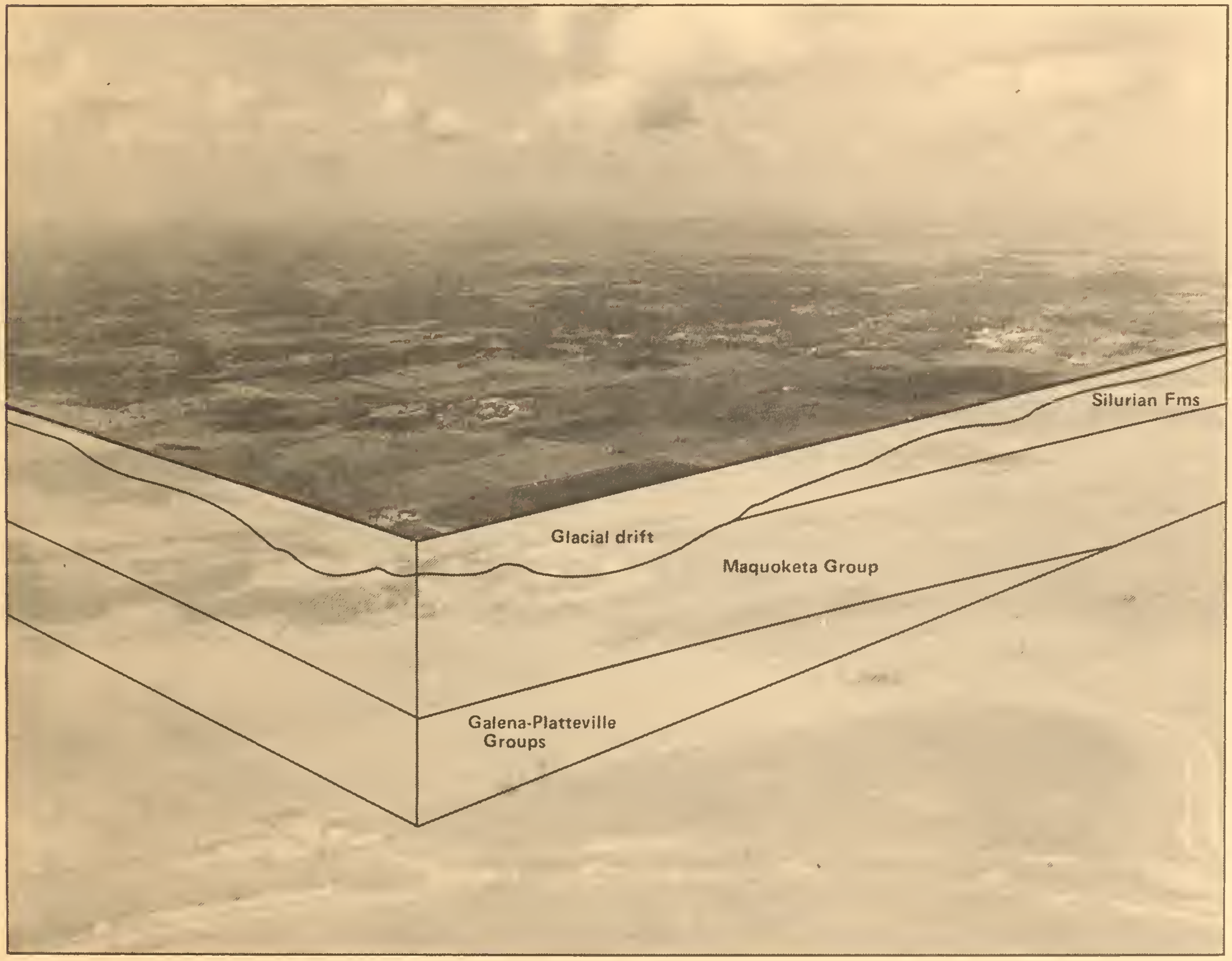
EGN 111

R. L. LANGENHEIM, JR.
DEPT. GEOL. UNIV. ILLINOIS
254 N. H. B., 1301 W. GREEN ST.
URBANA, ILLINOIS 61801

Geological-Geotechnical Studies for Siting the Superconducting Super Collider in Illinois:

Preliminary Geological Feasibility Report

J.P. Kempton, R.C. Vaiden, D.R. Kolata
P.B. DuMontelle, M.M. Killey and R.A. Bauer



Illinois Department of Energy and Natural Resources
STATE GEOLOGICAL SURVEY DIVISION

ENVIRONMENTAL GEOLOGY NOTES 111
1985

Geological-Geotechnical Studies for Siting the Superconducting Super Collider in Illinois:

Preliminary Geological Feasibility Report

J.P. Kempton, R.C. Vaiden, D.R. Kolata
P.B. DuMontelle, M.M. Killey and R.A. Bauer

ILLINOIS STATE GEOLOGICAL SURVEY
Morris W. Leighton, Chief

Natural Resources Building
615 East Peabody Drive
Champaign, Illinois 61820

ENVIRONMENTAL GEOLOGY NOTES 111
1985

Digitized by the Internet Archive
in 2012 with funding from
University of Illinois Urbana-Champaign

http://archive.org/details/geologicalgeotec111kemp

FIGURES

TABLES

Geological-Geotechnical Studies for Siting the Superconducting Super Collider in Illinois:

Preliminary Geological Feasibility Report

INTRODUCTION

The need to probe the fundamental nature of matter and energy dictates the need for higher energy particle accelerators. With the recent radical improvement in magnet technology, it has become possible to build an accelerator with an energy of about 20 trillion electron volts (TeV). The preliminary design and cost estimates for a Superconducting Super Collider (SSC) are now being prepared by physicists from the national laboratories and the university community.

At the Fermi National Accelerator Laboratory (Fermilab) in Batavia, Illinois, the world's most advanced, high-energy accelerator has just begun operation: the Tevatron—the first to use superconducting magnets—has accelerated protons nearly to its design energy of 1 TeV. The SSC project is a natural extension of Fermilab, which could be used as an injector for the proposed facility.

The design for the Superconducting Super Collider is still evolving, but the current plan is to construct a ring, circular to elliptical (including two straight segments), roughly 20 to 30 miles (32 to 48 km) in diameter, and ideally lying in a flat plane—although one or two bends are technically possible. Clearly, the SSC would extend well beyond the present Fermilab borders.

Although the use of the Tevatron as an injector for the SSC would save a significant amount of money, the suitability of the topography and geology of the Fermilab environs must be demonstrated. A preliminary review of the local geological literature (Huson *in* Slansky, 1983) indicates no major restrictions to placement of the ring in that region.

In June 1983, the Illinois State Geological Survey (ISGS) was asked to determine site suitability from a geological perspective. It was agreed that the work would consist of four phases: (1) collecting and organizing existing geological data needed to select possible sites; (2) investigating a selected region near Fermilab to locate the most suitable circular corridor; (3) verifying predicted conditions within the corridor by drilling test holes, and presenting the results in a final geological report; and (4) continuing to act as geological consultants during the site selection process.

This report constitutes phase 1: a preliminary compilation of existing geologic maps, reports, and other readily available geologic data. Maps and cross sections have been specifically prepared to focus on the geologic units relevant to ring siting; geologic units have been described and characterized to a geologically and economically practical depth (about 600 ft [180 m]). These data provide a provisional base for determining overall geologic suitability for locating an accelerator up to 30 miles (48 km) in diameter. The report indicates problem areas as well as areas and geologic units that appear most suitable for the ring.

Superconducting Super Collider

The SSC is a scientific instrument for exploring the basic structure of nature. In a sense, it's a giant microscope for focusing on the building blocks of nature and for revealing the forces that hold the universe together.

Enormous energy is required to observe objects at subatomic level. The SSC would accelerate protons to 20 trillion electron volts (TeV). Although this energy is not large on an absolute scale (about the same as a falling raindrop), it is concentrated into the space occupied by a single proton. This concentration creates higher penetrating power upon impact, just as a rifle bullet penetrates deeper than a larger object with the same energy. A head-on collision of two moving objects enhances the effect. In fact, this is how a 20-TeV colliding beam accelerator would operate: two beams of high-energy particles would collide at nearly the speed of light. By observing the collisions, physicists will be able to examine particle structure at a size and energy far beyond present reach.

High-energy concentration or density also means high temperatures—even greater than those of stars. From other observations, astronomers tell us that the universe behaves as if its parts are expanding from some primeval explosion. Only near the time of this hypothesized "Big Bang" of creation would temperatures have been as high. The SSC will simulate the conditions of high density and temperature occurring during the "Big Bang." Because it is such a large step beyond our existing accelerators, the SSC may reveal an entirely new range of phenomena.

At present, the nation's lead in high-energy physics greatly depends on the existing 1-TeV accelerator at Fermilab. To maintain the lead, the High Energy Physics Advisory Panel recommended in July 1983 that the Office of Energy Research of the U.S. Department of Energy initiate research to develop and build an accelerator with about 20 times the energy of Fermilab's Tevatron. Various designs for a superconducting super collider are now under investigation.

The exact size of the SSC has not yet been determined. It will depend on the strength of the magnets needed to keep the particles moving in a circular orbit. The superconducting magnets in the Tevatron have a peak magnetic field of 4.5 Tesla (T). If magnets with similar strength are used in the SSC, that would increase the scale of the Tevatron's 1-km radius by a factor of 20, the ratio of their energies. If stronger magnets can be developed, however, the size of the SSC will be reduced proportionally. Research and development on magnet technologies will continue for the next year or two before a decision is made on the strength of the SSC magnets.

The location of the SSC will be decided on the basis of a national competition, similar to the process used for deciding to locate Fermilab in Batavia. Several states other than Illinois have already shown interest. Undoubtedly, many will submit sites for consideration.

Proposed Site in Illinois

To use the Tevatron as an injector, the SSC must be located at Fermilab. It would extend well beyond the present site boundaries, so it would need to be a benign, unobtrusive neighbor to nearby communities. In general, issues involving the siting of the accelerator range from geographical to human.

Geographical/natural	Social/human
Topographic relief	Population density
Surface materials: types and properties	Electrical power
Bedrock strength, stability	Transportation network
Surface water drainage	Industrial, business, and labor support
Groundwater flow patterns	Housing, schools, recreational facilities
Water quality and quantity	Land use and ownership
Weather conditions	Site flexibility for future options

To minimize the human and ecological impact of constructing and operating the SSC, as well as keep the costs of purchasing land as low as possible, it was decided to investigate the area west of Fermilab. The population density is considerably lower in that direction (fig. 1). Recent studies (Baker et al., 1983; Huson, 1983) suggest this area meets most of the social requirements and probably most of the engineering and construction requirements (Slansky, 1983).

Two possible scenarios have been suggested: Huson (1983) describes a ring west of the Fox River with an extraction line (tunnel) from the Tevatron under the river; the ring

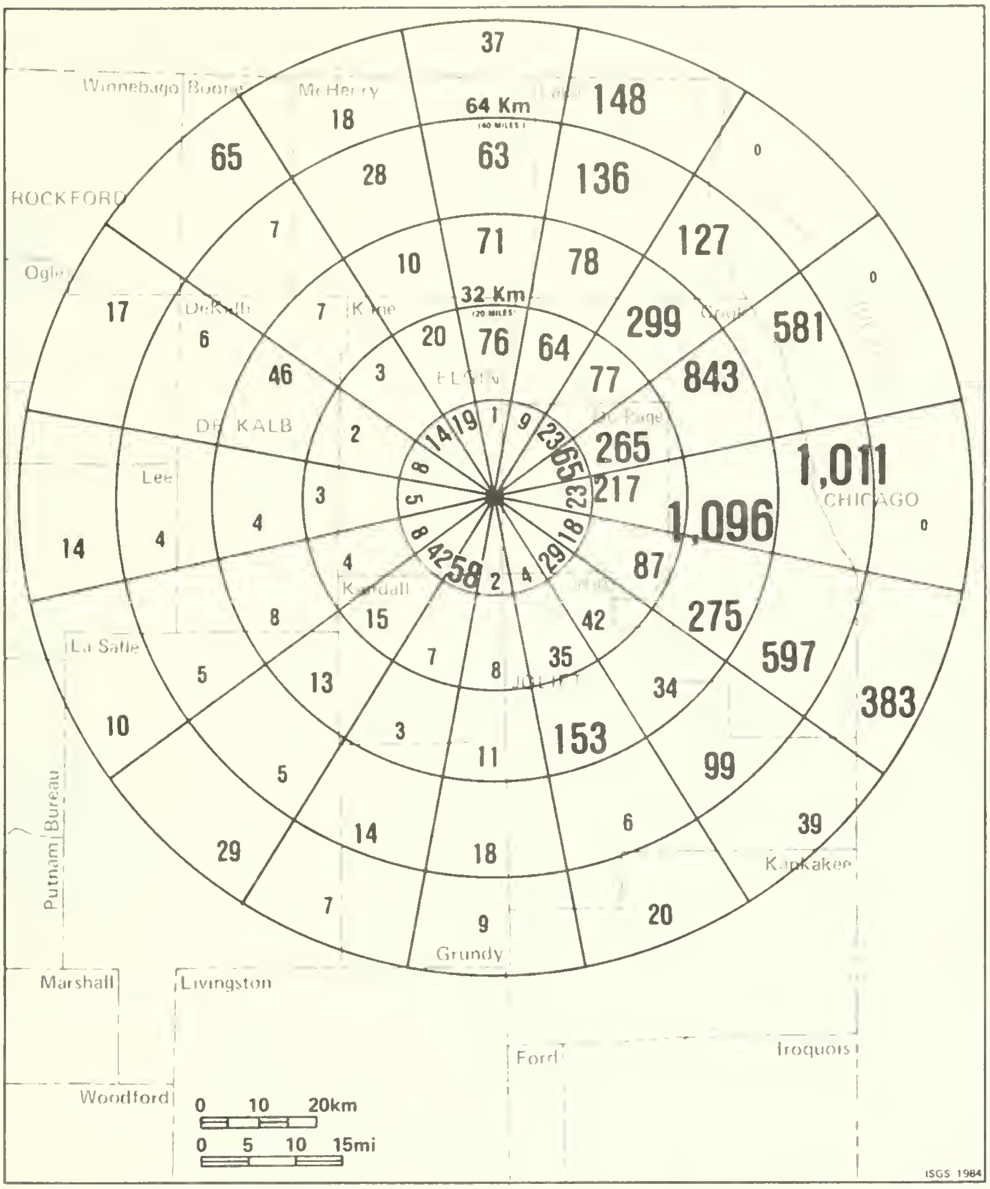


Figure 1.
Population distribution—1980, regional area surrounding Fermi National Accelerator Laboratory. (Numbers represent nearest 1000.)

would be mainly in De Kalb and Kane Counties but intersect a small part of northern Kendall County. This scenario leaves open the choice of ring depth. After crossing the river, the beam could either be directed downward and injected into a ring placed at some depth, or it could be steered upward and injected into a ring near the land surface. The other scenario would have the 20-TeV ring pass under the Fermilab site. In that case, the beam extracted from the Tevatron would be directed downward. Since the 20-TeV ring would have to pass under the Fox River, this option dictates a minimum depth.

The region selected for this study covers the areas involved in both scenarios. As shown in figures 2 and 3, the area extends about 6 miles east, 20 miles north, 20 miles south, and 40 miles west of Fermilab. It includes a total of 36 townships; each township is 6 miles on a side, or 36 square miles. The total area covered by the base map (fig. 2) is 1,296 square miles.

Geologic and Hydrogeologic Factors

Any site selected for the accelerator ring must be geologically suitable—both for the construction and the long-term operation of the SSC.

Three designs for construction have been considered: a shallow trench at the surface (cut-and-cover technique), a shallow tunnel in glacial drift, and a deep tunnel in bedrock.

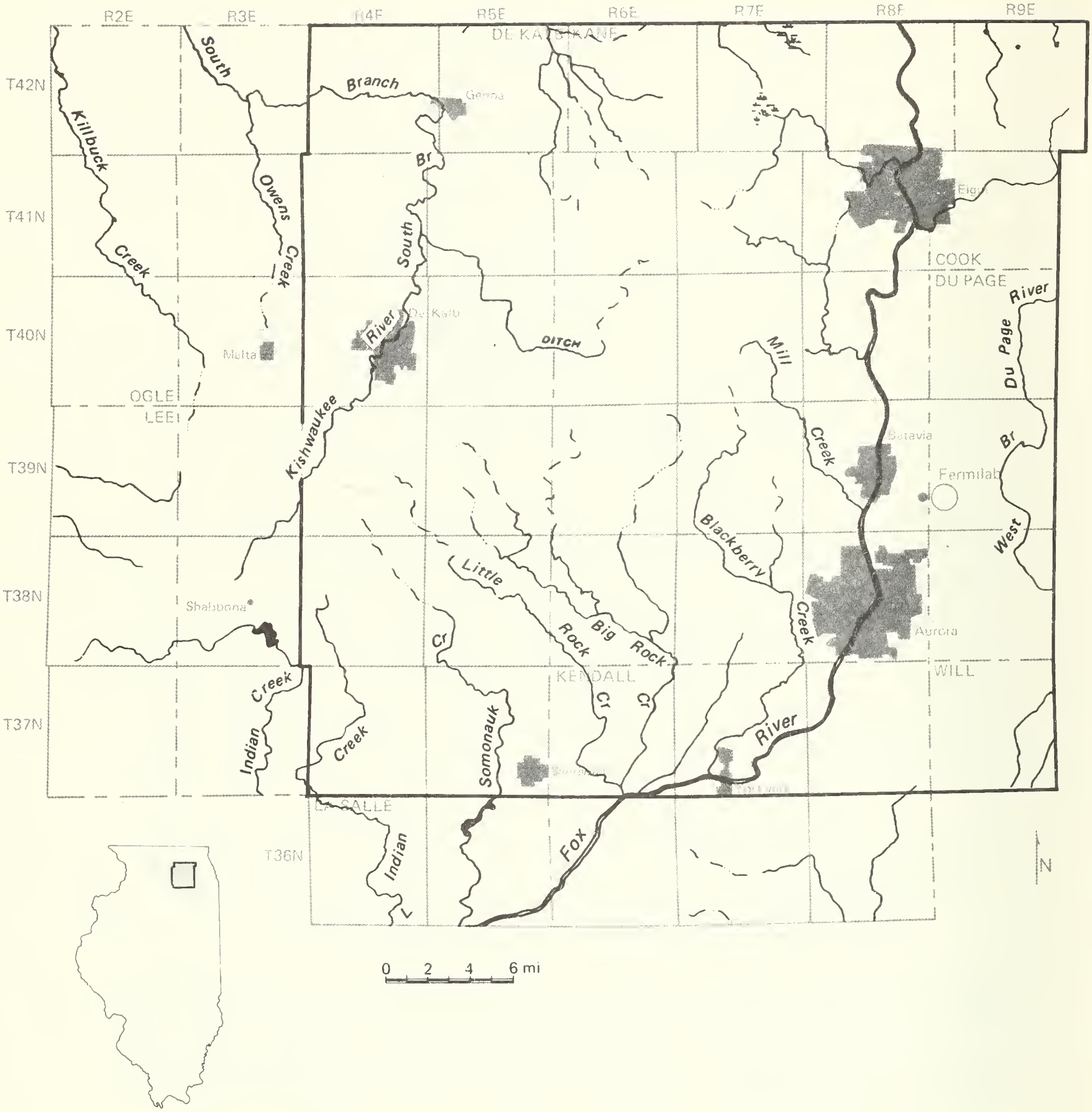


Figure 2a.
Principal streams and municipalities in the study area.

As a result, the geologic materials and their hydrogeologic properties must be evaluated from the surface to a depth of several hundred feet. Primary factors to consider include

- thickness, distribution, and character of glacial drift and rock units, from the surface to about 600 feet deep;
- stability of the earth's crust, including fractures and faults;
- seismicity: the potential effects of earthquakes:
- stability and strength of bedrock for tunnel construction;
- sufficiency of supplies and protection of groundwater resources.

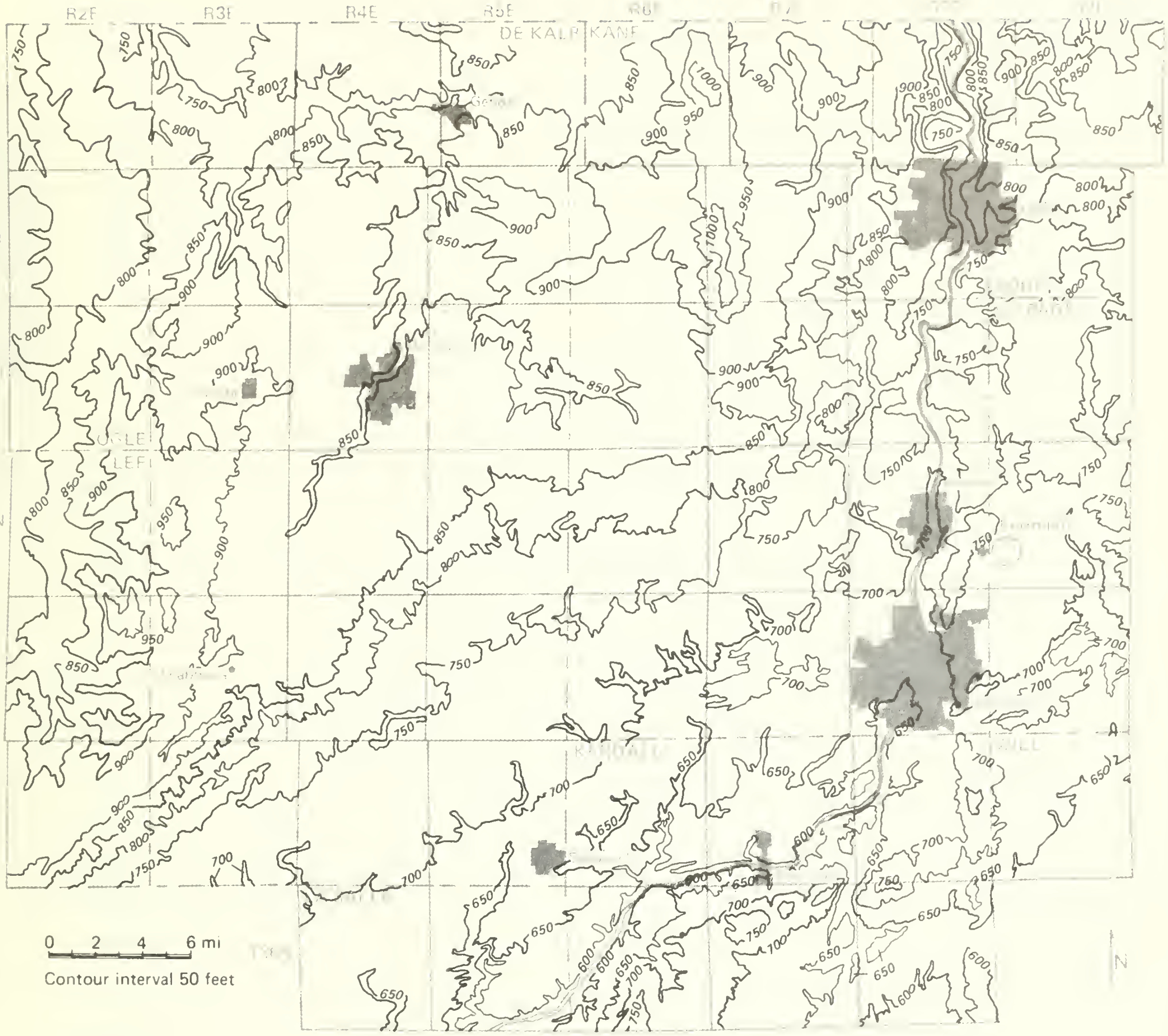


Figure 2b.
Generalized topography of the study area.

REGIONAL GEOLOGIC SETTING

Sources of Data

Considerable geologic data is available for the region covered in this study. The information summarized in this report is sufficient to provide a preliminary assessment of the region as a site for the location of the SSC. Sources include

- local and regional geologic studies conducted by the ISGS and made available in its reports, including graduate theses;
- logs and samples of water wells and engineering borings in the files of the ISGS;
- records of subsurface drilling and sampling programs conducted for water resources studies of northeastern Illinois;
- regional reports and information on seismic activity, crustal stability, and earthquake history.

A few recent, specific studies and data sets provide the backbone of the geologic and hydrogeologic maps and discussions presented here: studies of the bedrock by Buschbach (1964), Hughes, Kratz, and Landon (1966), Willman (1973), Willman and Kolata (1978), and Kolata and Graese (1983); reports on the glacial deposits by Kempton (1963, 1966), Kempton and Hackett (1968a, 1968b), Kempton and Gross (1971), Gross (1969), Landon and Kempton (1971), Wickham (1979), Wickham and Johnson (1981), and Brossman (1982); and other regional reports by Piskin and Bergstrom (1967, 1975), Willman and Frye (1970), Willman et al. (1975), and Willman (1971). County and regional studies relating geology to land-use planning include Gross (1970) for De Kalb County, Kempton et al. (1977) for northeastern Illinois, and Gilkeson and Westerman (1976) for Kane County; these include discussions of aquifer distribution and engineering characteristics of surficial deposits.

Geologic Framework

The following summary places the geology of the proposed northern Illinois site into regional perspective and presents some basic geologic principles and definitions.

The generalized geology of Illinois is depicted in figures 3 and 4. Bedrock materials are generally categorized as (1) the Precambrian granite, which forms the basement (underlying the formations shown on fig. 3); (2) the indurated sedimentary rock succession (shale, sandstone, limestone, and dolomite) of the Cambrian through Pennsylvanian Systems; and (3) the nonindurated, relatively soft Cretaceous and Tertiary deposits. The Quaternary deposits (fig. 4), which include those materials deposited by the continental glaciers, are referred to as overburden, unconsolidated materials, or glacial drift. The terms glacial drift or drift are used in this report.

The sedimentary rock succession has been regionally warped and tilted, generally dipping toward southeastern Illinois where it is up to 15,000 feet thick in the center of the Illinois Basin. The youngest bedrock, composed primarily of shale and siltstone with some sandstone and relatively thin beds of limestone and dolomite, covers a large area of north-central, central, and southern Illinois.

Older rocks are at the bedrock surface in northern Illinois and portions of western and southwestern Illinois. The distribution pattern of these rocks is also controlled by the configuration and elevation of the bedrock surface (fig. 5). The overlying glacial drift forms a cap of variable thickness over the bedrock throughout most of the state (fig. 6 and Piskin and Bergstrom, 1975). Glacial deposits are usually thickest where they fill valleys that formed on the bedrock surface, but also may be relatively thick in end moraines (figs. 4 and 7) that mark the margin of some glacial advances.

The Cretaceous and Tertiary rocks are restricted to small areas of western and southern Illinois (fig. 3). They are composed primarily of bedded clays, silts, sands, and gravels. Since they are generally absent in northern Illinois, they will not be discussed further.

The glacial deposits (fig. 4) can be broadly categorized either (1) as materials deposited directly from the melting glacier, a mixture of pebbles and cobbles in a matrix of clay, silt, and sand (till); or (2) as materials carried out from the glacier by the meltwater and redeposited along meltwater rivers or in lakes. Sand and gravel (outwash) was deposited by the rapidly flowing meltwater rivers, whereas the silt and clay (lacustrine deposits) settled out in quiet-water lakes and ponds. Also present are windblown sand and silt (loess), recent river deposits (alluvium), slopewash (colluvium), and peat and muck.

Of these deposits, glacial till and outwash predominate. Glacial tills can be identified by dominant grain size and mineralogic characteristics. Where the bedrock is near the surface, only one till may be present. In the thicker drift areas, several tills as well as outwash and lacustrine deposits may be present. A more complete discussion of the glacial deposits of Illinois is given by Piskin and Bergstrom (1975) and by Willman and Frye (1970). The Handbook of Illinois Stratigraphy (Willman et al., 1975) summarizes the distribution of all geologic materials in Illinois.

