COOPERATIVE GROUNDWATER REPORT 10

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GEOLOGY, HYDROLOGY, AND WATER QUALITY OF THE CAMBRIAN AND ORDOVICIAN SYSTEMS IN NORTHERN ILLINOIS

Adrian P. Visocky, Marvin G. Sherrill, and Keros Cartwright

STATE OF ILLINOIS
DEPARTMENT OF ENERGY AND NATURAL RESOURCES

1985

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ABSTRACT

Cambrian and Ordovician strata provide much of the groundwater supply for approximately 250 municipalities and 150 industries in the northern half of Illinois. This report represents the cooperative effort of the Illinois State Water Survey, Illinois State Geological Survey, and U.S. Geological Survey to provide a current hydrogeologic evaluation of this water resource.

The Cambrian and Ordovician aquifers average approximately 1000 feet in thickness. Although numerous alternating layers of sandstones, limestone, and dolomites impart a heterogeneous character to them, these units are hydraulically interconnected and behave as a single aquifer. Hydraulic properties within the aquifers are generally affected by local or regional changes in thickness of the Ancell and Ironton-Galesville aquifers. Recharge occurs principally by vertical percolation of precipitation in areas where the Galena-Platteville Unit is the uppermost bedrock. Additional recharge in heavily pumped areas occurs through leakage across the Maquoketa Confining Unit.

This report introduces formal hydrostratigraphic names in describing major aquifers as divided into three aquisystems, each of which is subdivided into aquigroups. The three aquisystems and their aquigroups are: 1) Non-Indurated Rock Aquisystem, consisting of the Prairie Aquigroup - local and intermediate flow systems in alluvium, glacial drift, and Cretaceous and Tertiary sediments; 2) Indurated Rock Aquisystem, divided into a) Upper Bedrock Aquigroup - local and intermediate flow systems with connection to the Prairie Aquigroup, b) Mississippi Valley Bedrock Aquigroup - intermediate and regional flow systems in indurated rock that are always confined by indurated rock aquitards and whose base is the top of the Maquoketa Shale Group, c) Midwest Bedrock Aquigroup - intermediate and regional flow systems whose top is the top of the Maquoketa Shale Group or other confining units and whose bottom is at the top of the Eau Claire Formation or stratigraphically higher, and d) Basal Bedrock Aquigroup - intermediate and regional flow systems below the shale units of the Eau Claire Formation and above the crystalline basement rocks; and 3) Crystalline Rock Aquisystem, in which there are no significant aquifers in Illinois. The Midwest Bedrock Aquigroup

is basically the same as the "Cambrian-Ordovician Aquifer" in northeastern Illinois that has been previously described. It is the chief topic of concern in this report.

The practical sustained yield of the Midwest Bedrock Aquigroup was estimated to be 65 mgd (million gallons per day) in northeastern Illinois. Pumpage has exceeded this amount since about 1958. In north-central and northwestern Illinois, development has not exceeded the practical sustained yield, which is probably at least as great as that for northeastern Illinois. The practical sustained yield in western Illinois is limited by the amount of lateral inflow that can be induced and also by poor water quality.

Individual wells in the Midwest Bedrock Aquigroup in northern Illinois usually exceed 500 gpm (gallons per minute) in yield, but in western Illinois typical well yields are smaller. Total withdrawals from deep wells between 1971 and 1980 averaged 278.6 mgd. The largest withdrawals occur in Cook, DuPage, Kane, and Will Counties. Withdrawals have caused water levels to decline as much as 900 feet in parts of Cook, DuPage, and Will Counties. Dewatering of the upper aquifers in the Midwest Bedrock Aquigroup has begun in portions of the above four counties.

Groundwater in the "unconfined" area of the Midwest Bedrock Aquigroup is chemically homogeneous and low in total dissolved solids. However, significant vertical and areal changes in the chemical character of groundwater occur in the confined area. As water moves away from the recharge area to the east and south, it increases in total dissolved solids.

INTRODUCTION

Physical Setting

The Cambrian and Ordovician aquifers described in this report underlie most of the northern half of Illinois (fig. 1). The land surface configuration of most of this part of the state is the result of glaciation, and the physiographic features shown on figure 2 largely reflect this glaciation.

The study area is essentially a broad prairie plain, with the exception of the Rock River Hill Country and the Wisconsin Driftless Section in the northwest corner of the state (fig. 2). The soils are largely deep, black, and rich in organic content and lime, have good moisture-retaining capabilities, and form part of one of the richest agricultural belts in the world.

Relief in the study area ranges from a high of 1235 feet above sea level at Charles Mound in the northwest corner of the state (Jo Daviess County) to about 580 feet above sea level at Lake Michigan and about 420 feet above sea level at the juncture of the Illinois and Mississippi Rivers near Grafton (Jersey County). The greatest differences in local relief are near major valleys, particularly in the uplands of the northwest.

The climate in northern Illinois is continental, with warm summers and cold winters (fig. 3). The mean January temperatures range from about 20°F in the northwestern tip of the state (Jo Daviess County) to about 32°F near the confluence of the Illinois and Mississippi Rivers. Mean temperatures in July range from about 74°F to 80°F for the entire area. The length of the growing season for most of the area is in the 160- to 180-day range.

Average annual precipitation, like temperature, generally increases from north to south (fig. 4). The range of precipitation is from about 32 inches per year near Lake Michigan to about 38 inches per year in the southern part of the study area. February is normally the driest month, and June is the wettest.

A drainage map of Illinois is shown in figure 5. The major drainage ways are the Mississippi River and its tributaries along the western border of the study area, and the Illinois River and its tributaries in most of the central and eastern parts of the study area. In northeastern Illinois water

Figure 1. Location of study area

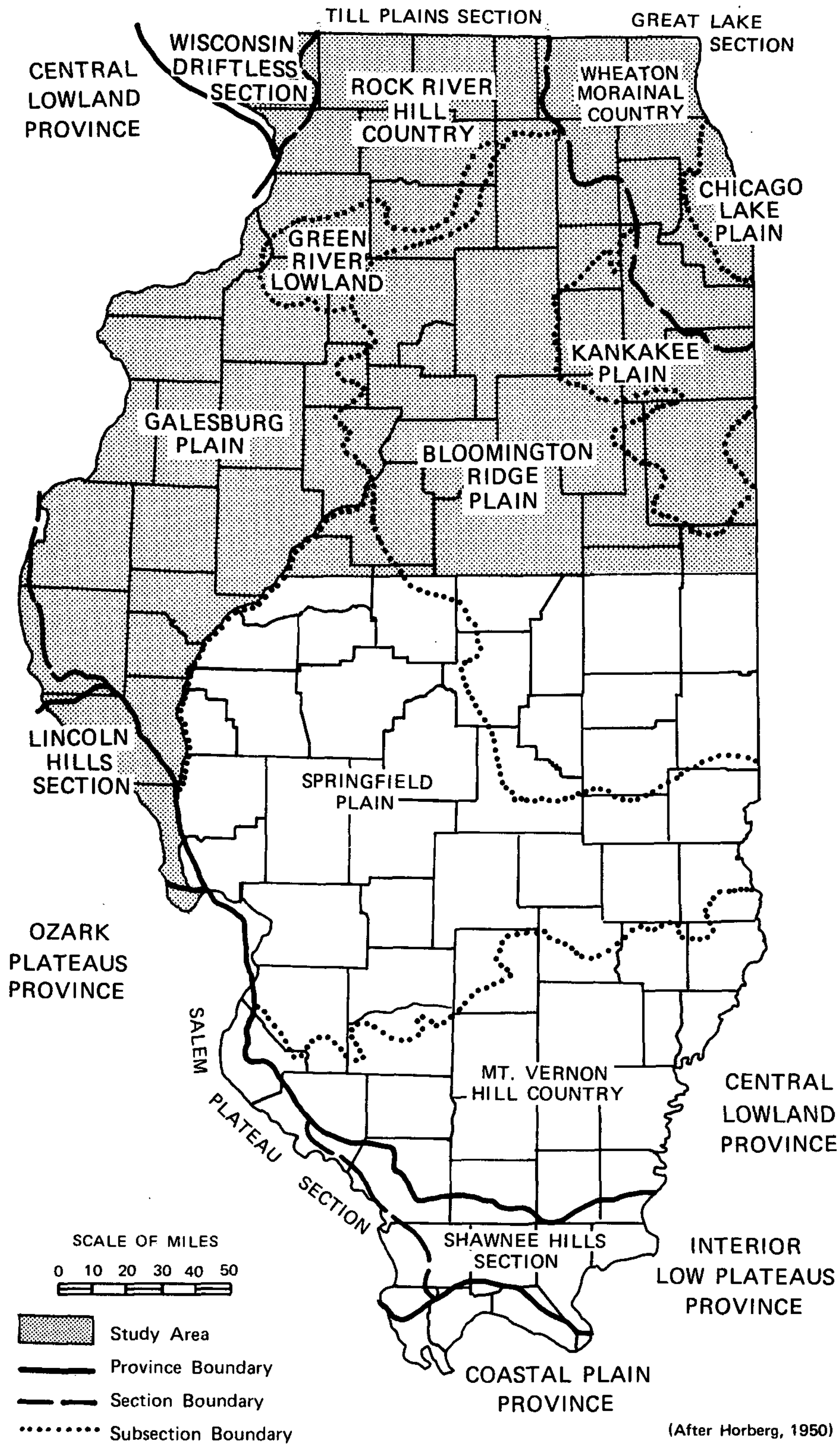


Figure 2. Physiographic divisions in Illinois

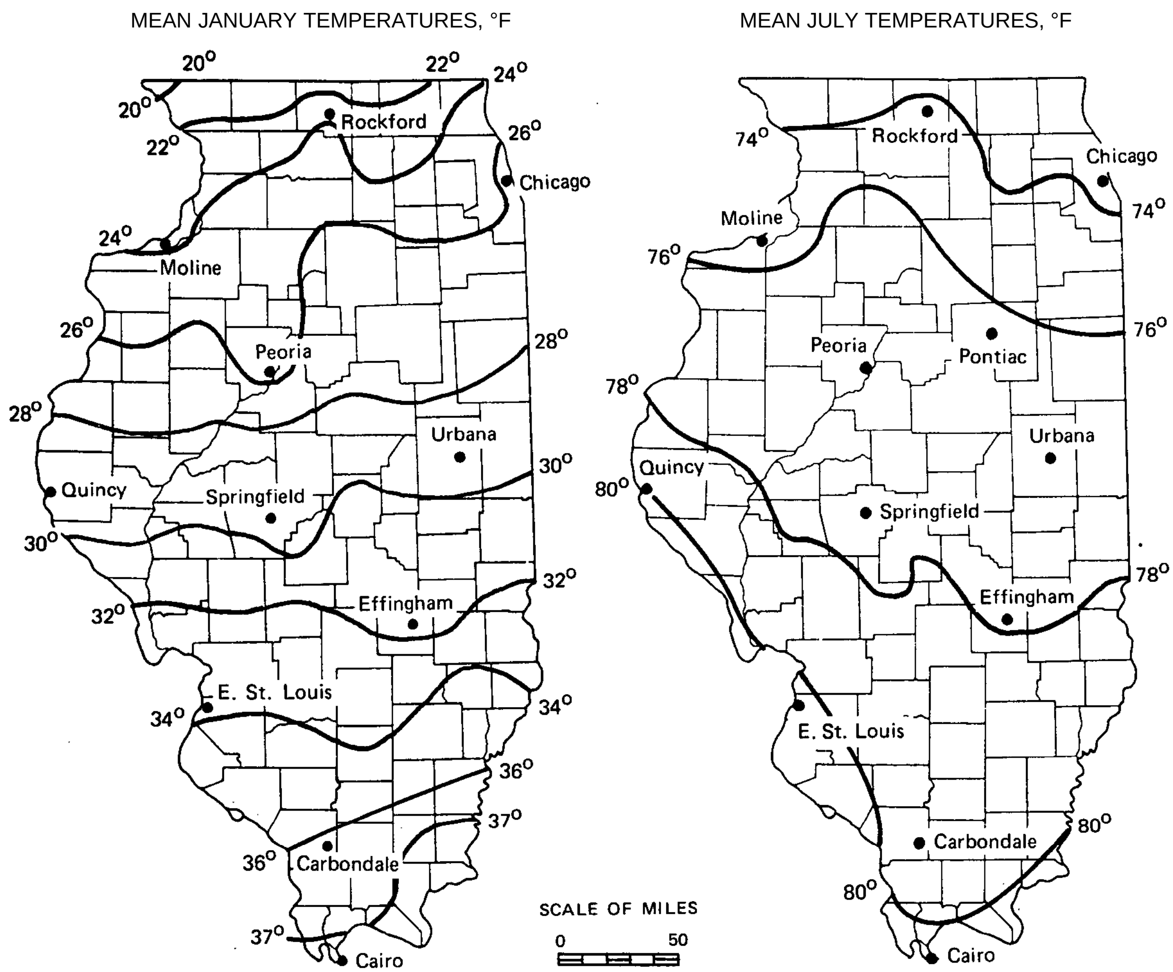


Figure 3. Mean January and July temperature for Illinois

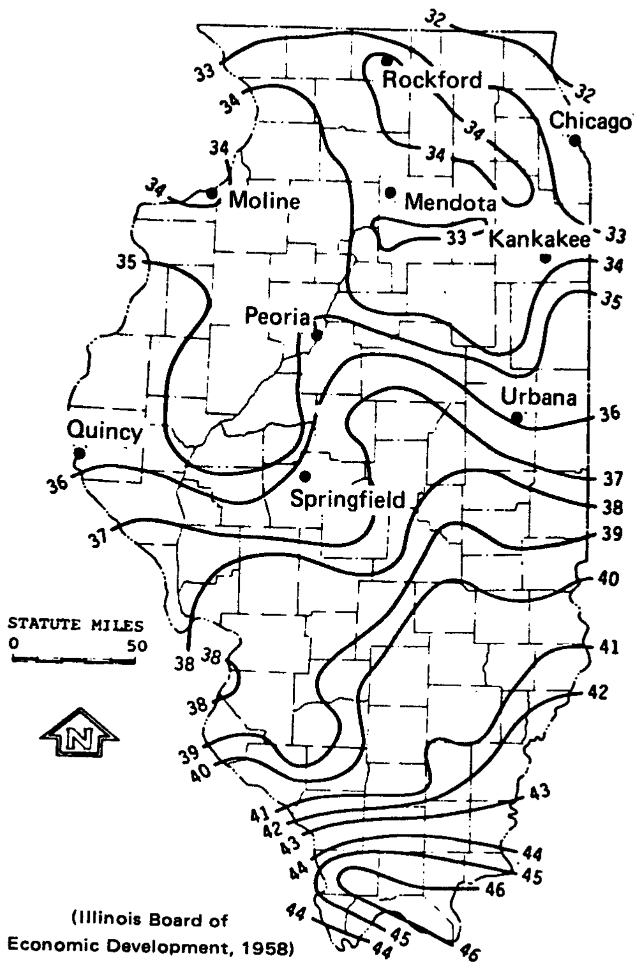


Figure 4. Average annual Illinois precipitation, in inches, derived from 1901-1944 data

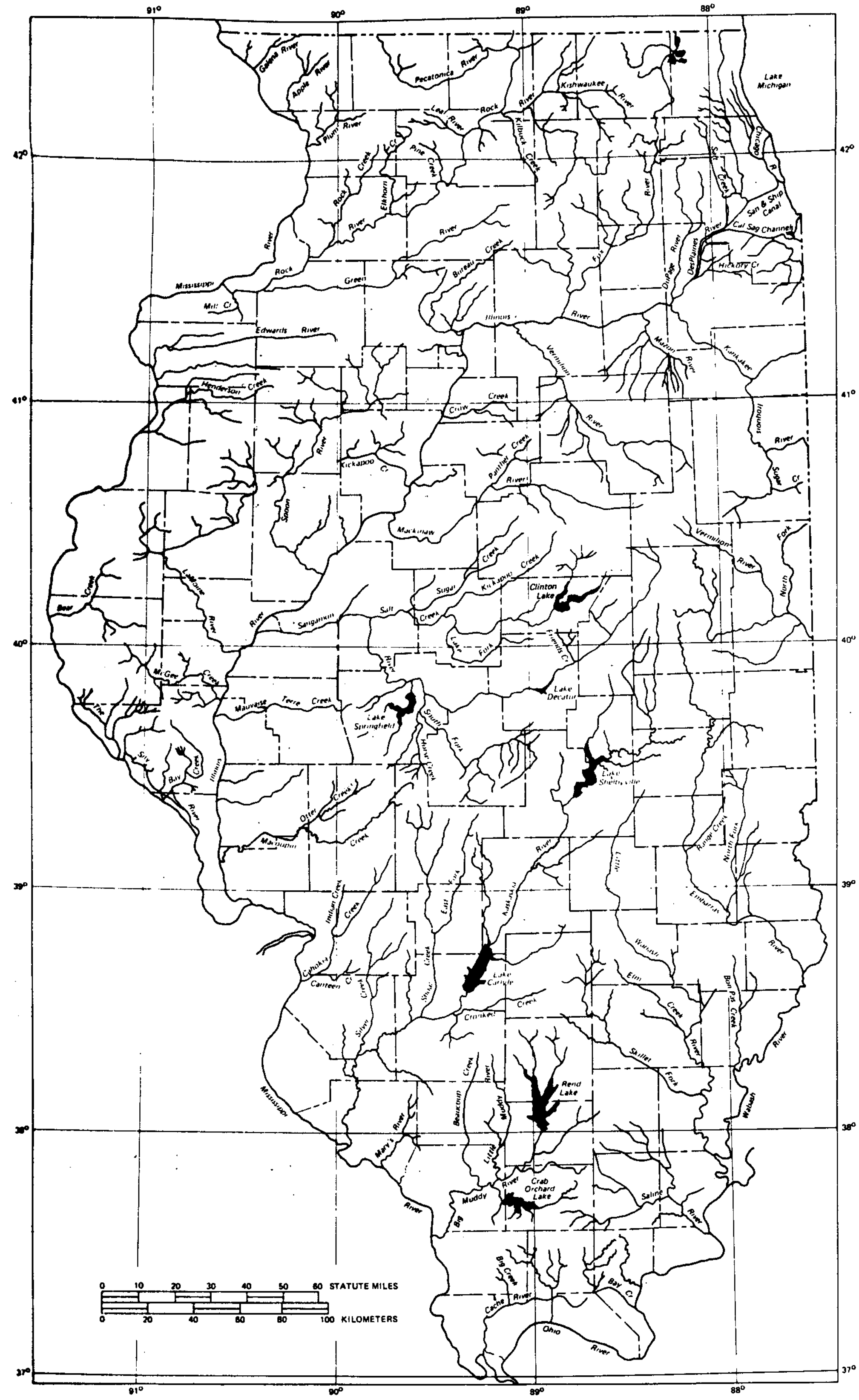


Figure 5. Drainage map of Illinois

drains into Lake Michigan; the drainage divide is only a few miles from the lake, so this drainage basin in Illinois is relatively small.

Purpose and Scope

Cambrian and Ordovician strata include many of the freshwater-bearing rocks in northern Illinois, and many cities, villages, industries, and individuals are dependent on these aquifers. Protection and management of this important groundwater resource is a major concern of state and local planning and management agencies, as well as water regulatory groups. Management decisions need to be based on a fundamental understanding of the aquifer system. The geologic, hydrologic, and chemical characteristics of the system need to be understood, as do the effects of past, present, and future pumpage.

This report represents the cooperative efforts of the U.S. Geological Survey, Illinois State Water Survey, and Illinois State Geological Survey to provide a current hydrogeologic evaluation of the Cambrian and Ordovician units in Illinois. The report presents information on the geology, hydrology, and water quality of the Cambrian and Ordovician units, and includes a history of groundwater development. Basic data are presented as maps, graphs, and tables to help those who formulate policy on water resource planning and development.

The investigation began in 1978 and has been conducted concurrently with the Northern Midwest Regional Aquifer System Analysis (RASA) study in Illinois and the nearby states of Wisconsin, Minnesota, Iowa, Missouri, and Indiana.

Methodology

The study utilized previously collected and reported data as well as data collected as a direct result of this investigation. Appendix A is a compilation of geologic, hydrologic, and water quality data for selected or key wells used during the course of this investigation. A description of the well numbering and location system is included. Although this appendix summarizes only a small part of the total data used in the study, it does show representative conditions on a county-by-county basis.

Much of the previously collected data used in this study is in the files of the Illinois State Geological Survey (ISGS) or the Illinois State Water

Survey (ISWS) or is contained in reports by these two agencies. Well drillers' logs and sample cutting analyses were obtained from the ISGS files and evaluated by ISGS and U.S. Geological Survey (USGS) personnel. Logs were utilized to determine stratigraphic contacts from which structural contour and isopach geologic maps were prepared or updated. Hydraulic data from ISWS files were summarized and evaluated, and interpretive maps and tables were prepared. Much of the data concerning water quality analyses, pumpage, and water level information also came from ISWS files or from published reports.

