and 100,000 were selected; the above values of r_w^2/t were used and various relationships calculated. A storage coefficient of 0.01 would move the lower boundary to a position F, as shown; if the storage coefficient were selected as 0.0001, the upper boundary would move to position A, as indicated. A mistake in estimating the storage coefficient does not cause a large error in the value of transmissibility.

The specific capacity variations with pumping period are in a downward direction with increased time; with radius increase, specific capacity increases, but not proportionately.

From the graph relationships shown in figure 17 and specific capacity from drillers' logs, a transmissibility range can be estimated for each control point. From this, a coefficient of permeability can be computed. A range of permeability values was computed for the hydrostratigraphic units by this method (table 5).

The values of permeability computed from drillers' logs are probably low in most cases due to the nature of the many assumptions described above. Well losses due to turbulent flow around the vicinity of a pumped well tend to give a greater drawdown than would exist under less turbulent conditions. The greater drawdown results in a lower specific capacity and a subsequent lower transmissibility and permeability determination. However, this is offset partially by the fact that most wells are likely to have a larger effective radius than that of the drilled hole, because of development during completion and pumping.

Transmissivities and permeabilities calculated from specific capacity data for the hydrostratigraphic units and for various slices and classes are given in tables 5 and 6.

TABLE 6 - AVERAGE PERMEABILITY (in gpd/ft^2) OF CLASSES IN VERTICAL VARIABILITY MAPS

Slice	Class			
	A	B	C	D
300 - 399	1090	—	—	—
400 - 499	993	2153	3817	1077
500 - 599	1876	2560	1181	885
600 - 699	1351	1489	1351	3138
700 - 799	178	1053	—	1200

The transmissibility for a given area in the slice maps of figures 11 to 15 can be estimated by multiplying the average sand and gravel thickness in a class as taken from table 4 by the average permeability of that class as taken from table 6.

Permeabilities of the hydrostratigraphic units increase downward, indicating a general grain-size increase of clastic deposits from the Wisconsinan deposits to the pre-Illinoian deposits in bedrock channels.

Permeability data for each class of the vertical variability slice maps (figures 11-15) show that a general agreement exists between high average permeabilities and the classes of highest average lithic percentage of sand and gravel.

Significance of Quantitative Methods

The successful solution of hydrologic problems depends upon the coverage and validity of hydrologic data. In many investigations, data from aquifer performance tests are limited or nonexistent, and there is neither sufficient finances nor time to accumulate these data. On the other hand, subsurface geologic information in the form of drillers' and geophysical logs may be comparatively abundant. The drillers' logs may include sufficient hydrologic data to permit estimates of aquifer characteristics on the basis of theoretical relationships. Quantitative geologic mapping techniques allow satisfactory use of the basic drillers' information for a variety of purposes. These methods have the advantages of being reasonably economical and expedient. Application of these techniques in conjunction with a limited aquifer testing program may provide an effective means for evaluating the regional transmissive and storage properties of unconsolidated materials in a basin. As the aquifers in drift are neither homogeneous nor isotropic with respect to permeability, these evaluations will be approximate.

The quantitative mapping techniques also allow satisfactory use of geologic data for construction of hydrologic models of aquifers. These in turn can be converted to analog models for study of aquifer responses to pumping. For example, quantitative mapping and hydrologic extrapolations result in improved transmissibility maps. The transmissibility values can be converted to values of electrical resistance and an electric analog model can be constructed (Walton and Prickett, 1963).

CONCLUSIONS

This investigation has emphasized the study and definition of permeable zones within the glacial drift of the Mahomet Valley region of east-central Illinois. A method of quantitative hydrogeologic mapping, which resulted in a three-dimensional analysis of drift of the Mahomet Valley region, was demonstrated.

Specific conclusions are as follows:

1. Three hydrostratigraphic units are present in the Mahomet Valley region. These units correspond approximately to Wisconsinan, Illinoian, and pre-Illinoian Pleistocene deposits. Percentage of permeable material in these units increases from Wisconsinan to pre-Illinoian.

Wisconsinan deposits are generally above 625 feet in elevation and contain aquifers that are only locally prominent. Illinoian deposits are generally between 625 feet and 500 feet in elevation and contain relatively widespread aquifers. Below 525 feet, generally, are pre-Illinoian deposits that contain high percentages of coarse sand and gravel aquifers that fill the major bedrock channels.