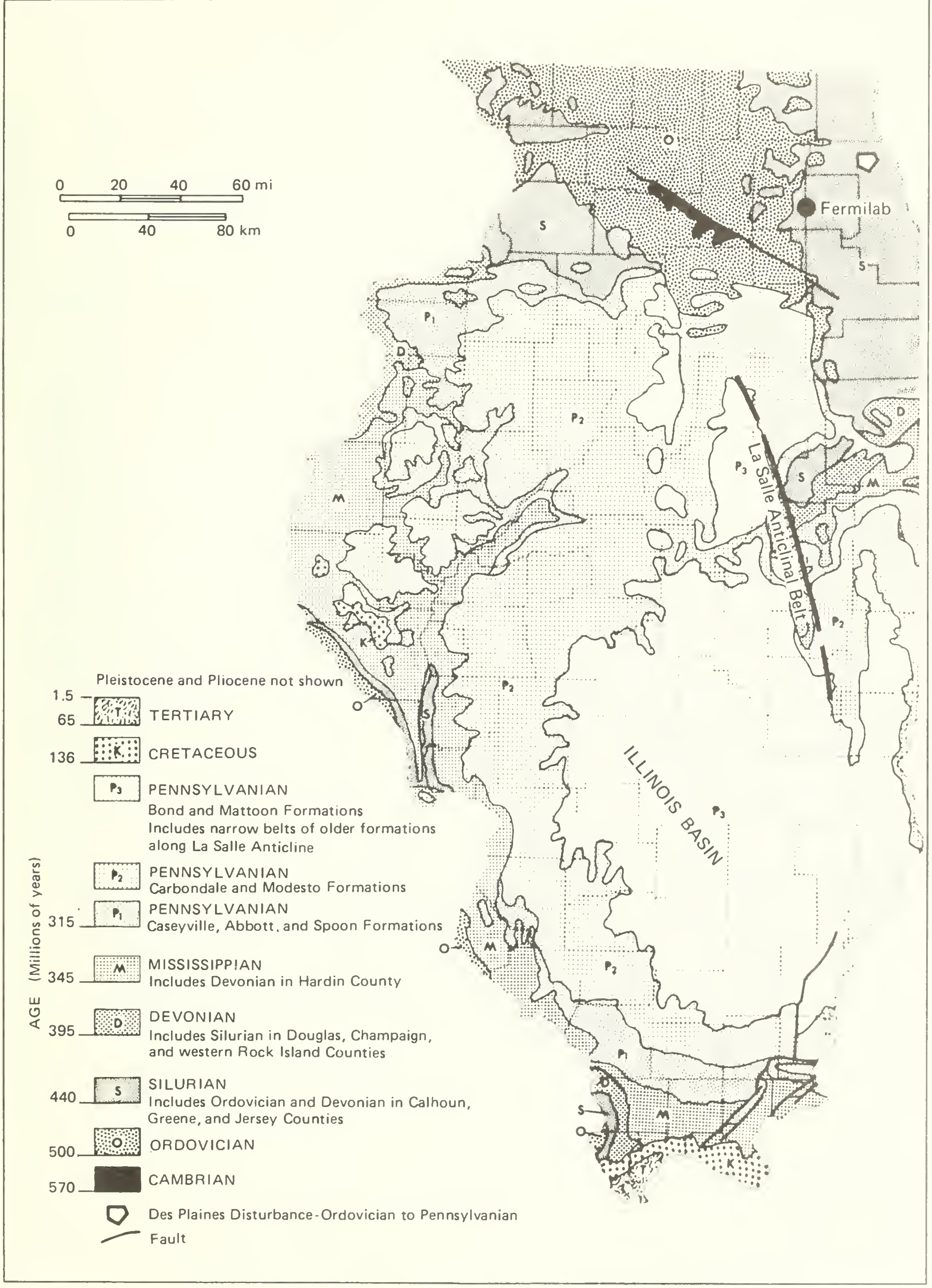


Figure 3.
Geology of the bedrock surface (modified from Willman and Frye, 1970).

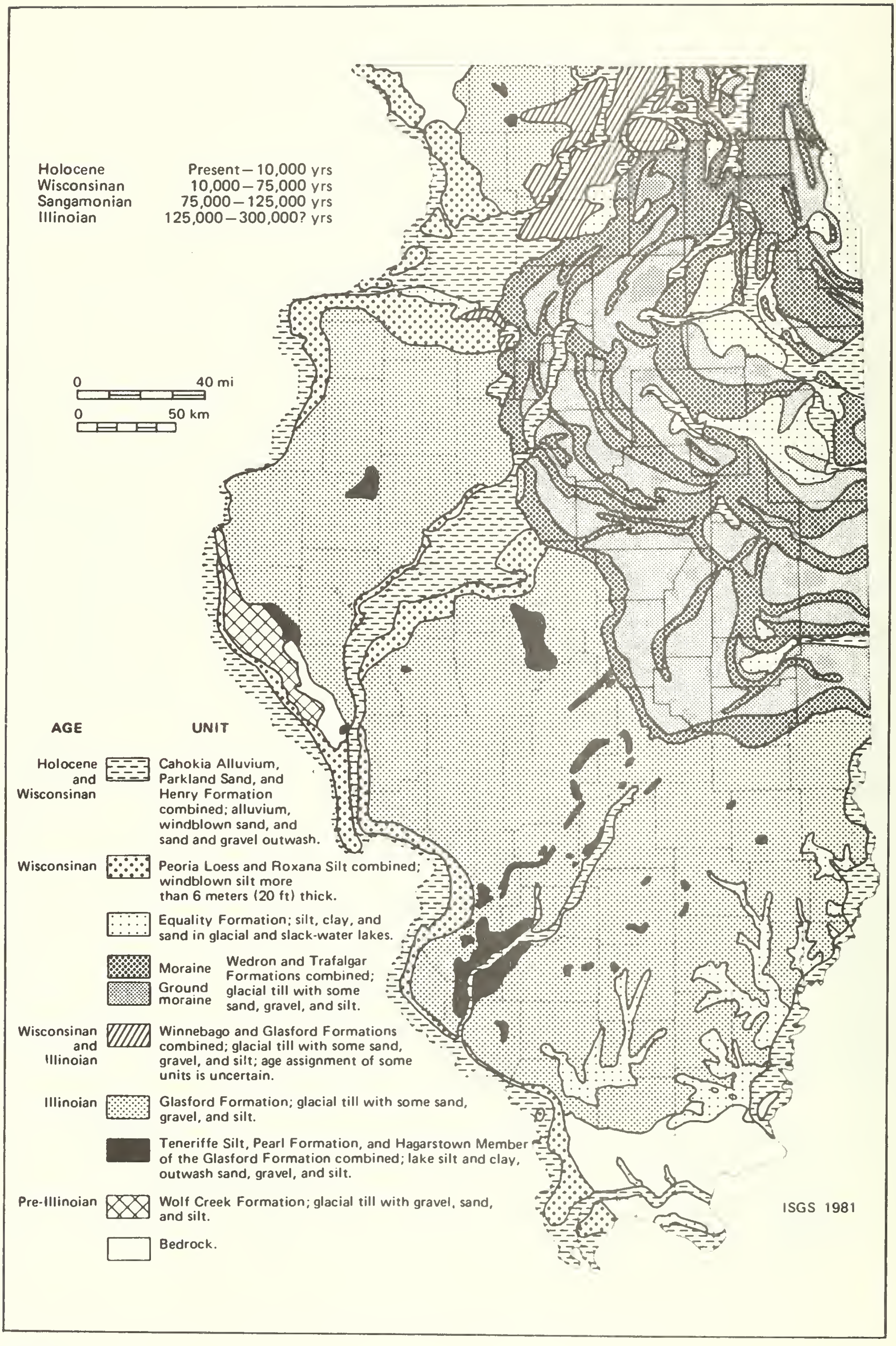


Figure 4.
Quaternary (surficial) deposits of Illinois.

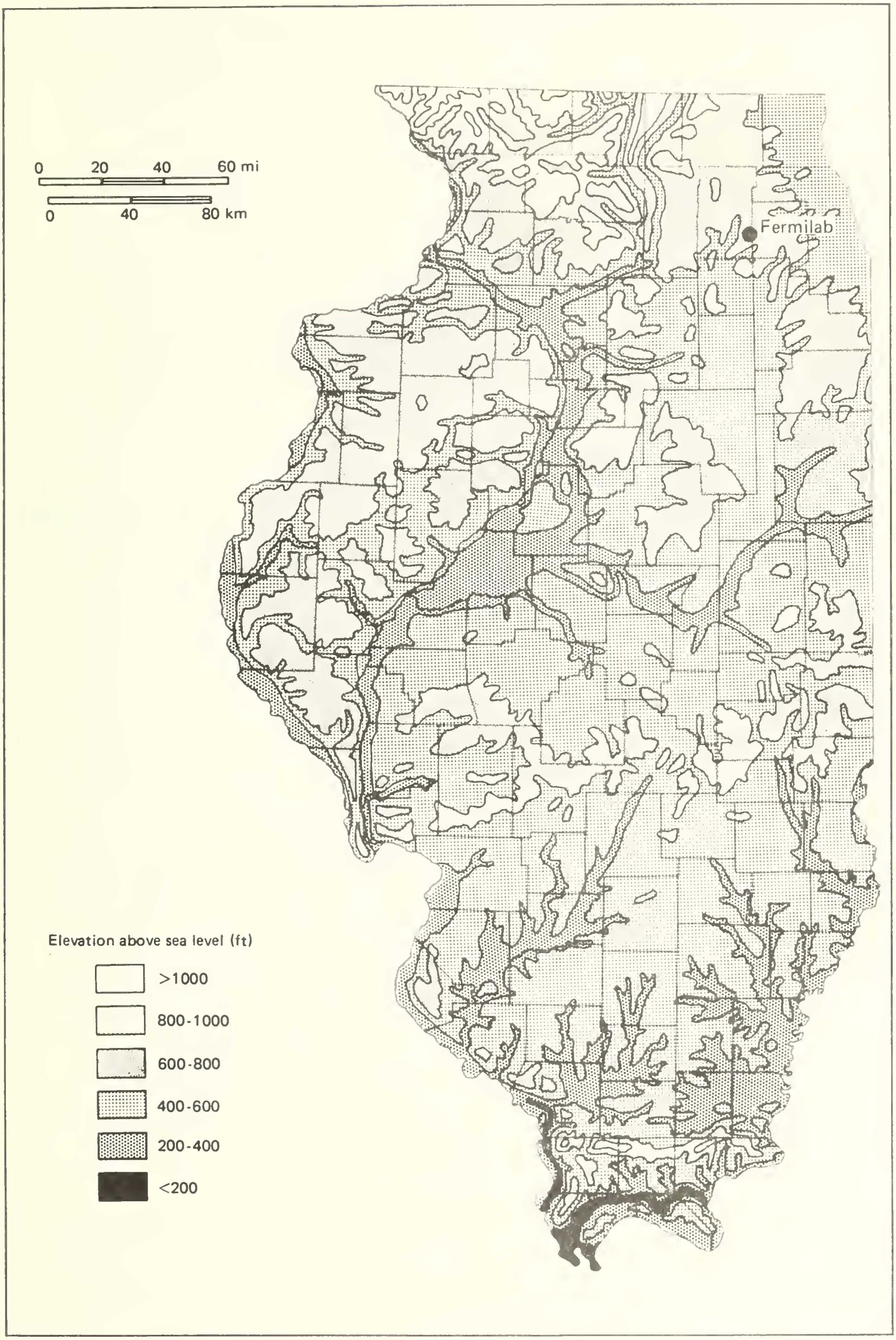


Figure 5.
Topography of the bedrock surface of Illinois (from Willman and Frye, 1970; summarized from Horberg, 1950, and others).

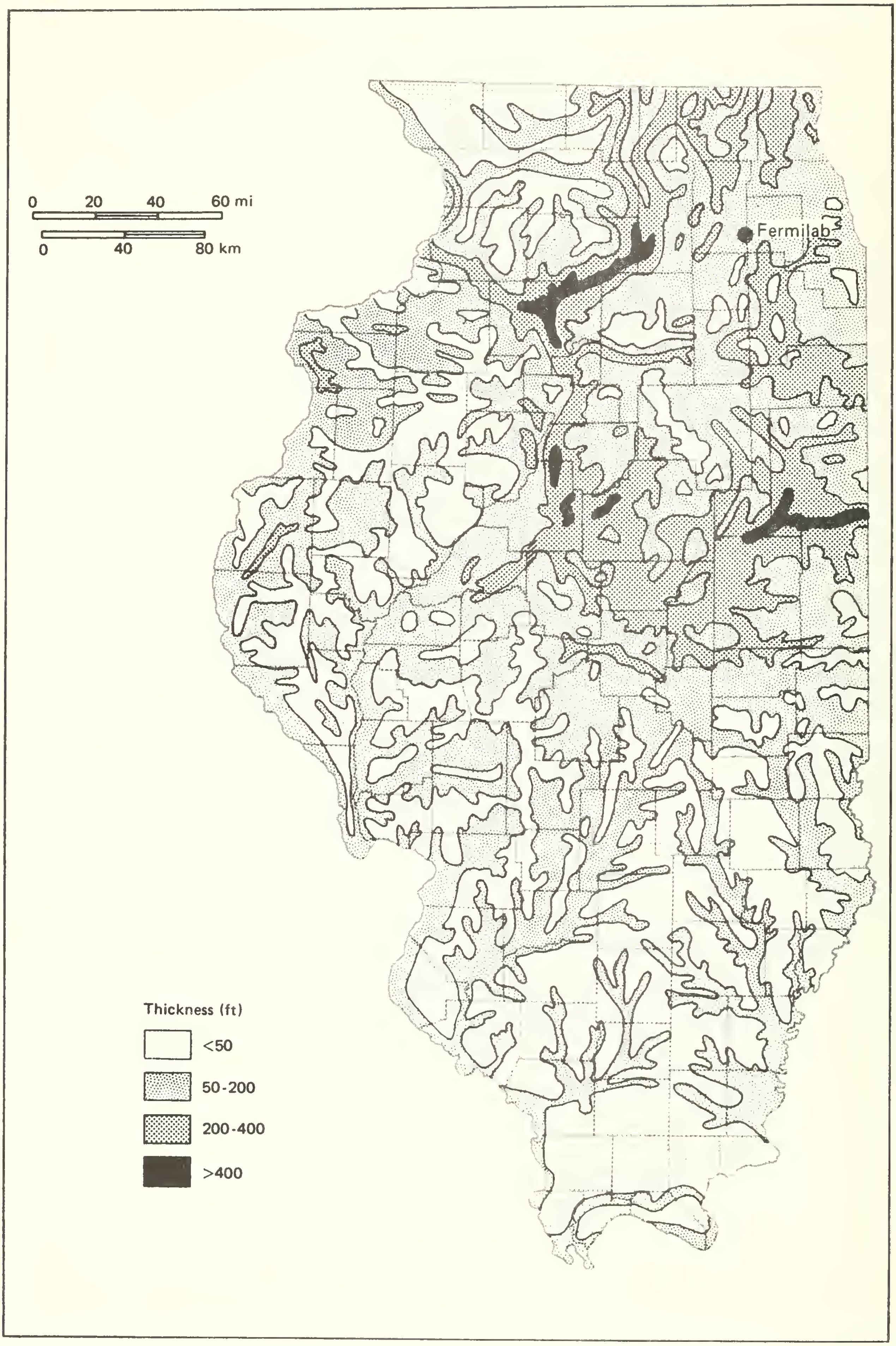


Figure 6.
Drift thickness (from Willman and Frye, 1970; summarized from Piskin and Bergstrom, 1967).

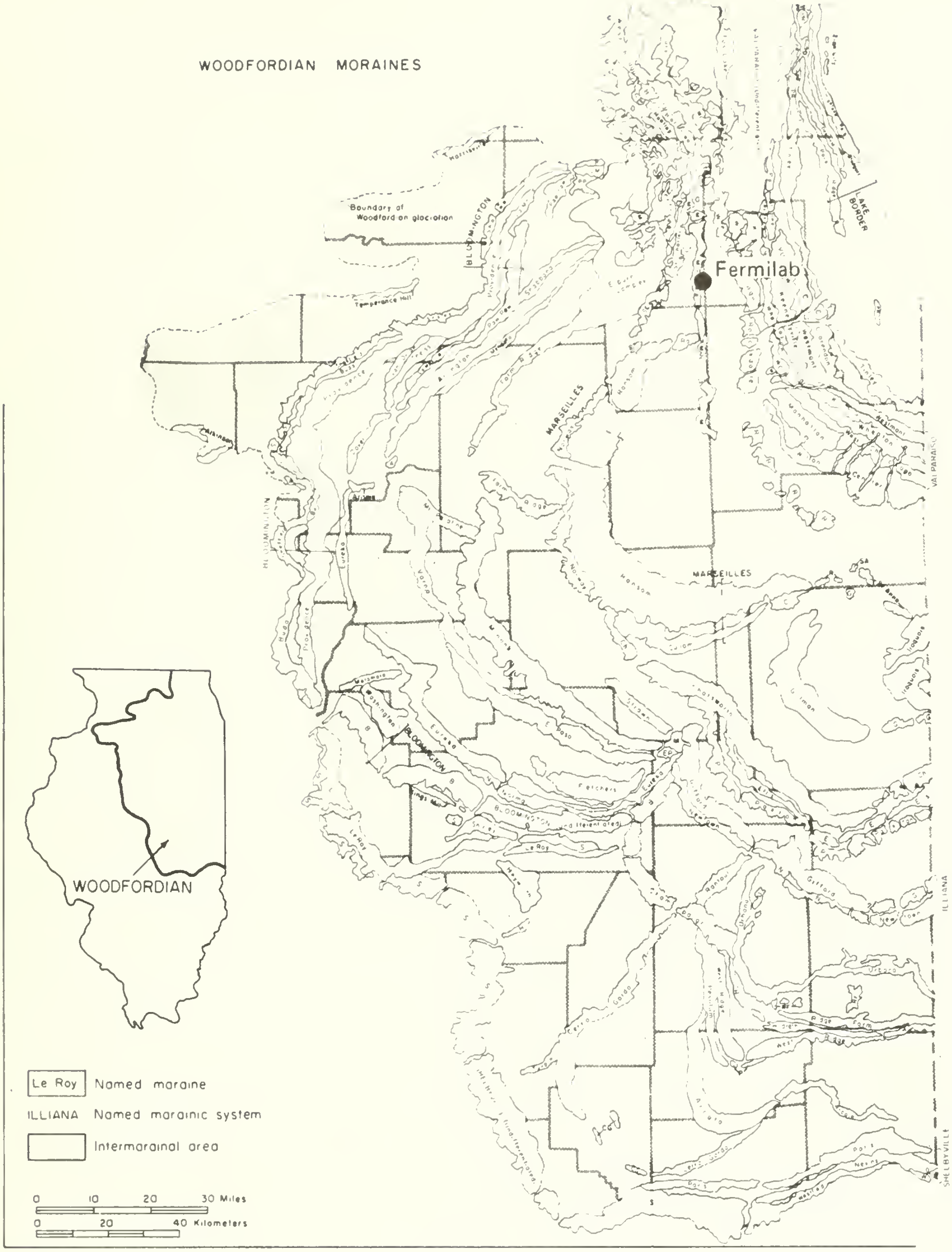


Figure 7.
Moraines of northeastern Illinois (from Willman et al., 1975).

GEOLOGIC FRAMEWORK OF THE ILLINOIS SITE

General

In De Kalb and Kane Counties and parts of adjacent counties, the drainage, topography, and glacial drift materials were largely produced by erosion and deposition by glacial ice and running water. The layered bedrock lies below the glacial drift at depths generally ranging from 50 to 300 feet. Locally in southeastern De Kalb County, these materials are more than 500 feet thick; elsewhere, as along parts of the Fox River valley, they are less than 50 feet thick, with bedrock occasionally exposed in quarries, along streams, and in roadcuts.

Figure 8a shows the classification and succession of the bedrock; figure 8b shows the classification and succession of drift units present in the study area. These deposits are classified both as time-stratigraphic units (System, Series, Stage) and as rock-stratigraphic units (Group, Formation, Member). The time-stratigraphic classification relates ages of rocks from area to area and serves as a basis for geologic time classification. The rock-stratigraphic classification differentiates rocks according to lithology or type of rock or material. In this study, rock stratigraphy is emphasized.

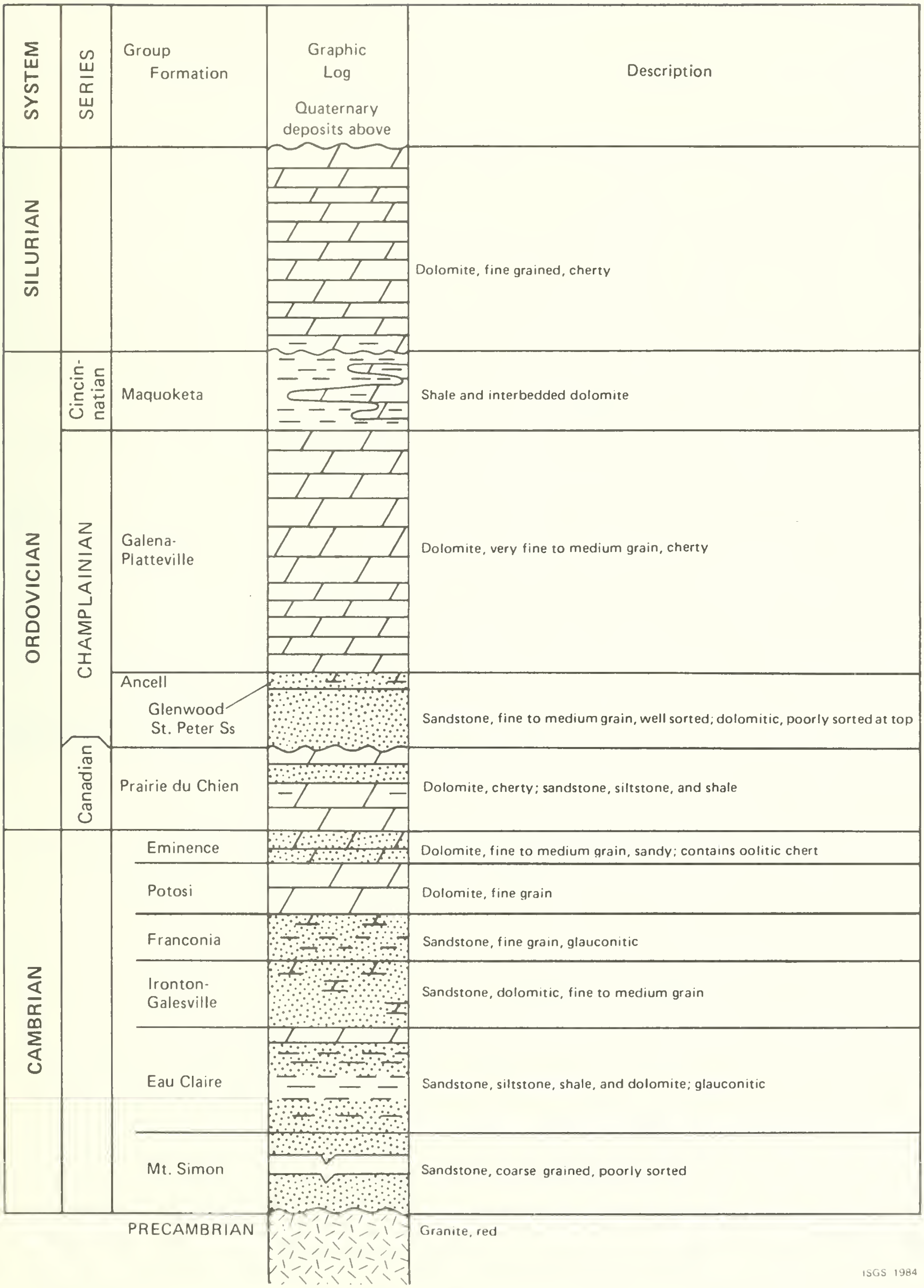
Bedrock

Bedrock within the area consists of Cambrian, Ordovician, and Silurian strata that have a combined maximum thickness of approximately 4000 feet (1200 m). These sedimentary rocks rest uncomformably on a basement of Precambrian granite (fig. 8a). The areal distribution of the bedrock formations directly below the glacial drift is shown in figure 9. Although numerous formational and subformational units are recognized in these strata, the geologic map shows only the following divisions: the Cambrian System; four rock units in the Ordovician System (the Prairie du Chien Group, the Ancell Group, the combined Galena and Platteville Groups, and the Maquoketa Group); and the Silurian System.

The distribution of bedrock units in Kane, Kendall, and De Kalb Counties is mainly the result of ancient tectonic activity on the Wisconsin Arch and Sandwich Fault Zone (fig. 10) and of postdepositional erosion. The Wisconsin Arch is a broad, positive (high) structural feature that extends from northern Wisconsin into northernmost Illinois. In Illinois the arch has gentle slopes, averaging approximately 100 feet (30 m) in 5 to 10 miles (8 to 16 km). The arch was truncated during a long period of erosion that exposed the older rock units at the bedrock surface along the crest of the arch. Within the study area, the Platteville and Galena Groups crop out beneath the younger Maquoketa Shale Group along a highly irregular boundary, which resulted largely from deep preglacial erosion of valleys into the bedrock surface. In parts of western De Kalb County and eastern Ogle County preglacial valleys are entrenched in rocks as old as the Ancell Group. Farther down the flank of the arch in eastern Kane County the Maquoketa crops out beneath Silurian dolomite formations along an equally irregular boundary.

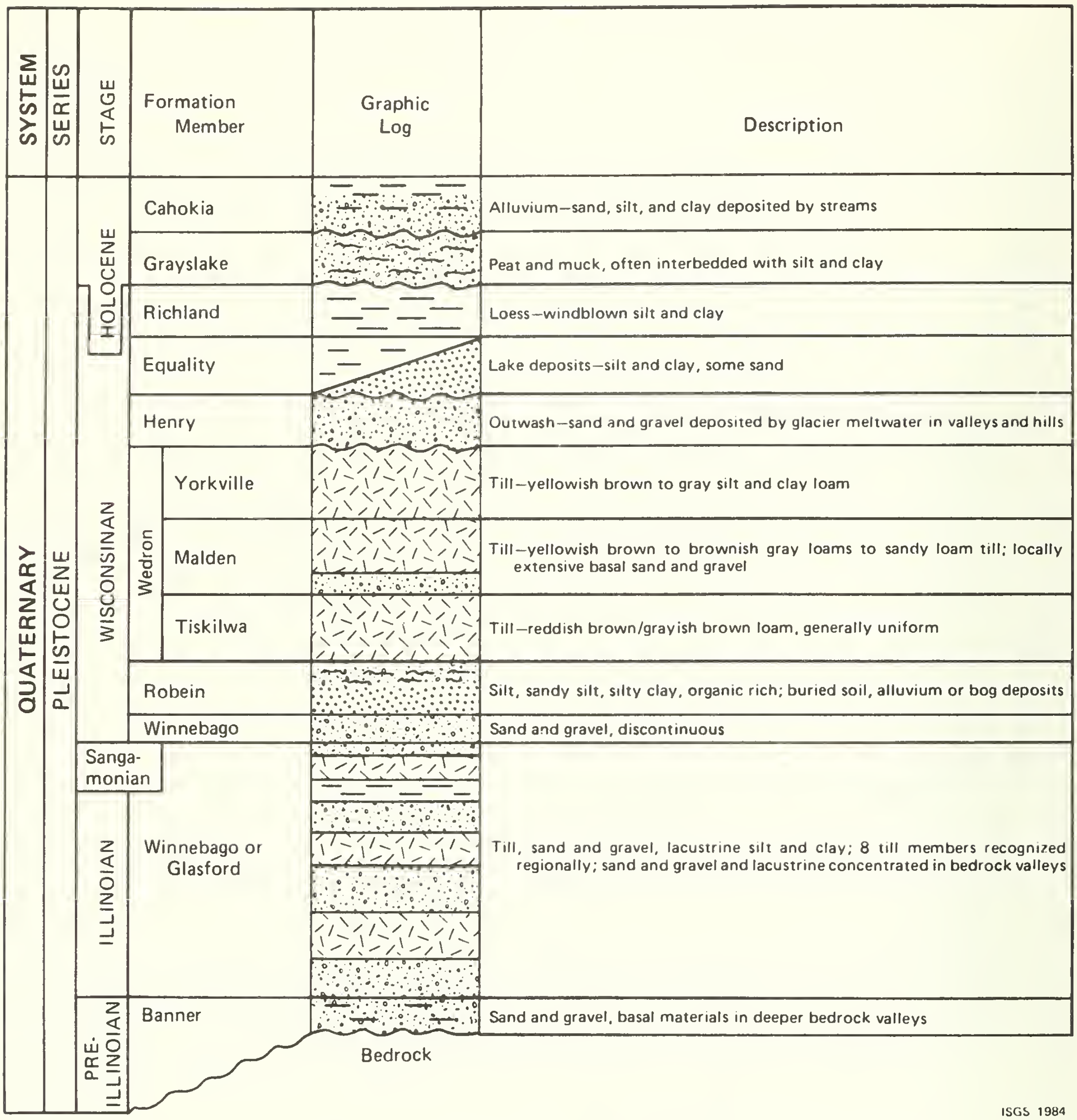
The Sandwich Fault Zone is a narrow zone (0.5 to 2 miles wide) of nearly vertical faults extending northwestward from Will County through Kendall and De Kalb Counties to Ogle County (Kolata et al., 1978). The fault zone is characterized by numerous faults, with vertical displacements ranging from a few inches to a few hundred feet. It has a maximum cumulative displacement of about 800 feet down to the north near the town of Sandwich in southeastern De Kalb County. The fault zone brings Cambrian and lower Ordovician rocks in juxtaposition with the Galena-Platteville and Ancell Groups in southern De Kalb County. Like the Wisconsin Arch, the uplifted side of the fault zone has been beveled by erosion and has no topographic expression at the bedrock surface. Because the topography of the area is subdued and glacial drift covers much of the bedrock, the fault zone is exposed at very few localities. Much information on the nature, age, extent, and magnitude of faulting is based on subsurface data. Geologic relationships suggest that the major movements in the fault zone took place about 300 million years ago (Kolata, Buschbach, and Treworgy, 1978; Kolata and Buschbach, 1976). It should be noted that there has been no displacement in the Sandwich Fault Zone or any other surficial fault in Illinois during historically observed earthquakes (Heigold, 1972).