Considerable new data were collected during the course of this investigation. The most notable effort was the drilling, sampling, and testing of a 3460-foot well extending into Precambrian bedrock at Illinois Beach State Park, Lake County, in the extreme northeast corner of Illinois (Nicholas et al., 1984). This test well provided much insight into the geologic, hydrologic, and water quality properties of the aquifers, particularly the deeper Cambrian units, and the depth to and character of the Precambrian basement rock in an area which had not been explored. Select zones in the test well -- including the Galena-Platteville, St. Peter, Ironton-Galesville, and Mt. Simon units -- were tested (with packers used to seal off the selected zones) to provide information on hydraulic and water quality properties of individual units. A suite of geophysical borehole logs were run in the well. Similar packer-testing and logging were conducted at two deep wells in Rockford and Galena. Additionally, several other wells were logged to provide information on well construction design, physical properties of the rock units, and hydraulic characteristics of the aquifers. The logging and packer-testing are summarized in appendix B.

A water level and pumpage survey for the Cambrian and Ordovician aquifers was conducted during the fall of 1980 by ISWS personnel. These data, along with previously collected data, were used in preparing major sections of the report.

Groundwater samples from several wells drawing water from a single aquifer were collected and analyzed. These analyses, plus those obtained from the packer-testing and from other previously sampled wells, provided water quality information summarized on the interpretive maps and in the text of the "Groundwater Quality" section of this report. Representative water quality analyses are shown in appendix C.

Previous Reports and Related Work

The geology and water resources of the Cambrian and Ordovician rocks in northern Illinois (particularly in the Chicago metropolitan area) have been studied in some detail, and several reports have been published that have major sections concerning these rocks. A general discussion was presented by the Illinois Department for Business and Economic Development (Water for Illinois, A Plan for Action, 1967). Horberg (1950) reported on the bedrock topography; stratigraphic features are discussed in detail in the Handbook of Illinois Stratigraphy by Willman et al. (1975). Buschbach (1964) and Willman (1971) discuss the Cambrian and Ordovician strata in northeastern Illinois. Buschbach (1965) also discusses these strata in western Illinois. The Galena and Platteville strata have been reported on by Bristol and Buschbach (1973) and by Willman and Kolata (1978). Emrich (1966) reports on the Ironton and Galesville strata in Illinois and adjacent states.

Groundwater conditions in northeast Illinois are described by Bergstrom et al. (1955); Suter et al. (1959); Hughes and Kraatz (1966); Schicht and Moench (1971); ISWS and Hittman Associates (1973); Schicht and Adams (1977); and Schicht, Adams, and Stall (1976). Hackett and Bergstrom (1956) and Brueckmann and Bergstrom (1968) describe groundwater conditions in northwestern Illinois. Well yields and aquifer conditions are discussed by Walton (1960) and by Walton and Csallany (1962).

Public water supplies and water quality are described by Hanson (1950, 1958, 1961); by Woller et al. (1973-present); by Larson (1963); and by Visocky et al. (1978).

Water use, pumpage, and water level conditions have been described by Walton, Sasman, and Russell (1960); Sasman, Prickett, and Russell (1961); Sasman, Baker, and Patzer (1962); Russell (1963); Walton (1964); Sasman (1965); Sasman and Baker (1966); Sasman, McDonald, and Randall (1967); Sasman, Benson, Dzurisin, and Risk (1973, 1974); Sasman et al. (1977, 1982); and Kirk et al. (1979, 1982).

Water management studies have been described by the Northeastern Illinois Planning Commission (1966, 1974, 1976); Moench and Visocky (1971); Schicht, Adams, and Stall (1976); Keifer and Associates (1977a,b); Singh and Adams (1980); and Visocky (1982).

Steinhilber and Young (1979) presented a plan for a regional study of the Cambrian and Ordovician units. Kontis and Mandle (1980) developed a data base for this same regional study.

Acknowledgments

This investigation was supported in part by funds provided through the University of Illinois by the U.S. Geological Survey, Water Resources Division. Many people in addition to the principal authors were involved in the preparation of this report. Much of the basic geologic data was assembled and evaluated by Susan S. Wickham, Heidi O. Minc, and Robert W. Ringler of the Illinois State Geological Survey. Robert W. Gilkeson of ISGS provided data and consultation concerning the geochemistry of the Cambrian and Ordovician aquifers. Robert T. Sasman and his staff from the Northern Regional Office of the Illinois State Water Survey were very helpful in furnishing water level and pumpage data.

Dean M. Mades and James R. Nicholas of the U.S. Geological Survey prepared major portions of the sections on pumpage and groundwater quality, respectively. They were also much involved in the data collection phases of the project, including the test drilling, borehole logging, packer work, and water quality sampling.

USGS staff who are working on the Northern Midwest Regional Aquifer System Analysis (RASA) study in Wisconsin, Iowa, Indiana, and Missouri, as well as personnel of state agencies in these surrounding states, cooperated in developing "best fit" interpretations along state lines. Helpful suggestions and criticisms were given by many other individuals from USGS, ISGS, and ISWS.

Roger Selburg of the Permit Section, Public Water Supply Division, Illinois Environmental Protection Agency, and Robert Grosso, Park Superintendent of Illinois Beach State Park, were particularly cooperative during this investigation. Many municipal and industry officials, engineers, and water well contractors generously provided geologic, hydrologic, and Water quality data.

Illustrations were prepared by William Motherway, Jr., Linda J. Riggin, and Vicki S. Stewart under the supervision of John W. Brother, Jr. Pamela S. Lovett typed the manuscript and final copy, and Gail Taylor edited the manuscript.

GEOLOGY

Introduction

A set of 15 maps of the thickness and surface configuration of the bedrock units of the northern half of Illinois was prepared. The stratigraphic correlation was coordinated with the other states which are a part of the Northern Midwest Regional Aquifer System Analysis. Well records which provided the data base for the maps were selected on the basis of 1) spacing of at least one well per township; 2) wells penetrating at least the Galena Group and, if possible, into the Ancell Group or Cambrian System; and 3) wells with samples or geophysical logs. In areas of dense well control, key wells were designated by the following criteria:

1) The deepest wells possible
2) Wells with existing samples of well cuttings or geophysical logs which could be studied
3) The most recently drilled wells
4) Wells with previous studies of well cuttings

The maps were then compared to maps from the adjacent states to insure that transitions were smooth across state lines. Both published and unpublished maps from Iowa, Missouri, Wisconsin, and Indiana were used to make final adjustments along state lines.

All new data points selected for this study were field checked for location and elevation and are considered accurate. Points used from previous studies were checked in the office but were not field verified. Any seemingly anomalous points were double checked.

The maps of the Maquoketa and Galena surfaces are considered to be the most accurate, since more data were available for them. The accuracy of the maps diminishes as the Precambrian is approached, since fewer and fewer data points are available for the map preparation.

Precambrian Surface

The map of the top of the Precambrian surface (fig. 6) is based on the 21 control points from wells within Illinois; data from wells in the bordering states of Iowa, Indiana, and Wisconsin; and interpretation of known structural elements present within the state. The new map shows considerable refinement from the map by Bell et al. (1964).

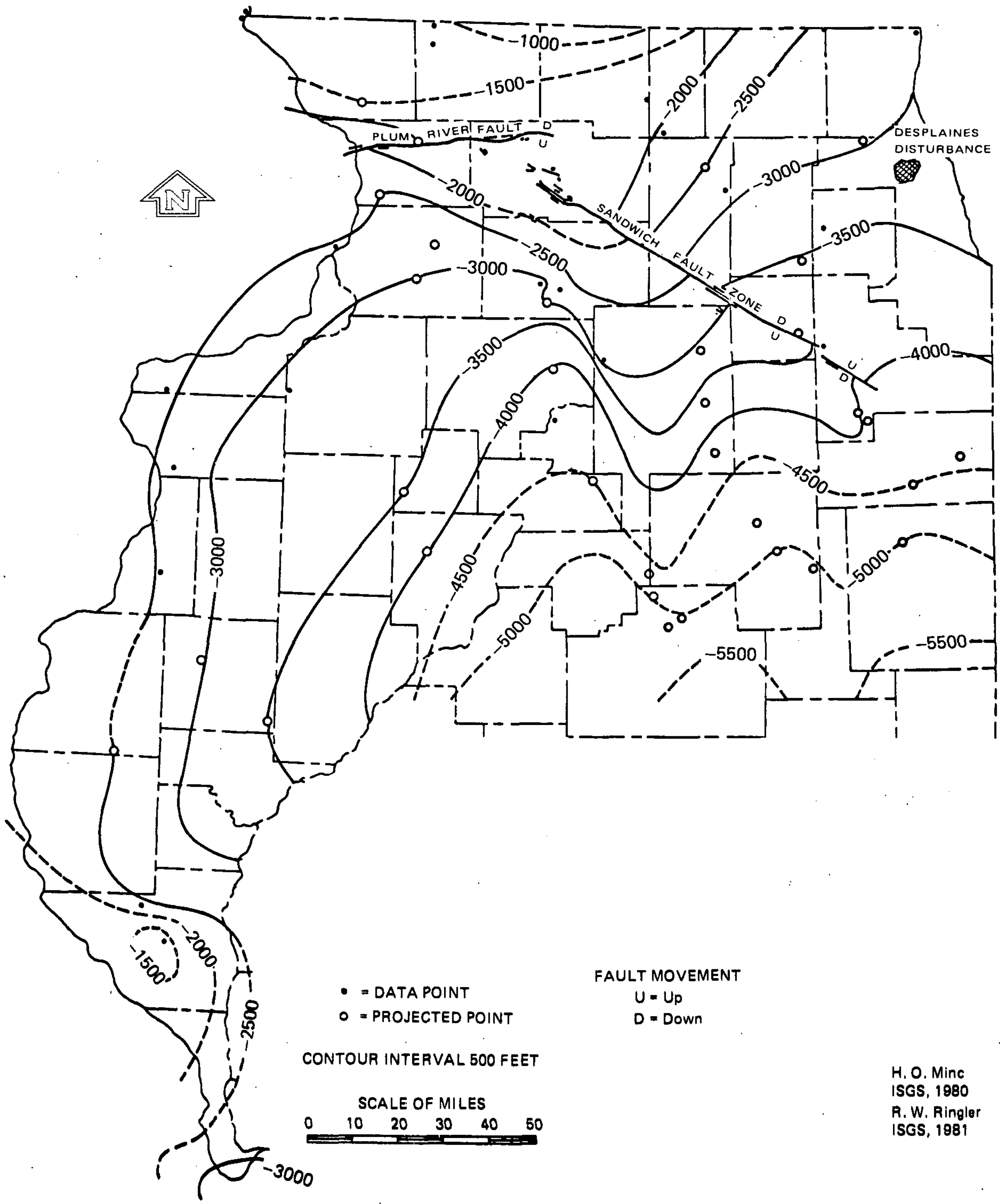


Figure 6. Elevation (MSL) of the top of the Precambrian rocks

Local relief of about 800 feet on the Precambrian surface is shown by comparison of two granite test wells 8 miles apart in Pike County in western Illinois. One well penetrated 440 feet of Eau Claire Formation and 444 feet of Mt. Simon Sandstone before encountering the basement at 2488 feet below mean sea level. The second well encountered only 74 feet of Eau Claire and no Mt. Simon before encountering basement rocks at 1409 feet below mean sea level. The rugged topography of the top of the Precambrian is also revealed by outcrops in the St. Francois Mountains of Missouri. Relief away from these localities, of course, is uncertain; buried Precambrian hills may underlie some of the structural highs in overlying strata.

The Precambrian rocks in Illinois apparently do not have a zone of deep weathering. Most wells encounter fresh-looking igneous rock. Also, the feldspar grains in the arkose that commonly overlies the Precambrian have a fresh appearance. Thus, any weathered material that developed on the basement rocks in Illinois was apparently removed by erosion before deposition of the Paleozoic sediments.

The basement rocks encountered in borings in and immediately adjacent to Illinois are of granitic or closely related composition. Granite, encountered in 17 of the 22 Illinois wells and in the three Iowa wells, is by far the most common rock type. Granodiorite, the next most abundant type, was encountered in four wells, all in northern Illinois. Rhyolite and granophyre were encountered in wells in south-central and southern Illinois. Bradbury and Atherton (1965) describe the petrography of the Precambrian rocks penetrated by wells in Illinois.

Cambrian and Ordovician Systems

The Cambrian and Ordovician rocks can be grouped into seven units that have hydrogeologic significance. These units are: 1) the Mt. Simon Sandstone and the Elmhurst Sandstone Member of the Eau Claire Formation; 2) Proviso and Lombard Members of the Eau Claire Formation that form a major confining unit; 3) the Ironton and Galesville Sandstones; 4) Middle Confining Unit, consisting of the units between the top of the Ironton and Galesville Sandstones and the base of the Ancell Group (St. Peter Sandstone), which include the Cambrian Franconia Formation, Eminence Formation, and Potosi Dolomite, and the Ordovician Prairie du Chien Group; 5) the Ancell Group;

6) the Ottawa Limestone Megagroup, consisting of the Galena and Platteville Groups; and 7) the Maquoketa Shale Group. A discussion of these units follows.

Elmhurst-Mt. Simon Sandstone

The Mt. Simon Sandstone, although not exposed, underlies all of Illinois except in local areas where it failed to cover hills on the eroded Pre-cambrian surface. It ranges in thickness from less than 500 feet in the southwest part of the study area to over 2600 feet in northeastern Illinois in Kendall, Grundy, eastern LaSalle, northeastern Livingston, western Kankakee, and northern Ford and Iroquois Counties (fig. 7). In general, the Mt. Simon consists of fine- to coarse-grained, partly pebbly, friable sand-stone, most of which is coarser-grained, more angular, and'more poorly sorted than younger Cambrian and Ordovician sandstones. It is dominantly white, but can be pink, red, yellow, or light greenish-gray. A basal zone as much as 350 feet thick is strongly arkosic, and beds of red and green micaceous shale occur locally in the upper 300 feet and lower 600 feet of the formation (Buschbach, 1975).

In the Rock Island region of western Illinois, the Mt. Simon is fine- to coarse-grained, poorly sorted, and generally friable, with some more compact zones which are cemented by silica or hematite. It is essentially non-dolomitic. The upper half contains interbedded red shale, and the lower half is pink and arkosic, with the amount of feldspar increasing downward (Buschbach, 1965).

In the vicinity of DeKalb County, the Mt. Simon contains zones of Well-developed cross-bedding in the coarser beds. Beds of red, green, and dark gray shale occur in the upper few hundred feet (Buschbach, 1970).

In the Chicago region, the sandstone is largely medium-grained, but some coarse-grained beds occur, especially in the upper part of the formation. The coarser beds are more abundant to the north, and granules up to 6 mm in diameter are common. The color may be pink, yellow, or white. Red, micaceous, hematitic beds also occur at some places in the northern counties. The sands are generally incoherent to friable and may be arkosic in places (Buschbach, 1964; Suter et al., 1959).

Near the Wisconsin border, the basal sand includes the basal member of the Eau Claire Formation, the Elmhurst Sandstone. The Elmhurst Sandstone is

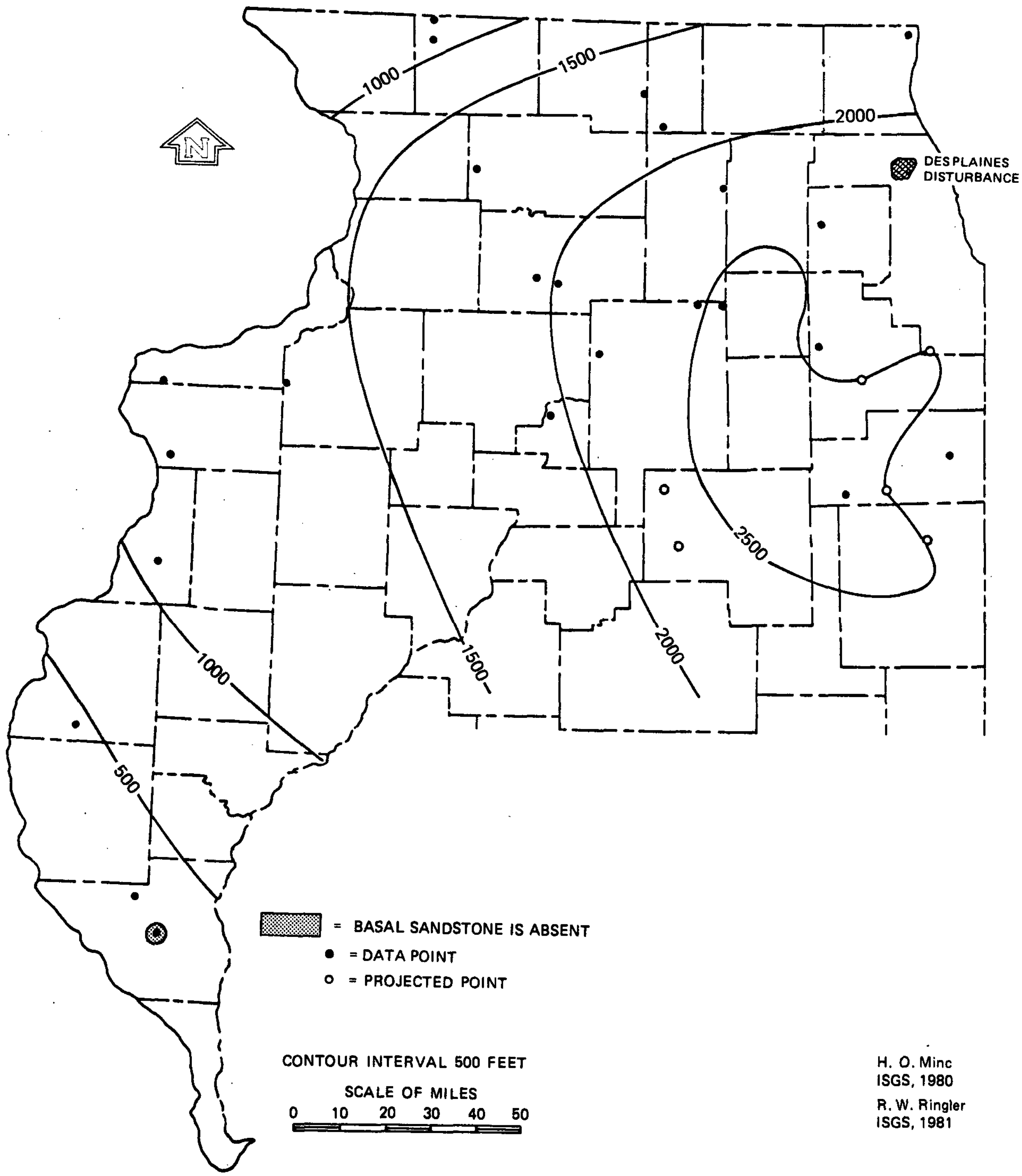


Figure 7. Thickness of the Elmhurst-Mt. Simon Sandstone

widely distributed in the northern half of Illinois and is 10 to 200 feet thick. Most of it is fine- to medium-grained, fossiliferous gray sandstone that contains various amounts of gray shale. Near the Wisconsin border, the amount of shale greatly diminishes and the Elmhurst becomes a fairly Clean sandstone (Willman et al., 1975).

The map of the surface configuration of the combined sandstones (fig. 8) was compiled mainly by using projected points from overlying units. Only 122 wells which penetrated the top of the sand were available for compilation of the map. Therefore, the accuracy of this map is limited, especially with regard to the northernmost part of the area, where the overlying confining unit contains interbedded sandstones.

The map of the thickness of the combined units (fig. 7) is based on even more limited data; only 38 wells with reliable data were available for this map. Much of this map was constructed by interpolation between the Pre-cambrian surface map (fig. 6) and the sandstone surface map (fig. 8). The sandstone is thickest in the eastern part of the study area and thins to the west and south.

Lombard and Proviso Members of Eau Claire Formation (Basal Sandstone Confining Unit)

The Basal Sandstone Confining Unit consists of dolomite and dolomitic sandstone, siltstone, and shale of the upper two members (Lombard and Proviso) of the Eau Claire Formation. The confining unit overlies the relatively clean Mt. Simon and Elmhurst Sandstones, and underlies the clean Galesville Sandstone. The different lithologies grade laterally from one to another within short distances. In northern and western Illinois, the Eau Claire becomes predominantly a dolomitic, fine- to medium-grained, gray sandstone, but it includes shaly siltstone and silty, sandy, glauconitic, brownish-gray dolomite. The siltstone is grayish-orange, micaceous, and compact; and the shale, which is most abundant near the middle of the formation, is silty, green to red, micaceous, and brittle. The Eau Claire thickens and becomes more shaly to the southeast.