A preferred orientation exists for many of the sand and gravel lenses, with elongation in a general north-south direction, parallel to direction of ice movement and to regional slope. Many of the aquifers are located in depressions that are related to either bedrock, Yarmouthian, or Sangamonian surfaces. Greatest thicknesses of sand and gravel occur where these depressions mark the juncture of tributary systems.

2. The quantitative methods utilized illustrate how limited data can be developed for a hydrogeologic analysis. These methods were chosen as one way to define the three-dimensional configuration of permeable materials in an economical and expedient manner.

Geological parameters to illustrate distribution of coarse-grained material are expressed as summation products of vertical position, thickness, and areal variation. These parameters are combined in vertical variability pattern maps for different elevation slices, and a series of classes are created in each slice. Each class has distinct characteristics of vertical and horizontal position of permeable materials including possible combinations of high and low center of gravity with either small or wide spreads. Percentage data are also included for each class. This quantitative procedure results in a satisfactory representation of the subsurface geologic conditions, leads to development of hydrologic data through empirical relationships with geologic data, and serves as a method of defining hydrogeologic conditions that can be modeled by analogs.

Potential areas of ground-water development are indicated with proper interpretation of the vertical variability maps. Sand and gravel deposits, if present, are likely to have the characteristics of the class in which they occur. These slice maps thus are useful to those seeking ground-water supplies.

3. A correlation analysis shows that features of the present topography cannot be used to predict bedrock topography in east-central Illinois. However, present topography may be a clue in helping to interpret the configuration of buried land surfaces if such surfaces are not deeply buried.

4. Aquifers within the three hydrostratigraphic units vary in their capacity to transmit and to yield water. From theoretical relationships between transmissibility and specific capacity, an average permeability was determined for the various units. From data available, permeability is shown as increasing downward, indicative of a general grain-size increase of clastic deposits from the Wisconsinan deposits to deposits in bedrock channels.

Permeability data for each class of vertical variability slice maps indicate that a general agreement exists between high average permeabilities and the classes of highest average lithic percentages of sand and gravel, as would be expected.

5. Drillers' logs have been shown to be of sufficient accuracy to warrant their use for preliminary analysis when more sophisticated data are not available or cannot be obtained due to budget limitations. The geologic and hydrologic data of these logs generally are consistent and reliable when descriptions of sample sets are used for control. Despite the variations in drillers' lithologic descriptions, this information is useful. Drillers' logs are especially useful in hydrogeologic studies if information also is given on well yield to permit specific capacity to be determined.

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APPENDIX A

Geologic Interpretation of Drillers' Logs

Section A

A drift sequence that includes multiple weathering zones is given here for comparison of information given on a driller's log and a geologic interpretation. No sample set was available for description.

Weldon City test hole, SE $\frac{1}{4}$ sec. 9, T. 19 N.,
R. 4 E., Nixon Township, DeWitt County.
Elevation: 710 feet. The total depth is 378
feet, of which 298 feet is drift. Drilled by
Johnson and Son.

<u>Driller's log</u>	<u>Depth to base (ft)</u>	<u>Geologic interpretation</u>
		Pleistocene Series
		Wisconsinan Stage
Soil and yellow clay	18	Loess and weathered till
Blue clay	33	Till, gray
Sand	34	Sand
Blue clay	67	Till, gray
		Sangamonian Stage
Drift, black, some water	69	Peat
Green to blue clay	72	Colluvium and/or till, gray-green
		Illinoian Stage
Blue clay, hard	99	Till, gray, indurated
Sand, water	99.5	Sand
Blue clay, hard	139	Till, gray
		Yarmouthian (?) Stage
Black gumbo	145	Peat and organic silt
Black drift	152	Peat
Green clay	158	Colluvium and/or till, gray-green
Sand, fine, water	158.5	Sand, fine grained
		Pre-Illinoian Stage (?)
Blue clay, soft	164	Till, gray
Hardpan	165	Till
Blue clay, hard over soft	241	Till, gray
		Pre-Illinoian (?) Weath- ered Zone
Brown drift	243	Peat, organic silt
Green clay	260	Colluvium and/or till, gray-green
Sand, water	260.3	Sand

Section A - Continued

<u>Driller's log</u>	<u>Depth to base (ft)</u>	<u>Geologic interpretation</u>
Blue clay	281	Pre-Illinoian Stage (?) Till, gray
Brown drift	289	Pre-Illinoian (?) Weath- ered Zone
Sand, water	289.3	Peat, organic silt
Green clay	298	Sand
		Colluvium and/or weathered bedrock, gray-green
		Pennsylvanian Series
Soapstone	378	Shale

Section B

A representative section of pre-Illinoian basal clastics is shown in the log of this test hole.