Cambrian System. Cambrian rocks in the area include the Mt. Simon Sandstone (oldest), Eau Claire Formation, Ironton-Galesville Sandstone, Franconia Formation, Potosi Dolomite, and Eminence Formation (fig. 8a). The Mt. Simon Sandstone is mostly white to pink, coarse grained, poorly sorted sandstone ranging from 1700 to 2600 feet thick. The Eau Claire Formation conformably overlies the Mt. Simon and consists of sand-



SYSTEM	SERIES	Group Formation	Graphic Log Quaternary deposits above	Description
SILURIAN				Dolomite, fine grained, cherty
ORDOVICIAN	Cincinnatian	Maquoketa		Shale and interbedded dolomite
	CHAMPLAINIAN	Galena-Platteville		Dolomite, very fine to medium grain, cherty
		Ancell Glenwood St. Peter Ss		Sandstone, fine to medium grain, well sorted; dolomitic, poorly sorted at top
	Canadian	Prairie du Chien		Dolomite, cherty; sandstone, siltstone, and shale
CAMBRIAN		Eminence		Dolomite, fine to medium grain, sandy; contains oolitic chert
		Potosi		Dolomite, fine grain
		Franconia		Sandstone, fine grain, glauconitic
		Ironton-Galesville		Sandstone, dolomitic, fine to medium grain
		Eau Claire		Sandstone, siltstone, shale, and dolomite; glauconitic
		Mt. Simon		Sandstone, coarse grained, poorly sorted
		PRECAMBRIAN		Granite, red

Figure 8a.
Stratigraphic column of bedrock units in northern Illinois.



ISGS 1984

Figure 8b.
Stratigraphic column of drift (Quaternary) deposits in northern Illinois.

stone, siltstone, shale, and dolomite; the Eau Claire is 350 to 450 feet thick in the area. Fine- to medium-grained, well sorted sandstone up to 220 feet thick characterizes the overlying Ironton-Galesville Sandstone. The Franconia Formation consists of fine-grained, dolomitic sandstone characterized by abundant scattered fine grains of glauconite; the Franconia is from 75 to 150 feet thick. Because it is a surface of relatively low erosional or depositional relief and can be easily recognized, the top of the Franconia is a useful structural horizon (fig. 10). Overlying the Franconia is the Potosi Dolomite, which consists of fine-grained dolomite containing drusy quartz; the Potosi is approximately 130 feet (39 m) thick in the area. It and the overlying Eminence Formation occur at the bedrock surface on the south side of the Sandwich Fault Zone in southern De Kalb County. the Eminence, which is the uppermost Cambrian formation in the area, is fine-to-medium-grained dolomite that commonly contains sand and oolitic chert; the Eminence is about 100 feet (30 m) thick.

Figure 9.
Areal geology of the bedrock surface in study area.

Ordovician System. The Prairie du Chien (oldest), Ancell, Galena-Platteville, and Maquoketa Groups constitute the Ordovician rocks in the area (fig. 8a). All these stratigraphic units occur at the bedrock surface in the area of the proposed accelerator ring. The Prairie du Chien Group consists primarily of cherty dolomite and interbedded sandstone but also contains some siltstone and shale. It ranges from a featheredge to about 400 feet thick.

The Ancell Group, which consists of the St. Peter Sandstone and Glenwood Formation, unconformably overlies the Prairie du Chien Group. The St. Peter is a pure, generally white, fine- to medium-grained, rounded, well sorted, friable sandstone between 150 and 250 feet thick. It is overlain by the Glenwood, a highly variable formation consisting of poorly sorted sandstone, silty dolomite, and green shale, all locally up to 75 feet thick.

The Galena and Platteville Groups (fig. 8a) consist of pure, partly cherty dolomite with a combined thickness of approximately 350 feet where they are overlain by the Maquoketa Shale Group. These rocks occur at the bedrock surface throughout a large part of western

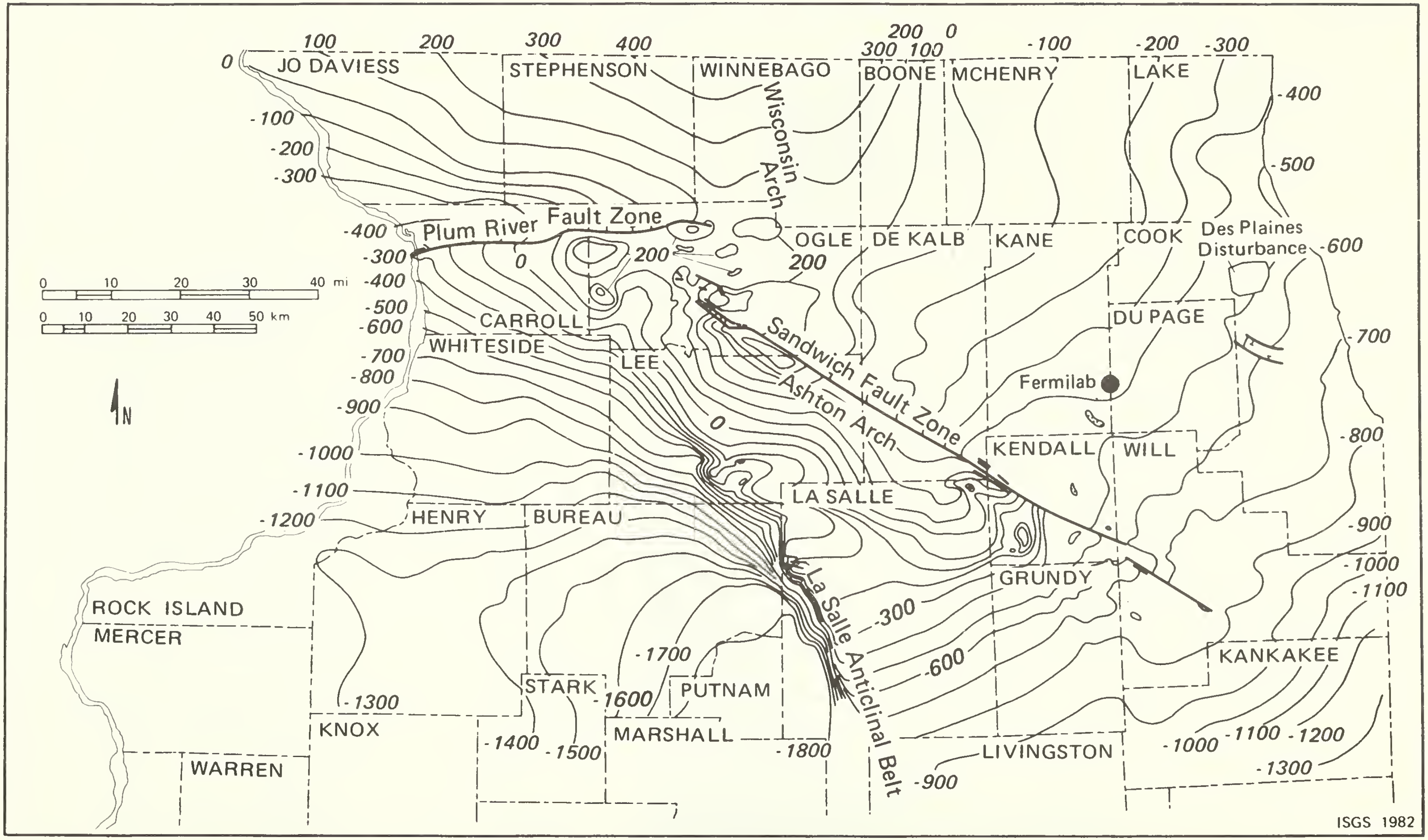


Figure 10.
Elevation of top of the Franconia Formation in the Cambrian System showing the major structural features in northern Illinois.

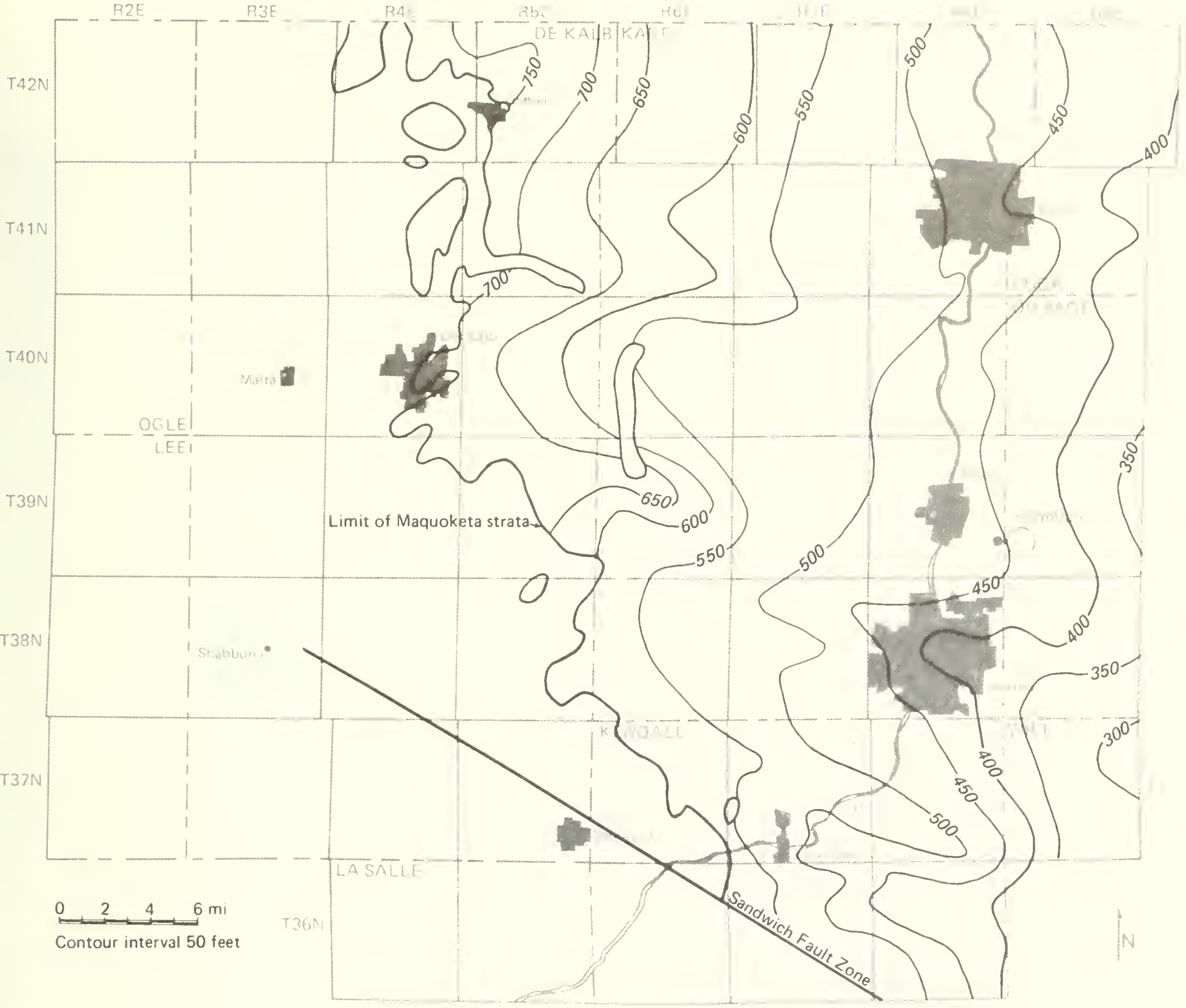


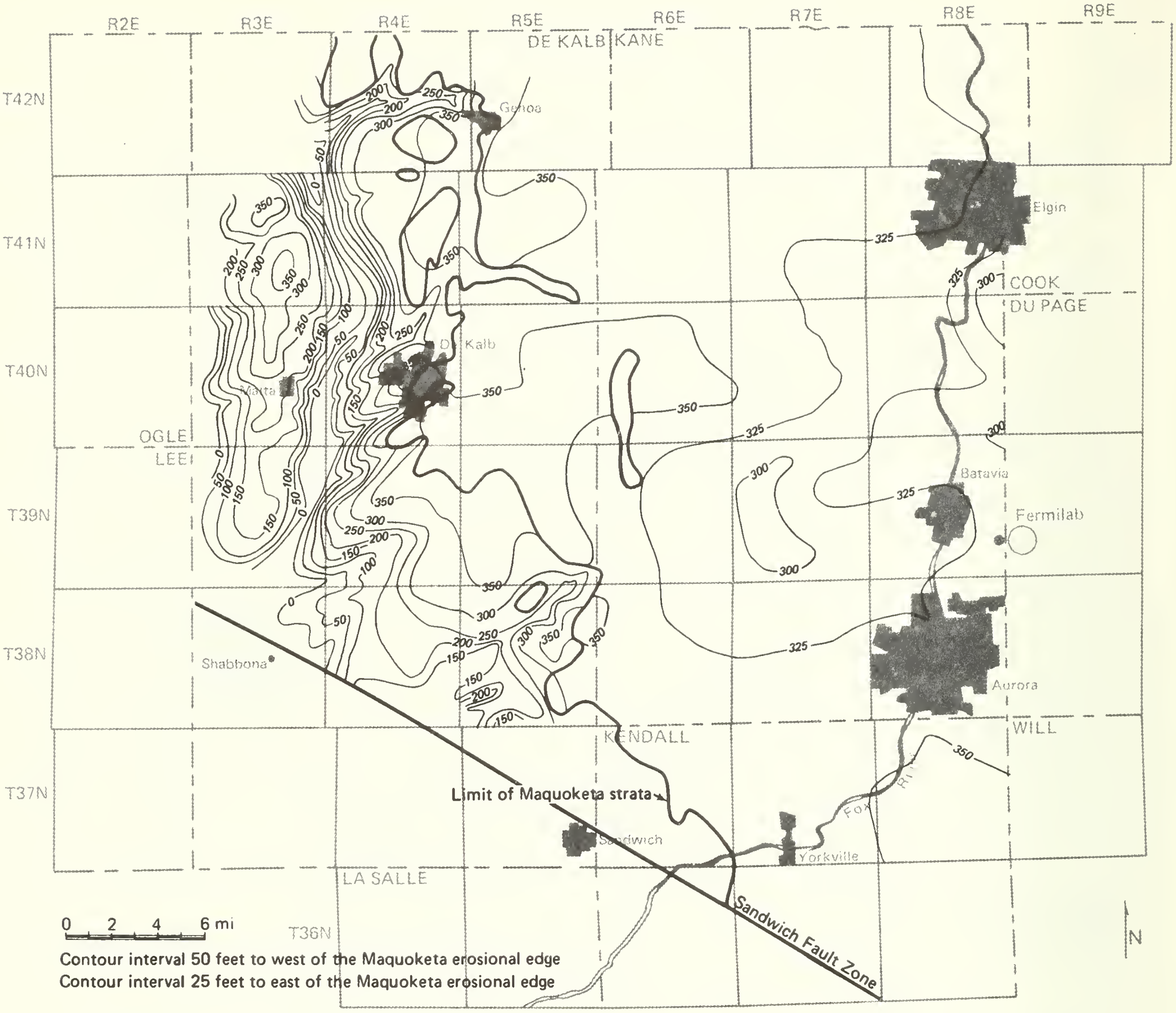
Figure 11.
Elevation of the top of the Galena Group where overlain by the Maquoketa Shale Group.

De Kalb County (Willman and Kolata, 1978). The upper 60 to 80 feet of Galena strata are chert-free, providing an important source of high-quality aggregate in northern Illinois.

Like the Franconia Formation the top of the Galena is a widespread, easily recognized, mappable surface (fig. 11) that reflects the structural movements that have taken place since the Galena was overlain by the Maquoketa Shale Group. Because of the numerous wells that have penetrated the Galena, it is the most reliable structural datum within the study area.

West of the limit of Maquoketa strata, the Galena and Platteville are deeply dissected by preglacial valleys (fig. 12). In parts of central De Kalb County the Galena and Platteville are cut out entirely by the Troy Bedrock Valley.

The Maquoketa Group, which overlies the Galena-Platteville, consists of shale and argillaceous dolomite that ranges in thickness from 100 to 200 feet (fig. 13). As a result of being deeply truncated by pre-Silurian erosion, the precise thickness at any given locality cannot be predicted with confidence (Kolata and Graese, 1983). In northern Kane and De Kalb Counties the Maquoketa consists primarily of argillaceous dolomite. This grades southward to mainly shale in Kendall County. In the area of Fermilab the Maquoketa can be expected to be approximately 130 feet thick, consisting primarily of dolomite and dolomitic shale.



Contour interval 50 feet to west of the Maquoketa erosional edge
Contour interval 25 feet to east of the Maquoketa erosional edge

Figure 12.
Thickness of Galena and Platteville Groups.

Silurian System. The Silurian System unconformably overlies the Maquoketa in northern Illinois. Where the Maquoketa is deeply dissected by pre-Silurian erosion, the Silurian strata tend to be shale and very argillaceous dolomite. Conversely, where pre-Silurian erosion was minimal, the overlying Silurian strata tend to be relatively pure, cherty dolomite. The Silurian thickens from an erosional featheredge in Kane and Kendall Counties (fig. 14) to as much as 300 feet to the east in the Chicago area. It is approximately 140 feet thick beneath Fermilab.

Pennsylvanian System. Pennsylvanian sandstone, shale, and coal may be present in a few small scattered outliers (isolated deposits) within the area. These rocks commonly occur in crevices, solution-collapsed structures, and lenticular remnants in depressions on the surface of Silurian and Ordovician carbonate rocks.

Bedrock Cross Sections

Figures 15a to 15f, a location map and series of cross sections, show the stratigraphic relations in the upper 300 feet or so of the bedrock within the study area. They also show the relative thickness of overlying glacial drift and the elevation of the land surface. The total

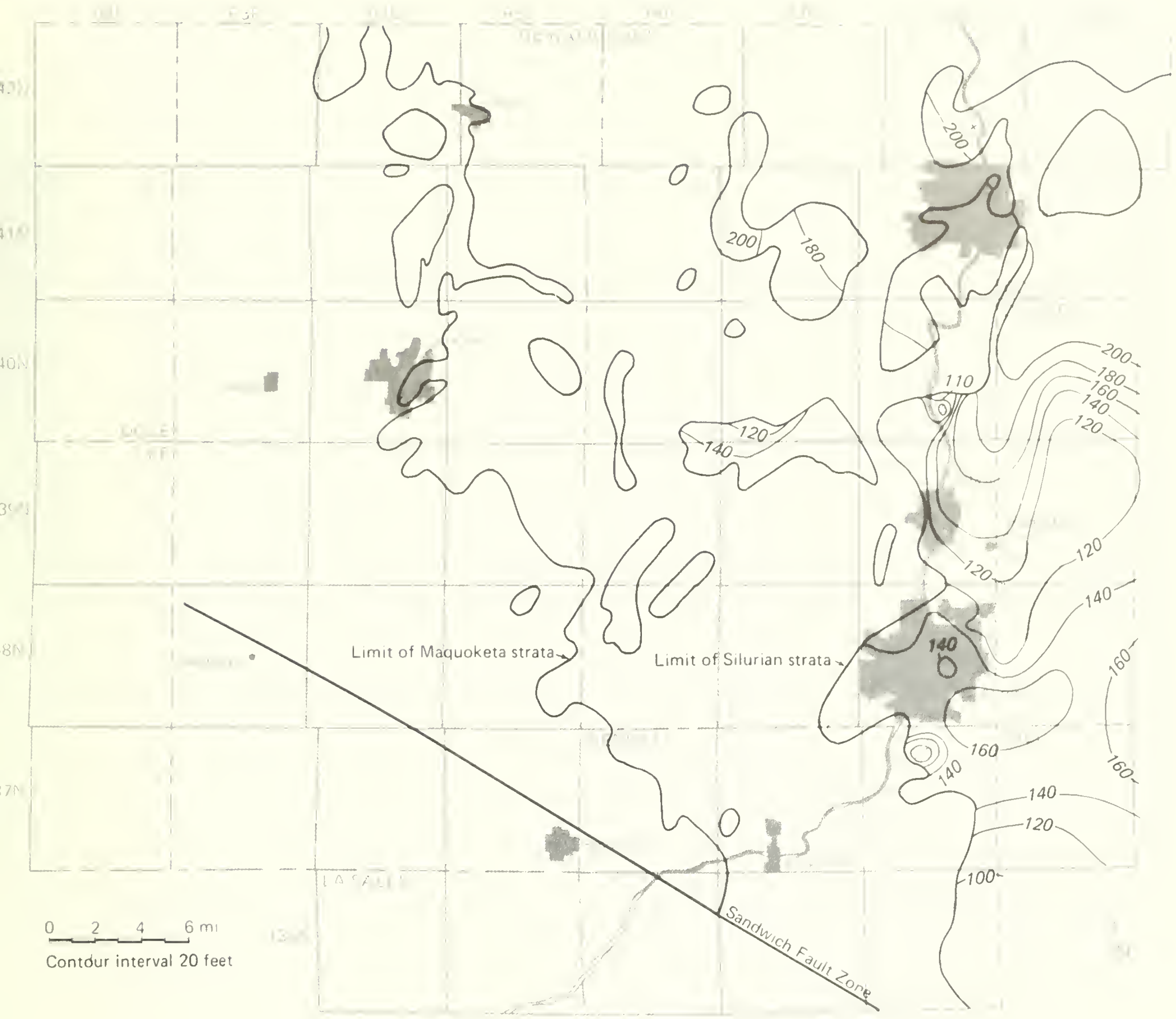


Figure 13.
Thickness of Maquoketa Shale Group where overlain by Silurian rocks.

depth of each control well is marked beneath each county location. Knowing the thickness of the bedrock units, it is possible to determine approximately what formation the well was finished in. Particularly notable features on these cross sections are the bedrock valleys, facies relations within the Maquoketa Shale Group (figs. 15b, c, and f), structural relief as seen on the top of the Galena-Platteville Groups, Sandwich Fault Zone (figs. 15d and e), and erosional featheredge of the Maquoketa and Silurian rocks (figs. 15b, c, and f).

Bedrock Topography

The bedrock topography map (fig. 16) was derived primarily from well data and bedrock outcrops. The map is a slightly modified version of one prepared by Wickham (1979), which was also a modification of maps prepared by R. H. Gilkeson (unpublished) and Kempton (McGinnis et al., 1963). The Kendall County portion of the map was prepared for this report from available well logs.

The bedrock surface is cut by deep bedrock valleys, which generally trend north-south or east-west. The Troy, Rock and "Newark" Bedrock Valleys (fig. 16) are the major early Pleistocene drainage features in the area. The deep, steep-sided, drainageways that cut into the bedrock were tributaries to the ancient Mississippi Valley system (Horberg, 1950).

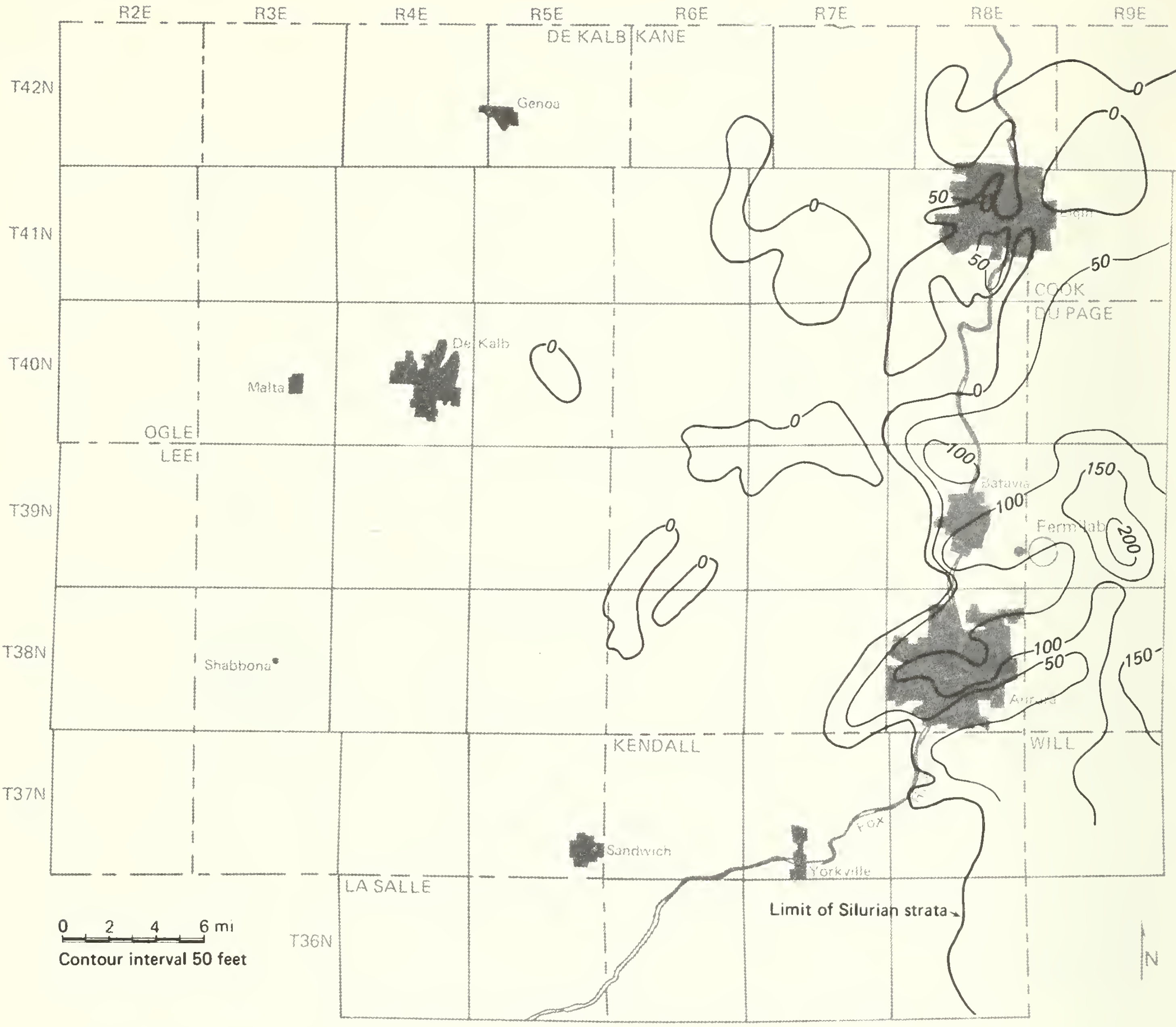


Figure 14.
Thickness of Silurian rocks.

The Rock and Troy Bedrock Valleys are parallel to each other along the western edge of the study area. They join to form the Paw Paw Valley in southeastern Lee County. The "Newark Valley," heading in northeastern Kane County, extends across the southern part of the study area and joins the Paw Paw Valley in Lee County. It was formerly thought to extend southward under Newark (Kendall County). A broad, shallow tributary trends northeast-southwest across the center of the area and joins the "Newark Valley" in southernmost De Kalb County.

Elevations of bedrock (fig. 16) range from less than 450 feet in the deepest portions of the Troy and Rock Bedrock Valleys to more than 800 feet in northern Kane County. Away from the bedrock valleys the average elevation of the bedrock uplands is between 700 and 800 feet, except in the southernmost portions of Kane and De Kalb and in Kendall Counties where it ranges from 550 to 650 feet. Bedrock outcrops are present in northwestern De Kalb County, and along the Fox River.

The general slope of the bedrock upland surface is about 5.5 feet per mile from west-northwest to east-southeast and is approximately the same as the regional dip of the bedrock structure.