In central and eastern Illinois the Eau Claire is dominantly dolomitic, orange to pinkish-gray siltstone and green, gray or red shale; but it also includes light gray, glauconitic, partly oolitic limestone and dolomite (Willman et al., 1975). In the DeKalb area, the Eau Claire consists of light-gray, fine-grained sandstone, siltstone, shale, and dolomite. It

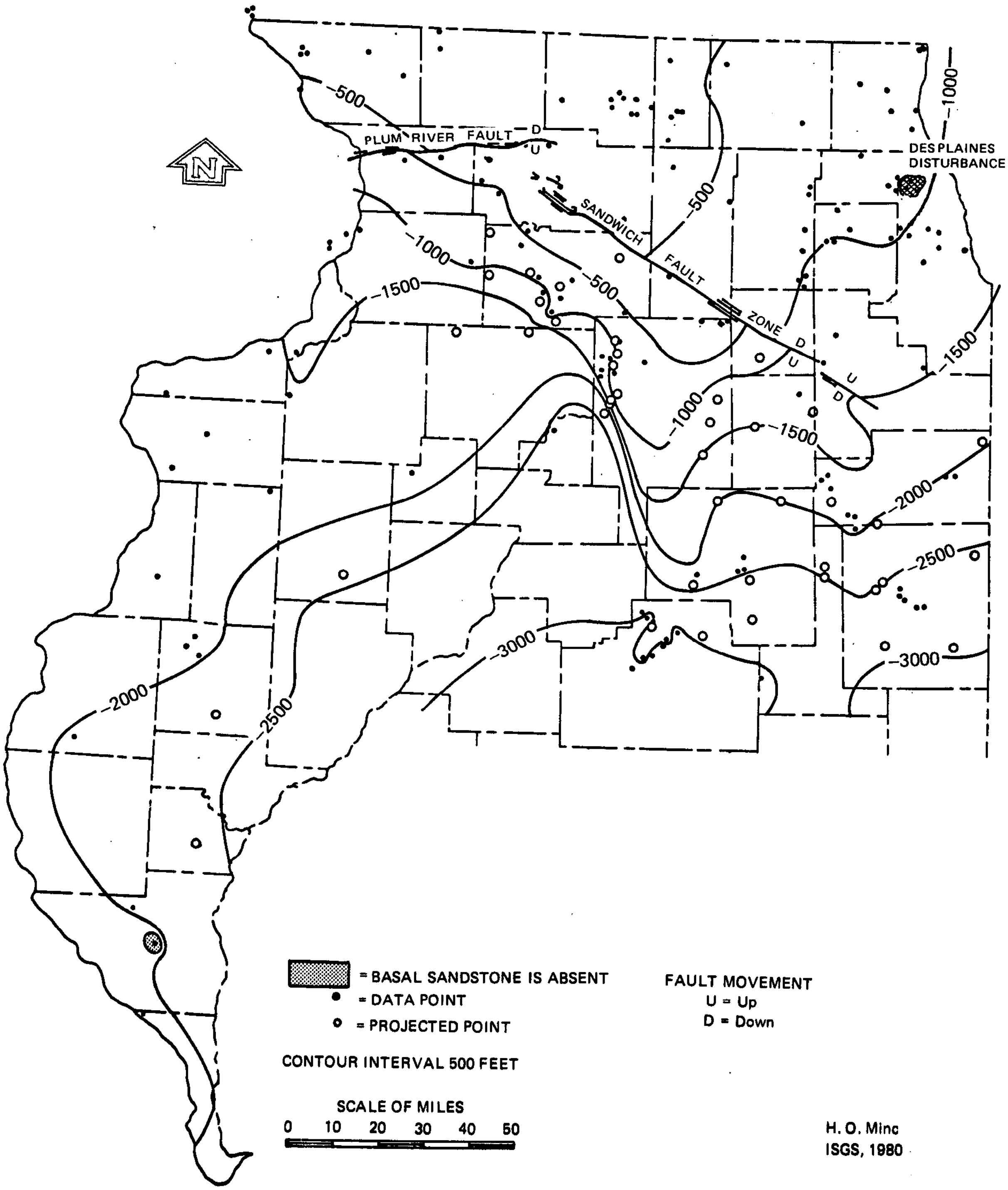


Figure 8. Elevation (MSL) of the top of the Elmhurst-Mt. Simon Sandstone

becomes sandier to the north, more shaly to the southeast, and more dolomitic to the southwest (Buschbach, 1970). Glauconite is abundant, especially in the Lombard Member.

In the Chicago region, the Lombard and Proviso Members are dolomitic, micaceous, fine- to medium-grained, compact sandstone with variable amounts of green to gray, sandy shale and siltstone and sandy brown dolomite. Cemented sandstone predominates in the Lombard member, and glauconite is common throughout the formation.

The thickness of the confining unit varies from less than 200 feet to 600 feet. The Eau Claire is much sandier in extreme northern Illinois, with finer grained sediments that are generally thinner; therefore, the basal sand confining unit is considerably thinner (fig. 9). Throughout the rest of the study area, the Eau Claire is a fairly uniform 200 to 400 feet thick, except for small areas in the southeastern and south-central parts of the study area, where the maximum thickness is over 600 feet.

The surface of the Eau Claire Formation dips to the southeast at about 11 feet per mile and reflects the general structural trend of the Illinois Basin and its surrounding positive features (fig. 10). The structurally highest part of the formation is north of the Plum River Fault Zone on the southern flank of the Wisconsin Arch. The Mississippi River Arch on the west is another positive structural element. The surface generally becomes lower to the south and southeast toward the deeper part of the basin. The major exception to this general trend is the structural high along the LaSalle Anticlinal Belt. This anticlinal belt is reflected as a structural high, trending southeastward through LaSalle, Livingston, and Ford Counties. The asymmetry of the belt is shown by the structural contours on the steep eastern flank and the much gentler western slope.

About 210 wells were available for development of figure 10, the surface of the Eau Claire Formation (the Basal Sandstone Confining Unit). Additional interpretation was possible by projecting down from the surface of the Ironton and Galesville Formations. Possible errors of a few feet up to a few hundred feet may exist on this map over short distances. The error increases where a facies change occurs from shale and dolomite to sandstone in northern Illinois; however, farther south the accuracy increases. Differentiation between the basal sandstone and the confining unit was based on the presence of significant shale content.

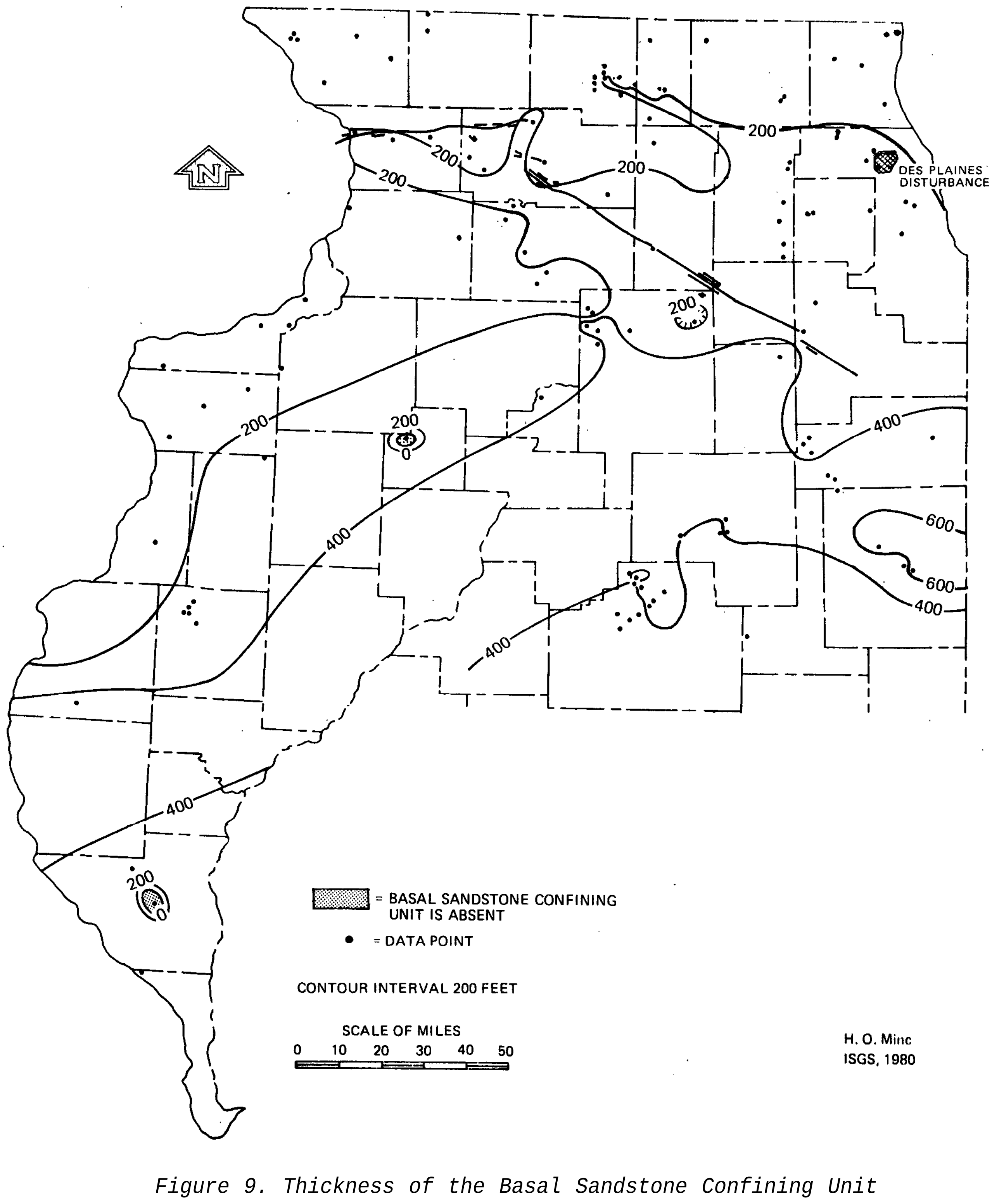


Figure 9. Thickness of the Basal Sandstone Confining Unit

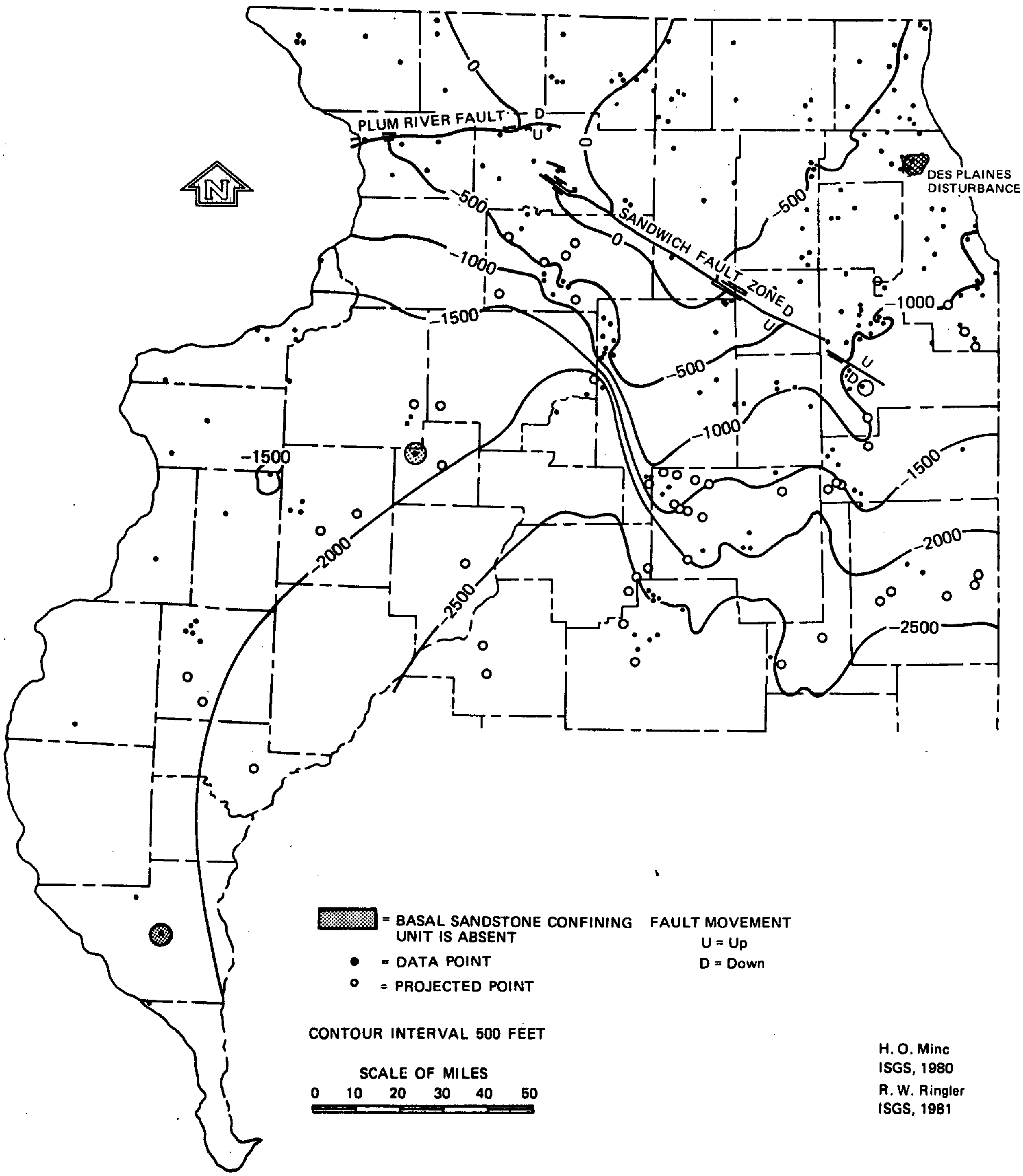


Figure 10. Elevation (MSL) of the top of the Basal Sandstone Confining Unit

The thickness of the Basal Sandstone Confining Unit was derived from 116 data points, limiting the accuracy of this map. A few areas may exist where Precambrian hills are present and where units either were never deposited or were eroded.

Ironton and Galesville Sandstones

The Ironton and Galesville Sandstones are thick and form an important source of groundwater in northern Illinois. The sandstones are separated mainly on the basis of texture and dolomite content. The Galesville Sandstone (Willman et al., 1975) is fine-grained, well-sorted sandstone, essentially free from shale and glauconite, whereas the Ironton is medium-grained. generally poorly-sorted, dolomitic sandstone. The Galesville occurs throughout the northern half of Illinois but is not exposed. It is commonly 40 to 100 feet thick. At its southern margin, the Galesville grades laterally through a 50-mile-wide zone from dolomitic sandstone to a non-sandy dolomite. The name Galesville is applied as far south as the sandy zone can be identified. The Galesville Sandstone consists of white to light buff, clean to locally silty, fine-grained, moderately well-sorted, friable, and generally non-dolomitic sandstone (Buschbach, 1964). Locally, light buff to pink dolomite is a cementing material. The Galesville appears to be conformable with both the overlying and underlying formations.

The Ironton Sandstone is a relatively coarse-grained sandstone overlying the finer-grained Galesville Sandstone and underlying the glauconitic, argillaceous sandstone of the Franconia Formation. It occurs throughout the northern half of Illinois but is not exposed. The Ironton is commonly 50 to 100 feet thick, but it is thinner in northwestern Illinois. Near the Wisconsin boundary, it is a medium-grained, poorly sorted, white sandstone with coarse-grained beds near the top. It generally contains light pinkish-buff dolomite as cementing material and as pebbles in conglomeratic layers. Farther south it is more dolomitic and at its southern margin it grades into sandy dolomite.

The carbonate content (all dolomite) of the Ironton and Galesville Formations ranges from zero to over 80%. In northern Illinois, the amount of dolomite increases gradually southward to the area of maximum thickness. The increase is primarily in the Ironton, except in the southern part, where the basal beds of the Galesville are also dolomitic. South of the area of maximum thickness, the dolomite content of both formations increases rapidly to a maximum at the southern limit of the formations. In eastern Illinois and Indiana, the dolomite content is much higher than in western Illinois and Iowa. Dolomite both cements sandstone and forms discrete beds in north, east, and east-central Illinois.

In the Chicago area and southward, lenses of fine to very finely crystalline, dark brown dolomite with minor amounts of very fine-grained sandstone are present at the base of the Galesville Sandstone. These coalesce to form one continuous unit with a maximum thickness of 50 feet in east-central Illinois.

Over 250 data points were used to compile the Ironton-Galesville thickness map (fig. 11). The Ironton-Galesville maintains a fairly uniform combined thickness of 150 to 200 feet over most of the study area. It ranges from a feather edge in the extreme southwest part to over 250 feet southwest of Chicago in southeastern Grundy County. The formation thins over the Wisconsin Arch, indicating that the arch actively influenced sedimentation during deposition of the Ironton and Galesville sands. During Ironton time, the inland sea over the Illinois Basin reached its farthest northward transgression (Emrich, 1966).

Over 280 wells were available to compile the map of the surface of the Ironton Formation (fig. 12). Additional points were also projected down from the Ancell Group surface. However, these data points were not sufficient to establish a 100-foot contour interval. The greatest accuracy exists in the northern part of the study area.

Knox Megagroup (Middle Confining Unit)

The dolomitic part of the Knox Megagroup (Swann and Willman, 1961) includes the strata between the base of the St. Peter Sandstone and the top of the Ironton Sandstone. It underlies all of Illinois except small areas in northern Illinois where an unconformity cuts entirely through the dolomitic formations and the St. Peter Sandstone rests on the Franconia Formation or, locally, on the Ironton Sandstone. Although dominantly dolomitic in the northern part of the state, the megagroup contains some relatively thin sandstones--the New Richmond and Gunter Sandstones, the Momence Sandstone Member of the Eminence Formation, the Jordan Sandstone, and numerous thin beds in the Shakopee Dolomite. The sandstones generally thin southward and