City of Decatur test hole no. 3, NW $\frac{1}{4}$ NE $\frac{1}{4}$ NE $\frac{1}{4}$ sec. 17, T. 18 N., R. 5 E., Willow Branch Township, Piatt County. Elevation: 680 feet. The total depth is 318 feet, of which 315 feet is drift. Drilled by Layne-Western, 1954. Sample set no. 24148, described by D. A. Stephenson.

<u>Driller's log</u>	<u>Depth to base (ft)</u>	<u>Geologic interpretation</u>	<u>Depth to base (ft)</u>
		Pleistocene Series	
		Wisconsinan Stage	
Soil and yellow clay	10	Silt, mottled dark gray and yellow-gray, sandy, loess and till	10
Blue clay	19	Silt, gray, calcareous, sandy, becoming gravelly to the bottom, till	27
Sand, gravel, and boulders	26	Silt, pinkish gray-brown, sandy, gravelly, calcareous, till	52
		Sangamonian Stage	
Blue clay	80	Silt, green-gray, sandy, clayey, calcareous, colluvium	62

Section B - Continued

<u>Driller's log</u>	<u>Depth to base (ft)</u>	<u>Geologic interpretation</u>	<u>Depth to base (ft)</u>
		Illinoian Stage	
Gray clay	110	Silt, predominantly gray, sandy, gravelly, zones of organic silt, calcareous, till and/or colluvium	125
Gray clay	180	Silt, pinkish brown-gray, sandy, calcareous, becoming silt, gravelly, at 180 feet, till	200
		Pre-Illinoian Stage	
		Gravel, subrounded to rounded, sandy, silty, some organic silt and wood, not too clean, outwash, probably top of the Mahomet Sand	295
Sand, gravel	315	Sand and Gravel, quartzose sand, predominantly medium to coarse grained; Mahomet Sand, clean	315
		Silt, gray, sandy, clayey, slightly calcareous, till (?) or weathered bedrock	318
		Pennsylvanian Series	
Shale	318	Shale	

Section C

This log illustrates the range of materials described by drillers as "hardpan."

Mansfield City well, SW $\frac{1}{4}$ NE $\frac{1}{4}$ NE $\frac{1}{4}$ sec. 10, T. 20 N., R. 6 E., Blue Ridge Township, Piatt County. Elevation: 725 feet. The total depth is 215 feet, of which 214.5 feet is drift. Drilled by Woolen Bros., 1938. Sample set no. 2718, described by D. A. Stephenson.

<u>Driller's log</u>	<u>Depth to base (ft)</u>	<u>Geologic interpretation</u>	<u>Depth to base (ft)</u>
----------------------	---------------------------	--------------------------------	---------------------------

Pleistocene Series
Wisconsinan Stage

Section C - Continued

<u>Driller's log</u>	<u>Depth to base (ft)</u>	<u>Geologic interpretation</u>	<u>Depth to base (ft)</u>
Yellow clay	15	Silt, yellow-brown to brown, sandy, loess and till	15
Blue clay	20	Silt, dark gray-green to green-gray, sandy, non-to slightly calcareous;	
Green clay	25	colluvium of intra-Wisconsin break	22
Hardpan	40	Silt, gray and yellow-gray, gravelly, oxidized, non-calcareous at top, till	40
Gravel, dry	42.5	Gravel, Sand, and Silt, gray, slightly calcareous, probably till	42.5
Hardpan, soft	51.5	Sangamonian Stage Silt, green-gray, gravelly, sandy, moderately calcareous, colluvium	51.5
Clay, soft, sandy	57	Post-Sangamon Deposits Silt, gray, sandy, calcareous, till	
Hardpan	68		60
Hardpan, sand streaks	74	Silt and gravel, gray and tan, calcareous, till	74
Hardpan, soft, sand seams	80	Gravel, some very coarse-grained sand, not clean, outwash or very gravelly till	80
Hardpan	85	Sand and Silt, gray-brown, calcareous, not clean, till or sandy outwash, some varved (?) lacustrine material at 87 feet	
Sand, clay	88		88
		Silt, gray and yellow-brown, sandy, calcareous, becomes red-gray-brown to bottom, till	101
		Silt, dark gray, sandy, calcareous, till	122
Hardpan	150	Silt, very dark gray, clayey, sandy, calcareous, till	128
		Silt, dark gray, sandy, calcareous, till	144
Sand, clay	155	Silt, yellow- to red-gray-brown, sandy, calcareous, till	
Hardpan, sand	161		161