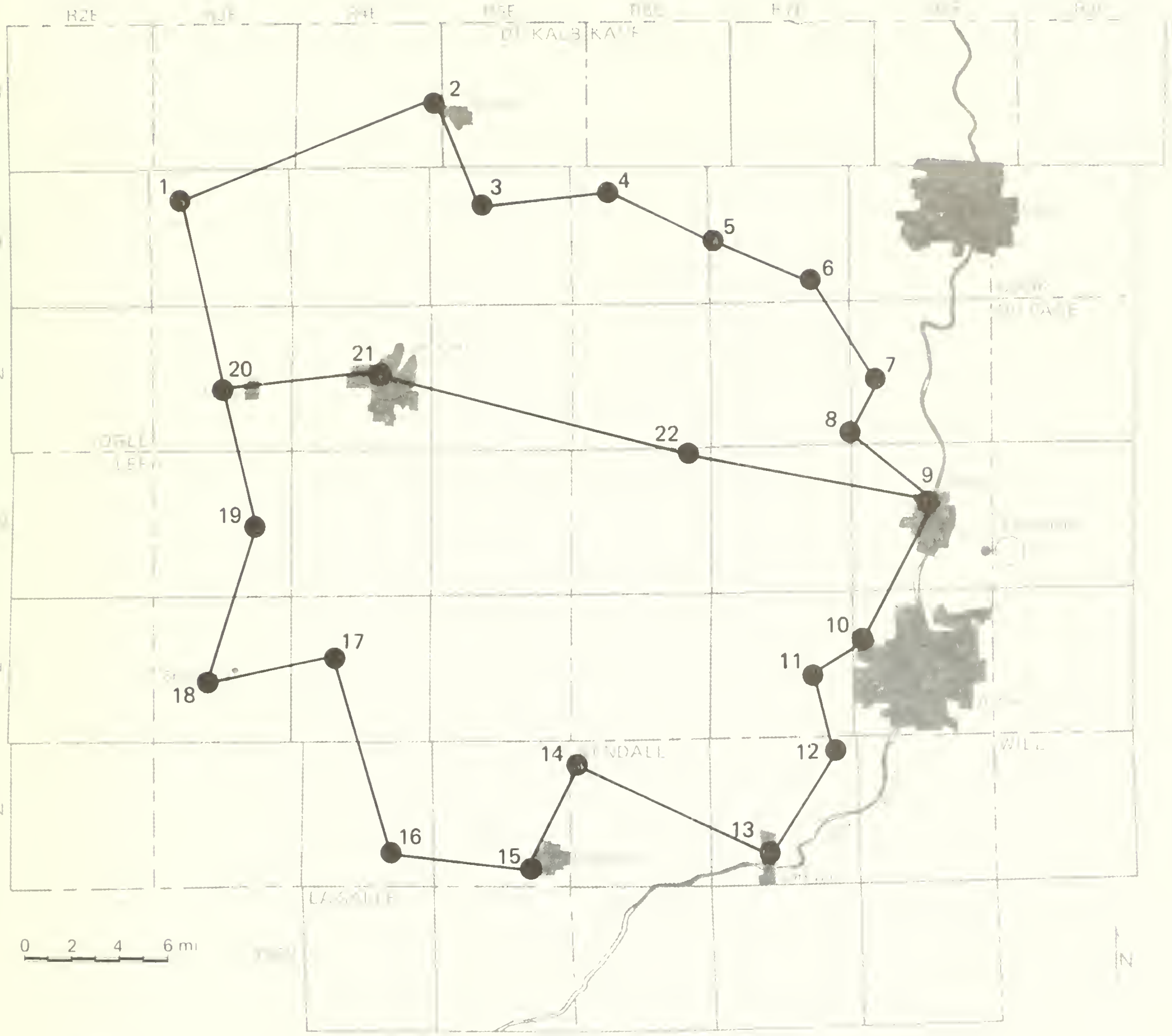


Figure 15a.
Location map for bedrock cross sections.

Glacial Drift and Surficial Deposits

The early continental glaciers that entered northern Illinois encountered a bedrock surface that had been eroded to essentially its present configuration. As each glacier covering the region melted, it left a capping debris over the surface. Drainage from the melting glaciers generally carried sand and gravel into the existing valleys, while the glaciers deposited layers of till over the uplands. These successive layers of drift almost totally masked the bedrock surface.

Over most of the area, till was deposited in relatively flat layers (ground moraine) that were often modified by later glacial and postglacial processes. Where the glacial terminus remained relatively stationary, large arcuate ridges (end moraines) built up (fig. 7). Some end moraines are non-homogeneous collections of material that may have inclusions of sand and gravel. The overall internal structure may be distorted by slippage along shear planes. Many are similar to the end moraines composed of Tiskilwa Till (Bloomington Morainic System, fig. 7), which exhibit considerable uniformity throughout their thickness (Wickham, 1979).

During the last stage of glaciation, the youngest glaciers that reached the eastern and northern portions of the region produced extensive erosion by meltwaters that appeared

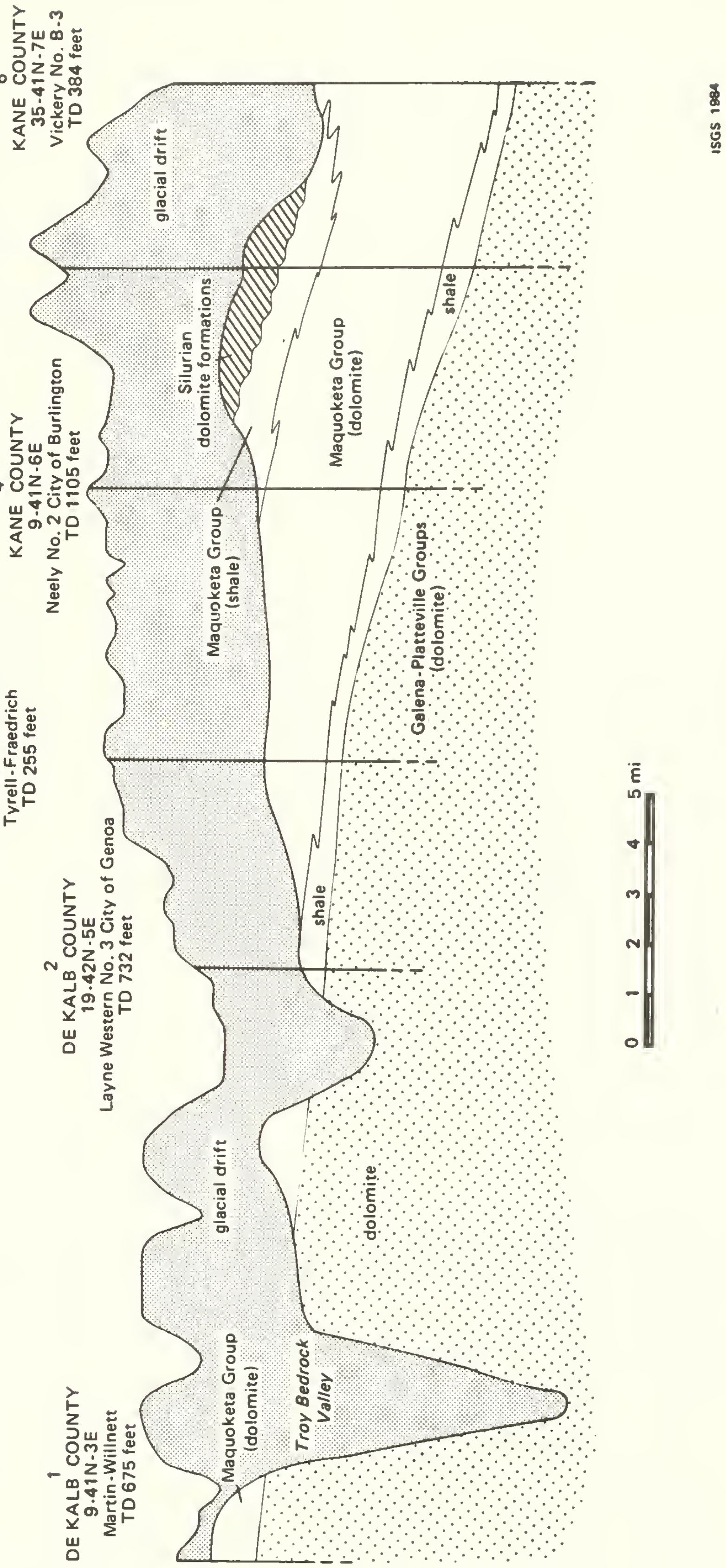


Figure 15b.
Northern E-W cross section.

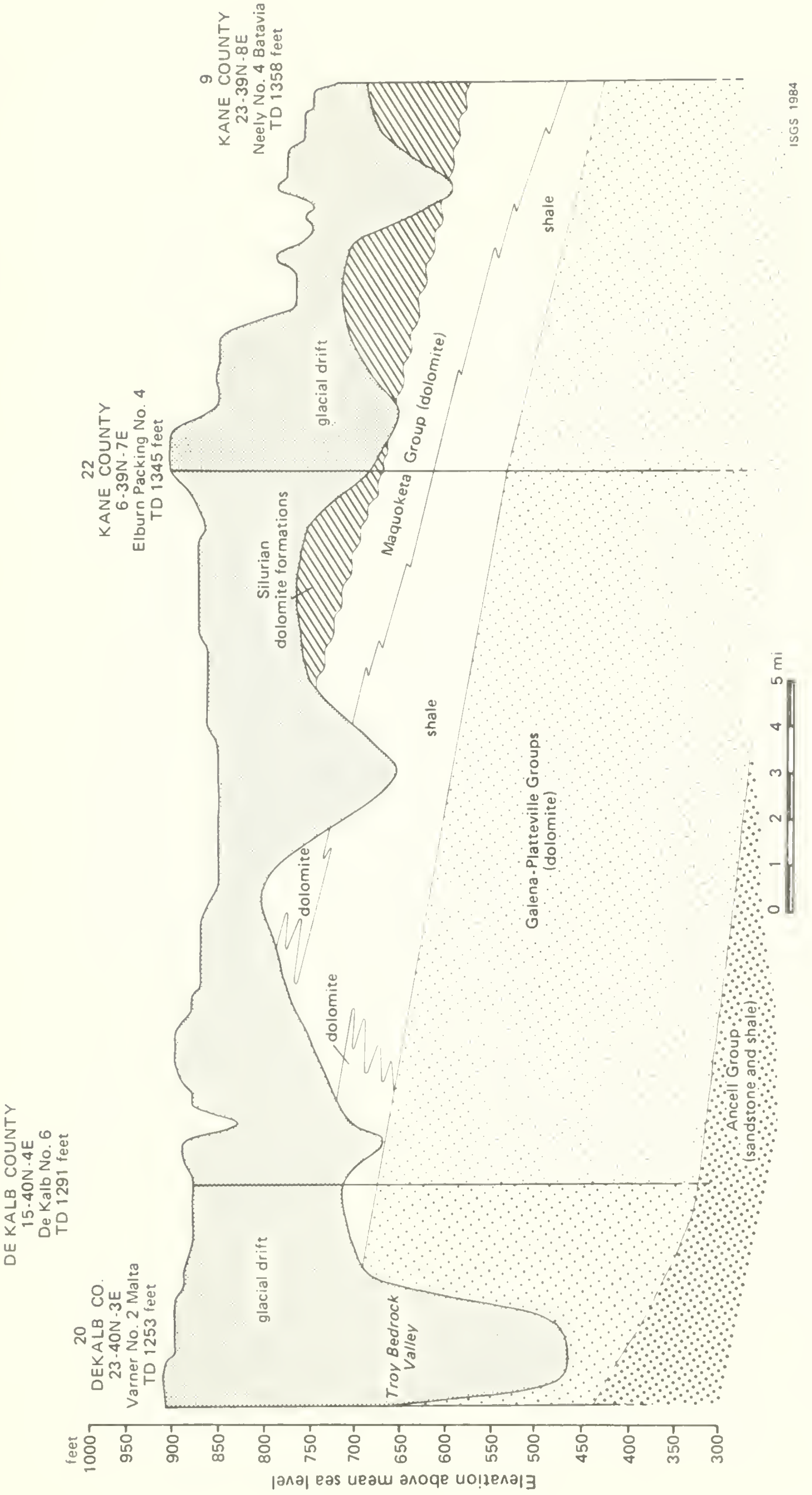


Figure 15c.
Central E-W cross section

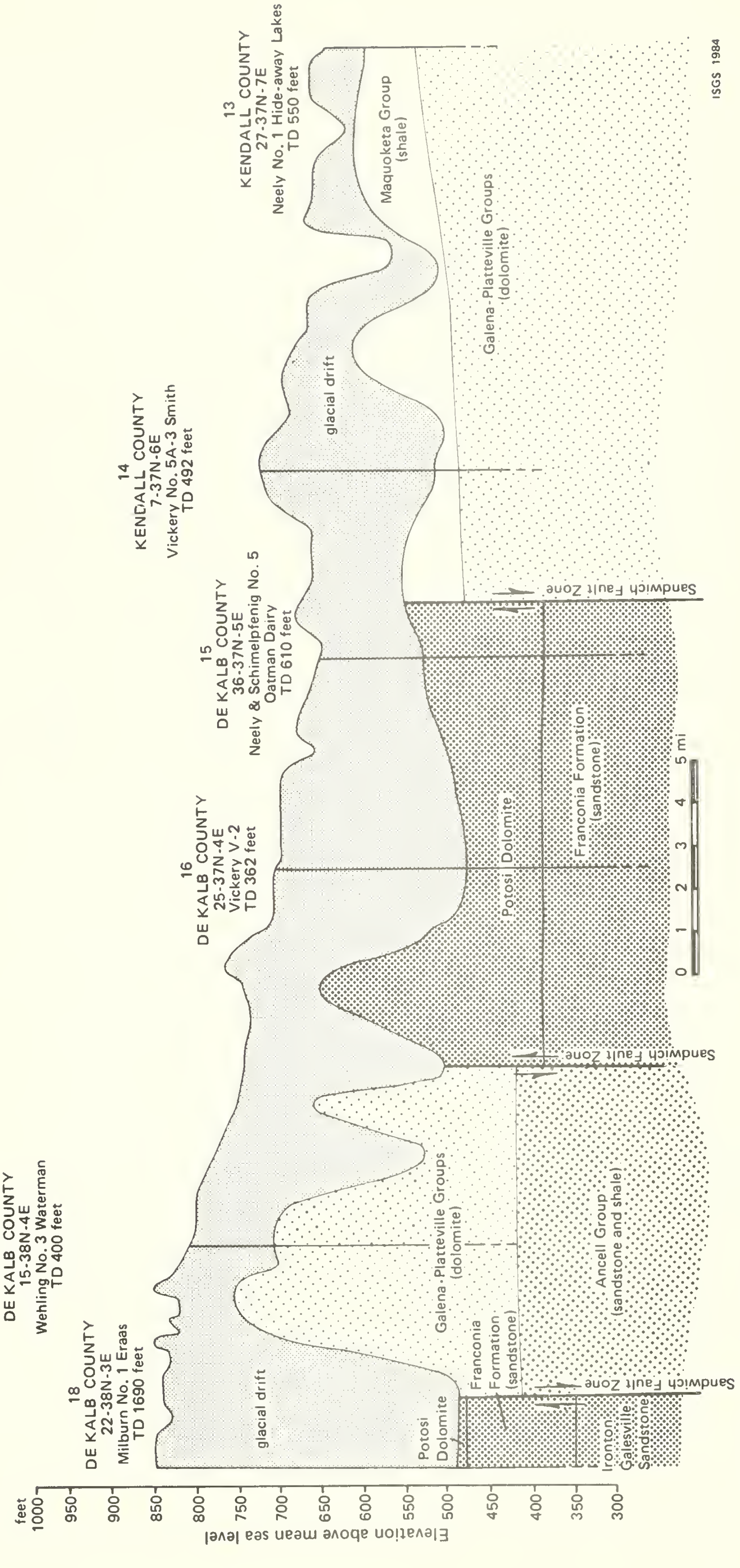


Figure 15d.
Southern E-W cross section.

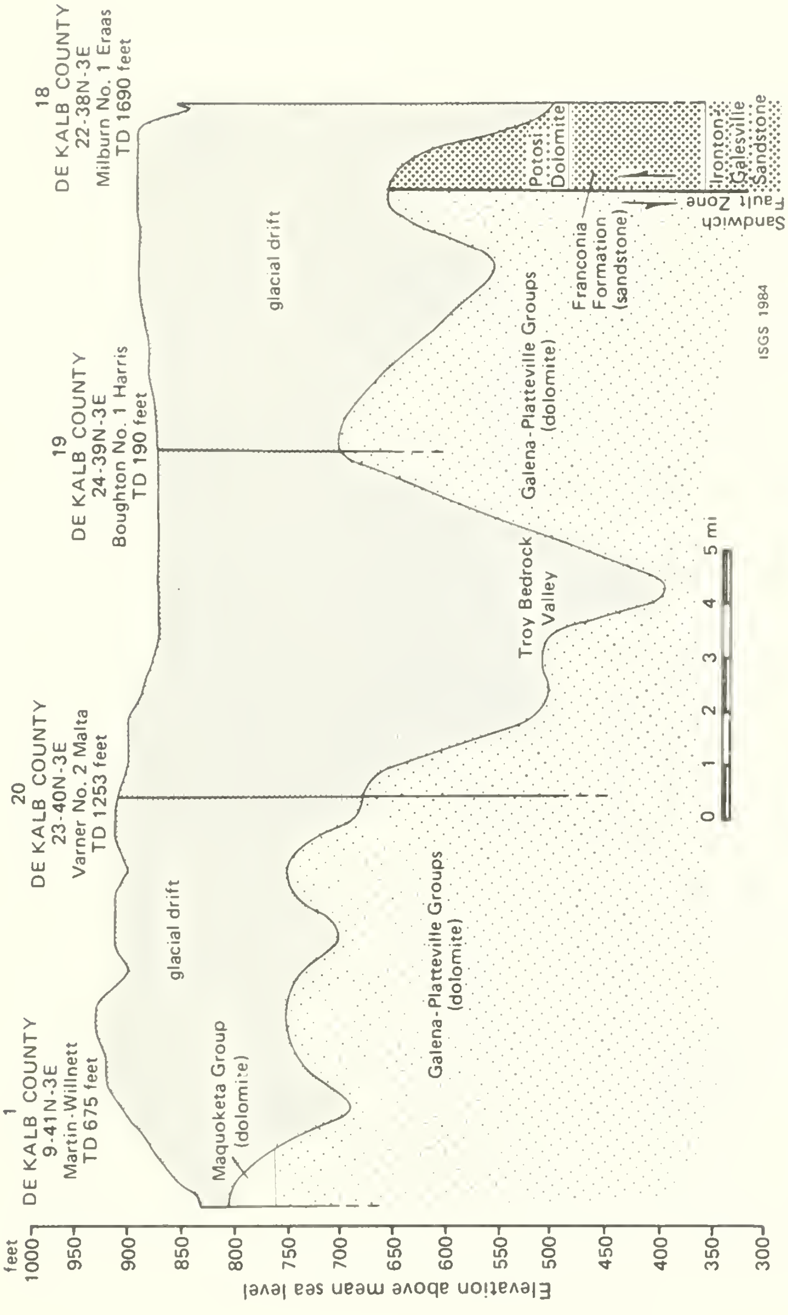


Figure 15e.
Western N-S cross section.

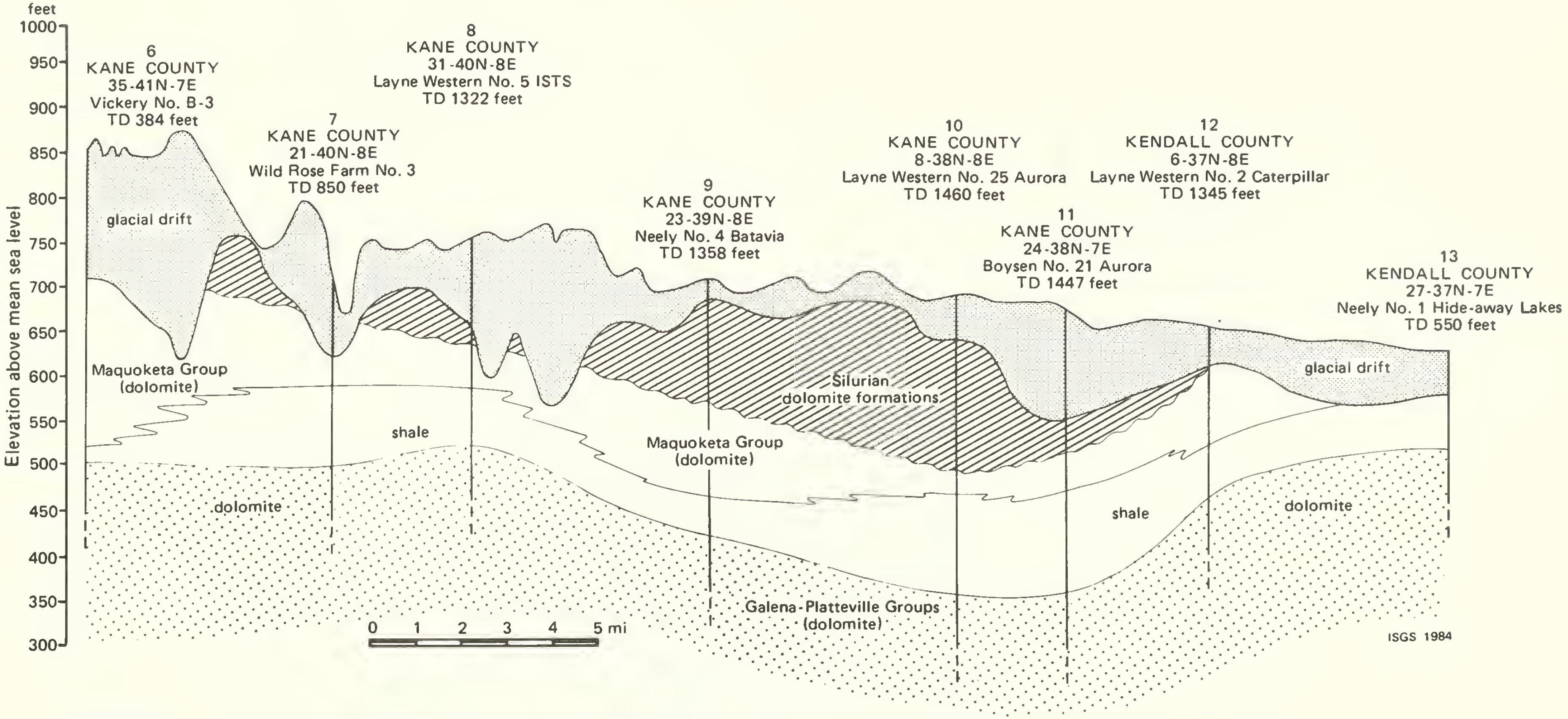


Figure 15f.
Eastern N-S cross section.

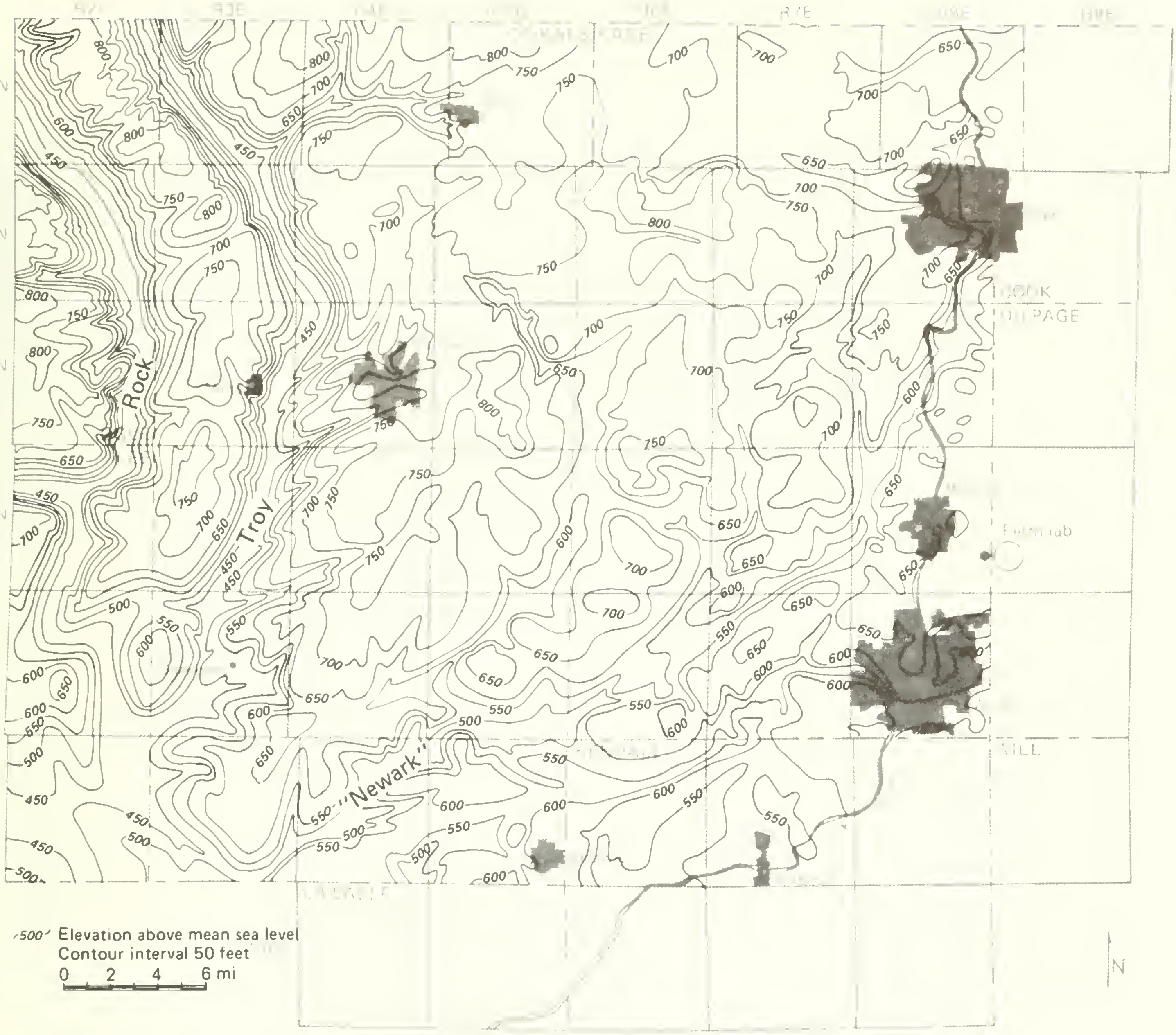


Figure 16.
Bedrock topography of study area (after Wickham, 1979).

to have removed some earlier drift, locally eroding to the bedrock surface as along the Fox River valley. During the last 12,000 years, recent (Holocene) alluvial and other sediments have been deposited on the developing modern surface (fig. 8b).

Drift Thickness. The drift thickness map (fig. 17) was derived from several sources. The De Kalb portion of the map was originally drafted by McComas (1969, unpublished) by comparing surface elevation with bedrock topography as established at that time. Wells from which the bedrock data were drawn were field checked in the 1960s. Modifications were made during the course of this study using recent confirmed and unconfirmed data. A Kane County map was prepared by Gross (1969) and redrawn using data provided by R. H. Gilkeson. Minor changes were made along the Kane-De Kalb county line for this study. Further map modifications, particularly in De Kalb County, are contemplated for the next phase of the study and for a current study of the water resources of Kane County. The Kendall County drift thickness map was prepared for this report and will also be further modified.

Since the ground surface topography is relatively flat, drift thickness generally mirrors bedrock topography over much of the area. Because of the steep bedrock valley walls,

Figure 17.
Thickness of glacial drift (compiled and modified from Gross, 1969; and McComas, 1969).

drift thickness may change enormously within a very short distance. Areas of lowest bedrock elevation generally have the thickest drift, while the reverse is true in areas of high bedrock elevation. Exceptions occur in northeastern Kane County, where the Marengo Moraine reaches elevations of greater than 1100 feet, primarily due to the combined effects of the great thickness of the Tiskilwa Till and the high bedrock elevation.

Drift thickness varies from zero to greater than 500 feet. The greatest thickness (300 to 500 feet) occurs in the Troy Valley in the southwest corner of De Kalb County and northward along the valley. Thicknesses between 150 and 300 feet generally occur in smaller bedrock valleys, in areas adjacent to bedrock valleys, and along the length of the Marengo Moraine. Remaining areas generally have between 100 and 150 feet of drift, with substantial areas of drift less than 100 feet thick, particularly in the southern part of the study area. There is no drift cover in small areas along the Fox River and in northern De Kalb County.

Classification, Distribution, and Description of the Drift. The assignment of various drift materials to specific formations and members or stages (and substages) is based on the recognition of the characteristics, sequence, and continuity of deposits (particularly of glacial tills) and their stratigraphic position relative to buried soils or other nonglacial deposits (fig. 8b). Several tills with identifiable characteristics have been recognized throughout the study area. Tills, outwash, and other related deposits differ from bedrock units not only in their physical characteristics and mode of deposition but also in their local thinning, thickening, and incorporation of underlying materials.