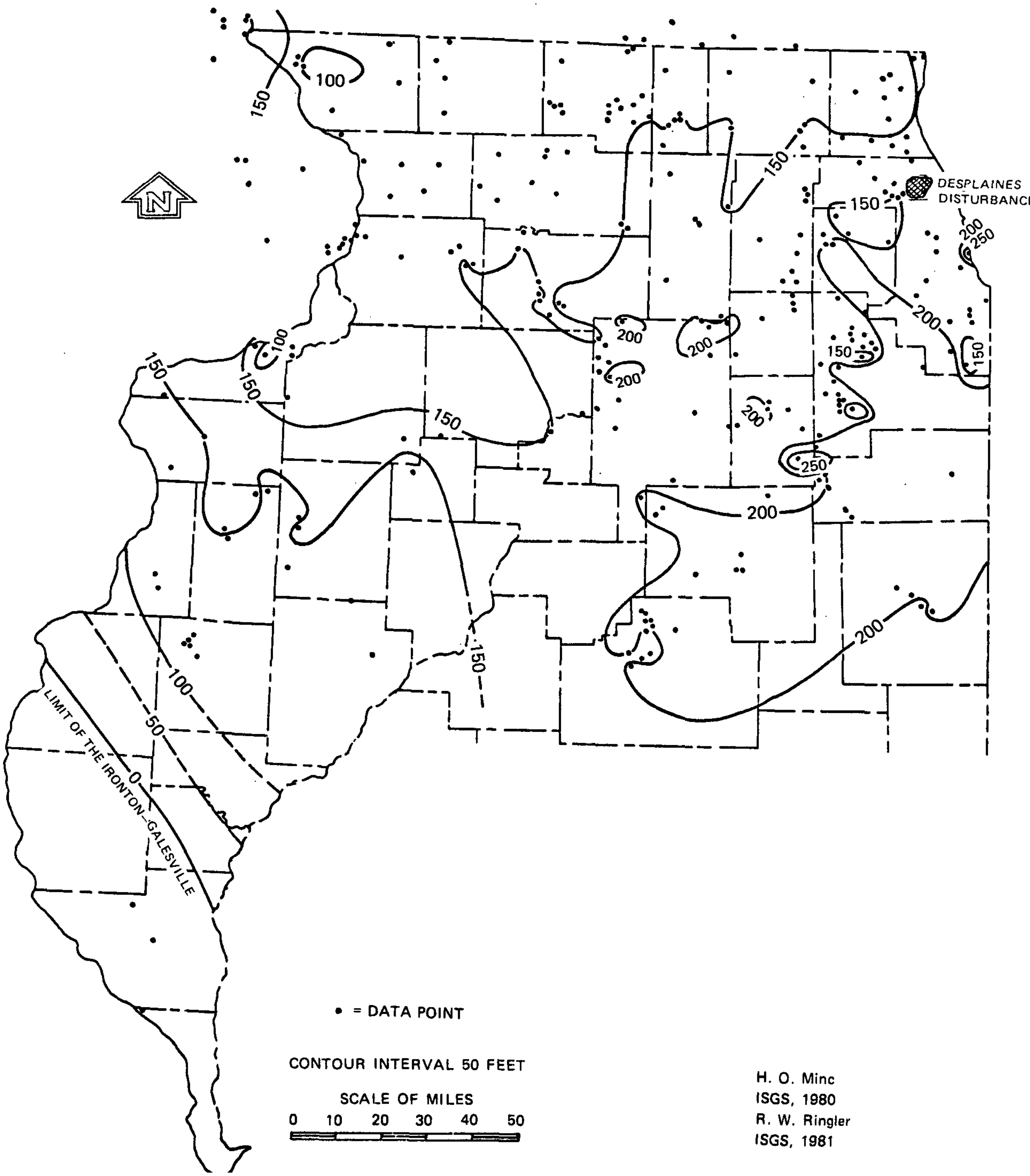


Figure 11. Thickness of the Ironton and Galesville Formations

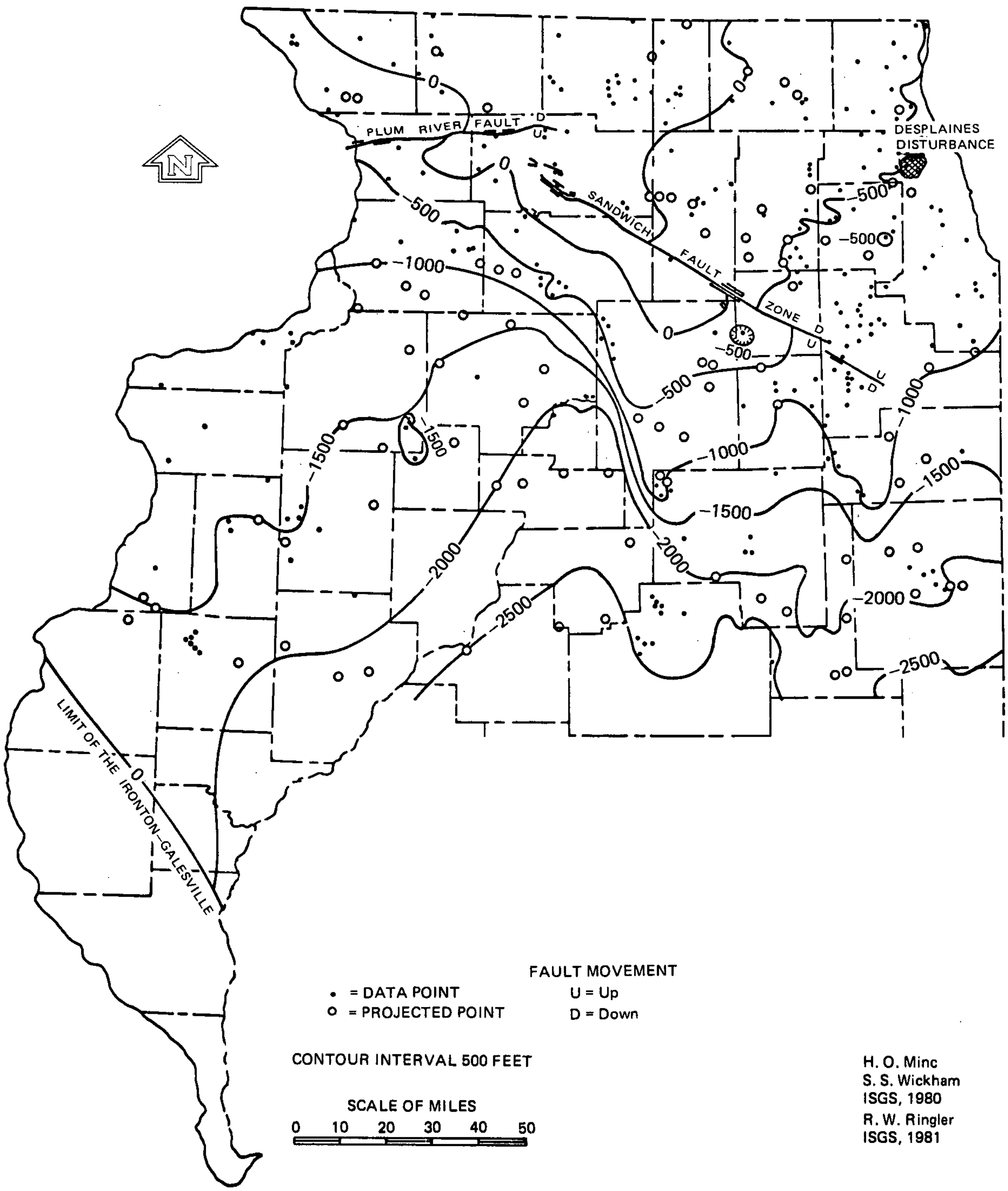


Figure 12. Elevation (MSL) of the top of the Ironton Formation

disappear near the middle of the state. The megagroup itself thickens from 300 to 500 feet in much of northern Illinois (fig. 13) to over 6000 feet in extreme southern Illinois. The southward thickening of the Knox in the study area is related to northward truncation of the upper part of the Shakopee Dolomite. In addition, the Franconia Formation and the Ironton and Galesville Sandstones grade southward into dolomite, resulting in repeated lowering of the base of the Knox until it reaches the top of the Mt. Simon Sandstone.

Over 280 wells were available to compile the thickness map of the geologic units between the base of the Ancell and the top of the Ironton (fig. 13). The rock interval between the Ancell and Ironton aquifers is mainly a confining unit except for a few small aquifers, such as the Jordan Sandstone. In many cases these sandstones are absent; therefore, they are more a local than a regional source of water. Many of the wells do not penetrate the entire thickness of the confining unit, so some of the contours are estimated from the available data.

In northern Illinois the units between the top of the Ironton Sandstone and the base of the Ancell Group consist of the Cambrian Franconia Formation, Potosi Dolomite, Eminence Formation, and Jordan Sandstone, and the Ordovician Prairie du Chien Group.

Franconia Formation. The Franconia Formation consists of glauconitic, argillaceous sandstone and dolomite underlying the Potosi Dolomite. It underlies all of Illinois and thickens southward from about 50 feet near the northern border of Illinois to about 500 feet in the southern part of the state. In extreme northern Illinois, the Franconia consists largely of gray to pink, glauconitic, silty, argillaceous, fine-grained, dolomitic sandstone that contains various amounts of red and green shale. Southward from that area the lowermost part of the Franconia becomes increasingly shaly (Davis Member) and the uppermost part grades to silty and sandy dolomite (Derby-Doerun Member). In north-central Illinois these two units are separated by a wedge of fine-grained, dolomitic sandstone similar to that which composes the entire Franconia of extreme northern Illinois. In the central part of the state, the glauconitic sandstone is absent, and the silty, shaly sandstone of the Davis is overlain by the relatively pure dolomite of the Derby-Doerun. In Illinois, the Franconia is comformable with overlying formations.

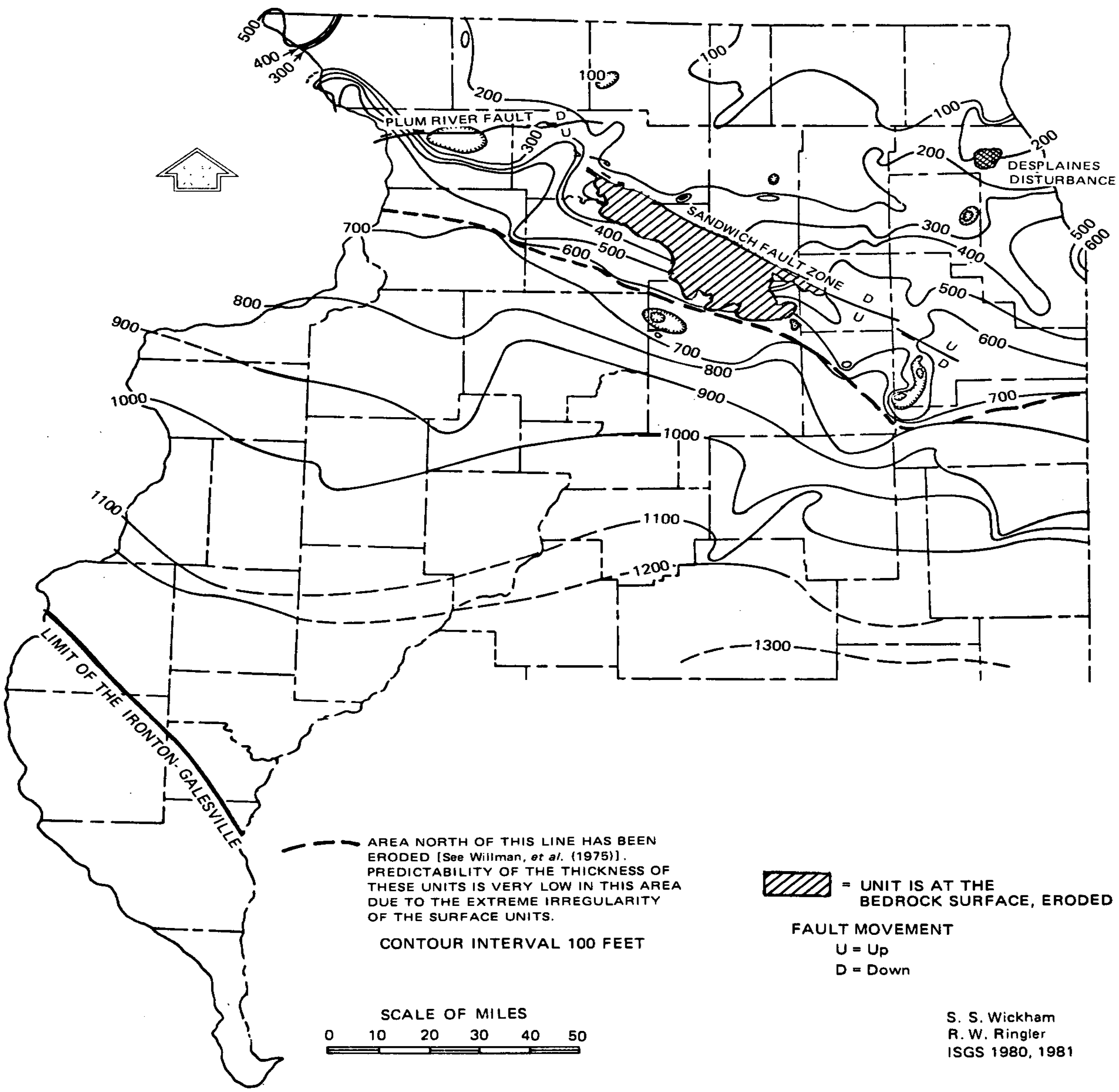


Figure 13. Thickness of units between the base of the Ancell Group and the surface (top) of the Ironton Formation

Potosi Dolomite. The Potosi Dolomite is a relatively pure dolomite overlying the Franconia Formation and underlying the Eminence Formation. The Potosi underlies essentially all of Illinois except in parts of northern Illinois where it is truncated by pre-St. Peter erosion. It consists of finely crystalline, pure to slightly argillaceous, brown to pinkish-gray dolomite that is very slightly glauconitic at the top and glauconitic and sandy at the base. Drusy quartz covers the surfaces of small cavities in most areas and characterizes the formation in both outcrop and well samples. In wide areas of northern Illinois, it is unconformably overlain by the St. Peter, but it is otherwise conformable with the Franconia below and the Eminence above.

Eminence Formation. The Eminence Formation is a sandy dolomite overlying the Potosi Formation. It underlies most of Illinois except in the northern part where it is truncated by the unconformity at the base of the St. Peter Sandstone. The Eminence is normally 50 to 250 feet thick where it is overlain by the Gunter Sandstone or Oneota Dolomite of the Prairie du Chien Group. It consists of light gray to brown or pink, sandy, fine- to medium-grained dolomite that contains oolitic chert and thin sandstone strata. The formation is generally conformable with overlying units, and in extreme northwestern Illinois it grades laterally into the Jordan Sandstone.

Jordan Sandstone. The Jordan Sandstone is the uppermost Cambrian formation in the extreme northwestern part of Illinois. In Jo Daviess and Carroll Counties it is a few to 75 feet thick, and in Iowa it becomes an important aquifer. The formation is a white to yellowish-gray, partly iron stained sandstone that is medium- to fine-grained at its base. In some places the upper part is coarse to very coarse-grained. It varies from thin- to thick-bedded, and cross-bedding is eommon.

Prairie du Chien Group. The Prairie du Chien Group, the youngest unit of the Knox Megagroup, is present throughout much of Illinois. However, it is almost entirely absent in the northern two tiers of counties and is missing locally in the rest of the northern third of the state. It is also absent in areas where Cambrian rocks crop out near the Sandwich Fault Zone and structural highs. The group thickens southward, chiefly by the addition of younger beds at the top. The group consists of cherty dolomite with some interbedded sandstone. It is subdivided into the Gunter Sandstone (basal), the Oneota Dolomite, the New Richmond Sandstone, and the Shakopee Dolomite.

Ancell Group

The Ancell Group (Templeton and Willman, 1963) is a predominantly elastic unit consisting of sandstone and argillaceous and sandy limestone and dolomite formations. It overlies the Prairie du Chien Group and older rocks and underlies the Platteville Group in northern Illinois (Willman et al., 1975). The Ancell is separated from the Platteville Group by a widespread unconformity of low relief, which is a useful structural horizon and can be recognized easily (Kolata et al., 1978). Ancell strata underlie most of the study area in northern Illinois and range in thickness from 100 to about 600 feet (fig. 14). The St. Peter Sandstone is the basal formation in the Group. North of a line running diagonally across the center of the state from Chicago to Quincy, the St. Peter is overlain by members of the Glenwood Formation. The members have a facies relation with the upper part (Starved Rock Member) of the St. Peter Sandstone. The Joachim Dolomite has a similar facies relationship to the St. Peter south of the line.

The Ancell Group has a fairly smooth upper surface, and therefore the mapping of it is considered quite accurate, except where data are sparse (fig. 15). Over 515 wells were used to compile this map; most of the data points are concentrated in northeastern Illinois. South and west of the Sandwich Fault Zone the available data are more sparse, and contours are less accurate. Points were also projected down from the Galena surface by subtracting the Galena-Platteville thickness from the elevation of the Galena surface.

The Ancell thickness (fig. 14) is highly variable because the base of the Ancell rests on an eroded surface. In the northern portion of the state, the base is extremely irregular and truncates several formations. The thickness may vary from just a few feet to 200 feet over short distances. About 415 wells were used to make the Ancell thickness map.

About 340 wells were available to make the map of the base of the Ancell Group (fig. 16). Because of the irregularity of the underlying surface, it was difficult to determine the topography of the surface, and much of the map is interpretative.