Section C - Continued

<u>Driller's log</u>	<u>Depth to base (ft)</u>	<u>Geologic interpretation</u>	<u>Depth to base (ft)</u>
		Silt, very dark gray-brown, granular gravel, sandy, calcareous, organic material, till and organic silt	177
		No samples	181
Hardpan	192	Silt, gray, varved, very calcareous, lacustrine	198
Gumbo, hardpan	200	Sand, medium to coarse grained, becoming clean and slightly gravelly at 204 feet; outwash, probably Mahomet Sand	208
Sand, coarse grained	210	Gravel, very coarse grained, becoming medium to fine grained toward bottom; outwash, Mahomet Sand	214.5
Sand, gravel	214	Pennsylvanian Series	
Sandstone	215	Sandstone	215

APPENDIX B

IBM Program for Vertical Variability Mapping Data

The moment method for continuous distributions is described in most textbooks on statistics (for example, Arkin and Colton, 1956; or Mode, 1951). In using such methods for the present application, the intervals between sand and gravel occurrences and the thicknesses of these segments are irregular. Krumbein and Libby (1957, p. 208-211) give a detailed discussion of derivations of equations for discontinuous distributions, shown in figure 5, directly from theory.

Following is a digital computer program that is designed to obtain center of gravity and standard deviation of any selected units. The program, written for an IBM 7094 at the Digital Computer Laboratory of the University of Illinois, was used to calculate vertical variability parameters for sand and gravel lenses within the glacial drift of east-central Illinois. If the distance between clastic lenses (h's) or thicknesses of clastic lenses (t's) exceeds eight in number, statement 101 must be increased to allow for this expansion; the corresponding "RIT" statements would also have to be modified.

IBM 7094 PROGRAM

Columns

1 5 7

```

C      VERTICAL VARIABILITY
      DIMENSION H(100), T(100)
100    FORMAT (215,F5.0)
101    FORMAT (8F5.0)
102    FORMAT (3X, 1H1, 10X, 3HCOG, 7X, 4HRCOG, 8X, 2HAV, 9X, 3HASD, 8X, 3HRSD)
103    FORMAT (1X, 14, F14.1, F10.3, F12.0, F11.0, F10.3)
104    FORMAT (14)
      WOT 6, 102
      RIT 7, 104, JAY
      DO 220 J= 1, JAY
      A= 0.0
      B= 0.0
      C= 0.0
      RIT 7, 100, 1, NMX, X
      IX=X
      DO 200 N= 1, NMX, IX
      RIT 7, 101, H(N), H(N+1), H(N+2), H(N+3), H(N+4), H(N+5), H(N+6),
1H(N+7)
200    RIT 7, 101, T(N), T(N+1), T(N+2), T(N+3), T(N+4), T(N+5), T(N+6),
1T(N+7)
      DO 210 N= 1, NMX
      A= A+T(N)
      HT= H(N)*T(N)
      B= B+HT
210    C= C+HT*H(N)
      COG= B/A

```

IBM PROGRAM - Continued

Columns

1 5 7

 $RCOG = COG/X$ $AV = C/A - (B/A)**2$ $ASD = SQRT(AV)$ $RSD = ASD/X$

WOT 6, 103, I, COG, RCOG, AV, ASD, RSD

220 CONTINUE

END

Illinois State Geological Survey Circular 409
51 p., 17 figs., 6 tables, app., 1967

CIRCULAR 409

ILLINOIS STATE GEOLOGICAL SURVEY

URBANA