The oldest glacial deposits recognized in the study area (fig. 8b) are products of several glaciations during pre-Illinoian, Illinoian, and possibly earliest Wisconsinan time (500,000 to 28,000 years ago). Older pre-Illinoian deposits (Banner Formation) have been tentatively identified in De Kalb County (Kempton, 1963). Deposits assigned to the Glasford and/or Winnebago Formations form the bulk of the surface deposits around the westernmost and northernmost portions of the area (fig. 3). Throughout the remainder of the region these older deposits are largely buried by Wisconsinan-age drift of the Wedron Formation (Woodfordian Substage).

The classification of the drift in the study area is changing considerably in light of continuing studies within the region, particularly for the Winnebago and Glasford Formations. Tills and associated deposits formerly thought equivalent to those of the Winnebago Formation in Boone or Winnebago Counties to the northwest (Berg et al., 1984) are now considered separate units within the Glasford Formation and are of Illinoian age. Work is currently underway to clarify these changes.

Each till is distinct in its physical and mineralogical characteristics, and retains these unique characteristics on a regionally stratigraphic basis (Kempton and Hackett, 1968a, 1968b). While a regional framework for these tills is beginning to emerge, additional data and study are necessary to define the succession and thus aid in their predictability.

Banner Formation. Deposits thought to be pre-Illinoian, mainly sand and gravel, have been described from well samples near the bottom of the drift filling the Troy Bedrock Valley in southern De Kalb County (Kempton, 1963). Hackett (1960) suggested that a thin basal sand in the Rock Bedrock Valley was also pre-Illinoian. Recent studies (Berg et al., 1984) have assigned these basal sands and related deposits in the Rock Bedrock Valley in Winnebago County to the Banner Formation. However, their presence in the study area has not been recently verified either in the Rock or Troy Bedrock Valleys.

Glasford Formation. The deposits assigned to the Glasford Formation lie directly above the bedrock and below the Wedron Formation or Robein Silt and also below those deposits correlative with the Winnebago Formation in Boone and Winnebago Counties. It appears likely that most deposits, particularly the tills, are Illinoian (fig. 8b) and should be assigned to the Glasford Formation; however, no formal assignment has been made as yet.

Figures 18a to 18e document the complexity, thickness, and extent of these deposits. While many hundreds of water well logs, available for the entire region, suggest their general lithic characteristics, roughly 30 to 40 test holes have also been sampled, logged, and described, geologically defining the entire succession. The appendix contains examples of these logs.

Although till appears to be the dominant material within the Glasford Formation, outwash sand and gravel as well as local deposits of lacustrine sand, silt, and clay occur frequently between tills. The thickest till sequences tend to lie above the bedrock uplands, while the thickest sand and gravel deposits tend to occur as fill in the buried bedrock valleys or in channels cut into the tills.

Winnebago Formation. The Winnebago Formation was named for tills and associated deposits that occur to the northwest of the study area in Winnebago and Boone Counties (Frye et al., 1969); the formation now appears to be restricted primarily to that area (Berg et al., 1984; Kempton et al., in preparation). Therefore, most deposits previously assigned to the Winnebago Formation in the study area (Kempton and Hackett, 1968a, 1968b; Kempton and Gross, 1971) are now thought to be older. Some outwash sand and gravel deposited directly below the Robein Silt or Wedron Formation materials may be related to

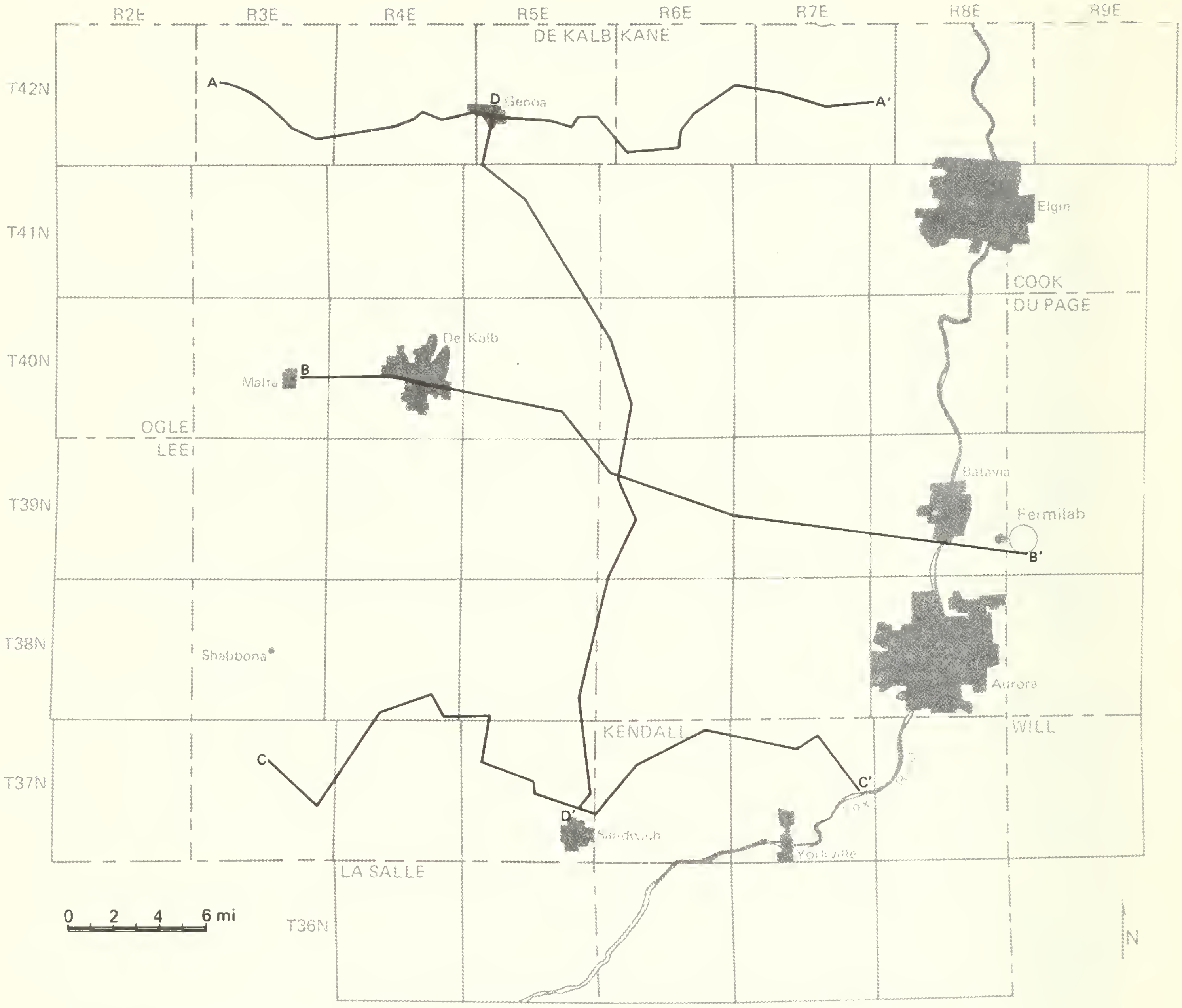
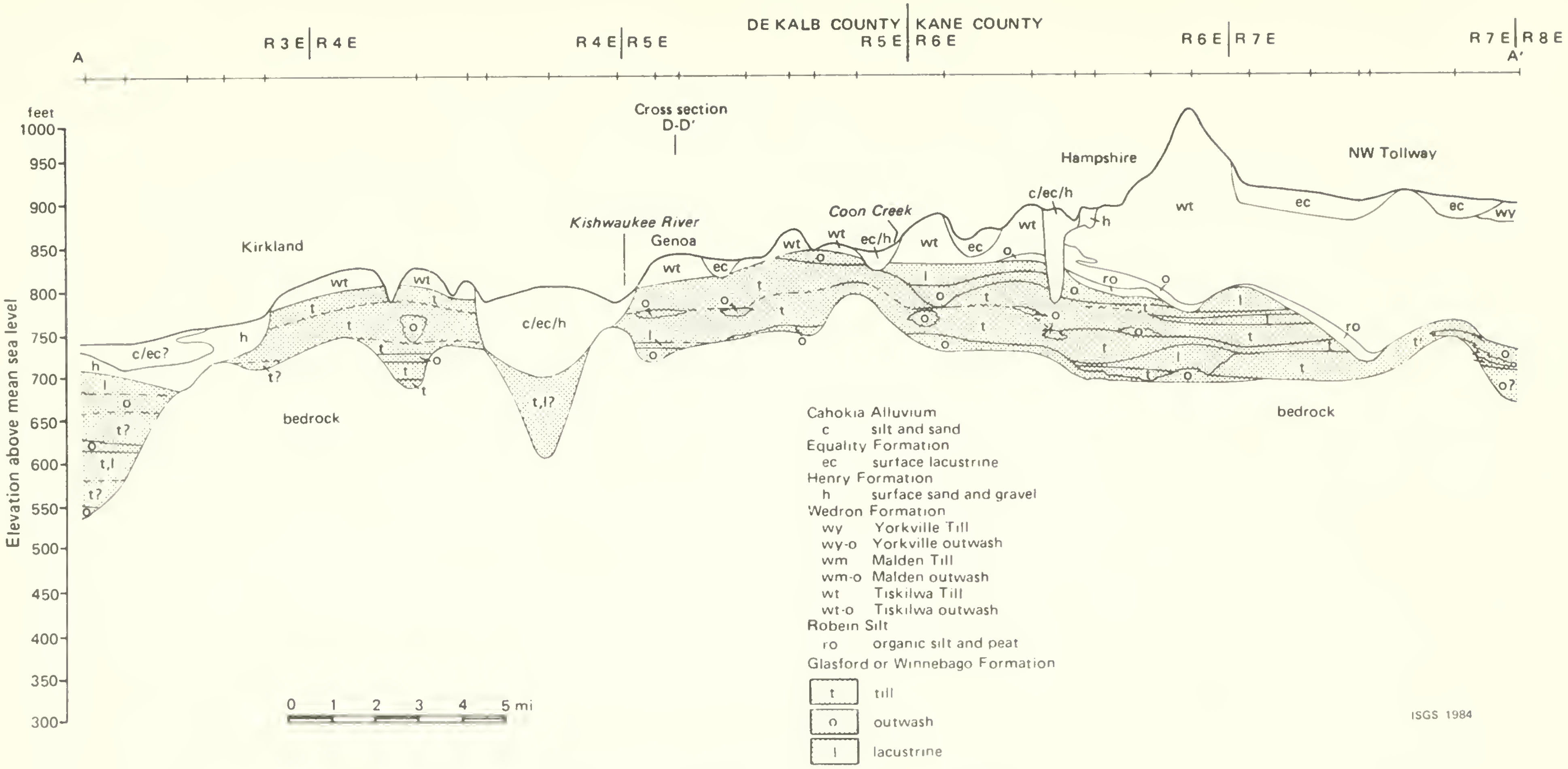


Figure 18a.
Location of drift cross sections.

outwash and tills of the Winnebago Formation. Until clearcut relationships can be established, however, none of these deposits has been formally assigned to the Winnebago.

Robein Silt. One significant marker horizon within the drift is the Robein Silt, a relatively thin, discontinuous succession of organic sediments and related deposits lying between the Glasford Formation or Winnebago Formation and the Wedron Formation (fig. 8b). It has been reported in numerous water well logs as "peat," "muck," "driftwood," and has been sampled during test drilling of several water-resource test holes. It may be a source of the methane gas that may be encountered in the drift (Meents, 1960; Coleman, 1976). While its local occurrence is not predictable, it is most frequently reported in a north-south band 10 to 15 miles wide in central Kane County (figs. 18a, b, and d).

Wedron Formation. The Wedron Formation (figs. 8b, and 18a-d) consists of a succession of tills, generally containing minor amounts of interbedded outwash sand and gravel and lacustrine silt and clay. Individual tills have been identified and mapped throughout the region. Three principal tills have been named: in ascending order they are the Tiskilwa, the Malden, and the Yorkville Till Members.



Location of wells and test holes from which logs were used to construct cross sections shown on line at top

Figure 18b.
Northern E-W cross section.

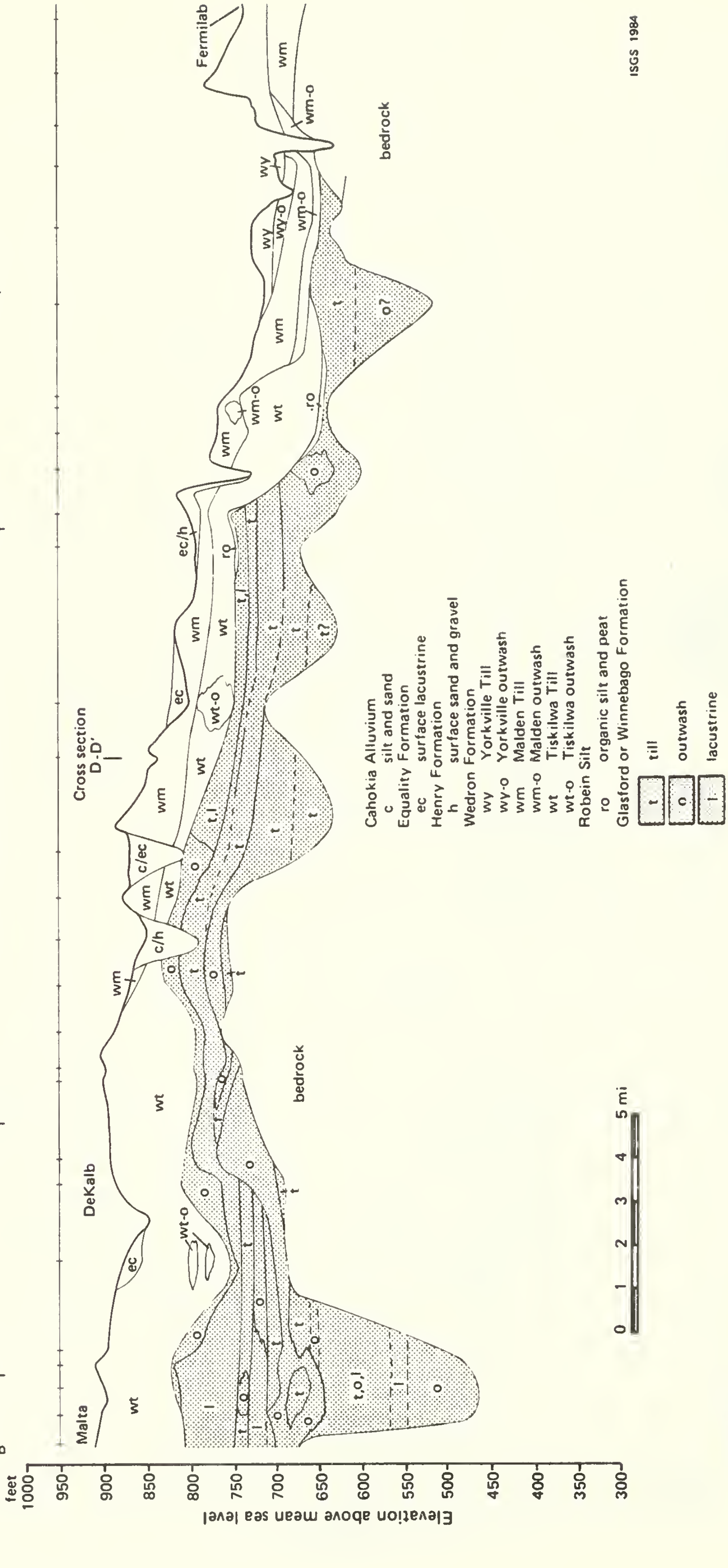


Figure 18c.
Central E-W cross section.

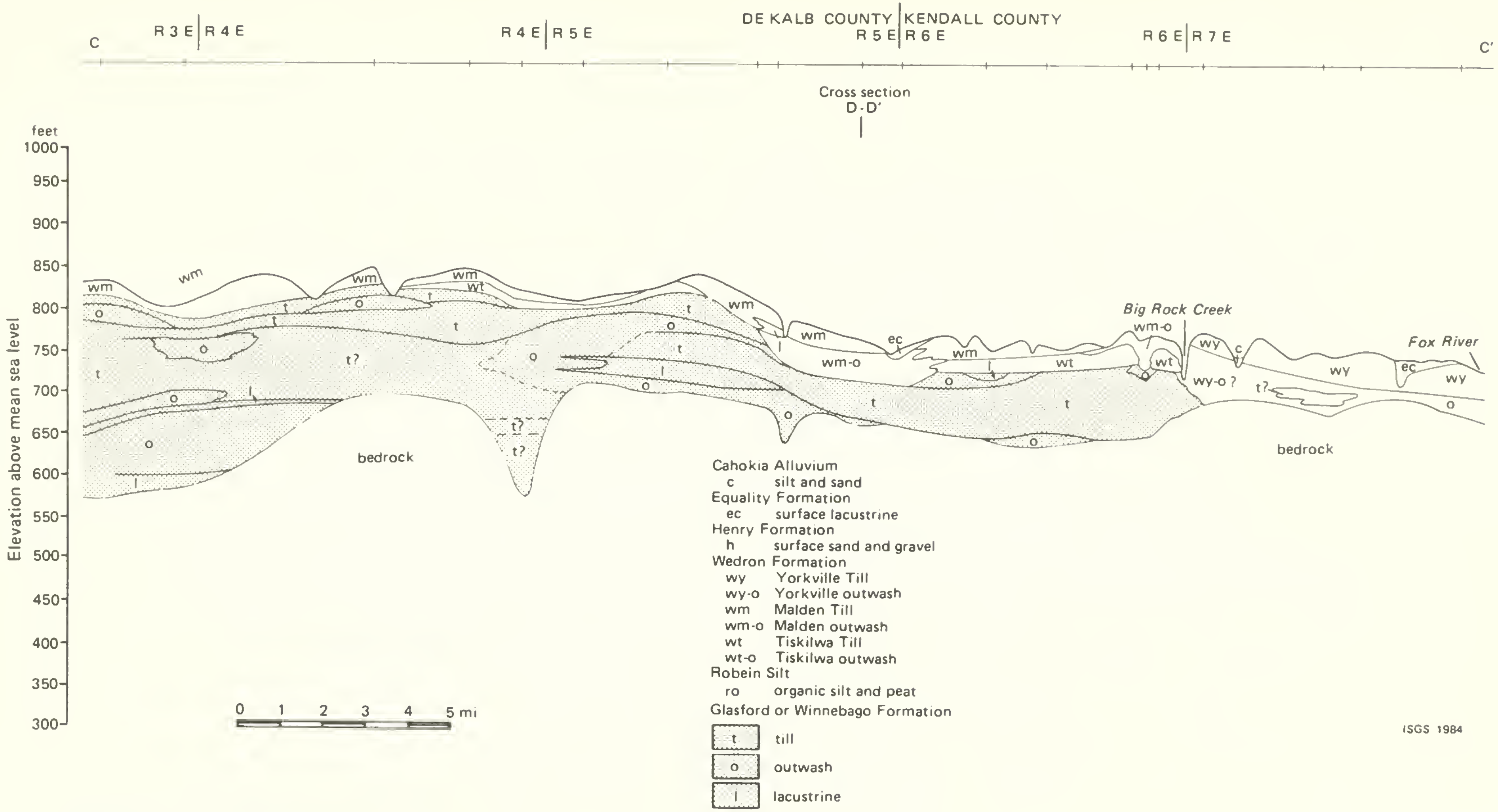


Figure 18d.
Southern E-W cross section.

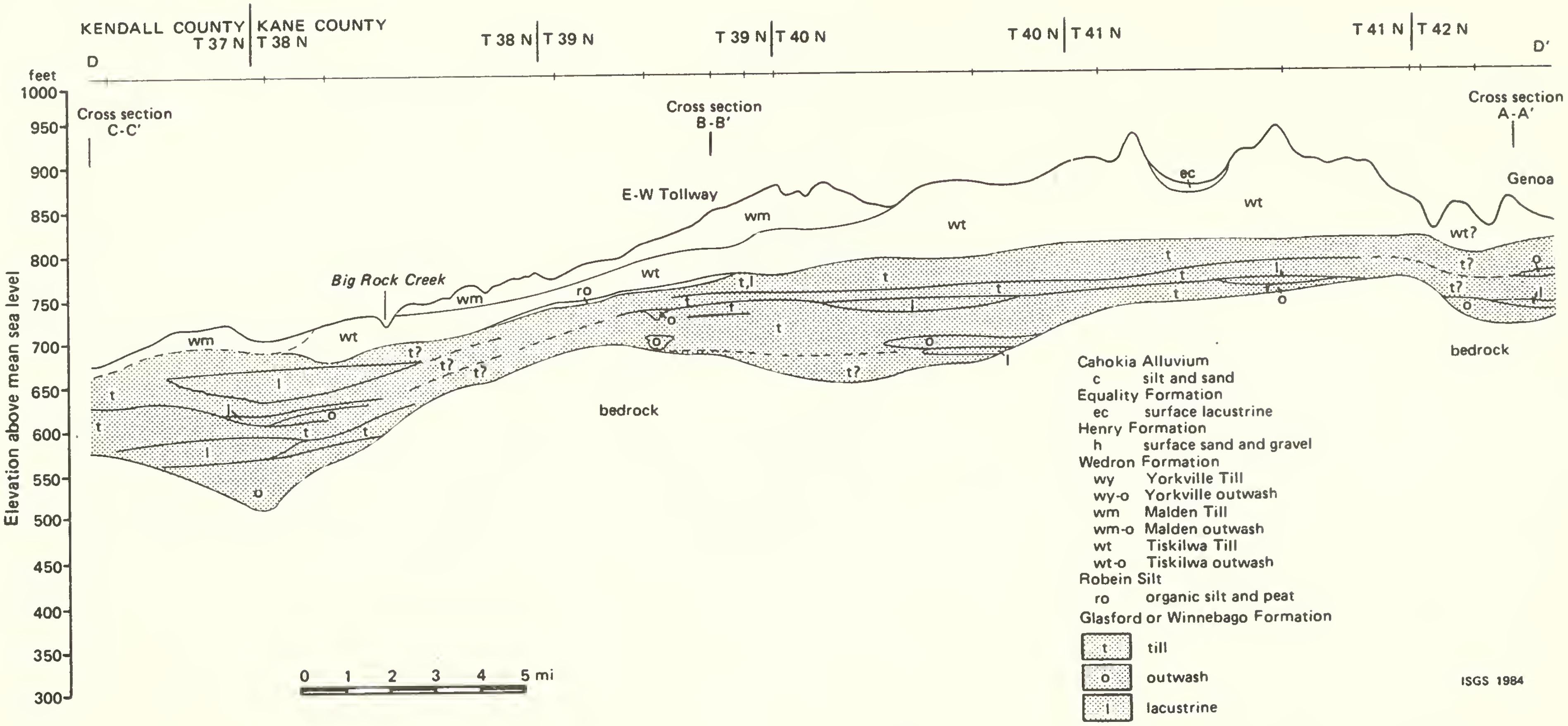


Figure 18e.
North-south cross section.

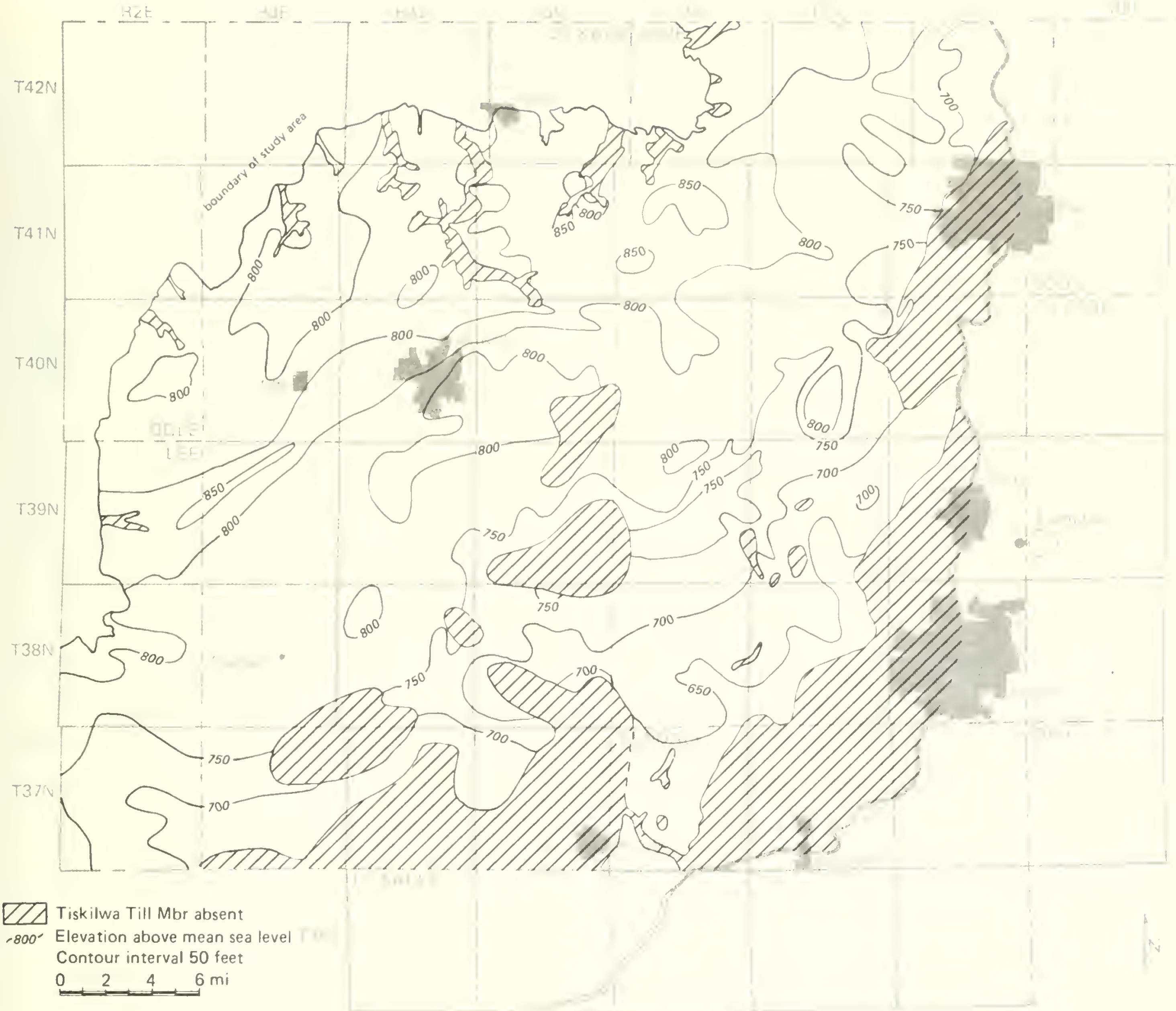


Figure 19.
Elevation, base of Tiskilwa Till Member (from Wickham, 1979).

Tiskilwa Till Member. This till is the thickest, most intensively studied drift unit of the area. The most recent study by Wickham (1979) is the basis for the following description and for figures 16, 19, 20, and 21. The glacier that deposited the Tiskilwa Till about 23,000 years ago advanced into the area (Kempton and Gross, 1971) over tills and outwash of the Glasford and Winnebago Formations and local deposits of the Robein Silt. The elevation of this ancient land surface is shown on figure 19.

The Tiskilwa is a remarkably homogeneous, calcareous, loam to clay loam till; it has an unoxidized color of brown to grayish brown with a pink cast and is typically described as pink or red sandy till or clay in well logs. Although it is generally uniform with a weak blocky structure, it may contain thin, discontinuous layers of gravel, sand, and silt.

The till matrix has an average composition of 35 percent sand, 39 percent silt, and 26 percent clay (table 1). The till contains less sand but more clay in the western part of the area. Fine to coarse gravel and cobbles are common; some boulders are present. The upper part of the Tiskilwa often contains variably textured till interbedded with thin layers of sorted gravel, sand, silt, and clay (ablation till). Some sorting has taken place, and ablation deposits are frequently coarser and less massive than the usual Tiskilwa Till; however, they are not easily distinguishable from the underlying till. A basal zone, noted also in the Tiskilwa, is finer grained.

Table 1. Properties of geologic units in northeastern Illinois (modified from Kempton, Bogner, and Cartwright, 1977, except where noted). The information in this table accompanies the text on engineering properties.