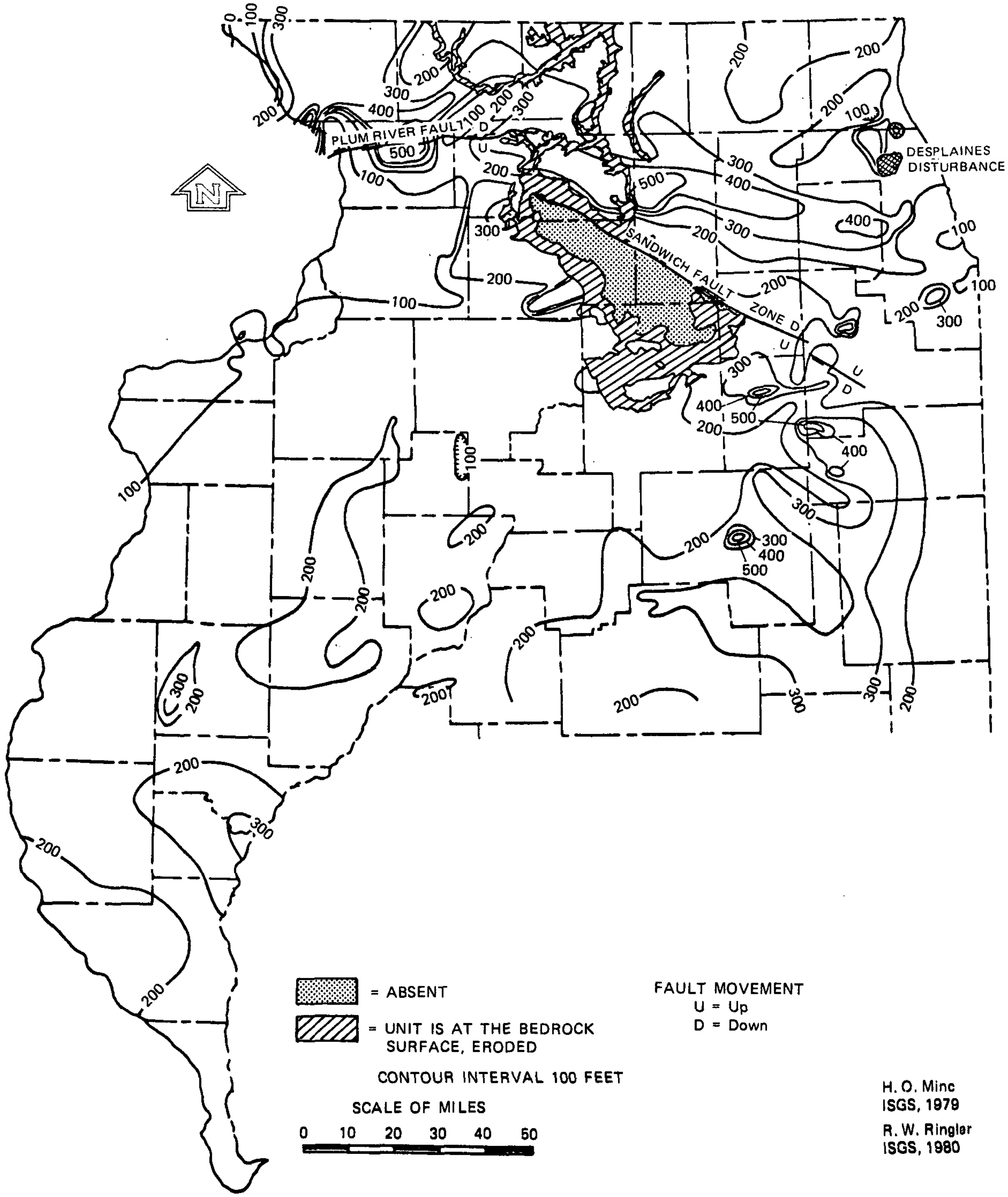


Figure 14. Thickness of the Ancell Group

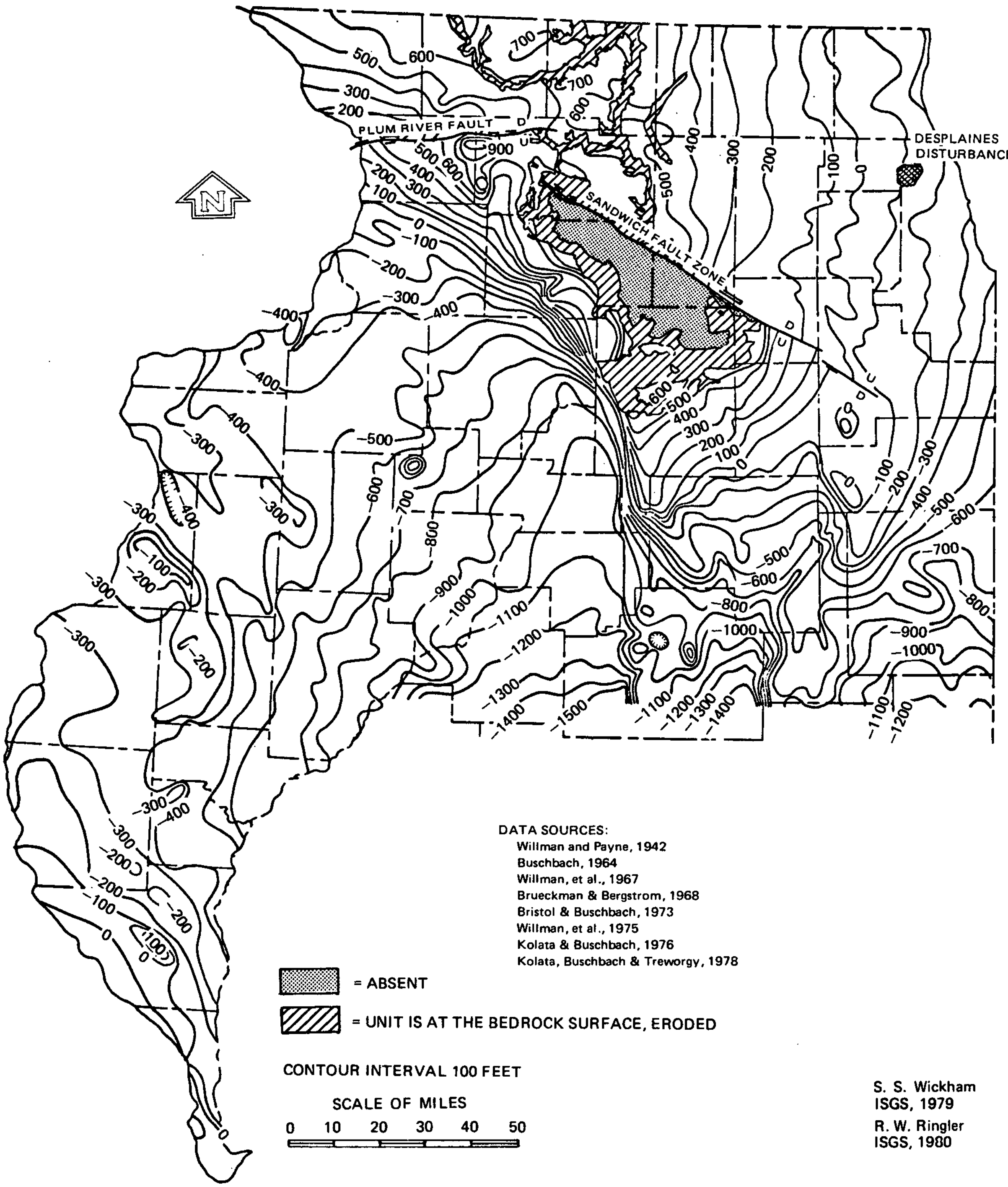


Figure 15. Elevation (MSL) of the top of the Ancell Group

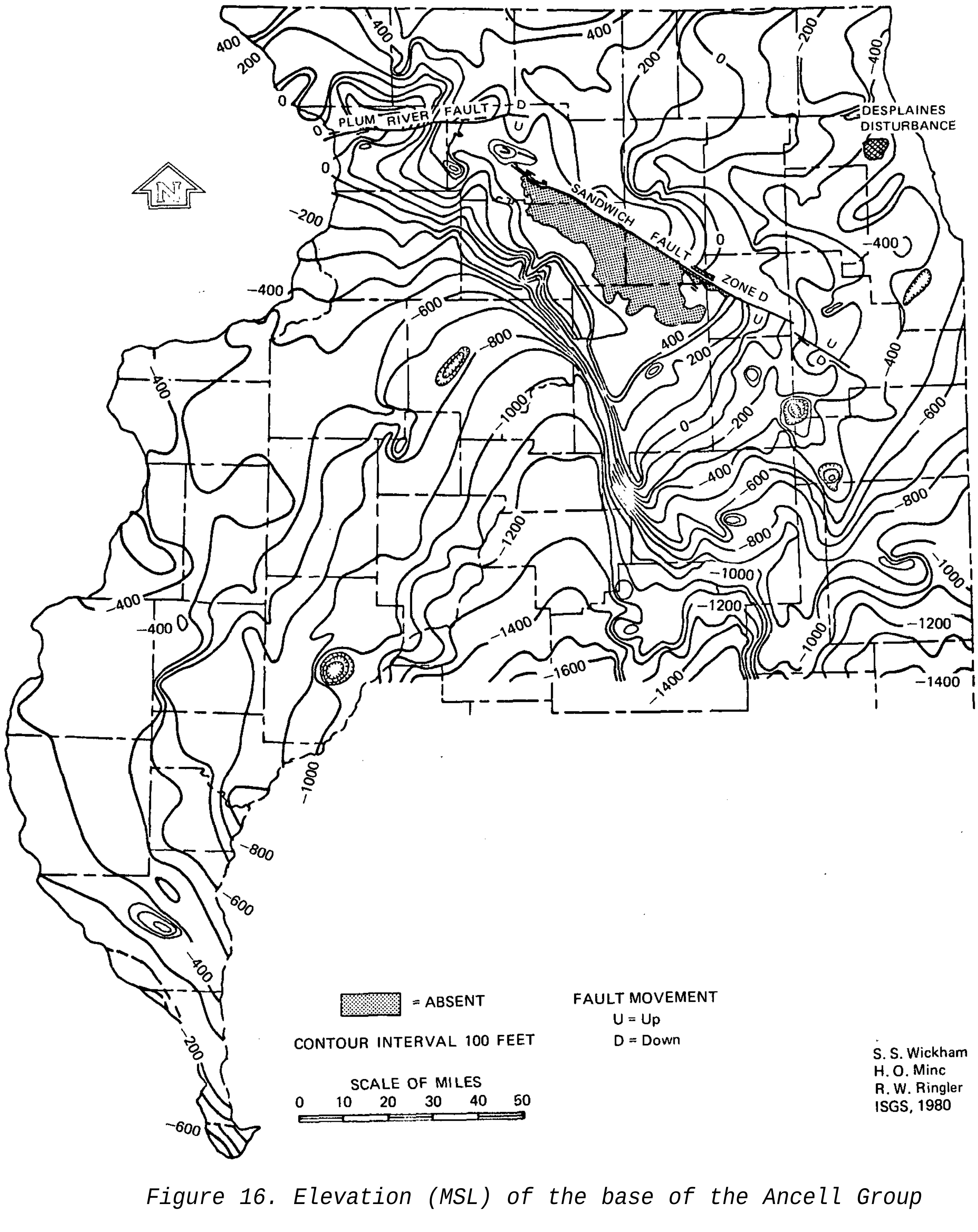


Figure 16. Elevation (MSL) of the base of the Ancell Group

St. Peter Sandstone. The St. Peter Sandstone is restricted to the relatively pure sandstone present in most of Illinois below the Platteville Group carbonates and the Glenwood Formation elastics and overlying the carbonates of the Knox Megagroup. Because of a major unconformity at its base, the St. Peter truncates formations as old as the Franconia Formation (Templeton and Willman, 1963; Buschbach, 1964).

The St. Peter is composed mainly of quartz sand that is normally pure and very fine- to coarse-grained. It is chiefly fine- to medium-grained, very well sorted, friable, and thick to very thick-bedded, with cross-bedding common locally (Templeton and Willman, 1963; Buschbach, 1964). Its color is normally white, but it may be pink, buff, or reddish brown. Most sand grains are well rounded and frosted; the degree of rounding and frosting decreases with decreasing grain size so that very fine grains are generally angular and clear. The St. Peter commonly contains less than 2% silt and 1 to 3% disseminated clay, but it is locally very silty in western Illinois. Its heavy mineral suite is limited to the highly resistant minerals, tourmaline and zircon.

The St. Peter fills irregularities on a complex surface which includes both karst and erosional features. Where the sandstone is abnormally thick, the underlying carbonates are reciprocally thinned (Buschbach, 1961). The pattern of variation in thickness suggests deposition in previously eroded channels and adjacent uplands (Suter et al., 1959). The St. Peter is 100 to 200 feet thick over most of northern Illinois except in a band 40 to 50 miles wide north of the Sandwich Fault Zone, where thicknesses of 400 to 600 feet are encountered. Where abnormal thicknesses are found, the lower section (Kress Member) may consist of fine- to coarse-grained, pink to reddish-brown sandstone with varying amounts of shale, chert, and dolomite fragments (Suter et al., 1959).

From north-central Illinois to southeastern Missouri, the St. Peter consists of a lower, fine-grained unit, the Tonti Sandstone Member, and an upper, medium-grained unit, the Starved Rock Sandstone Member. The St. Peter sands were derived chiefly from erosion of pre-existing sandstones, of which the Cambrian Galesville Sandstone may be a chief source. From its area of maximum thickness in north-central Illinois, the Starved Rock Member grades northward into the Glenwood Formation and southward into the Joachim Dolomite.

Glenwood Formation. The Glenwood Formation, the upper part of the Ancell Group, is widely present in northern Illinois, with the same distribution as the St. Peter Sandstone. It underlies the Platteville Group, and is separated from it by a widespread and sharp unconformity of minor relief. The Glenwood is absent in some localities, especially near the Wisconsin state line (Willman et al., 1975). The formation is generally 25 to 50 feet thick and is characterized by abrupt and irregular variations in thickness. It is thickest along its southern margin just north of where it grades into the Starved Rock Member of the St. Peter Sandstone. Its maximum known thickness is 150 feet at Galesburg in Knox County.

The Glenwood is composed primarily of sandstone possessing a distinctive bimodal texture. Known as the Glenwood texture, it consists of medium to coarse, well-rounded quartz grains of the St. Peter type in a matrix of very fine sand and coarse silt. The sandstone is commonly dolomitic and has a high silt and clay content and abundant accessory garnets and other heavy minerals. The clay fraction contains illite and authigenic potassium feldspar. Fine-grained, impure dolomite and light green shale are found in the middle and upper portions of the formation. The northern distribution, variable lithology, and general absence of normal marine fauna suggest that the Glenwood sediments were derived from two different terrains and deposited in brackish, muddy water of a shallow marine basin (Templeton and Willman, 1963).

Ottawa Limestone Megagroup

The Ottawa Limestone Megagroup (Swann and Willman, 1961) consists of the dominantly carbonate rocks overlying the St. Peter Sandstone and underlying the dominantly elastic rocks of the Maquoketa Shale Group. In northern Illinois, it consists largely of the Galena and Platteville Groups, but locally it includes carbonate members of overlying and underlying formations. The Ottawa Megagroup underlies most of the state and thickens from about 300 feet in northern Illinois to 1300 feet in southern Illinois. In local areas where the St. Peter Sandstone is absent, the Ottawa Megagroup rests on the Knox Megagroup.

The Galena and Platteville Groups consist of a nearly continuous sequence of carbonate rocks that are generally 250 to 450 feet thick in northern and western Illinois, thickening southward into the Illinois Basin (fig. 17). Over 470 data points were used to draw the Galena and Platteville thickness map. The map provides a fairly accurate portrayal of the Galena and Platteville thickness, except in the erosional areas where the thickness may vary greatly due to the topographic relief. These groups form the bedrock surface and are widely exposed in an area of about 2900 square miles (Willman and Kolata, 1978). Although largely dolomitic, both groups contain limestone in parts of the area. The carbonates are relatively pure and generally contain less than 10% impurities, mostly argillaceous material and chert. The siliceous detrital minerals are finely disseminated in the limestone and dolomite and consist largely of quartz in silt and sand-size grains and a variety of silicates, mostly clay minerals, feldspar, and heavy minerals.

Platteville Group. The Platteville Group (Templeton and Willman, 1963; Willman and Kolata, 1978) includes the dominantly limestone formations that overlie the Glenwood Formation of the Ancell Group and underlie the Spechts Ferry or Guttenberg Formations of the Galena Group. Across central Illinois it overlies the St. Peter Sandstone; farther south it overlies the Joachim Dolomite. The group is only about 30 to 45 feet thick in extreme western and northwestern Illinois, but it thickens to 135 feet in the Dixon area and southward to over 600 feet in the extreme southern part of the state (Willman et al., 1975).

In northern Illinois, the Platteville Group is largely blue-gray, lithographic, partly dolomite-mottled limestone, but in some areas it is gray, very fine-grained, cherty dolomite. It is divided into the Plattin Subgroup (stratigraphically above) which is dominated by the typical limestone facies, and the Pecatonica Formation, a persistent dolomite in the northern area.

Galena Group. The Galena Group (Templeton and Willman, 1963) consists of limestone and dolomite formations overlying the Platteville Group and underlying the Maquoketa Shale Group. The Galena Group is present in all of Illinois except in the areas where older rocks are exposed in central-northern Illinois, in Calhoun County, and in an area along the crest of the LaSalle Anticlinal Belt where the Galena strata were eroded before deposition of Pennsylvanian sediments. The Galena Group is 250 to 275 feet thick in the northern outcrop area, but the upper part is truncated by the Maquoketa Shale in central Illinois. The group is divided into two subgroups (Willman and

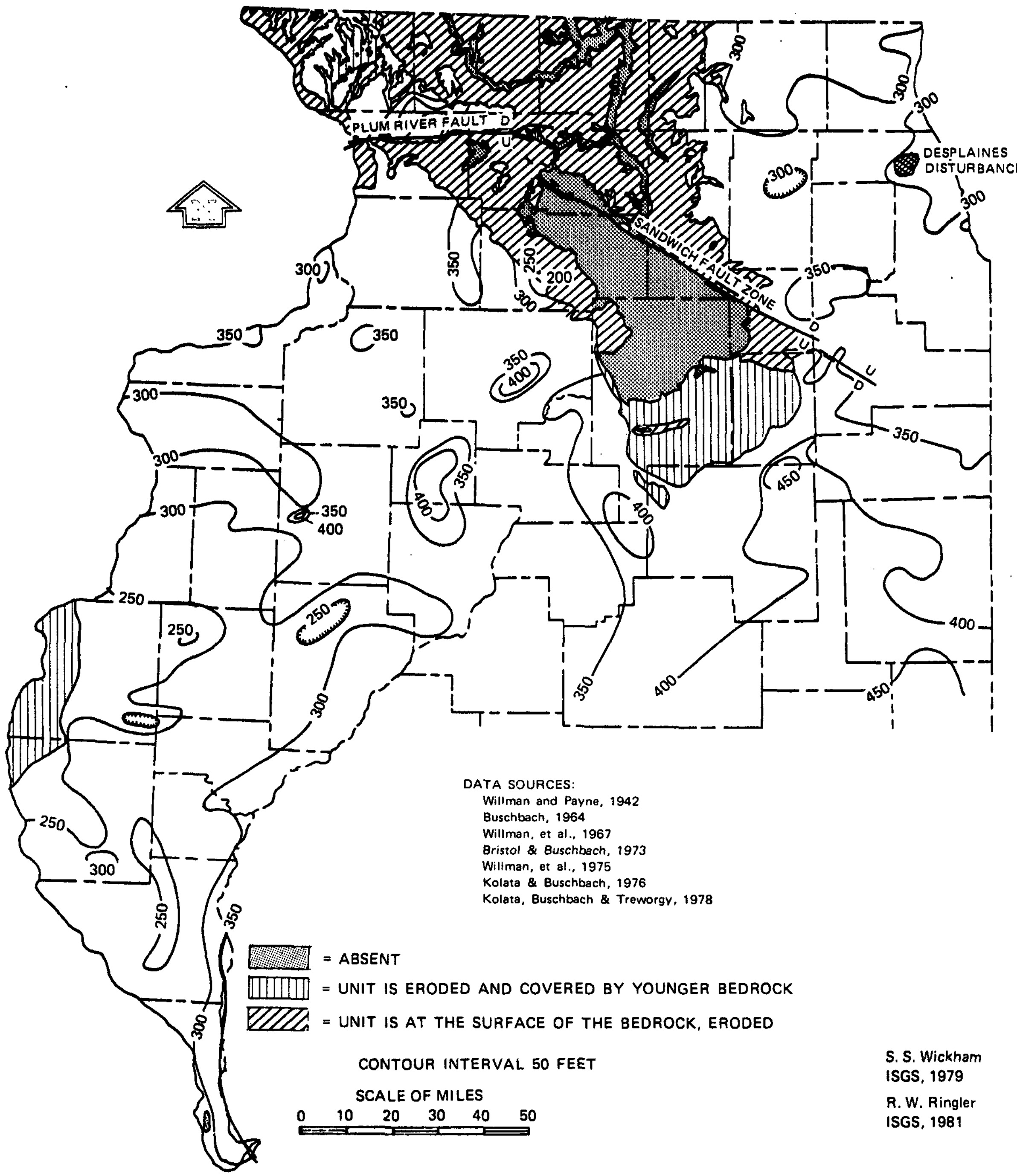


Figure 17. Thickness of the Galena and Platteville Groups

Kolata, 1978) -- the Decorah at the base is a shaly unit, and the Kimmswick above it is relatively pure limestone and dolomite.

A previously published structural contour map of the configuration of the surface of the Galena Group (Bristol and Buschbach, 1973) was used in this study. Some minor revisions have been made, especially near the borders of Illinois, to better match the maps of adjacent states (fig. 18). The map of the Galena surface probably is the most accurate of any in this report. It is an easily identified formation and has a uniform surface, and a large number of control wells were available.

Maquoketa Shale Group

The Maquoketa Shale Group is present throughout most of Illinois, except south of the Sandwich Fault Zone and in portions of northern and northwestern Illinois, where it has been removed by erosion. Unconformities separate it from the underlying Galena Group and the overlying Silurian dolomites and younger rocks. The sub-Silurian unconformity is erosional, and valleys up to 100 feet deep are cut into the top of the Maquoketa. In western Illinois, the sub-Kaskaskia unconformity at the base of the Middle Devonian rocks cuts through the Silurian System and into the Maquoketa. Farther west the Maquoketa is completely absent (Willman et al., 1975).

The Maquoketa Shale Group is normally about 200 feet thick in Illinois (fig. 19), with a maximum of 250 to 300 feet. The Maquoketa thickness map is quite accurate, with over 610 data points available. However, where the surface is eroded, the surfaces are not accurately portrayed, because the thickness in these areas may vary from a few feet to 200 feet within short distances.

There is an abundance of data for the map of the Maquoketa surface (fig. 20), with over 685 wells available. To provide the most nearly accurate portrayal of the Maquoketa surface in relation to its adjacent formations, additional points were projected by adding the Maquoketa thickness to the Galena-Platteville surface. The Maquoketa surface map is quite accurate except where pre-Silurian, pre-glacial, and modern erosion has occurred.

In most of Illinois, the Maquoketa consists of three formations: 1) the Scales Shale, a lower, dominantly shale unit; 2) the Fort Atkinson Limestone, a middle dolomite and/or limestone and shale; and 3) the Brainard Shale, an