Unit		N	qu	W	dd	gr	sd	st	cl
Cahokia Alluvium	x	8.2	1.2	26.1	107	5.8	28.7	44.7	26.6
	n	25	15	23	7	44	48	48	48
	R	2-25	0-2.9	11-51	100-117	0-51	0-59	16-73	6-49
Grayslake Peat	x	1.9	0.28	111.8	52	2	8	52.4	39.6
	n	20	10	20	5	6	10	10	10
	R	0-5	0.1-0.5	34-265	30-74	0-3	0-23	26-72	22-61
Richland Loess	x	12	2.1	24	101	1	7	50	43
	n	6	10	10	5	8	8	8	8
	R	9-19	0.4-3.9	20-31	94-104	0-3	0-15	40-61	35-53
Equality Formation Carmi Member	x	20.1	1.2	27.9	95.8	0.8	8.5	60	31.5
	n	154	126	191	65	172	198	198	198
	R	1-75	0.1-6.6	8-100	43-131	0-26	0-82	9-94	2-84
Equality Formation Dolton Member	x	20	–	–	–	6.3	38.8	46	15.2
	n	19	–	–	–	13	13	13	13
	R	7-39	–	–	–	0-30	12-91	7-81	2-63
Henry Formation Mackinaw & Batavia Members	x	22	(1.5)	(17)	–	28.5	52.7	32.5	14.8
	n	251	(4)	(19)	–	112	113	113	113
	R	3-119	(0.7-2.3)	(11-23)	–	0-76	5-91	2-92	0-53
Yorkville ablation	x	20	2.9	13	126	12	26	42	32
	n	29	48	55	25	80	80	80	80
	R	11-26	0.6-8.3	10-24	114-136	2-40	7-53	17-66	15-90
Yorkville Till Member	x	24.4	3.62	17.0	117	3.4	10.2	46.5	43.3
	n	98	582	992	608	379	987	987	987
	R	3-106	0.6-10	9.2-35	92-138	0-29	0-54	18-83	13-68
Yorkville composite	x	21.3	3.3	14.9	120	6.9	16.7	43.3	40
	n	134	139	192	77	204	206	206	206
	R	3-106	0.6-9.7	10-31	94-136	1-40	2-53	17-75	13-90
Yorkville Till* Member	x						15	42	43
	s					9.0	8.5	11.6	
	n						84	84	84
Yorkville ** (Unit B, no. 1)	x		3.2	16.5	115.3		9	53	38
	n		7	97	36		107	107	107
Yorkville** (Unit B, no. 2)	x		ND	18.5	114.0		8	44	48
	n			29	7		30	30	30
Malden Till Member	x	17	2.1	13	128	13	36	43	21
	n	33	37	44	13	54	54	54	54
	R	5-100	0.5-4.5	9-25	119-135	0-32	4-57	23-63	6-38
Malden Till Member*	x						32	46	22
	s						6.4	4.9	5.4
	n						28	28	28
Malden (Unit C, no. 3)**	x		5.2	12.8	ND		33	45	22
	n		1	16			21	21	21
Malden (Unit C, no. 4)**	x		3.0	11.8	130.2		26	47	27
	n		2	31	11		37	37	37
Malden (Unit C, no. 5)**	x		2.6	15.0	122.1		20	43	37
	n		8	37	10		37	37	37
Malden & ? (Unit D, no. 6)**	x		ND	20.8	107.0		8	36	56
	n			101	53		81	81	81
Malden Outwash	x	32	–	11	104	5	55	34	11
	n	44	–	3	1	13	13	13	13
	R	6-100	–	8-13	–	0-23	3-83	4-80	0-29
Tiskilwa ablation	x	28	2.3	10.6	–	16.9	42.8	39.4	17.8
	n	132	12	105	–	41	43	43	43
	R	6-77	1.4-6.2	6-30	–	5-70	16-62	18-54	8-37
Tiskilwa Till Member	x	36	2.8	12	124.3	6.7	35.1	38.3	26.6
	n	166	182	334	84	315	315	315	315
	R	7-90	0.5-9.7	8-18.3	82.9-156	0-25	4-52	28-71	6-45

Table 1. *Continued*

Unit		N	qu	W	dd	gr	sd	st	cl
Tiskilwa Till Member	x						35	39	26
	s						9.6	5.2	6.1
	n						850	850	850
Tiskilwa (Unit E, no. 7)	x		ND	10.1	127.5		40	45	15
	n			25	2		29	29	29
Robein Silt									
Glasford Formation									
Banner Formation									

x	mean
n	number of tests or samples
R	range of data; low-high
s	standard deviation
N	number of blows per foot (Standard Penetration Test)
qu	unconfined compressive strength in tons per square foot
W	natural moisture content in percent
dd	dry density in pounds per cubic foot
gr	percent of gravel in total sample
sd	sand, 2 to 0.62 mm
st	silt, 0.62 to .0039 mm
cl	clay, <.0039 mm
ND	no data
*	from Wickham, 1979
**	from Landon and Kempton, 1971

The Tiskilwa Till is present through much of the study area (fig. 20). Its greatest thickness in the study area occurs beneath the Marengo Moraine (fig. 7) in the north-central part of Kane County, where it exceeds 200 feet. Thicknesses of 100 to 150 feet over large areas are common in the east, north, and central parts of De Kalb County and in northern Kane County. With some exceptions, a northeast-southwest trending line drawn through the center of the study area separates areas of thinner Tiskilwa (less than 50 feet) in the southeast from thicker till in the northwest (fig. 20). A major exception is the Marengo Moraine, a ridge extending south into central Kane County. The Tiskilwa is absent locally in the north, primarily in river valleys where erosion has occurred. Till along the Kishwaukee River valley has been thinned or removed, cutting the northern half of the Tiskilwa deposit into two segments. The till appears to be absent in two large areas near the center of the study area and in other areas near the irregular southern boundary of the till.

The thinning and absence of Tiskilwa Till beneath areas of younger glacial deposits in the south is attributable to both fluvial and glacial erosion. Meltwaters flowing along the Fox River have substantially eroded the till present in the valley in both Kane County and northern Kendall County. In southern Kane County, erosion by younger glaciers is a probable cause for the thinning of the Tiskilwa Till.

The Tiskilwa extends to near the eastern edge of Kane County; its eastern boundary may not extend much more than 1 or 2 miles east of the Fox River. Thin wedges of the till extend into northern Kendall and southern De Kalb Counties. In the west the Tiskilwa thins abruptly as its western boundary extends north through eastern Lee and Ogle Counties and east through northern De Kalb County. The Tiskilwa is present throughout northeast Kane County and extends north into McHenry County.

The topography of the Tiskilwa Till surface is parallel to land surface over much of the area, except where covered by Equality Formation lacustrine sediments and Henry Formation glacial outwash sand, or in the south and southeast where the Tiskilwa is covered by relatively thin Malden or Yorkville Tills. Its surface elevation is at a maximum along the end moraines to the north and west, and decreases toward the southeast.

The topography of the sub-Tiskilwa surface is somewhat more complex (fig. 19) and generally drops toward the southeast: the southeastern half of the area is somewhat irregular, and the northwestern half is an irregular surface at an average elevation of 750 to 800 feet, bisected by a northeast-southwest trending buried ridge of up to 850 feet elevation.

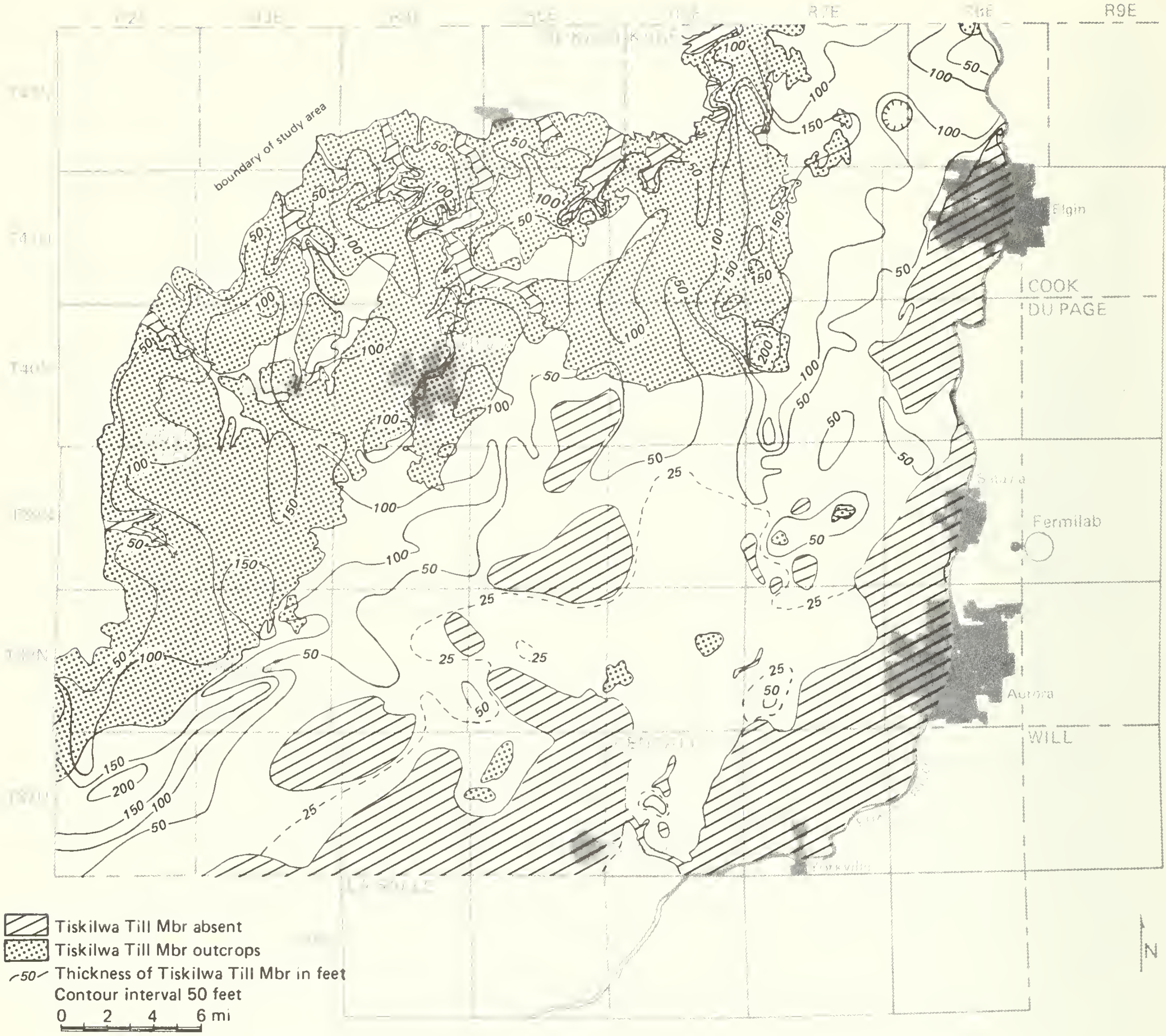


Figure 20.
Thickness of Tiskilwa Till Member (from Wickham, 1979).

Malden Till Member. The Malden Till overlies the Tiskilwa Till in the southern half of Kane County and approximately the southern third of De Kalb County (fig. 21). In comparison to the Tiskilwa, it is relatively thin, probably averaging little more than 30 feet thick. It is a yellowish brown, tan, or gray, predominantly sandy to silty till averaging 36 percent sand, 43 percent silt, and 21 percent clay (table 1). Locally it is quite gravelly and/or contains inclusions of sand and gravel and pink Tiskilwa Till incorporated from below. Inclusions of underlying till may have mixed thoroughly enough to create a mixed till of highly variable composition and texture. Extensive areas are covered by this "mixed composition" till (fig. 21), and it may completely replace the Tiskilwa in some areas. The end moraine that marks its margin in west-central Kane County and in east-central and south-central De Kalb County is very hilly or knobby, many of the hills being composed partially of sand and gravel with till inclusions.

In the southeastern portions of the study area the Malden Till is thin or absent, probably the result of erosion by late glacial meltwater floods along the Fox River. Throughout the southernmost portions, the Malden and the underlying Tiskilwa Till are quite thin (fig. 18c-d). Also in this area a locally significant outwash sand and gravel directly underlies the Malden. This outwash is the surficial material in some areas of northwestern Kendall County where the Malden Till has been eroded.

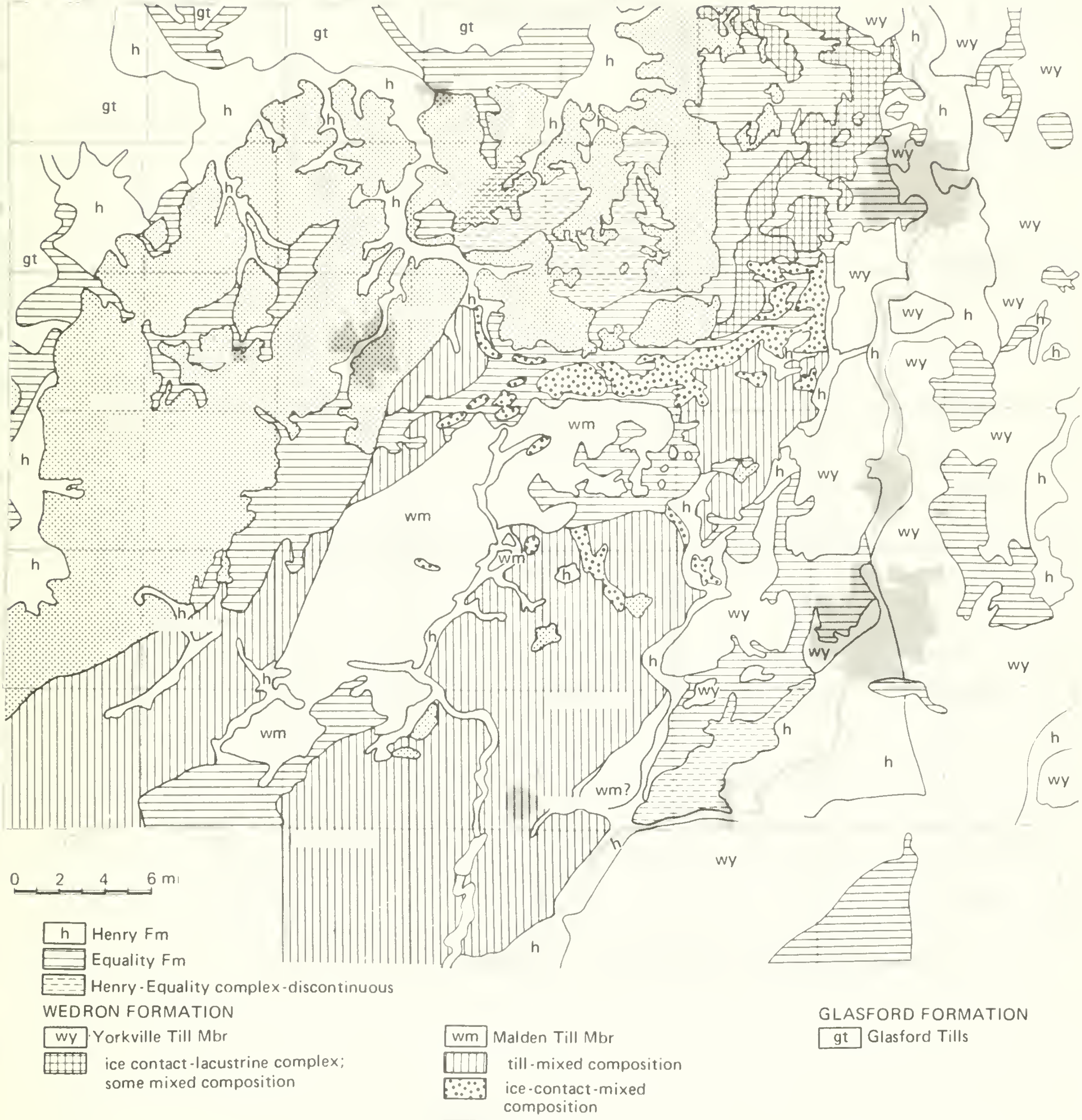


Figure 21.
Surficial geology (from Wickham, 1979).

Yorkville Till Member. The Yorkville Till overlies the Malden Till near the eastern edge of the study area (figs. 21 and 18b) and directly overlies the Tiskilwa Till in the northeast (fig. 18a). It is a very clayey, silty, gray till (generally more than 40% clay; table 1) with little sand (less than 15%). Color varies from brown or grayish brown in the upper oxidized portion to dark gray at depth. Numerous dolomite pebbles are characteristically present. The Yorkville may be more than 50 feet thick, but generally appears to be 20 to 30 feet thick where it is present in the study area. The Fermilab Tevatron has been placed in this till.

The Yorkville deposits mapped (fig. 21) are actually a complex series; composition varies due to differences in formation and deposition. The composition of the basal Yorkville deposits is consistent with the general description provided above; however, the upper deposits have typically been modified to some extent by water and mass wasting processes to form ablation till. These deposits are usually more sandy and may be less compact than basal till. Ablation till, not mapped separately, is included in the "normal" Yorkville deposits on figure 21. Landon and Kempton (1971) have noted these two phases at the existing Fermilab. A more detailed study of this till is reported by Kemmis (1981).

Extensive lacustrine (lake) deposits are associated with the Yorkville Till west of Elgin. When these silt and clay deposits are intermixed with stratified silt, clay, sand and gravel, they are referred to as ice-contact drift. Ice-contact drift is composed of materials deposited in or on ice; when the ice melts, these remain as characteristic features on the land surface. Some mixed-composition till, resulting from the incorporation of basal tills (Malden and Tiskilwa) during Yorkville Till deposition, is also present. The Yorkville mixed-composition till is identical to Malden mixed-composition till and is differentiated by stratigraphic position. All three types (lacustrine deposits, ice-contact drift, and mixed-composition drift) are mapped as part of the Yorkville lacustrine/ice-contact complex (fig. 21).

Thick outwash deposits may be present beneath the Yorkville Till in the southeast, and have been mapped as wy-o on the cross sections (fig. 18c). They may be exposed in some areas where the Yorkville Till has been eroded.

Henry Formation. The Henry Formation consists of discontinuous glacial outwash deposits composed predominantly of sand and gravel (table 1). It is a surficial or near surficial deposit, generally overlain only by loess (windblown silt), Cahokia and Equality Formations, and modern soils. The Henry Formation may vary from thin, well sorted sheet-like deposits to hills of poorly sorted silt, sand, and gravel. The hills are ice-contact deposits formed within or under the glacier and are generally quite discontinuous and limited in area. They are not mapped separately in this report. Several of these features are fairly prominent landforms located west of the Fox River in central Kane County.

Thin sheets of Henry Formation present in the study area are believed to be glacial outwash plain and valley train deposits and may be relatively continuous and widespread. Distribution is generally limited to narrow bands along present river valleys (former glacial drainageways) throughout the study area. Extensive deposits of Henry are present near the eastern and southern edges of the study area on either side of the Fox River (fig. 21) as well as near the northern and northeastern edges along the Kishwaukee River valley.

Because Equality and Henry Formation deposits were often formed simultaneously or alternately, they are usually intermixed and difficult to differentiate, so they are mapped as the Henry-Equality complex (fig. 21). Extensive areas covered by these generally thin deposits (less than 20 ft thick) are present in the southeast (west of the Fox River) and in the northern part of the study area near the Kane-De Kalb boundary.

Equality Formation. Areas mapped as Equality Formation were formerly covered by extensive lakes formed during and just following the final retreat of glaciers. The deposits consist mainly of silts and clays (table 1), with sand generally as a minor constituent.

Lacustrine deposits dating from earlier times are not considered Equality Formation but are instead mapped as part of the formation in which they occur (Wedron or Glasford).

The Equality Formation is discontinuously present throughout the study area (fig. 21) and may be mixed with Henry Formation deposits. Large areas covered by lacustrine deposits are present southwest of De Kalb (along the south branch of the Kishwaukee River), in the northeast (west of Elgin), and in the southwest and southeast corners of the study area. The Equality is generally thin (less than 20 ft) and often overlies sand and gravel of the Henry Formation (fig. 18a).

Cahokia Alluvium. The Cahokia Alluvium is the proper formation name for recent deposits in the flood plains and channels of modern rivers. The formation is generally composed of silt with discontinuous sand and gravel lenses. The sediments are generally deposited during flood intervals, and in the study area, they are probably rather thin (10 to 20 ft or less). This formation is not mapped on figure 21 but is shown on several cross sections (figs. 18a, b, and c). It often overlies Henry and Equality deposits (fig. 18a). Although found throughout the study area, it is limited to the immediate vicinity of area rivers and streams.

ENGINEERING PROPERTIES OF GEOLOGIC UNITS

The engineering properties discussed in this section are based on data gathered and summarized from previous studies. These include the report on the stratigraphy of the current Fermilab site (Landon and Kempton, 1971) a report on regional geology for planning in northeastern Illinois (Kempton et al., 1977), a master's thesis based on data gathered from drilling for the present Fermilab ring (Kemmis, 1978), and a master's thesis involving a comprehensive regional study of the Tiskilwa Till (Wickham, 1979).

The engineering properties listed in table 1 are N for number of blows per foot (Standard Penetration Test), Qu for unconfined compressive strength in tons per square foot, W for natural moisture content, expressed as a weight percent, and dd for dry density in pounds per cubic foot.

> *Standard Penetration Test,* determined during drilling, is the number of blows (N) required to drive a sampler 12 inches into a soil material by dropping a 140-pound hammer a distance of 30 inches; it is an empirical test commonly used to indicate relative in situ bearing strengths of materials. Table 2 indicates groupings of approximate bearing strengths of clayey and sandy soils.
>
> Unconfined compressive strength in tons per square foot (Qu) is an additional measure of bearing strength. Most data under this heading were obtained by standard field methods. Table 2 includes unconfined compressive strength categories for clayey and sandy soils.
>
> Natural moisture content (W) is expressed as a percentage of the weight of water in the sample relative to the oven-dry weight of the sample. Table 3 categorizes materials by natural moisture content.
>
> Dry density (dd) determinations are given in pounds per cubic foot. Table 4 categorizes rock and soil. Soil referred to by the geotechnical engineer is equivalent to glacial drift.

Table 2. Groupings of approximate bearing strengths (after Terzaghi and Peck, 1967; from Bergstrom, Piskin, and Follmer, 1976).

	Clayey soils				Sandy soils	
	Relative strength	Field test	Unconfined compressive strength (tons/ft^2)	Standard penetration test, blow count*	Standard penetration test, blow count*	Relative density
Low	Very soft	Easily penetrated several inches by fist	0.25	2		
	Soft	Easily penetrated several inches by thumb	0.25-0.5	2-4	4	Very loose
Medium	Medium	Can be penetrated several inches by thumb with moderate effort	0.5-1.0	4-8	4-10	Loose
	Stiff	Readily indented by thumb, but penetrated only with great effort	1.0-2.0	8-15	10-30	Medium
High	Very stiff	Readily indented by thumbnail	2.0-4.0	15-30	30-50	Dense
	Hard	Indented with difficulty by thumbnail	>4.0	>30	>50	Very dense

*Blow count for 12-inch penetration (140-lb hammer; drop of 30 in.).

Table 3. Natural moisture content (Bergstrom, Piskin, and Follmer, 1976).

	Moisture content (% dry wt)	Materials
Very high	>100	Organic materials, including peat
High	50-100	
Medium	30-50	Materials rich in organic matter or alluvial silts and clays
Low	10-30	Loess, coarse alluvium, colluvium, or weathered till
Very low	<10	Unweathered till, desiccated materials, or bedrock

Table 4. Dry density weight (Bergstrom, Piskin, and Follmer, 1976).

	Soil		Rock	
	lb/ft^3	g/cc	lb/ft^3	g/cc
Very high	>145	>2.3		
High	120-145	1.9-2.3	>170	>2.7
Medium	100-120	1.6-1.9	145-170	2.3-2.7
Low	90-120	1.4-1.6	120-145	1.9-2.3
Very low	<90	<1.4	<120	<1.9

Table 1 also lists average percentages of gravel in the total sample; of sand, silt, and clay in the sample matrix; and of the clay mineral composition of the less-than-2-micrometer fraction.

Physical Characteristics of the Drift

The tills and sand and gravel deposits in this region range from medium to high in bearing strength. The wide range of blow counts in the sand and gravel units probably indicate the variability of these materials.

Loess, fine-grained lake sediments, and alluvium also exhibit variable strength characteristics. Landscape position and moisture content account for wide variations in some units. Alluvium and lake sediments, where lowest on the landscape, are most likely to exhibit high moisture content, depending on the season of the year and the amount of recent precipitation. Loess, which generally mantles the uplands, exhibits low bearing strength when saturated; when dry and well drained, it is capable of medium to high bearing strengths. It is also highly susceptible to piping (subsurface erosion) when wet.

Coarse-grained, well sorted (poorly graded) sediments such as sands and gravels tend to have higher moisture content than poorly sorted (well graded) deposits because of their higher porosity and permeability. Deposits that are poorly sorted contain significant amounts of fine-grained sediments, tend to exhibit a low porosity and permeability, and therefore, have a lower moisture content. Consequently, well sorted sands and gravels exhibit good drainage; whereas poorly sorted sediments such as till and very fine-grained loess, lacustrine silts, and clays do not.

Loess and some alluvial deposits average high in expandable clay minerals. As mentioned earlier, geologic materials that contain an appreciable percentage of expandable clay minerals have a high shrink-swell potential. Fine-grained alluvial silts and sands situated in poorly drained positions on the landscape have a high potential for frost heave.

None of the geologic units listed should cause excavation costs to be higher than normal. Some may form unstable slopes in excavations, particularly saturated loess, alluvium, lake sediments, and unconfined sand lenses. In general, glacial till is a good fill material for construction purposes. One potential problem is that till units may include cobbles and boulders of different sizes, causing difficulties in drilling, excavation, or tunneling. "Boulder pavements" may also occur between glacial deposits or at the base of large buried stream valleys.

Physical Characteristics of the Bedrock

Some physical characteristics of the bedrock are described in table 5, which presents some additional detail on the various groups, formations, and members described in the stratigraphic section of this report (fig. 8a). Available physical strength data for the various rock units are presented as a range of values. These values should be used with caution since they represent results from a limited number of samples at various depths, from different locations. To paraphrase an important principle stated in the 1982 Annual Book of Standards of the American Society for Testing and Materials, strength properties of

Table 5. Physical properties of bedrock units.*

		Unconfined compressive strength (psi)	Indirect tensile strength (psi)	Tangent modulus (psi x 10^6)	Number of samples
Cambrian System					
Mt. Simon Sandstone	Sandstone, coarse grained, friable; may contain quartz pebbles up to about 4 mm across.				
Eau Claire Formation	Sandstone, dolomitic; siltstone, shaley; and dolomite, silty, sandy, glauconitic.				
Galesville Sandstone	Sandstone, fine grained, moderately well sorted, friable; generally nondolomitic but local dolomite cement may be found.				
Ironton Sandstone	Sandstone, coarse grained, poorly sorted; generally contains dolomite as cement and dolomite pebbles in conglomeratic layers.				
Franconia Formation	Sandstone, fine grained, glauconitic, silty, argillaceous, dolomitic.				
Potosi Dolomite	Dolomite, finely crystalline, pure to slightly argillaceous.				
Eminence Formation	Dolomite, fine to medium grained, sandy; contains oolitic chert and thin beds of sandstone.				
Ordovician System					
Prairie du Chien Group	Dolomite, cherty; some interbedded sandstone.				
Shakopee Dolomite		8,200-11,000	800-1,100	1.4-3.8	8
Ancell Group	Sandstone, friable or weakly cemented; limestone and dolomite, argillaceous, sandy.				
Platteville Group	Dolomite, fine grained, cherty.				
Galena Group	Dolomite, medium grained, cherty.				
Maquoketa Group	Shale, dolomitic, silty; locally contains interbeds of fine- to medium-grained dolomite and/or limestone.				
Fort Atkinson Dolomite		18,000-36,000	1,300-2,400	3.3-6.0	8
Silurian System					
	Dolomite, pure, cherty.	5,600-36,000	700-2,200	1.2-4.8	12

*Random samples from air-dried cores. Data from ISGS Rock Mechanics data base.

rock cores as measured in the laboratory generally do not accurately reflect properties of large-scale rock masses in the field because the latter are often influenced by joints, faults, inhomogeneities, weakness planes, and other factors. Laboratory values obtained from intact specimens must therefore be used with proper judgment in engineering applications.

Unconfined compressive strength measurements are determined using standard length-to-diameter ratios of 2. Samples must be tested before the natural water content evaporates from the core. This test indicates the load-bearing strength of the rock. Indirect tensile strength measurements are used to measure the maximum stress the sample can withstand without pulling apart. Samples must be tested with natural moisture contents to achieve good test results. Tangent modulus is a standard method to determine the relationships of stress to strain in a rock. The strength values presented in table 5 are based on air-dried samples taken from northern Illinois.

Future geotechnical studies must include field and laboratory testing of Quaternary materials and bedrock as a basis for better definition of the engineering characteristics of these units and the conditions that will be encountered during excavation, drilling, tunneling, and construction phases of the project.

HYDROGEOLOGY

Source, Movement, and Availability of Groundwater

The relationship of water to the geologic materials within the region must be understood to provide a basis for evaluating site suitability.

In Illinois, the source of groundwater is precipitation—both rain and snow infiltrating loose particles of the soil and eventually percolating downward. Below a certain depth, called the "top of the zone of saturation" or "water table," almost all openings (pores) in the earth materials are filled with water. (Above the water table, pore spaces are filled with both water and air.) This definition of water table is *independent* of the character of earth materials; therefore, it is *not related* to the availability of groundwater to wells. A tightly packed, fine-grained material may be completely saturated with water, yet the yield and rate of recharge (movement of water into a well) would not be sufficient for use.

Groundwater is stored in the zone of saturation in openings ranging in size from tiny pores between particles of clay and silt, to small pores in sandstone, to larger pores between grains of sand and gravel, to large crevices or solution channels in dolomite and limestone. The pore space of an earth material is its porosity, expressed as a percentage of total volume of the material. The size and interconnection of the pores determine how easily earth materials transmit water under a pressure gradient—from areas of high potential energy to areas of low potential energy. This is referred to as the hydraulic conductivity. Permeability refers to the capacity of an earth material to transmit any fluid; whereas hydraulic conductivity refers to the interaction of both material and water.

Under natural conditions, the water table roughly parallels the surface topography: it rises under the uplands and intersects the ground surface in the lowlands, forming perennial streams, lakes, swamps, and springs. Groundwater enters these surface-water bodies because of gravity flow from adjacent areas where the water table is higher. From season to season and year to year, the position of the water tables and the discharge of groundwater to streams fluctuate. During wet periods, for example, the water table is usually at or near the surface.

The water table can be located in any material. Even after a well has been drilled below the water table, groundwater is only rapidly available from material with sufficient hydraulic conductivity. Thus, the presence of water does not necessarily mean the presence of an aquifer. Any large excavation below the water table—even in materials with low hydraulic conductivity—will fill with water, though very slowly.

An aquifer is a natural earth material that yields sufficient water to a well to satisfy the need for drilling it. Thus, an aquifer supplying adequate water for a single residence might not be an aquifer for a municipality. For this report, the term aquifer refers to earth materials capable of supplying water to several residences.

Aquifers may be unconfined or confined. In an unconfined aquifer, the water table is the top of the water-yielding materials; no impermeable materials overlie the aquifer, confining it. In a confined aquifer, also known as an artesian aquifer, the groundwater is confined under pressure greater than atmospheric pressure by overlying, relatively impermeable materials. This pressure causes the water in a well to rise above the top of the aquifer. A well in which water rises to land surface is a flowing artesian well.

In some places, materials above the main water table become saturated, resulting in perched water tables: for example, several feet of windblown silt (loess) may overlie a clay-rich glacial till. Because silt is more porous than clay, water will generally move more easily through the loess than through the clay and collect just above the clay, producing a saturated zone or perched water table. Also, small, relatively thin sand and gravel layers between loess and clay-rich till might form perched aquifers, although they rarely yield enough water to supply even a small household.

Water Resource Distribution

Two principal types of materials yield groundwater in Illinois: (1) sand and gravel deposits within glacial drift and along river valleys; and (2) sandstone, limestone, and dolomite formations within bedrock. Table 6 summarizes the water-yielding potential of the geologic units in the study area.

Table 6. Geologic units as potential aquifers

Geologic unit	Water-yielding characteristics
Glacial drift	Yields highly variable; largest supplies from thick, extensive sand-and-gravel beds within Glasford and Henry Formations.
Silurian	Local availability from fractures mainly in eastern most portion of area; small to moderate supplies.
Maquoketa	Small supplies locally from fractured dolomite and/or shale; generally not water-yielding.
Galena-Platteville	Small to moderate supplies where fractured and not overlain by Maquoketa.
Ancell (Glenwood-St. Peter)	Moderate supplies.
Prairie du Chien	Small to moderate supplies; locally large in southern part of area.
Eminence-Potosi	May yield small supplies where fractured.
Franconia	Generally not water yielding; small supplies locally.
Ironton-Galesville	Highly productive aquifer in central and western parts of area; large supplies; extensively used in eastern portion of area.
Eau Claire	Generally not water yielding. Lower sandstone included with Mt. Simon.
Mt. Simon	Moderate to large quantities of water; water quality good at top but deteriorates with depth.
Precambrian granite	Not water yielding.

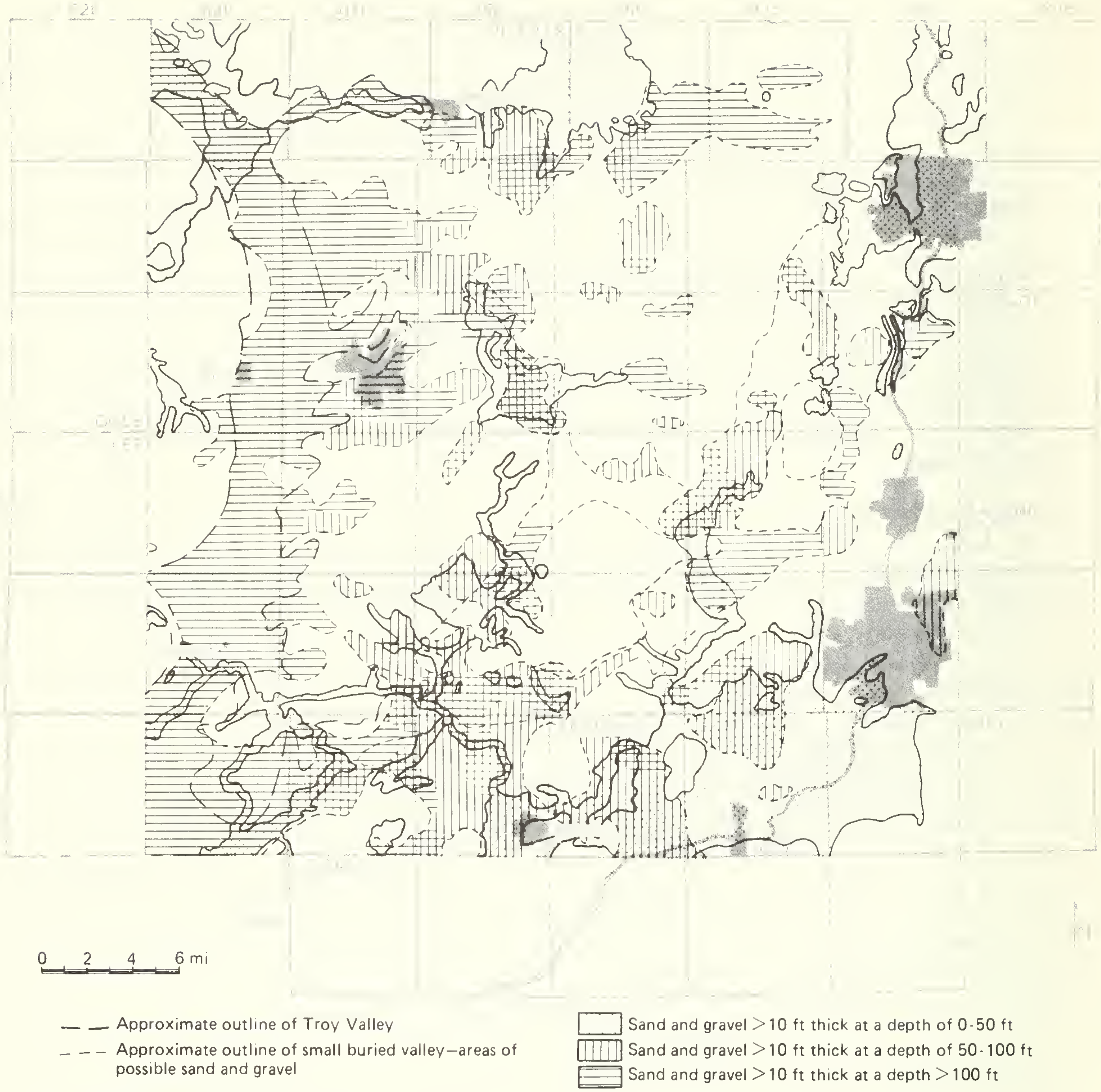


Figure 22.
Potential surficial and buried sand-and-gravel aquifers.

Drift aquifers include several basic types—each exhibiting a different water-yielding capacity and suitability for use by households, municipalities, industries, and others. For example, drift often contains relatively thin, discontinuous deposits of sand and gravel. Due to their low yields, these water-bearing deposits are only suitable for small, domestic supplies. Although they may be encountered at any depth within the drift, the most common location is just above or resting on the bedrock. In much of the study area, particularly in De Kalb County, these deposits are frequently passed because of the excellent groundwater potential of deeper bedrock aquifers.

The south, east, and southeastern parts of the study area have fairly widespread, thick, deposits of water-bearing sand and gravel, which are commonly used for domestic water supplies (fig. 22). At present, most wells in this area use a bedrock aquifer instead of drift sources. In the future, the easy accessibility of these shallow aquifers may considerably increase their use. Small to moderate water supplies are generally available from these deposits.

The Troy Bedrock Valley contains thick deposits of sand and gravel (fig. 18b), generally below an elevation of 600 feet; thicknesses of more than 100 feet have been reported. Well data indicate, however, that the deposits may be much thinner or even absent in some areas, particularly above an elevation of 600 feet. Possibly because of this as well as the fact that the underlying bedrock (Galena-Platteville dolomite west of the Maquoketa boundary, and St. Peter Sandstone) has excellent groundwater potential, high-capacity wells develop most or all of their yield from the deeper bedrock. However, some domestic and other low-yield wells may not penetrate the entire drift thickness in the buried valleys because adequate domestic supplies can be obtained from small deposits at much shallower depths.

The prospect for developing groundwater supplies from the bedrock are good over the entire study area. Silurian dolomite, which is generally fractured and creviced, is commonly used as an aquifer east of the Fox River. West of the Fox River, the thin scattered patches of Silurian rocks are generally unsuitable for aquifer development.

Much of the bedrock directly below the drift west of the Fox River, extending across Kane County into northeast De Kalb County, is the Maquoketa Shale Group. The dolomite within the Maquoketa is occasionally utilized by domestic or farm wells in Kane County. Moderate supplies for subdivisions may also be available in a few locations. Because the shale facies of the Maquoketa generally has low permeability, it does not yield water except where it is fractured. Locally, fractures may permit the construction of low-yield wells.

The Galena-Platteville dolomite underlies the entire study area north of the Sandwich Fault, except in part of the Troy Bedrock Valley. The Galena-Platteville is generally a reliable source of groundwater where it lies directly below the drift; it may yield moderately large supplies where fractures are encountered in the upper 75 feet. A large number of domestic, industrial, and municipal wells develop supplies from the Galena-Platteville in De Kalb County. It is common to drill through water-bearing sands into the bedrock, partly because the dolomite has a potentially higher yield, and partly because it is easier to construct wells in this type of bedrock. East of the boundary of the Maquoketa Group, relatively few wells obtain water from the Galena-Platteville where it lies below the Maquoketa.

The St. Peter Sandstone and the lower Ordovician/upper Cambrian dolomite and sandstone may yield moderate to large quantities of groundwater. These rocks immediately underlie the drift just south of the Sandwich Fault and are a common source of groundwater in that area. North of the fault they are generally used for municipal or industrial supplies.

POTENTIAL GEOLOGIC CONSTRAINTS

Seismicity

The seismic risk map for the conterminous United States, developed by Algermissen (1969), shows that this area can expect only minor damage from future seismic activity. Probabilistic horizontal acceleration caused by earthquakes in northern Illinois (Algermissen et al., 1982) is not expected to exceed 4 (as a percentage of gravity) in 50 years or 9 in 250 years (fig. 23). Because historic data are scarce, accurate predictions are extremely difficult.

Since 1804, only seven historical earthquakes have been epicentered in northern Illinois (Heigold, 1972). None of these quakes has had a maximum intensity above VI on the modified Mercalli Intensity Scale, which ranges from I to XII. (An intensity of VIII on this scale corresponds to the lower limit of serious damage to manmade structures [Heigold, 1972]). As mentioned earlier in the discussion of bedrock geology, no displacement along the Sandwich Fault Zone has occurred in historical times nor has any movement been recognized in mapping Quaternary units that may be as old as 400 thousand years in this region.

Although the seismic risk for any part of the state is low, a repeat of the events that occurred in the New Madrid Seismic zone (fig. 23) during the winter of 1811-12 could have some effect on Illinois. To assess the potential risk for different areas of the Midwest,

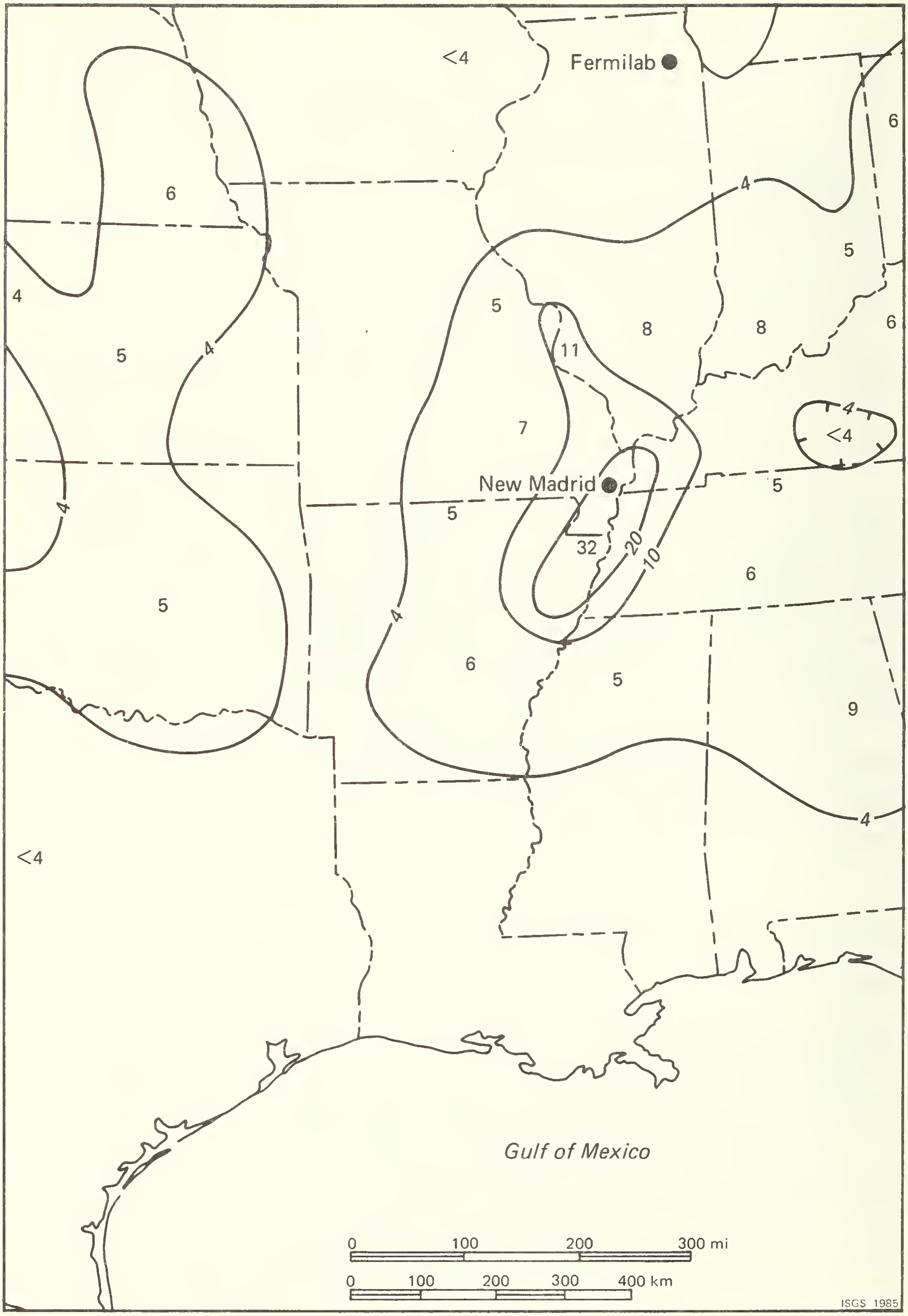


Figure 23.
Preliminary map of horizontal acceleration (expressed as percent of gravity) in rock with 90 percent probability of not being exceeded in 50 years (modified from Algermissen et al., 1982).

Otto W. Nuttli (1978) constructed an intensity map for one of the largest earthquakes of the 1811-12 sequence (December 16, 1811). An evaluation of the effects on northern Illinois rated a seismic intensity no greater than VII on the modified Mercalli Intensity Scale. Detailed data are available for historical earthquakes in and near Illinois (Heigold, 1972).

Nuttli and Herrmann (1978) have formulated an empirical equation for particle acceleration and velocity, and this may be relevant to a consideration of seismic risk in the vicinity of the ring. The recommended relation for maximum horizontal acceleration for the central United States is

$$\log_{10} a_H \text{ (cm/sec}^2\text{)} = \begin{array}{ll} -0.36 + 0.52\, m_b - 0.00 \log_{10} R & R \leqslant 15 \text{ km} \\ 0.84 + 0.52\, m_b - 1.02 \log_{10} R & R \geqslant 15 \text{ km} \end{array}$$

with a standard error of estimate corresponding to a factor of about 2.0. The relation for maximum velocity is given as

$$\log_{10} v_{max} \text{ (cm/sec)} = -2.92 + 1.0\, m_b - 1.0 \log_{10} R$$

Finally, soils in the region of the Fermilab site do not generally have characteristics that would make them susceptible to liquefaction from an earthquake.

Subsidence

The land surface may subside due to natural causes such as collapse of natural caverns in karst regions. Man-induced subsidence may result from collapse of subterranean openings produced by some mining operations or by withdrawing water too quickly from loose sediments.

The region does not have karst-type bedrock that would be expressed on the surface as sinkhole terrain. The upper surface of buried formations may exhibit some of these features, but usually the openings are filled by deposits. There are no underground mining operations in the region that could possibly fail and cause subsidence. Glacial activity preloaded the surficial materials in such a manner that all units except for recent streambed alluvium have been preconsolidated to a dense state. No case of subsidence has ever been reported from dewatering of these sediments.

Slumping

A ring of the size being discussed would cross and pass beneath Somonauk Creek, Big Rock Creek, Little Rock Creek, and the South Branch of the Kishwaukee River. Stream banks and adjacent floodplain areas may present some unstable conditions, which could affect surface construction activities and facilities unless proper construction techniques are employed.

EVALUATION OF THE GEOLOGY

Groundwater as a Geotechnical Problem

Identifying and mapping the distribution of materials that may cause problems when saturated or under hydrostatic pressure is particularly useful information for tunneling, shallow foundations, and excavations where slope stability may be a problem. Since a high water table and/or perched water are both likely to occur in the surficial materials of the study area, cut-and-fill operations must be designed to take these conditions into account.

Surface drainage is influenced by topography, by infiltration rates related to the characteristics of surficial materials, and by the position of the water table. In those parts of the study area with gentle slopes underlain by glacial tills or other fine-textured materials, the top of the zone of saturation roughly parallels the land surface; it is likely to be at rather shallow depths and will locally intersect the land surface in depressions and along streams. In areas of coarser deposits such as sand and gravel, surface drainage is usually good due to relatively rapid infiltration and a generally lower water table.

Construction problems. High water-table and perched-aquifer conditions (see Hydrogeology, p. 44) can occasionally cause problems in below-surface, and particularly, near-surface construction projects. Soft foundations and unstable cuts in excavations are common during wet periods. In some places drainage must be engineered under the most severe conditions. Unstable slopes may result from exposure of materials that flow easily (such as sand) when support is removed. A high water table also produces unstable conditions: interstitial water may reduce strength in fine-grained materials, such as silt, which collapse if the sides of the excavation are cut too steeply. In addition, a large excavation that extends below the water table must be engineered to maintain dry conditions in the planned working space. The soils or rocks seep water into underground openings at a rate dependent upon their hydraulic conductivity.

Geological Features

Some features of the site will influence design and orientation of the ring regardless of the construction technique used. Most prominent is the Sandwich Fault Zone located at the southern end of the site. This fault has been inactive for millions of years; however, it represents a significant geologic feature due to the rapid variations of materials across the zone as well as the crevices and breaks caused by the fault. Consequently, the faulted area is not well suited to underground tunneling techniques.

Natural waterways will also affect ring orientation (fig. 2a). The Fox River is especially significant because it bottoms on bedrock in the region west of Fermilab. If any part of the SSC is to be situated west of the Fox River, it will have to pass under the river; therefore some tunneling through rock will be required. Other important waterways are the Big Rock Creek and the Kishwaukee River, which are not as deep as the Fox River and would affect either surface or shallow tunneling construction. These minor waterways and some lakes occur throughout the site and will have to be considered in the final ring location.

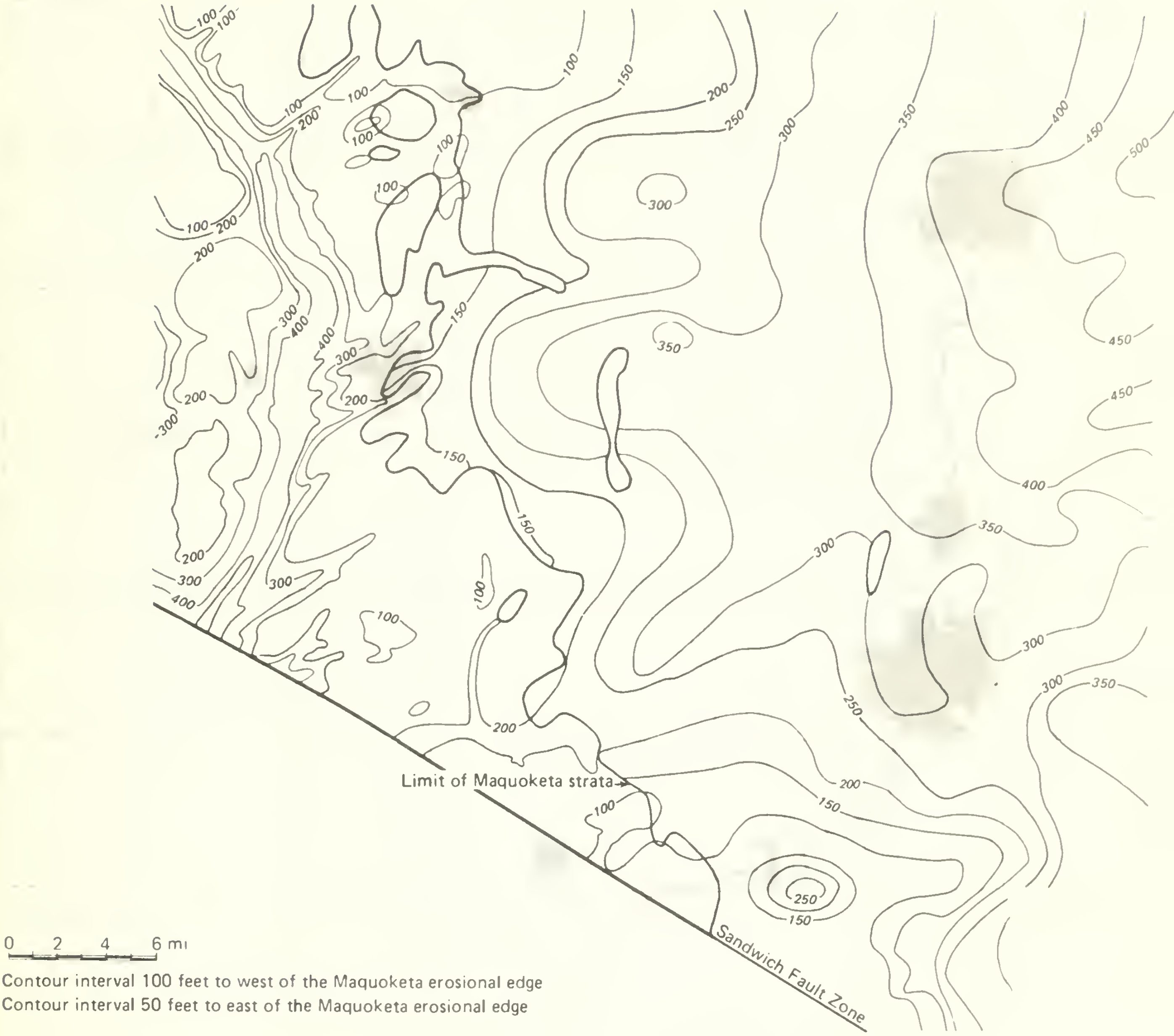
Another significant geological feature is the Troy Bedrock Valley lying along the western edge of the region. Although not visible from the surface, the valley cuts into the bedrock and is filled with glacial drift. In tunnel construction, transitions between rock and drift are avoided when practical because these different materials require different tunneling techniques. The uniform till above the valley is suitable for either surface or shallow tunnel construction.

Factors Related to Surface Construction. Surface deposits vary over the region (fig. 21). Wedron Formation tills predominate, but there are large areas of mixed composition and/or sand and gravel. The characteristics of these tills are generally suitable for surface construction (table 1).

Cut-and-cover methods of surface construction are complex. Although the topography of the region is relatively flat, local variations in elevation of 50 feet or more are common, and the site slopes from northeast and southwest by about 150 feet. Various waterways and lakes in the area would restrict surface construction; and most likely, some shallow tunneling would be required even for a predominantly surface ring (fig. 2a). Most importantly, such construction would be highly visible, affecting highways, power lines, farmland, and forests.

None of these factors preclude the possibility of a cut-and-cover approach, but would nevertheless have to be considered in choosing such a site.

Factors Related to Shallow Tunnel Construction. Shallow tunnel construction would take place in the glacial drift—avoiding sand and gravel if possible—at depths suggested by figures 19 and 20, above the Glasford or Winnebago Formations. The Tiskilwa Till is especially



Contour interval 100 feet to west of the Maquoketa erosional edge
Contour interval 50 feet to east of the Maquoketa erosional edge

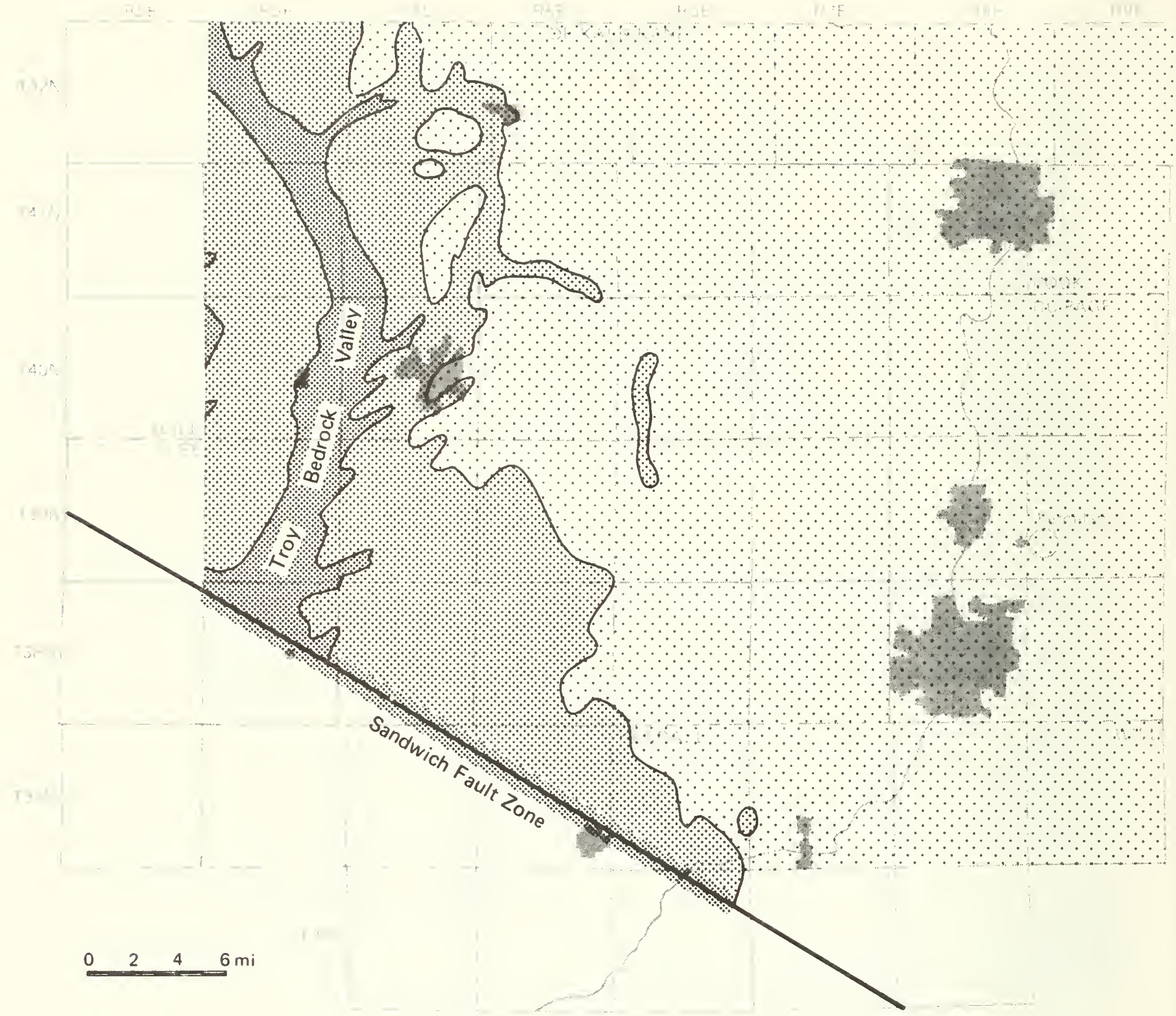
Figure 24.
Depth to the top of the Galena Group.

attractive because of its very uniform composition over the entire area. The till is a locally thick, uniformly mixed material with very low permeability, similar to the clay till at the Fermilab site.