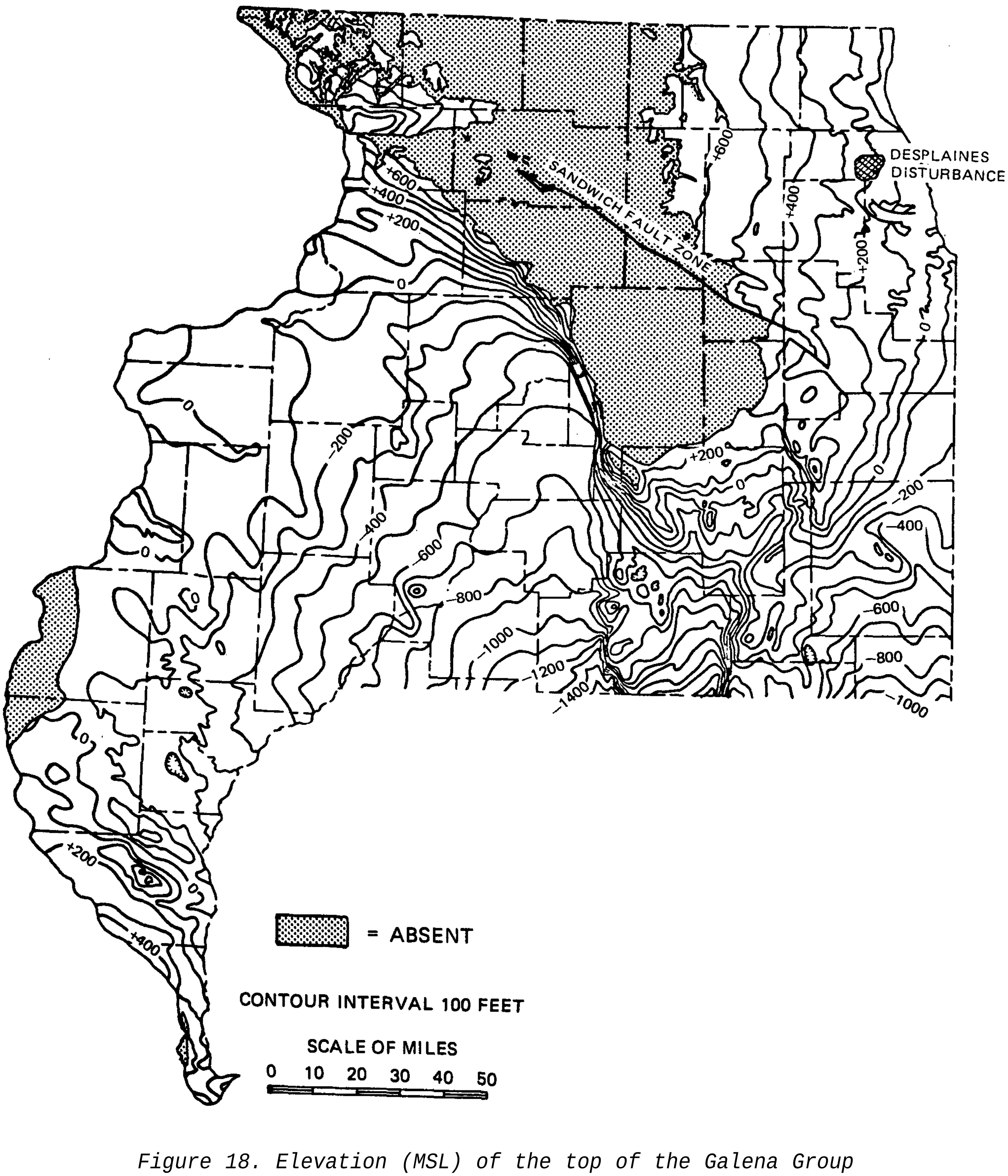


Figure 18. Elevation (MSL) of the top of the Galena Group

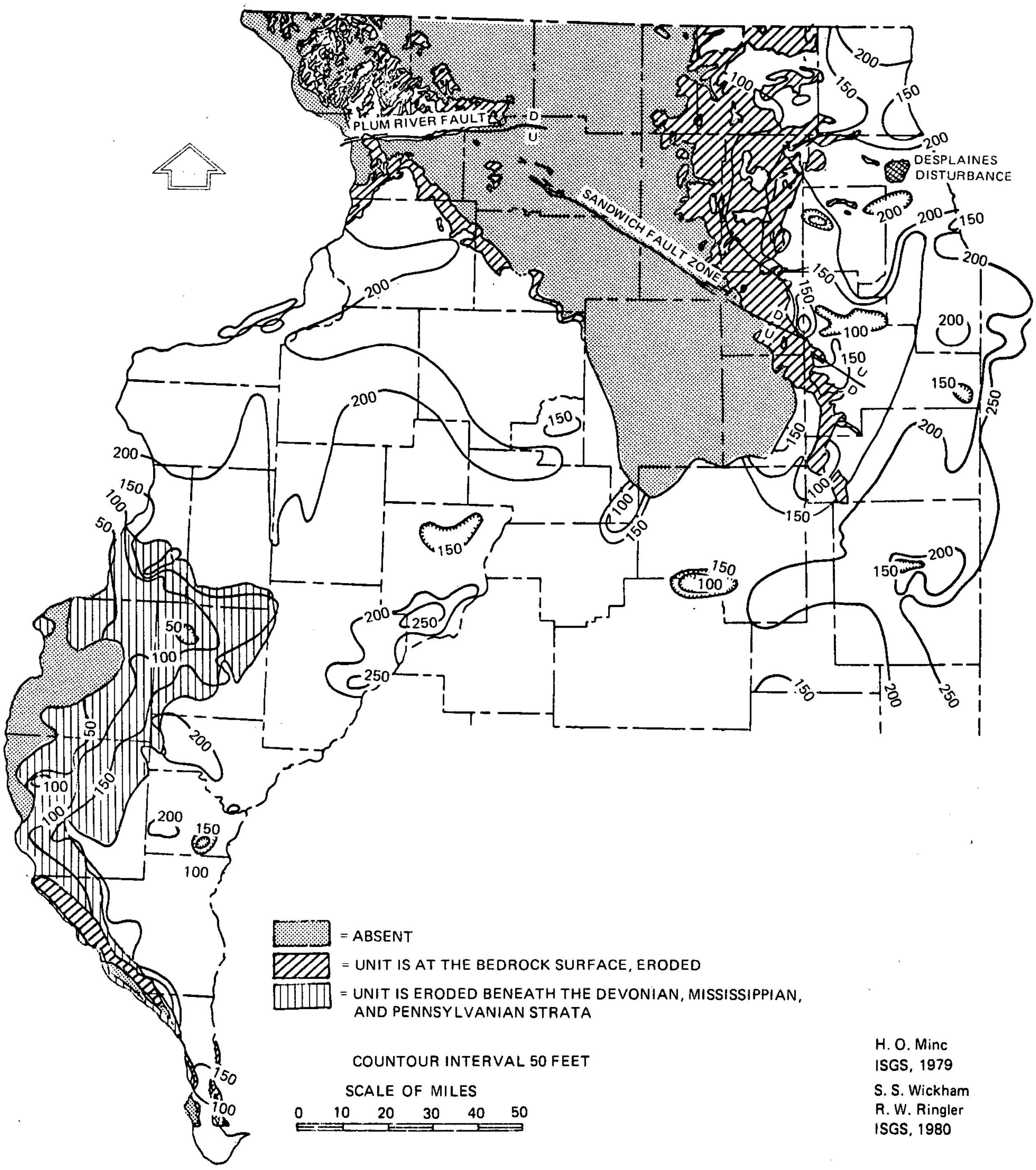


Figure 19. Thickness of the Maquoketa Shale Group

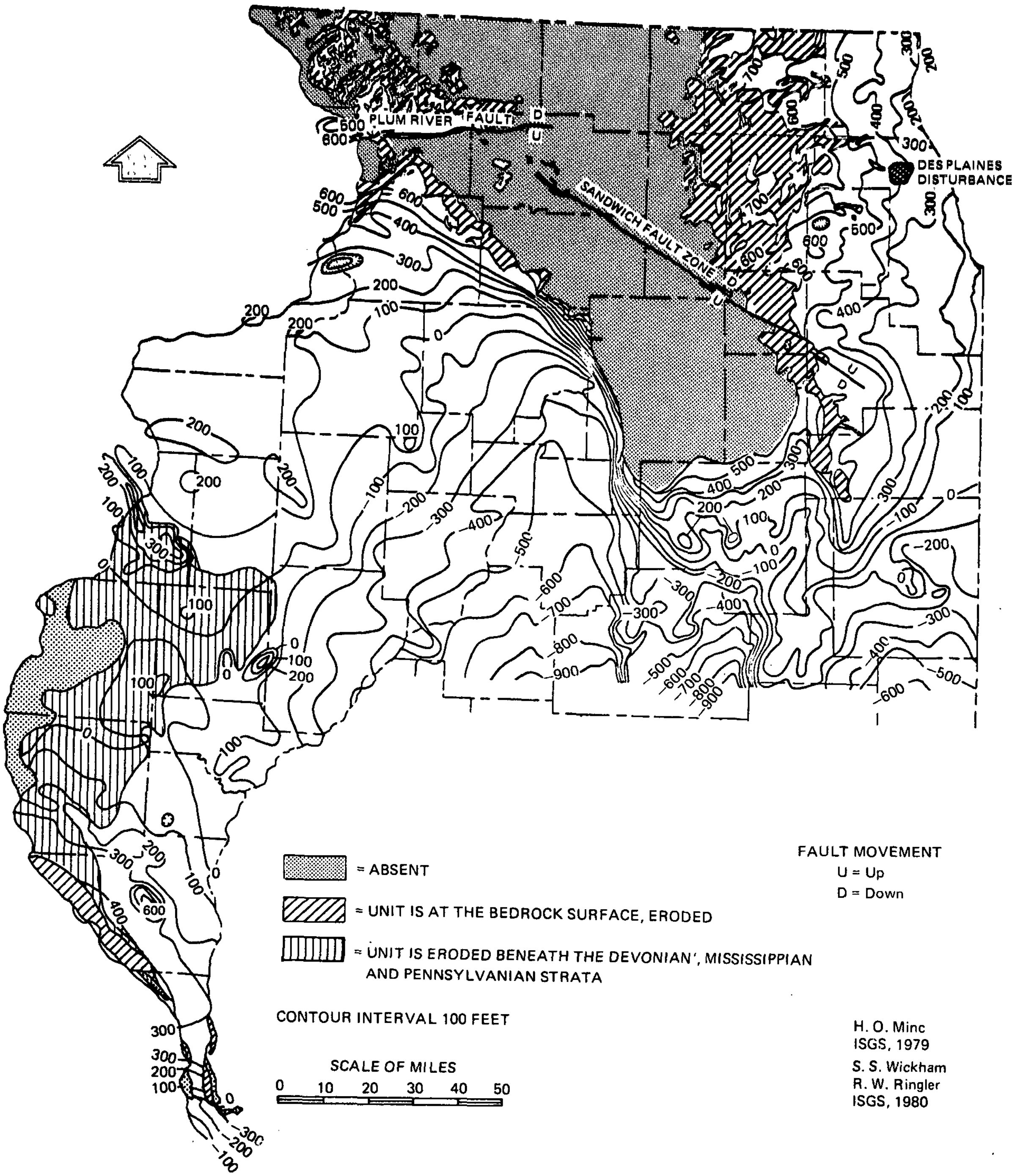


Figure 20. Elevation (MSL) of the top of the Maquoketa Shale Group

upper dolomitic shale. In northern Illinois, the Neda Formation, a red and green shale and hematitic oolite, is locally present at the top of the group (Suter et al., 1959; Willman et al., 1975).

Scales Shale. The Scales Shale (Templeton and Willman, 1963), the lowermost unit of the Maquoketa Shale Group, is present throughout most of the state except in north-central and extreme western Illinois, where it has been removed by post-Ordovician erosion. Throughout the state, the Scales Shale has a range of 50 to 150 feet, but it is generally 75 to 100 feet thick. It is light olive gray to olive gray, weak to brittle, silty dolomitic shale interbedded with layers of fine-grained, silty dolomite. Locally, the shale is greenish-gray in its lower 5 to 10 feet (Buschbach, 1964).

Fort Atkinson Limestone. The middle unit of the Maquoketa Shale Group, the Fort Atkinson Limestone (Willman et al., 1975), is widely distributed in the subsurface of Illinois. It ranges from 15 to 20 feet thick near Rock Island (Rock Island County) to 5 to 50 feet thick in the Chicago area (Cook County). Its composition is highly variable. In northwestern Illinois it is very shaly and is inseparable from the shales above and below. In other areas it contains limestone that is laterally equivalent to shale elsewhere in the formation. It changes over short distances from white or pink, coarse-grained, crinoidal limestone to brown, fine-grained dolomite or gray, argillaceous limestone. In some areas, the upper portion is limestone and the lower is dolomite. The interbedded shale is generally green or brown and silty, and dolomitic or calcitic. Its amount varies greatly.

Brainard Shale. The Brainard Shale occurs throughout the area of the Maquoketa Group except where it has been truncated by unconformities. Where it has not been affected by post-Ordovician erosion, it is normally about 75 to 100 feet thick (Willman et al., 1975). It is a silty, dolomitic, weak, greenish-gray shale interbedded with varying amounts of silty, greenish-gray dolomite and, less commonly, limestone. In extreme northeastern Illinois it grades to partly silty dolomite that is light gray to light greenish-gray in color, partly black speckled, fine- to coarse-grained, and commonly interbedded with greenish-gray shale. The Brainard Shale is lighter colored and softer than the Scales Shale, and is commonly fossiliferous.

Neda Formation. The Neda Formation, the uppermost unit of the Maquoketa Shale Group, is present locally in northern Illinois, generally occurring where the Maquoketa is thicker than 190 feet and the basal Silurian formations are thin or missing (Buschbach, 1964; Willman et al., 1975). It consists largely of weak red or green shale that contains flattened, hematitic, goethitic or limonitic oolites and interbedded pink or green dolomite. The Neda has a gradational contact with the underlying Brainard Shale and is unconformably overlain by the Silurian System and younger rocks.

Post-Ordovician Systems

Post-Ordovician deposits are not a detailed part of this study; they are described only briefly in the following sections.

Silurian System

The Silurian System underlies most of Illinois and makes up large portions of the bedrock surface in northeastern and northwestern Illinois (Willman et al., 1975). It is also exposed in the river bluffs at the confluence of the Illinois and Mississippi Rivers in western Illinois (fig. 21). The system has a maximum thickness of nearly 1000 feet at some pinnacle reefs in the area east of East St. Louis; however, the system is more commonly 400 to 600 feet thick. The Silurian thins and has been completely removed by erosion to the north and west. Preglacial erosion has produced deep valleys in the bedrock surface, and the thickness of the upper unit may change abruptly over short distances.

The Silurian rocks are almost entirely dolomite in the northern part of the state (Willman, 1943, 1973). In the lower third of the system, the frmations maintain distinctive characteristics and lateral continuity over long distances. Where reefs are present in the upper part of the system, the sediments have abrupt lateral variations in lithology, and few units can be widely traced. The northern reefs, in the Racine Formation, are mainly pure dolomite. The interreef rocks are generally less pure, varying from cherty, silty dolomite to argillaceous dolomite. However, in northwestern Illinois, the interreef rocks, except in local areas, are nearly pure dolomite, similar in lithology to the reef rock.

The Silurian System is divided into three series: the Alexandrian Series (Zeizel et al., 1962; Willman, 1973), and the overlying Niagaran and Cayugan Series. Only the Alexandrian and Niagaran are present in northern and western Illinois. The Silurian System unconformably overlies the

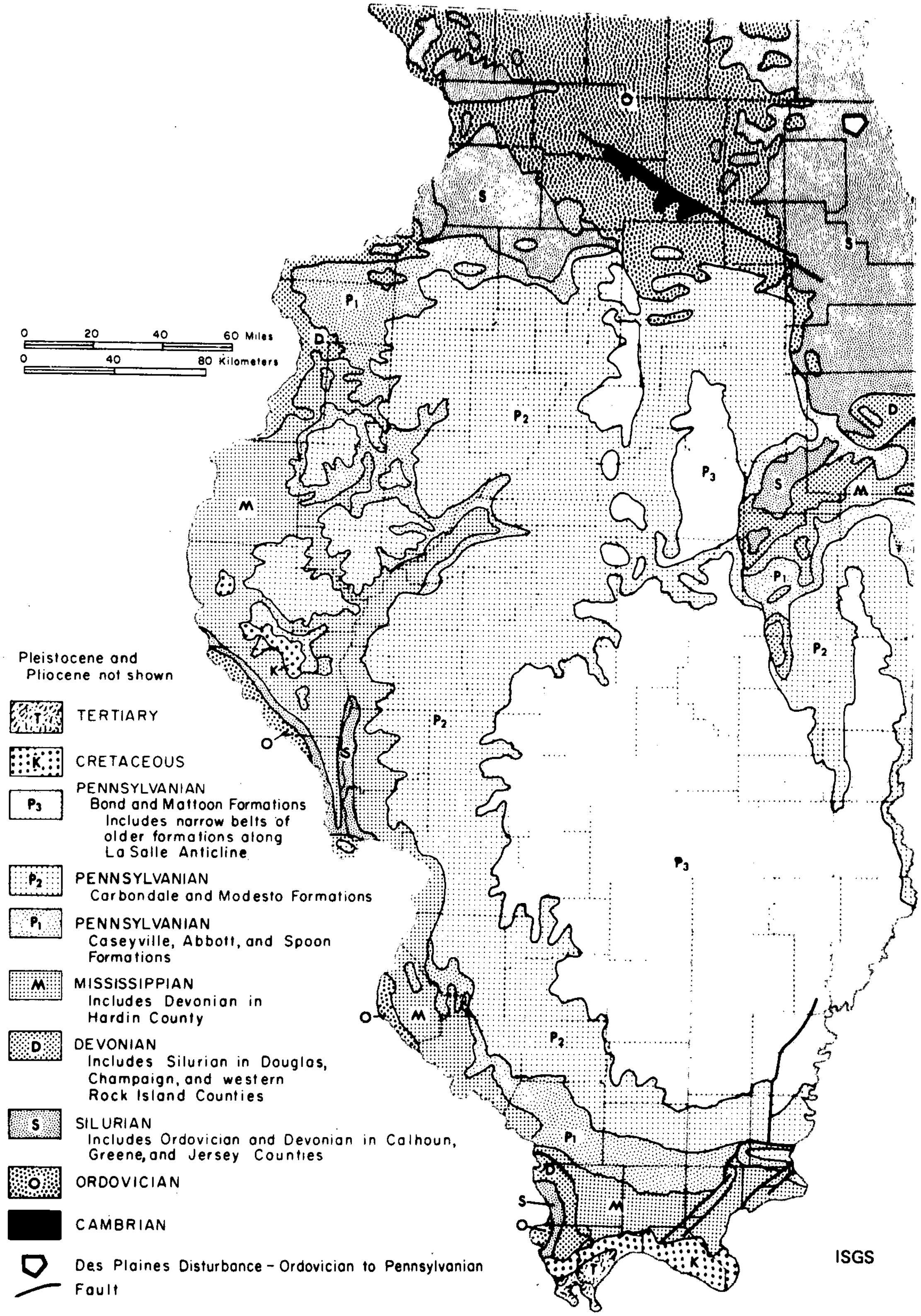


Figure 21. Bedrock geology of Illinois

Maquoketa Group, generally the eroded surface of the Brainard Shale. Locally erosion has cut through the shale to the top of the Fort Atkinson Limestone. There is also a major unconformity between the Silurian System and the overlying Middle Devonian System and younger rocks.

Devonian System

The Devonian System (Willman et al., 1975) may originally have covered all of Illinois, but if so, it was eroded from the northern part of the state, largely before Pennsylvanian time. It occurs in parts of the southeastern and most of the western portions of the area covered by this report. The Devonian is less than 200 feet thick in large parts of central and western Illinois, but thickens slightly toward the northwest and dramatically toward the deep part of the basin to more than 1800 feet.

The Devonian System is divided into three series. The Lower Devonian Series occurs only in southern Illinois and is not present within the area of this report. The Middle Devonian Series is largely limestone and dolomite, and the Upper Devonian Series is dominantly black, gray, and green shale, although smaller amounts of limestone and siltstone are present.

Carboniferous Systems

The Carboniferous rocks in Illinois consist of two systems, the Mississippian and Pennsylvanian, separated by a major angular unconformity. The Mississippian System is dominantly carbonate, consisting of about 55% limestone and dolomite, 35% shale and siltstone, and about 10% sandstone. The Pennsylvanian System is dominated by shale, containing about 50% shale, 40% sandstone and siltstone, 5% limestone, 1 to 2% coal, and minor amounts of siderite and chert (Atherton and Palmer, 1979).

Mississippian rocks occur in the subsurface over the southern two-thirds of the state (Willman et al., 1975), where they are overlain mostly by Pennsylvanian rocks, except in the western part where they are overlain by glacial till (fig. 21).

In Illinois, the Mississippian System is divided into three series. The Kinderhookian Series at the base consists mainly of normal marine, fine-grained, elastic, sedimentary rocks. The relatively thick Valmeyeran Series in the middle includes biogenic limestone which outcrops along the outer edges of the basin in western and northwestern Illinois. The thick, Chesterian Series, at the top, is confined to the deeper part of the basin and does not occur within the study area.

Strata of the Pennsylvanian System constitute the bedrock surface in about two-thirds of Illinois (Willman et al., 1975). Throughout most of the area in which they occur (fig. 21) they are covered by unconsolidated Pleistocene deposits, but in many areas they have been exposed by stream erosion. The maximum thickness of the Pennsylvanian in Illinois is about 2500 feet in the southeastern part of the state. The formations generally thicken from northern and western Illinois toward the south and southeast. In much of the Pennsylvanian area of western and northern Illinois, most of the members of the three lowest formations are relatively thin or missing, and in places along the LaSalle Anticlinal Belt, the base of the Carbondale Formation rests directly on the Ordovician St. Peter Sandstone. However, in the extreme northwest, in Rock Island and Mercer Counties, the three lowest formations are all present.

The Pennsylvanian System is characterized by many vertical changes in lithology, commonly abrupt, that produce more than 500 distinguishable units of sandstone, siltstone, shale, limestone, coal, and clay (Kosanke et al., 1960). Many of these units are laterally extensive, and even though they vary lithologically, they can be correlated widely because of their positions relative to continuous marker units, usually limestones, black fissile shales, or coals. Shale (dominantly gray with smaller amounts of red, green, and black) and underclay commonly form 65 to 70% of the sequence.

Cretaceous and Tertiary Systems

The Cretaceous System (Willman et al., 1975) is restricted to five counties in extreme southern Illinois, and to areas in Pike and Adams Counties in western Illinois (fig. 21). The Cretaceous rocks in western Illinois (Frye et al., 1964) are elastic rocks, largely sand, and as much as 100 feet thick. They are the easternmost outliers of Cretaceous sediments that formerly covered the region east of the Rocky Mountains and north of the Ozarks.

The Tertiary System (Willman et al., 1975) is extensive in extreme southern Illinois and also occurs in small, widely scattered areas in western and northern Illinois (fig. 21). Tertiary deposits in northern and western Illinois consist of scattered deposits of brown, chert gravel -- the Grover Gravel of Pliocene age (Willman and Frye, 1970).

The existence of these scattered Cretaceous and Tertiary deposits has little or no influence on groundwater conditions in the northern two-thirds of Illinois. However, widespread erosion that took place during the long interval between the end of the Pennsylvanian and into and during the Quaternary has produced a bedrock surface that at least locally influences groundwater movement and recharge to the bedrock aquifers.

Quaternary System

Surficial deposits assigned to the Quaternary System, Pleistocene Series, blanket nearly all of Illinois. The thickness, lithology, and physical and mineralogical properties of these deposits, predominantly glacial in origin, may have a significant effect on the chemistry, rate, and amount of water entering the bedrock aquifers. There is evidence that continental glaciation caused regional changes in the groundwater flow systems and altered the chemistry of the groundwater in the bedrock (Gilkeson et al., 1981).

Extensive studies have been conducted on these deposits; therefore, this section will only briefly summarize the most pertinent aspects which must be considered in relationship to the bedrock aquifers. Additional details on these deposits may be obtained from published reports (e.g., Frye et al., 1962, 1963, 1969; Willman et al., 1963; Willman and Frye, 1970; Willman, 1971 ; and Piskin and Bergstrom, 1975) and many unpublished reports, manuscripts, and data sources in the files of ISGS.

The principal Pleistocene surficial deposits are glacial materials deposited during numerous ice advances and retreats which occurred over most portions of the state. In some areas thick loess or valley fill sand and gravel are the principal deposits. Only northwestern Illinois (mainly Carroll and central Jo Daviess Counties), a small area of western Illinois (Calhoun County and portions of Pike and Adams Counties), and the extreme southern portion of the state have not been covered by glaciers. The thickness of these deposits (Piskin and Bergstrom, 1975) ranges from zero to about 600 feet (fig. 22). Although these deposits, both glacial and interglacial, have been assigned to the Nebraskan, Aftonian, Kansan, Yarmouthian,

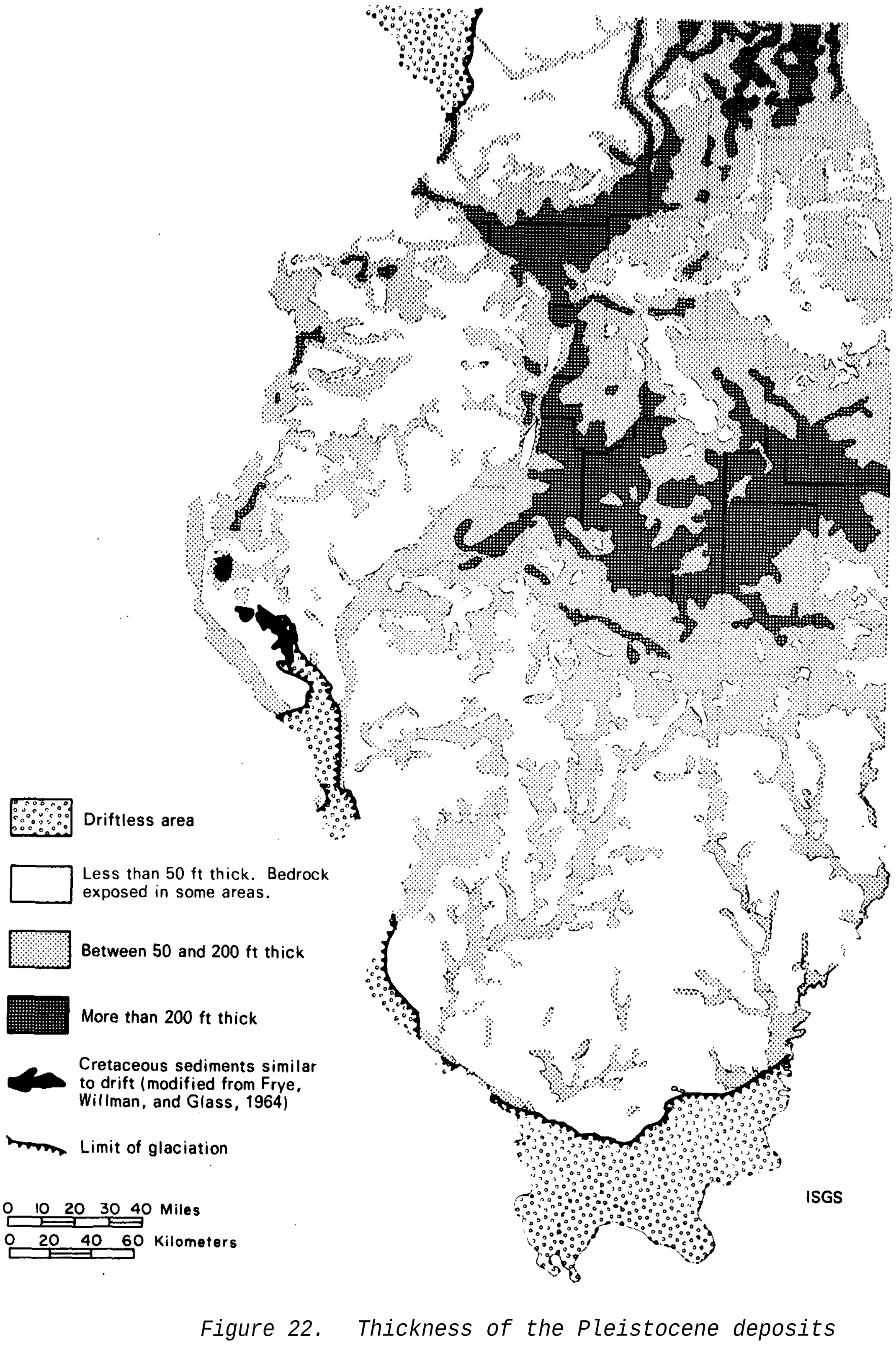


Figure 22. Thickness of the Pleistocene deposits

Illinoian, Sangamonian, Wisconsinan, and Holocene Stages, they have also been included in numerous formations and members on the basis of their lithologic characteristics and stratigraphic position.

The topography of the bedrock surface (Horberg, 1950; Willman and Frye, 1970) is characterized by a number of long, relatively wide and deep valleys, significant portions of which are now completely or partially buried by Quaternary glacial deposits. It is also characterized by extensive, relatively flat upland surfaces developed on the Pennsylvanian rocks of the central part of the state, and by relatively hilly, irregular topography developed mainly on the older Paleozoic rocks in northern and western Illinois. In these latter two areas, the bedrock valleys have locally been eroded into and through two or more of the aquifer or nonaquifer systems. Since the overlying Quaternary sediments blanket most of the state, covering the bedrock uplands and at least partially filling the bedrock valleys, the relationship between the bedrock topography and the distribution and thickness of Quaternary materials is often both locally and regionally quite obvious (fig. 22).

The distribution of the principal surficial Pleistocene deposits is shown on figure 23. While pre-Illinoian deposits form the principal surface materials in only a small portion of western Illinois (western Hancock, Adams, and Pike Counties), they occur extensively in the subsurface in sizable areas of western Illinois (Enion, Wolf Creek and Alburnett Formations) and central and east-central Illinois (Banner Formation). Scattered pre-Illinoian deposits have also been reported in the subsurface of parts of northern and south-central Illinois.

Two of the largest areas of surficial outwash, the Green River-Lower Rock River Basin (Leighton, Ekblaw, and Horberg, 1948) and the Havana region of the Illinois River (Walker et al., 1965), in northern and western Illinois, respectively, contain sand and gravel deposits that are locally continuous from land surface to bedrock; fine-grained Holocene alluvium (Cahokia Alluvium) is also present along streams. Surficial glacial outwash sand and gravel (Henry Formation) is present extensively in the form of outwash plains, valley trains, and kames in McHenry and Kane Counties in northeastern Illinois (Masters, 1978).

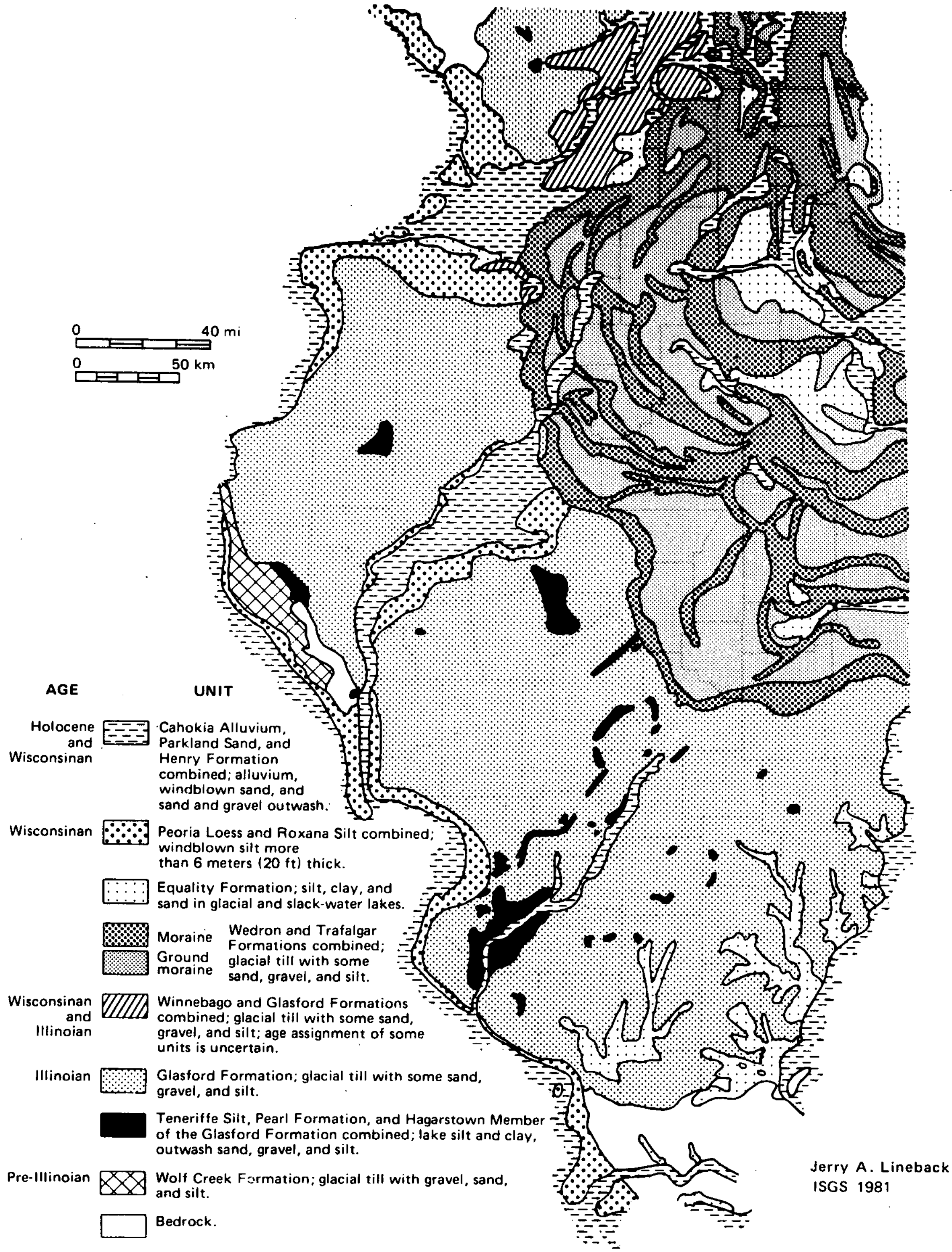


Figure 23. Quaternary deposits of Illinois

HYDROGEOLOGY

Introduction

Formal names of hydrostratigraphic units in Illinois are in the process of change to reduce confusion with rock stratigraphic terminology. The interim revised terminology for hydrostratigraphic units will be used in this report. This terminology (Cartwright, 1983) divides the hydrogeologic units into three major aquisystems, each of which is subdivided into aquigroups. The aquigroups, also shown on figure 24, are defined and then described in more detail in the following sections.

All aquisystems and aquigroups are present in the northern part of the state. The Cambrian and Ordovician aquifers studied comprise the Basal Bedrock and Midwest Bedrock Aquigroups, and in some areas are classified as the Upper Bedrock Aquigroup. Detailed descriptions of all the geologic units are given in the "Geology" section of this report.

Aquisystems and Aquigroups

Crystalline Rock Aquisystem

There are no significant aquifers within this aquisystem in Illinois.

Indurated Rock Aquisystem

Basal Bedrock Aquigroup. The Basal Bedrock Aquigroup is characterized by intermediate and regional groundwater flow systems in indurated rocks and is always overlain by indurated rock confining units. This aquigroup includes productive sandstone aquifers below thick, regionally extensive shale of the Eau Claire Formation. This aquigroup is basically the same as the "Mt. Simon Aquifer" previously defined in northeastern Illinois (Suter et al., 1959).

The Basal Bedrock Aquigroup is comprised of the rocks of the Mt. Simon Formation and the Elmhurst Sandstone Member of the Eau Claire Formation. The sandstones lie on the Precambrian granite (fig. 6).

The aquigroup is more than 2500 feet thick in east-central Illinois and northward and westward (fig. 7). The aquigroup varies from fine- to coarse-grained sandstone. Shale beds, a few feet to several tens of feet thick, are found throughout the aquigroup. The shale probably is lenticular in nature and not continuous over large areas. Much of the sandstone is moderately

SYSTEM	SERIES AND MEGAGROUP	GROUP AND FORMATION	HYDROSTRATIGRAPHIC UNITS Aquigroup	HYDROSTRATIGRAPHIC UNITS aquifer/aquitard	LOG	THICKNESS (ft)	DESCRIPTION
Quaternary	Pleistocene	Undifferentiated	Prairie	Pleistocene		0 – 600	Unconsolidated glacial deposits - pebbly clay (till) silt, and gravel. Loess (windblown silt), and alluvial silts, sands and gravels.
Tertiary & Cretaceous		Undifferentiated	Prairie			0 –100	Sand and silt.
Carboniferous: Pennsylvanian		Undifferentiated	Upper Bedrock: Mississippi Valley	Pennsylvanian		0 – 500	Mainly shale with thin sandstone, limestone and coal beds.
Carboniferous: Mississippian	Valmeyeran	St. Louis Ls Salem Ls Warsaw Ls Keokuk Ls Burlington Ls	Upper Bedrock: Mississippi Valley	St. Louis - Salem aquifer Keokuk – Burlington aquifer		0 – 600	Limestone, cherty limestone, green, brown and black shale, silty dolomite.
Carboniferous: Mississippian	Kinderhookian	Undifferentiated	Upper Bedrock: Mississippi Valley				
Devonian		Undifferentiated	Upper Bedrock: Mississippi Valley	Devonian		0 – 400	Shale, calcareous; limestone beds, thin.
Silurian	Niagaran	Port Byron Fm Racine Fm Waukesha Ls Joliet Ls	Upper Bedrock: Mississippi Valley	Silurian dolomite aquifer		0 – 465	Dolomite, silty at base, locally cherty.
Silurian	Alexandrian	Kankakee Ls Edgewood Ls	Upper Bedrock: Mississippi Valley	Silurian dolomite aquifer			
Ordovician	Cincinnatian	Maquoketa Shale Group	Upper Bedrock: Midwest Bedrock	Maquoketa confining unit		0 – 250	Shale, gray or brown; locally dolomite and/or limestone, argillaceous.
Ordovician	Mohawkian (Ottawa Ls Megagroup)	Galena Group Decorah Subgroup Platteville Group	Upper Bedrock: Midwest Bedrock	Galena-Platteville unit		0 – 450	Dolomite and/or limestone, cherty. Dolomite, shale partings, speckled. Dolomite and/or limestone, cherty, sandy at base.
Ordovician	Mohawkian	Ancell Gr: Glenwood Fm	Upper Bedrock: Midwest Bedrock	Ancell aquifer		100 – 650	Sandstone, fine- and coarse-grained; little dolomite; shale at top. Sandstone, fine- to medium-grained; locally cherty red shale at base.
Ordovician	Chazyan	Ancell Gr: St. Peter Ss	Upper Bedrock: Midwest Bedrock	Ancell aquifer			
Ordovician	Canadian (Knox Megagroup)	Prairie du Chien Group: Shakopee Dol New Richmond Ss Oneota Dol Gunter Ss	Midwest Bedrock	Middle confining unit: Prairie du Chien		100 – 1300	Dolomite, sandy, cherty (oolitic), sandstone. Sandstone, interbedded with dolomite. Dolomite, white to pink, coarse-grained, cherty (oolitic), sandy at base.
Cambrian	St. Croixian (Knox Megagroup)	Jordan Ss Eminence Fm–Potosi Dolomite	Midwest Bedrock	Middle confining unit: Eminence-Potosi			Dolomite, white, fine-grained, geodic quartz, sandy at base.
Cambrian	St. Croixian (Knox Megagroup)	Franconia Fm	Midwest Bedrock	Middle confining unit: Franconia			Dolomite, sandstone, and shale, glauconitic, green to red, micaceous.
Cambrian	St. Croixian	Ironton Ss Galesville Ss	Midwest Bedrock	Ironton-Galesville aquifer		0 – 270	Sandstone, fine- to medium-grained, well sorted, upper part dolomitic.
Cambrian	St. Croixian	Eau Claire Fm	Basal Bedrock	Eau Claire		0 – 450	Shale and siltstone; dolomite, glauconitic; sandstone, dolomitic, glauconitic.
Cambrian	St. Croixian	Mt. Simon Fm	Basal Bedrock	Elmhurst-Mt. Simon aquifer		0 – 2600	Sandstone, coarse-grained, white, red in lower half; lenses of shale and siltstone, red, micaceous.
Pre-Cambrian			Crystalline				No aquifers in Illinois

Note: The rock-stratigraphic and hydrostratigraphic-unit classifications follow the usage of the Illinois State Geological Survey

Figure 24. Stratigraphy and water-yielding properties of the rocks and character of the groundwater in the study area

DRILLING AND CASING CONDITIONS	WATER-YIELDING PROPERTIES	CHEMICAL QUALITY OF WATER	WATER TEMPERATURE °F
Boulders, heaving sand locally; sand and gravel wells usually require screens and development; casing in wells into bedrock.	Sand and gravel, permeable. Locally, wells yield as much as 3000 gpm. Specific capacities vary from about 0.1 to 5600 gpm/ft.	TDS generally between 400 and 600 mg/L. Hardness 300–400 mg/L. Iron generally 1–5 mg/L.	50 – 64
Shale requires casing.	Extremely variable. Sandstone and limestone units generally yield less than 10 gpm.	TDS extremely variable regionally and with depth. North-central Illinois, 500–1500 mg/L; southern, 500–3000 mg/L. Hardness: 150–400 mg/L north; 150–1000 mg/L south. Iron generally 1–5 mg/L.	53 – 57
	In southern two-thirds of state yields generally less than 25 gpm.	TDS ranges between 400 and 1000 mg/L. Hardness is generally between 200 and 400 mg/L. Iron: 0.3–1.0 mg/L.	53 – 59
Upper part usually weathered and broken; crevicing varies widely.	Yields inconsistent. Major aquifer in NE and NW Illinois. Yields in fractured zones more than 1000 gpm.	TDS: 350–1000 mg/L; Hardness: 200–400 mg/L; Iron: 0.3–1.0 mg/L.	52 – 54
Shale requires casing.	Shales generally not water yielding. Crevices in dolomite units yield small local supplies.		
Crevicing commonly where formations underlie drift. Top of Galena usually selected for hole reduction and seating of casing.	Where overlain by shales, crevicing and well yields small. Where overlain by drift wells yield moderate quantities of water.	For Midwest Bedrock Aquigroup as a whole, TDS ranges from 400 to 1400 mg/L in NW and up to 2000 mg/L in south. Hardness ranges from 175 mg/L in northern recharge areas to 600 mg/L in E. Cook and S. Fulton Counties. Iron generally less than 1.0 mg/L.	52 – 73
Lower cherty shales cave and are usually cased. Friable sand may slough.	Small to moderate quantities of water. Transmissivity approximately 15 percent of that of the Midwest Bedrock Aquigroup.		
Crevices encountered locally in the dolomite, especially in the Eminence-Potosi. Casing not required.	Crevices in dolomite and sandstone yield small to moderate quantities of water. Transmissivity approximately 35 percent of that of the Midwest Bedrock Aquigroup.		
Amount of cementation variable. Lower part more friable. Sometimes sloughs.	Most productive unit of the Midwest Bedrock Aquigroup. Yields over 500 gpm common in northern Illinois. Transmissivity approximately 50 percent of that of the Midwest Bedrock Aquigroup.		
Casing not usually necessary. Locally weak shales may require casing.	Shales generally not water yielding.		
Casing not required.	Moderate quantities of water in upper units. Comparable in permeability to the Glenwood-St. Peter Sandstone.	Varies northwest to southeast and with depth. At shallower depths, TDS: 235–4000 mg/L, Hardness: 220–800 mg/L, Iron: 0.1–20 mg/L. High chloride concentrations with depth.	51 – 62 in the north 80 or more in the south

Figure 24. Concluded

well cemented and therefore has a relatively low hydraulic conductivity. The upper 300 to 600 feet is generally friable, and several friable zones are found in the unit. The degree of cementation decreases to the north toward the Wisconsin state line and increases southward toward the Illinois Basin.

The sandy lower zones of the Eau Claire Formation increase in thickness in relation to the total thickness of the formation. The shales become thinner and probably become lenticular in character. When sandstone becomes the predominant lithology, it yields significant water.

The Basal Bedrock Aquigroup is separated from the production zones of the Midwest Bedrock Aquigroup by the shales of the Eau Claire Formation. The confining unit is formed by the predominantly shaly upper part of the Eau Claire Formation (fig. 9). The Eau Claire Formation gradually becomes sandier to the north and west. However, the shale of the Proviso Siltstone Member is quite persistent and forms a barrier between the aquifers of the Basal Bedrock Aquigroup and the Ironton-Galesville aquifer of the Midwest Bedrock Aquigroup above.

Wells near the Wisconsin border penetrate increasing amounts of sandstone interbedded with the shales. Detailed studies of wells in the northern tier of counties show that 50 to 60% of the upper Eau Claire is sandstone. Thus, wells which penetrate the confining unit may obtain moderate yields of water from this zone. Nevertheless, the shales are laterally continuous, in contrast to shales in the Elmhurst-Mt. Simon aquifer which are lenticular in character. The sandstones in the Eau Claire confining unit may or may not be continuous. Thus, despite the sandy character of the Eau Claire Formation, the shales are persistent throughout the state and form a major aquitard.

Less is known about the confining unit in western Illinois. It appears to become quite sandy, as in northern Illinois.

Midwest Bedrock Aquigroup. The Midwest Bedrock Aquigroup is characterized by intermediate and regional groundwater flow systems in indurated rock that are overlain by indurated rock confining units. The top of the aquigroup is defined as the top of the Maquoketa Shale Group or other confining units where the Maquoketa is absent. The base of the aquigroup is at the top of the Eau Claire Formation or stratigraphically higher where the Ironton and Galesville Sandstones are absent. This aquigroup is basically the same as the "Cambrian-Ordovician Aquifer" previously defined in northeastern Illinois (Suter et al., 1959).

In northern Illinois the Midwest Bedrock Aquigroup consists of rock from the base of the Galesville Sandstone up through the top of the Maquoketa Shale Group. The Ironton-Calesville and Glenwood-St. Peter Sandstones are the principal water-producing zonea in this region and are of principal concern in this report. The lower boundary of the Midwest Bedrock Aquigroup is at the base of the Galesville Sandstone in northern Illinois. Where the Ironton-Galesville feathers out, the boundary rises along vertical cutoffs to either the porous sandstone of the St. Peter or to the lowest productive aquifer in the Knox Megagroup.

Ironton-Galesville Aquifer. The Ironton-Galesville aquifer is described in detail in the "Geology" section. This sandstone (fig. 11) is the moat uniform and productive zone in the Cambrian and Ordovician Systems in Illinois north of the Illinois River.

South of the Illinois River the sandstone becomes finer, gradually changing to a shale and then dolomite (in this Same stratigraphic position) in the deeper parts of the Illinois Basin. This change is also reflected in the water quality trends in the aquifer.

Middle Confining Unit. The strata between the top of the Ironton-Galesville and St. Peter Sandstone (Ancell) are highly variable in thickness (fig. 13) as a result of the erosion which took place before the deposition of the St. Peter. This surface has been described both as a karat surface and as one with deep valleys (Buschbach, 1961). While there is evidence to support both hypotheses, it is clear that if karat did develop, there is no remnant of the high permeability which must have existed.

The confining unit is mainly dolomite and shale with some sandstone. The dolomite and sandstone contribute considerable quantities of water to wells. Two of the sandstones are major aquifers in some regions. The Jordan Sandstone, which is extensively used in Iowa, is present along the western edge of the state in sufficient thickness to be productive; some wells in the Rock Island-Moline area penetrate to the Jordan.

The New Richmond Sandstone is tapped by wells in parts of LaSalle and Grundy Counties where it is relatively thick. In much of this area the St. Peter is near the land surface and partly eroded, while the New Richmond is confined and has considerable artesian head.

Ancell Aquifer. The St. Peter Sandstone, along with the overlying Glenwood Sandstone when present (see "Geology" section), forms the second principal aquifer of the Midwest Bedrock Aquigroup. This sandstone is widespread in the north-central United States and is present under the entire state, except where it has been eroded (fig. 15).