An important consideration for construction in till of this area is the abundance of data available on drift composition from existing well borings. The cross sections given in this report are based on only a fraction of the total data available. The extreme variation in local drift composition is an important factor to be considered relative to tunneling performance, equipment selection, and cost.

Although the well drilling data constitute an advantage, the wells themselves represent a potential problem. The tunnel will have to avoid the wells or the wells will have to be replaced. This may be the most important environmental impact of a shallow tunnel.

Factors Related to Bedrock Tunnel Construction. A deep tunnel would be constructed in bedrock below the glacial tills. Figure 15 shows bedrock depths. The Galena-Platteville Dolomite is attractive for tunneling because of its consistent and predictable composition. The Maquoketa Shale Group, by comparison, has a mixed composition consisting of shale and argillaceous or clayey dolomite.



⁚ Most suitable for accelerator ring. Tunnel in Galena-Platteville Dolomite; lies below Maquoketa shale.

░ Some limitations for accelerator ring in Galena-Platteville Dolomite; lies directly below glacial materials.

▓ Least suitable for tunnel in bedrock; Galena-Platteville absent or highly fractured along Sandwich Fault Zone.

Figure 25.
Relative geologic suitability of the Galena-Platteville Dolomite for tunneling.

An important advantage of construction in the Galena-Platteville is that at sufficient depths a flat ring could be situated entirely in this relatively homogeneous medium. The location of a flat ring would be about 400 feet above sea level or a depth between 250 and 500 feet deep (fig. 24). (At Fermilab, the top of the Galena is about 350 feet deep.) Figure 25 shows the relative suitability of the Galena-Platteville Dolomite for tunneling.

During the record-breaking production of the deep tunnel project (TARP) in Chicago, a great deal of experience was gained that would apply to the SSC situation. The properties of rocks as well as general geologic conditions in the area proposed for the SSC ring site are expected to be similar to the conditions encountered by the TARP project.

SUMMARY AND CONCLUSIONS

A 20-TeV accelerator could be built in association with the Fermilab site in a number of different ways, yet the possibilities are reduced by some general considerations. The lower population density west of Fermilab favors a ring location in that direction. The use of the Tevatron as a preaccelerator (injector) for the SSC would require connecting the new machine to the existing site either by an injection line that passes under the Fox River, or by an intersection with the SSC. The geological factors that would influence site selection fall into at least three distinct categories, depending on the means of construction employed for the ring: surface construction (cut-and-cover methods), shallow construction (tunnel mainly in till), or deeper construction (tunnel in bedrock).

This report presents geologic data necessary for an initial evaluation of potential SSC sites using the Fermilab Tevatron as an injector. This favorable geologic environment suggests that there are many potential, local sites that merit further evaluation. The final choice of ring location will also depend on the accelerator design and engineering factors as well as on environmental, human, and financial considerations.

ACKNOWLEDGMENTS

All of us have been infected by the excitement and enthusiasm that the high energy physics community has for the proposed Superconducting Super Collider. The importance of the SSC as an essential tool for basic research has been made clear to us by Leon Lederman, Director of Fermilab, and the members of his staff. In particular, we would like to thank J. Lach, S. I. Baker, L. V. Coulson, A. J. Elwyn, R. Stefanski, and E. Treadwell, who have answered our innumerable questions about high energy physics, the SSC, and how it might be located relative to the existing Fermilab accelerator complex.

Many members of the Illinois State Geological Survey have taken part in the study and aided in the preparation of this report. Robert C. Vaiden and Jacquelyn L. Hannah were employed specifically for this project; Vaiden was supported in part under contract to the Illinois Department of Energy and Natural Resources. Hannah contributed significantly to the compilation and preparation of the maps and cross sections. The study has drawn heavily from published and unpublished reports, ideas, data, and efforts of many past and present members of Fermilab and ISGS. This study has been strongly supported by the Chief and Chief Emeritus of the State Geological Survey, Morris W. Leighton and Robert E. Bergstrom.

APPENDIX. Selected sample description logs of water wells and test holes for both the bedrock and drift

Cliff Neely No. 4 City of Batavia
Drilled: May 1953
Location: NW SW NW (1500 ft N line, 450 ft W line) Sec. 23, T 39 N, R 8 E; Kane County
Elevation: 716 ft estimated from topographic map ISGS sample set no. 23325
Summary sample study by G. H. Emrich 2/57

	Thickness (ft)	Bottom (ft)
No sample	30	30
SILURIAN SYSTEM		
Dolomite, very silty, light gray to buff, extra fine to very fine crystalline	10	40
Dolomite, silty, light gray to light grayish buff, extra fine to fine, crystalline	25	65
Dolomite, slightly silty, buff to light pinkish buff, extra fine to very fine, crystalline	10	75
Dolomite, silty to very silty, buff to buffish gray, very fine to fine, crystalline	25	100
Dolomite, slightly silty, buffish gray to grayish buff, very fine to medium, crystalline, porous	20	120
Dolomite, silty, buff to buffish gray, very fine to fine, crystalline, trace of glauconite	25	145
ORDOVICIAN SYSTEM		
Cincinnatian Series		
Maquoketa Shale Group		
Dolomite, slightly silty, light gray to light buffish gray, very fine to fine, little medium, crystalline; trace of shale, light greenish gray, weak to top	25	170
Dolomite, slightly cherty, slightly silty to very silty, light gray to light greenish gray, very fine to fine, crystalline; trace of shale, very dolomitic, silty, light green, weak	15	185
Dolomite, slightly cherty, slightly silty, light grayish buff, very fine to fine, crystalline; trace of shale, as above	15	200
Shale, dolomitic, slightly silty, brown to grayish brown, weak; little dolomite, very silty, brown to light buff, very fine to fine, crystalline, speckled (black)	10	210
Dolomite, slightly cherty, very silty, brown to grayish brown, very fine to fine, crystalline speckled (black); shale, as above	5	215
Shale, slightly silty, dolomitic, light greenish buff to buff, weak; dolomite, very silty, greenish brown, light buff, very fine to fine, crystalline, slightly speckled (black)	5	220

Dolomite, cherty, very silty, gray to grayish buff, very fine to fine, crystalline, slightly speckled (black)	22	242
Shale, silty, dolomitic, brown to grayish brown, weak, tough; little dolomite, as above	23	265
Shale, as above	28	293
Champlainian Series		
Galena and Platteville Groups		
Dolomite, slightly silty, buff to gray, extra fine to fine, crystalline line	7	300
No samples	530	830
Ancell Group		
St. Peter Sandstone		
Sandstone, white to light buff, very fine to coarse, rounded, frosted, incoherent	15	845
Sandstone, white to light gray, fine to coarse, rounded, frosted, incoherent	5	850
Sandstone, cherty, slightly silty, white to light buff, fine to coarse, rounded, frosted, incoherent	5	855
Prairie du Chien Group		
Oneota Formation		
Dolomite, slightly cherty (oolitic), slightly silty, light buff to pinkish buff, very fine to fine, crystalline	15	870
Dolomite, slightly oolitic, silty, light buff to buff, very fine to medium, crystalline, dolomite crystals	15	885
Dolomite, slightly cherty (oolitic), silty, pinkish buff to light buff, very fine to fine, crystalline	12	897
Sandstone, slightly dolomitic, white to light buff, fine to coarse, few granules, rounded, incoherent; shale, slightly sandy, light greenish gray to light gray, weak	13	910
Shale, dolomitic, slightly cherty, red to brownish red, little purple, weak	5	915
Sandstone, white to light gray, fine to coarse, few granules, rounded, incoherent, little compact; dolomite, slightly sandy, light gray to light pinkish buff, extra fine to fine, crystalline	10	925
Dolomite, slightly silty, light gray to grayish buff to pinkish buff, extra fine to fine, crystalline	25	950
Dolomite, very silty (coarse), light gray to grayish buff, extra fine to very fine, crystalline	15	965
CAMBRIAN SYSTEM		
Potosi Dolomite		
Dolomite, silty to slightly silty, grayish buff to buff, extra fine to fine, crystalline, little geoditic quartz	30	995
Dolomite, slightly silty and argillaceous, buff to grayish buff, very fine to fine, crystalline, geoditic quartz	20	1,015
Dolomite, slightly silty, buff to brownish buff, extra fine to fine, crystalline	10	1,025

Dolomite, slightly silty, buff to pinkish or reddish buff, very fine to fine, crystalline	18	1,043
Dolomite, silty to very silty, buff to buffish red, very fine to fine, crystalline, slightly sandy at base	23	1,066
Franconia Formation		
Shale, glauconitic, silty, gray to light greenish gray, weak, little brittle; little dolomite at base, glauconitic, extremely silty, gray, very fine to fine, crystalline	16	1,082
Sandstone, glauconitic, dolomitic, light gray to light buffish gray, fine to medium, incoherent, little compact	11	1,093
Shale, glauconitic, sandy, silty, gray to greenish gray, weak; dolomite at base, glauconitic, very sandy, gray to greenish gray, fine, crystalline	22	1,115
Shale, slightly glauconitic and silty, gray to light greenish gray, weak	10	1,125
Dolomite, very sandy, glauconitic, gray to greenish gray, very fine to fine, crystalline; sandstone, glauconitic, light gray, fine to medium, little coarse, incoherent	17	1,142
Ironton Sandstone		
Sandstone, dolomitic, slightly silty, light gray to light buff, fine to coarse, incoherent, little compact	18	1,160
Sandstone, slightly dolomitic, light gray to light buff, very coarse to coarse, granules, little medium to fine, incoherent, little compact	10	1,170
Sandstone, very silty, slightly dolomitic, light gray to light buff, very fine to very coarse, few granules, incoherent, little compact	10	1,180
Sandstone, slightly silty, white to light gray, very fine to medium, little coarse to very coarse, incoherent	35	1,215
Sandstone, dolomitic, light gray to light buff, very fine to medium, little coarse to very coarse, incoherent, little compact	12	1,227
Sandstone, white to light gray, fine to coarse, rounded, incoherent	53	1,280
Galesville Sandstone		
Sandstone, silty to slightly silty, white to light gray, very fine to coarse, rounded, incoherent	20	1,300
Sandstone, white to light gray, very fine to fine, little medium to coarse, rounded, incoherent	15	1,315
No sample	5	1,320
Eau Claire Formation		
Sandstone, white to light buff, very fine to coarse, rounded, incoherent; dolomite, very silty, grayish brown, very fine to fine, crystalline	10	1,330
Sandstone, very silty, light buff to white, very fine to fine, little medium, incoherent; little dolomite, very sandy, brownish gray, very fine, crystalline	5	1,335
Shale, slightly silty and dolomitic, buffish gray to gray, weak, little brittle to tough	10	1,345
Shale, slightly glauconitic and dolomitic, gray to greenish gray, weak, little brittle	10	1,355
Shale, slightly silty, buffish gray, weak	3	1,358

ISGS 7
Drilled: July 30, 1971
Location: SE SW SE (20 ft S line, 1650 ft E line of SE) Sec. 36, T 40 N, R 3 E; De Kalb County,
Elevation: 865 ft
Summary sample study by J. P. Kempton and others 1972-1984
Reed, P. C., 1976, Data from controlled drilling program in Boone and De Kalb Counties, Illinois, EGN 77, Core no. 10661

	Thickness (ft)	Bottom (ft)
QUATERNARY SYSTEM		
Wedron Formation		
Tiskilwa Till Member		
Till, loamy clay, mottled yellow-brown with pink clast, calcareous	11.5	11.5
Till, loamy clay, red-brown, calcareous	109.5	121
Glasford Formation		
Sand, fine grained, brown, well sorted, with silt, some organic material; (at base) predominantly silt, some clay, calcareous	29	150
Till, loamy, mottled light yellow brown, oxidized, calcareous	7	157
Clay, silty, gray brown, calcareous	13	170
Till, loamy, brown with pink cast, calcareous	24	194
Sand, loamy, pale brown, with gravel, calcareous	14	208
Silt, light yellow-brown with olive cast, some organics, bedded, calcareous	6.5	214.5
Sand, fine to coarse grained, well sorted, light brown gray, some fine gravel, calcareous	32.5	247
Sand, fine, well sorted, light brown gray, calcareous	8	255
Sand, fine to medium, well sorted, light brown gray, calcareous	20	275
Sand, very fine, pale brown, calcareous	16	291
Sand, fine, bedded, pale brown, grading to silt, pale brown, clayey toward base, calcareous	23	314
Sand, fine to medium, yellow brown, oxidized, loose, non-calcareous	10?	324?
Sand, gravel, pebbly, with silt, light olive brown, somewhat calcareous, paleosol	10?	334
Gravel, with pebbles, silt and clay, light yellow brown, calcareous	13.5?	347.5
Sandy loam, olive yellow, oxidized, calcareous	5.5	353
Sand, medium, light yellow brown, with fine gravel, calcareous	31	384
Sand, medium, light yellow brown, with fine gravel and cobbles, calcareous	5	389
		Total Depth

ISGS 25
Drilled: June 6, 1972
Location: NE NE NW (5000 ft S line, 3000 ft E line) Sec. 13, T 40 N, R 7 E; Kane County
Elevation: 785 ft
Summary sample study by J. P. Kempton and others 1972-1984
Reed, P. C., 1975, Data from controlled drilling program in Kane County, Illinois, EGN 75, Core no. 10170

	Thickness (ft)	Bottom (ft)
QUATERNARY SYSTEM		
Modern Soil		
Topsoil, sandy, dark gray	.5	.5
Equality Formation		
Clay, sandy, mottled gray brown	3.5	4
Sand, fine, silty, brown	5.5	9.5
Silt, clayey, gray, bedded	4.5	14
Wedron Formation		
Malden Till Member		
Clay, silty, gray, till?	5	19
Sand, very fine grained, brown gray, with wood fragments, clay seams	3	22
Sand, silty, gray, with gravel seams	4	26
Tiskilwa Till Member		
Till, gray-brown with pink cast, not oxidized	9	35
Till, silty, gray brown, oxidized	6?	41
Robein Silt		
Silt, brown gray, oxidized, organic (peat)	3.5	44.5
Silt, gray, oxidized, calcareous	7	51.5
Glasford Formation		
Till, silty to sandy clay, gray to brown gray, with gravel, boulders	18.5	70
Till, clayey to sandy silt, gray to brown gray with boulders, sand and gravel seams	21.5	91.5
ORDOVICIAN SYSTEM		
Maquoketa Shale Group		
Shale	16.5	108
		Total Depth

REFERENCES

Algermissen, S. T., 1969, Seismic risk studies in the United States: World Conference on Earthquake Engineering, 4th, Proceedings of the Chilean Association for Seismology and Earthquake Engineering, Santiago, Chile, reprint, p. 1-10.

Algermissen, S. T., D. M. Perkins, P. C. Thenhaus, S. L. Hanson, and B. L. Bender, 1982, Probabilistic estimates of maximum acceleration and velocity in rock in the contiguous United States: USGS Open File Report 82-1033.

American Society of Testing and Materials, 1982, Annual Book of ASTM Standards, Part 19, Natural Building Stones, Soil and Rock, Philadelphia, Pa., p. 492.

Baker, S., A. Elwyn, J. Lach, and A. Read, 1983, Tunneling beyond the Fermilab Site: Fermilab Report TM-1218.

Berg, R. C., J. P. Kempton, and A. Stecyk, 1984, Geology for planning in Winnebago County: Illinois State Geological Survey Circular 531, 69 p.

Bergstrom, R. E., K. Piskin, and L. R. Follmer, 1976, Geology for planning in the Springfield-Decatur region, Illinois: Illinois State Geological Survey Circular 497, 76 p.

Brossman, J., 1982, Surficial geology of Kendall County: M.S. thesis, Northern Illinois University.

Buschbach, T. C., 1964, Cambrian and Ordovician strata of northeastern Illinois: Illinois Geological Survey Report of Investigations 218, 90 p.

Coleman, D. D., 1976, The origin of drift-gas deposits as determined by radiocarbon dating of methane: Ninth International Radiocarbon Conference, University of California, Los Angeles amd San Diego, June 20–26, 1976.

Frye, J. C., H. D. Glass, J. P. Kempton, and H. B. Willman, 1969, Glacial tills of northwestern Illinois: Illinois State Geological Survey Circular 437, 47 p.

Gilkeson, R. H., and A. A. Westerman, 1976, Geology for planning in Kane County, *in* Geology for Planning in Northeastern Illinois, II: Illinois State Geological Survey open file report prepared for the Northeastern Illinois Planning Commission.

Gross, D. L., 1969, Glacial geology of Kane County, Illinois: Ph.D. thesis, University of Illinois at Urbana-Champaign, 211 p.

Gross, D. L. (compiler), 1970, Geology for planning in De Kalb County: Illinois State Geological Survey Environmental Geology Notes 33, 26 p.

Hackett, J. E., 1960, Groundwater geology of Winnebago County: Illinois State Geological Survey Report of Investigations 213, 63 p.

Heigold, P. C., 1972, Notes on the earthquake of September 15, 1972, in northern Illinois: Illinois State Geological Survey Environmental Geology Notes 59, 15 p.

Horberg, L., 1950, Bedrock topography of Illinois: Illinois State Geological Survey Bulletin 73, 111 p.

Hughes, G. M., P. Kratz, and R. A. Landon, 1966, Bedrock aquifers of northeastern Illinois: Illinois State Geological Survey Circular 406, 15 p.

Huson, R., 1983, Potential 20 TeV site in Illinois-De Kalb, *in* Slansky, Site Atlas for the Superconducting Super Collider, Los Alamos National Laboratory.

Kemmis, T. J., 1978, Properties and origin of the Yorkville Till Member at the National Accelerator Site, northeastern Illinois: M.S. thesis, University of Illinois, Urbana-Champaign, 331 p.

Kemmis, T. J., 1981, Importance of the regelation process to certain properties of basal tills deposited by the Lawrentide ice sheet in Iowa and Illinois: Annals of Glaciology, 2, p. 147-152.

Kempton, J. P., 1963, Subsurface stratigraphy of Pleistocene deposits of central-northern Illinois: Illinois State Geological Survey Circular 356, 43 p.

Kempton, J. P., 1966, Radiocarbon dates from Altonian and Two Creekan deposits at Sycamore, Illinois: Illinois Academy of Science Transactions, v. 59, no. 1, p. 39.

Kempton, J. P., J. E. Bogner, and K. Cartwright, 1977, Geology for planning in northeastern Illinois, VIII. Regional Summary: Illinois State Geological Survey unpublished maps and open file report, prepared for the Northeastern Illinois Planning Commission.

Kempton, J. P., and D. L. Gross, 1971, Rate of advance of the Woodfordian (late Wisconsinan) glacial margin in Illinois: Stratigraphic relations and radiocarbon evidence: Geological Society of America, v. 82, p. 3245-3250.

Kempton, J. P., and J. E. Hackett, 1968a, The Late-Altonian (Wisconsinan) glacial sequence in northern Illinois, *in* Means of Correlation of Quaternary Successions: Proceedings of the VII Congress of INQUA, University of Utah Press, v. 8, p. 535-546.

Kempton, J. P., and J. E. Hackett, 1968b, Stratigraphy of the Woodfordian and Altonian drifts of northern Illinois, *in* The Quaternary of Illinois: University of Illinois College of Agriculture Special Publication 14, p. 27-34.

Kempton, J. P., R. C. Berg, H. D. Glass, L. R. Follmer, in preparation, Revision of the stratigraphy and nomenclature on north-central Illinois tills: A preliminary report.

Kolata, D. R., and T. C. Buschbach, 1976, Plum River Fault Zone of northwestern Illinois: Illinois State Geological Survey Circular 491, 20 p.

Kolata, D. R., T. C. Buschbach, and J. D. Treworgy, 1978, The Sandwich Fault Zone of northern Illinois: Illinois State Geological Survey Circular 505, 26 p.

Kolata, D. R., and A. M. Graese, 1983, Lithostratigraphy and depositional environments of the Maquoketa Group (Ordovician) in northern Illinois: Illinois State Geological Survey Circular 528, 49 p.

Landon, R. A., and J. P. Kempton, 1971, Stratigraphy of the glacial deposits at the National Accelerator Laboratory site, Batavia, Illinois: Illinois State Geological Survey Circular 456, 21 p.

Lineback, J. A., 1979, Quaternary deposits of Illinois: Illinois State Geological Survey Map.

McComas, M. R., 1969, Drift thickness of De Kalb County: Illinois State Geological Survey unpublished open file map.

McGinnis, L. D., J. P. Kempton, and P. C. Heigold, 1963, Relationship of gravity anomalies to a drift-filled bedrock valley system in northern Illinois: Illinois State Geological Survey Circular 354, 24 p.

Meents, W. F., 1960, Glacial-drift gas in Illinois: Illinois State Geological Survey Circular 292, 58 p.

Nuttli, O. W., and R. B. Herrmann, 1978, U.S. Army Engineers Waterways Experiment Station Miscellaneous Paper S-73-1.

Piskin, K., and R. E. Bergstrom, 1967, Glacial drift in Illinois: Thickness and character: Illinois Geological Survey Circular 416, 33 p.

Piskin, K., and R. E. Bergstrom, 1975, Glacial drift in Illinois: Thickness and character: Illinois Geological Survey Circular 490, 35 p.

Slansky, R., 1983, Site Atlas for the Superconducting Super Collider, Los Alamos National Laboratory, Los Alamos, New Mexico.

Terzaghi, K., and R. B. Peck, 1967, Soil Mechanics in Engineering Practice (second ed.): John Wiley and Sons, New York, 729 p.

Wickham, S. S., 1979, The Tiskilwa Till Member, Wedron Formation: A regional study in northeastern Illinois: M.S. thesis, University of Illinois, Urbana-Champaign, 229 p.

Wickham, S. S., and W. H. Johnson, 1981, The Tiskilwa Till, a regional view of its origin and depositional processes: Annals of Glaciology, 2, p. 176–182.

Willman, H. B., 1971, A summary of geology in the Chicago area: Illinois State Geological Survey Circular 460, 77 p.

Willman, H. B., 1973, Rock stratigraphy of the Silurian System in northeastern and northwestern Illinois: Illinois State Geological Survey Circular 479, 55 p.

Willman, H. B., E. Atherton, T. C. Buschbach, C. Collinson, J. C. Frye, M. E. Hopkins, J. A. Lineback, and J. A. Simon, 1975, Handbook of Illinois stratigraphy: Illinois State Geological Survey Bulletin 95, 261 p.

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

Willman, H. B., and D. R. Kolata, 1978, The Platteville and Galena Groups in northern Illinois: Illinois State Geological Survey Circular 502, 75 p.

GLOSSARY

ablation till — after deposition, till has been modified by water and mass wasting processes. Ablation till may be more sandy and less densely compacted than unmodified till.

accretion gley — fine-grained and organic materials, which slowly accumulate in poorly drained depressions with intermittent water saturation.

alluvium — the general term for all sediments deposited in land environments by streams.

argillaceous — rock composed of or containing clay-size particles; rock containing an appreciable amount of clay.

artesian conditions — where an aquifer is confined between impermeable layers and the water in the pores of the aquifer is not open to atmospheric pressure, but occurs at greater pressures.

artesian well — one in which the water level rises above the top of a confined aquifer, whether or not the water flows at the land surface.

attenuation capacity — the ability of a material to adsorb and return certain anions and cations in an exchangeable state.

basement — the crust of the earth below sedimentary rocks. In Illinois, these rocks consist primarily of red granite.

cation exchange capacity — the capacity of a soil to sorb or hold cations and to exchange species of these ions in reversible chemical reactions; important for studies of soil fertility and nutrition studies, as well as for soil genesis and containment attenuation.

chert — hard, dense, cryptocrystalline, sedimentary rock, composed predominantly of silica.

colluvium — a body of sediment that has been deposited by any process of mass wasting or by overland flow.

cross section — a diagram or drawing that shows geologic features transected by a given plane.

dolomite — a variety of limestone rich in magnesium carbonate.

drift — a general term applied to all rock material (clay, sand, gravel, boulders) transported by a glacier and deposited directly by or from ice, or by water flowing from a glacier.

drusy — containing many small, irregular cavities lined with small projecting crystals.

end moraine — a ridge-like accumulation of drift, deposited by a glacier along its front margin.

esker — a body of ice-contact stratified drift shaped into a long narrow ridge, commonly sinuous.

flood plain — that part of any stream valley that is inundated during floods.

fluvial — produced by the action of streams or rivers.

formation — in lithostratigraphy, the primary rock units that possess distinct lithologic features, reflecting a genetic relationship.

friable — easily broken, poorly cemented rock.

glauconite — dull green, earthy or granular minerals of the mica group, an iron-clay indicative of a marine environment.

kame — a body of ice-contact stratified drift shaped as a short, steep-sided knoll or hummock.

kame moraine — a terminal moraine that contains numerous kames.

kettle — a closed depression in drift, created by the melting out of a mass of underlying ice.

lacustrine — produced by or formed in a lake.

leachate — a solution obtained by leaching; water percolated through soil containing soluble substances, and containing amounts of these substances in solution.

lithology — a description of rocks based on characteristics such as color, structures, mineralogic composition, and grain size.

loess — wind-deposited silt, usually containing some clay and some fine sand.

member — subdivision of a formation, generally of distinct lithologic character or of local extent.

mineral — a naturally formed chemical element or compound having a definite chemical composition, and usually, a characteristic crystal form.

nonattenuated ions — ions which are not adsorbed onto materials that they pass through due to their chemical composition and concentration.

oolitic — composed of small, round accretionary bodies, generally of calcium carbonate.

outlier — area or group of rocks surrounded by outcrops of older age.

outwash plain — sheet-like deposits of sand and gravel transported away from the ice by meltwater streams along the front of the glaciers.

peat — a brownish, light weight mixture of partly decomposed plant tissues in which the parts of plants are easily recognized.

perched water table — unconfined groundwater separated from an underlying main body of groundwater by an unsaturated zone.

permeability — capacity of a material to transmit a fluid. Degree of permeability depends upon the size and shape of the interconnecting voids. It is measured by the rate at which a fluid of standard viscosity can move a given distance through a given interval of time.

release rate — rate at which attenuated ions are released into the groundwater.

soil — the unconsolidated mineral matter on the surface of the earth; it has been subjected to and influenced by genetic and environmental factors of parent material, climate, organisms and topography all acting over a period of time.

solution collapse — collapse due to the solution of underlying rock, typically in limestone.

stratigraphy — that branch of geology that treats the formation, composition, sequence and correlation of the rock units as part of the earth's crust.

tectonic — produced by earth movements.

Tesla — a unit of magnetic field strength equal to 10,000 Gaus.

till — a nonstratified glacial deposit containing a wide range of grain sizes.

till plain — an extensive area, with a flat to undulating surface underlain by till, which is commonly covered by ground moraine and subordinate end moraines.

topographic map — map showing the topographic features of a land surface generally by means of contour lines.

transmissibility — rate of flow (gal/day) through a vertical section of an aquifer with a defined width and hydraulic gradient.

valley train — a long narrow body of outwash confined within a valley.

Graphic Artists: Jacqueline Hannah, Pamella Foster
Typographer: Gail Taylor

Kempton, J. P. (John P.)
Geological-geotechnical studies for siting the Superconducting Super Collider in Illinois : preliminary geological feasibility report / J. P. Kempton . . . and others. — Champaign, IL : Illinois State Geological Survey, 1985.
63 p. ; 28 cm. — (Environmental geology notes ; 111)

1. Geology—Illinois, Northeastern. 2. Particle accelerators—Siting—Illinois. 3. SSC. I. Title. II. Title: Preliminary geological feasibility report. III. Series.

Printed by authority of the State of Illinois/1985/3000