The thickness (fig. 14) averages about 200 feet; however, the thickness varies greatly from less than 100 feet to over 600 feet. The thickening reflects the irregular base of the formation; the surface is fairly regular. The lower Kress member, which accounts for much of the increase in thickness, frequently adds little to the yield of wells, being a rubble-like deposit in a clay or shale matrix. Thus, the yield does not increase proportionally to increases in thickness.

Galena-Platteville Unit. The Galena-Platteville Unit is found throughout most of Illinois. It overlies the Ancell aquifer and sometimes forms part of the confining unit for that aquifer, although it is locally productive. In northeastern Illinois and south of the Illinois River, the Galena-Platteville Unit is overlain by the Maquoketa Shale Group or younger shales. Although it yields some water in this situation, the yield generally is only a small portion of the total water yielded to wells penetrating the deeper sandstones as part of the Midwest Bedrock Aquigroup. Locally, larger supplies are obtained from the Galena-Platteville. In northwestern Illinois the Galena-Platteville Unit immediately underlies glacial deposits or is exposed at the surface (fig. 17). The Maquoketa Shale Group is present above the Galena-Platteville in small areas. In this region, the Galena-Platteville dolomites become part of the Upper Bedrock Aquigroup.

Maquoketa Confining Unit. The Maquoketa Shale Group (fig. 19), where present, forms the principal confining bed for the Midwest Bedrock Aquigroup in northern and western Illinois. The Maquoketa Shale Group is described in some detail in the "Geology" section of this report. Little water, if any, is obtained from the shale. Where the Maquoketa directly underlies the glacial deposits, limited amounts of water are obtained from joints and fractures. Some dissolution has occurred in the Middle Fort Atkinson Limestone, where it is overlain by Silurian and Quaternary deposits, and has increased yields somewhat.

Mississippi Valley Bedrock Aquigroup. The Mississippi Valley Bedrock Aquigroup is characterized by intermediate and regional groundwater flow systems in indurated rock that are overlain by indurated rock confining units. The base of this system is at the top of the Maquoketa Shale Group (this is the only aquigroup boundary which cannot move stratigraphically). The aquigroup consists of rocks from the Pennsylvanian System through the Silurian System in the southern three-fourths of Illinois; the aquigroup is not present in northern Illinois.

In the southwestern part of the region studied, where Mississippian and Pennsylvanian rock are present, the shales confine several moderately productive aquifers. The primary water-yielding zones are dolomites of the Devonian and Silurian Systems and sandstones and carbonates of the Mississippian System. Some sandstones are also present in the Pennsylvanian, but these generally have very low productivity.

Devonian and Pennsylvanian shales are present throughout most of the area south of the Illinois River, and form the principal confining units within the aquigroup. The upper boundary of the Mississippi Valley Bedrock Aquigroup rises stratigraphically to include the uppermost aquifer confined by indurated rocks and all the confining units below the Upper Bedrock Aquigroup.

Upper Bedrock Aquigroup. This aquigroup consists of local and intermediate flow systems in indurated sediments with open connection to the Prairie Aquigroup so that water quality is related to that in the Prairie Aquigroup. This aquigroup is basically the same as the "Shallow Dolomite Aquifer" as previously defined in northern Illinois (Suter et al., 1959).

The Galena-Platteville Unit, the Maquoketa Confining Unit, and, locally, the Ancell aquifer become part of the Upper Bedrock Aquigroup in north-central Illinois, where they are exposed at the surface or overlain by glacial deposits. These aquifers are moderately productive. In this region dissolution of the rock by groundwater has occurred, enlarging the joints and fractures in the rock and increasing its permeability. The degree of jointing and fracturing and dissolution decreases with increasing depth of penetration in the rock. Most of the water is obtained in the uppermost 100 feet of rock.

The most significant and productive aquifer of the aquigroup is the Silurian Dolomite aquifer, which underlies northeastern Illinois and a small part of northwestern Illinois (fig. 21). In these areas, large yields are sometimes obtained, reducing the dependence on the Cambrian- and Ordovician-age aquifers.

The only other significant aquifers which make up the Upper Bedrock Aquigroup in the region studied are the Mississippian carbonate rocks in the southwestern part of the region (fig. 21).

Non-Indurated Rock Aquisystem

Prairie Aquigroup. This aquigroup consists of local and intermediate flow systems in nonindurated geologic materials consisting of alluvium, glacial drift, and Cretaceous and Tertiary sediments. The major component of recharge to the system is local precipitation. The aquigroup is confined locally by fine-grained nonindurated sediments (referred to as confining units or aquitards). In some regions the Prairie Aquigroup is 400 to 500 feet thick, while in others it is 0 to 50 feet thick.

HYDROLOGY

Hydraulic Properties

The principal hydraulic properties which influence well yields and water-level response to pumpage in the Cambrian and Ordovician aquifers are transmissivity and storage coefficient. Regionally, the leakage coefficient also plays an important role in influencing water levels. The capacity of an aquifer to transmit groundwater is expressed by the transmissivity, which is defined as the rate of flow of water through a unit width of the aquifer. under a unit hydraulic gradient. The storage properties of an aquifer are expressed by the storage coefficient, which is defined as the volume Of water released from or taken into storage per unit surface area of the aquifer per unit change in head normal to that surface.

For confined (artesian) conditions, in which water levels rise above the top of the aquifer in wells penetrating the aquifer, water released from or taken into storage is attributed solely to compressibility properties of the aquifer and water. Such coefficients are usually very small. On the other hand, where unconfined conditions (water table) prevail, in which water levels in wells represent the top of the saturated thickness of the aquifer, water released from or taken into storage is attributed almost entirely to gravity drainage or refilling of the zone through which the change of the water table takes place. A small portion of the water volume change comes from the compressibility of the aquifer and water, as in the artesian case, but this volume is proportionately nearly insignificant.

Most of the available data on hydraulic properties are from the Midwest Aquigroup. The storage coefficients for the confined aquifer are generally 10^{-5} to 10^{-3}. Water-table storage coefficient data for the Midwest Aquigroup have never been obtained from tests, because until recently the aquifers have remained under artesian conditions. Typical values of water-table storage coefficients in unconsolidated material range from 0.01 to 0.3.

The rate of vertical leakage of groundwater through a confining bed in response to a given vertical head gradient is dependent upon the vertical hydraulic conductivity of the confining bed. In cases where the confining bed is not well defined or is unknown, Hantush (1956) suggested the use of the term leakage coefficient, which is the ratio of the vertical hydraulic conductivity of the confining bed to its thickness. It is defined as the quantity of water that crosses a unit area of the interface between an aquifer and its confining bed divided by the head loss across the confining bed.

Aquifer Tests

The hydraulic properties of aquifers and confining beds may be determined by means of aquifer tests wherein the effect of pumping a well at a known constant rate is measured in the pumped well and in observation wells penetrating the aquifer. Graphs of drawdown versus time or drawdown versus distance from the pumped well are used to solve formulas which express the relationship between the hydraulic properties of an aquifer and its confining bed, if present, and the lowering of water levels (drawdown) in the vicinity of a pumping well. Graphical analyses may utilize the leaky artesian formula (Hantush and Jacob, 1955), the nonequilibrium formula (Theis, 1935), or the modified nonequilibrium formula (Cooper and Jacob, 1946). Type-curve and straight-line methods for graphical analysis were described by Walton (1962). Test data collected under water-table conditions may be analyzed by methods devised by Boulton (1963) and described by Prickett (1965). Where geohydrologic boundaries are known to exist, their effect on drawdown can be determined by means of image-well theory, described by Ferris (1959).

Basal Bedrock Aquigroup. Aquifer test data from the Basal Bedrock Aquigroup were available from three long-term tests at gas storage project sites (Illinois State Water Survey and Hittman Associates, 1973). The tests were conducted at pumping rates of 80, 45, and 56 gpm for periods of 48, 40, and 18 days, respectively. At least five observation wells were available at each site; however, because of the partial penetration effects caused by the great thickness of this aquifer system, data from distant (greater than 1.5 times the aquifer thickness) observation wells were given preference over data from wells closer to the pumped well, in order to minimize distortions caused by partial penetration of wells.

Data from the distant observation wells were analyzed by graphical techniques described in the above references. The results are summarized in table 1.

Table 1. Hydraulic Properties in the Basal Bedrock Aquigroup

Gas storage site	General location	Average transmissivity (gpd/ft)	Average storage coefficient
Ancona	NW LaSalle Co.	10,600	1.8×10^{-4}
Pontiac	Central Livingston Co.	1,635	1.3×10^{-4}
Hudson	NW McLean Co.	980	5.2×10^{-4}

Table 2. Storage Coefficients of the Midwest Bedrock Aquigroup

Location	Well owner	Date of test	Storage coefficient
Cook County	Corn Products Corp., Argo	10/43	0.00016
Kane County	City of Elgin	4/44	0.00068*
Knox County	City of Knoxville	3160	0.00057
Will County	Blockson Chemical Co., Joliet	3151	0.00037
Will County	Kankakee Ordinance Works, Joliet	3143	0.00018
		Average	0.00039

*Well also open to Basal Bedrock Aquigroup

Midwest Bedrock Aquigroup. Because most wells tapping the Midwest Bedrock Aquigroup are open to several aquifers as well as to the Middle Confining Unit, the aquigroup behaves more or less as a single hydraulic system. Hydraulic properties determined from aquifer tests, therefore, represent the combined properties of all units beneath the Maquoketa Confining Unit. Pumping tests in the Midwest Bedrock Aquigroup have been made at approximately 220 sites within the study area. Tests involving observation wells were made at only five of these sites. The effects of leakage were negligible during the tests, and analysis was limited to the use of nonleaky or modified nonequilibrium formulas. The storage coefficient was not determined from pumped well data, since the effective radius of the well cannot normally be estimated with sufficient accuracy. Storage coefficients determined at five sites are presented in table 2. Transmissivity values determined from the controlled tests are included in Appendix A and were used to prepare figure 25.

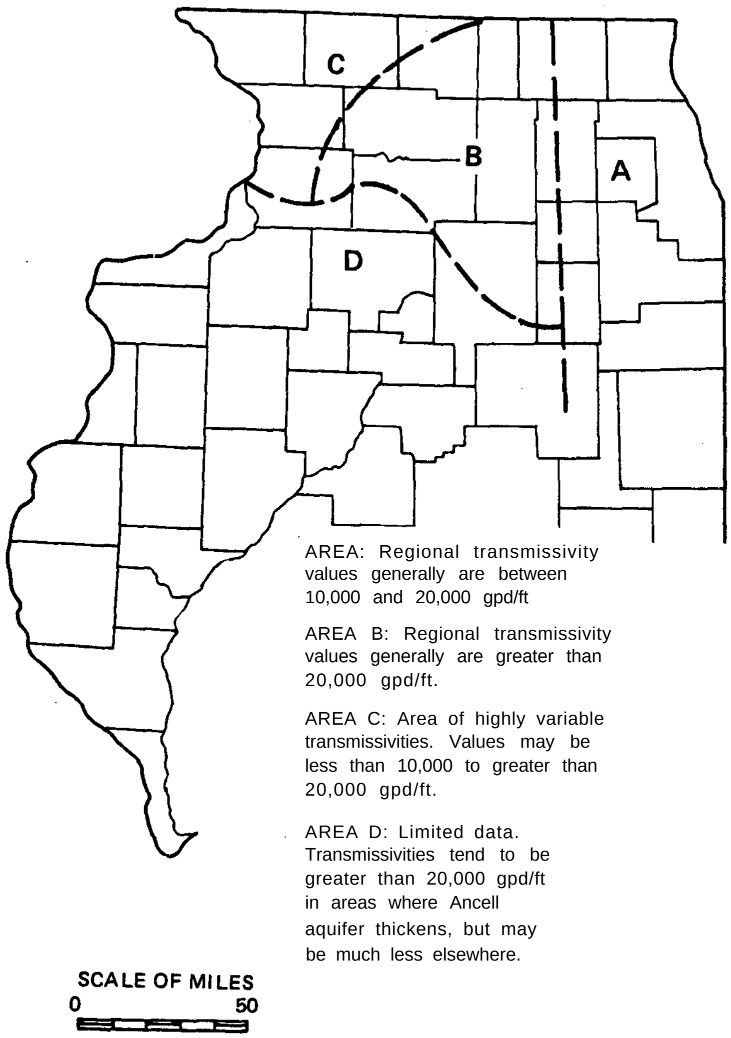


Figure 25. Regional transmissivities in the Midwest Bedrock Aquigroup

Lithologic changes within the Ancell and Ironton-Galesville aquifers appear to have an effect on transmissivities of the Midwest Bedrock Aquigroup. The thickness of the Ironton-Galesville aquifer generally increases from the northwest to the southeast (see fig. 11), while that of the Ancell aquifer is highly variable locally (fig. 14). Transmissivities are generally increased by local or regional thickening of these two formations. In addition, the transmissivity of the Midwest Bedrock Aquigroup increases significantly where the overlying Maquoketa Confining Unit is absent.

In Area A of figure 25, the aquifers of the Midwest Bedrock Aquigroup are overlain by the Maquoketa Confining Unit, and regional values of transmissivity may vary from 10,000 to 20,000 gpd/ft. Locally, however, where the Ancell aquifer thickens at the expense of underlying, less permeable, carbonate rocks, transmissivities may exceed 20,000 gpd/ft. In Areas B and C, wells in the Midwest Aquigroup are often open to shallower aquifers which may affect the transmissivities measured. In the recharge area to the west of the Maquoketa Confining Unit border (Area B), transmissivities generally exceed 20,000 gpd/ft. In Area C the Maquoketa and the Galena-Platteville Unit are highly dissected by streams, and as a result, transmissivities vary in this region from fewer than 10,000 to more than 20,000 gpd/ft. Another factor which probably contributes regionally to the lower transmissivity values is the thinner Ironton-Galesville section in this area. The higher values of transmissivity are usually accounted for by the locally thicker Ancell aquifer, as well as a local absence of the Maquoketa. Area D is a region where transmissivity data are sparse and variable. The Midwest Bedrock Aquigroup is confined under the Maquoketa Confining Unit and other overlying rocks, as in northeastern Illinois. Transmissivities in this region are as low as 5,000 gpd/ft, but may exceed 20,000 gpd/ft.

Upper Bedrock Aquigroup. Six aquifer tests were made at five sites in DuPage County between 1955 and 1980. At this location the Upper Bedrock Aquigroup is composed of dolomites of Silurian age. According to Zeizel et al. (1962) the Upper Bedrock Aquigroup is highly fractured and in many places is under leaky artesian conditions. Transmissivities and storage coefficients are highly variable both regionally and among the various observation wells in aquifer tests. Values of transmissivity and storage coefficient ranged from 10,500 to 85,400 gpd/ft and from 9.0×10^{-5} to 3.5×10^{-4}, respectively. Data from other areas in Illinois are not available for the Upper Bedrock Aquigroup.

Specific Capacity Analyses

One means of expressing the yield of a well is by use of the specific capacity, which is defined as the yield of the well in gallons per minute per foot of drawdown for a given pumping period and discharge rate. Walton (1962) showed that the Theis nonequilibrium formula can be expressed in terms of the theoretical specific capacity of a well discharging at a constant rate in a homogeneous, isotropic, areally infinite, nonleaky aquifer.

The theoretical specific capacity of a well varies with the radius of the well and the pumping period. For instance, a 30-inch diameter well has a specific capacity about 13% greater than that of a 12-inch diameter well. The theoretical specific capacity decreases with the length of the pumping period, since drawdowh continuously increases with time.

Head losses within the well, known as well losses, must be accounted for before drawdown data can be used in the specific capacity formula to estimate hydraulic properties. Jacob (1947) and Rorabaugh (1953) described graphical methods to compute the well loss coefficient from data collected during a step-drawdown test in which the well pump is operated during several successive and equal time periods at constant fractions of the final pumping rate.

Where applicable, additional corrections must be made to drawdown data for the effects of partial penetration and for decreases in saturated thickness under water-table conditions. None of the specific capacity data for the Midwest Bedrock Aquigroup were affected by water-table conditions. The effects of partial penetration within the Midwest Bedrock Aquigroup could not be assessed because of the heterogeneous character of the various hydrogeologic units within the aquigroup. It is believed, however, that the majority of wells penetrating the Midwest Bedrock Aquigroup generally receive groundwater flow from the most productive units within the system and that the effects of partial penetration are not significantly large. Partial penetration effects, likewise, are not considered significant in the Upper Bedrock Aquigroup, since wells in that system generally penetrate its most productive upper zones, which are more creviced than are those at depth. Data from the Basal Bedrock Aquigroup are extremely limited. There is evidence that the units within this system are stratified, and the effect of such stratification in such a thick aquifer system cannot be evaluated at present.

All specific capacity data were corrected for well losses and adjusted to a common well radius (0.5 foot) and a common pumping period (12 hours) for purposes of comparison. From these data, values of aquifer transmissivity were derived from the relationship between transmissivity and specific capacity given by the modified nonequilibrium formula (Walton, 1962). TO solve this formula the storage coefficient must be assumed, based upon whether aquifer conditions are water table or artesian.

Basal Bedrock Aquigroup. Specific capacity data are available for just one well open only to the Basal Bedrock Aquigroup. The well, located in northern Cook County, had an adjusted specific capacity of 0.6 gpm/ft. The effects of partial penetration in this well could be large, since the ratio of vertical to horizontal hydraulic conductivity is believed to be about 0.3 to 0.4 (Illinois State Water Survey and Hittman Associates, 1973) and the thickness of the aquigroup is approximately 2000 feet in northern Cook County.

Midwest Bedrock Aquigroup. Specific capacity data were collected during well production tests at approximately 570 sites. The transmissivity for each data value was then obtained from the relationship between transmis-Sivity and specific capacity described above. Transmissivity values obtained from specific capacity were used to help prepare figure 25.

Upper Bedrock Aquigroup. Csallany and Walton (1963) ‘studied yields of wells in the Upper Bedrock Aquigroup in northern Illinois. The massive amounts of data (approximately 1000 production tests) available, however, yielded specific capacity values which were extremely variable and interpretatively intractable. Csallany and Walton solved this problem by treating the data statistically, whereby adjusted specific capacities were divided by the depths of penetration of the wells and plotted as frequency graphs. It had been known that crevicing and depth of well strongly influence well yields. Csallany and Walton’s study, however, also indicated a correlation between well yields and bedrock upland areas and areas where sand and gravel were present in the glacial drift immediately above the bedrock. The 50% frequency value of unit specific capacity (yield per foot of penetration) for bedrock upland areas, for example, was 0.24 gpm/ft/ft, whereas in bedrock valleys the 50% frequency value was only 0.065 gpm/ft/ft. Where sand and gravel in the drift overlaid the bedrock, the 50% value of unit specific capacity was 0.26 gpm/ft/ft, whereas if the glacial drift material was till, the 50% value was 0.06 gpm/tt/ft.

Leakage Coefficient

Values of the leakage coefficient of a confining layer are normally determined by analysis of long period (24 hours or more) aquifer tests, involving time-drawdown data from one or more observation wells. Such was the case with the Upper Bedrock Aquigroup. Within the Basal and Midwest Bedrock Aquigroups, however, leakage due to pumpage from a single well is too small to be observed in a typical well test, and a regional analysis must be made using flow-net and mass balance analyses.

Basal Bedrock Aquigroup Confining Unit. Schicht, Adams, and Stall (1976) used flow-net analysis of earlier work by Walton (1960) to estimate the average coefficient of vertical hydraulic conductivity for the confining unit of the Basal Bedrock Aquigroup as 3.0×10^{-5} gpd/ft^2. The leakage coefficient for this confining unit can be estimated, therefore, by dividing the vertical hydraulic conductivity at a given location by the thickness of the confining unit. Figure 9 shows that the thickness of the confining unit in the study area varies from 0 to 600 feet but is generally from 200 to 400 feet thick. The leakage coefficient, therefore, is estimated to be between 7.5×10^{-8} and 1.5×10^{-7} gpd/ft^3 throughout much of the study area.

Midwest Bedrock Aquigroup Confining Unit. The Maquoketa Shale Group forms the confining unit of the Midwest Aquigroup in large parts of north-eastern Illinois and also in portions of northwestern Illinois. As shown in figure 19, the Maquoketa Shale Group has a maximum thickness of about 200 feet in the Chicago area and thins to the north and west. The changes in artesian pressure produced by pumping in the Midwest Aquigroup have been pronounced and widespread and have caused large differentials in head above and below the Maquoketa. As a result, appreciable quantities of water have moved downward through the Maquoketa as leakage, as will be discussed in the section, "Recharge and Movement of Groundwater."

Walton (1960) made a regional flow-net analysis of the Chicago area and determined a leakage coefficient for the confining unit of 2.5×10^{-7}

gpd/ft^3, which is comparable to that of the Basal Bedrock Aquigroup confining unit.

Piezometric Surface of Midwest Bedrock Aquigroup

The piezometric surface of an aquifer is an imaginary surface which marks the height to which water will rise in artesian wells penetrating the aquifer. If the water level elevations in such wells are plotted on a map and contoured, it is called a piezometric surface map. The piezometric surface map is actually a map of the hydraulic head in the aquifer. The water table is a particular piezometric surface for unconfined aquifers. Under isotropic conditions (aquifer hydraulic properties independent of direction) groundwater travels downgradient at right angles to the water level contours (isopiestic lines), and, therefore, a piezometric surface map is useful in indicating directions of groundwater flow. The literature also often refers to these maps as potentiometric surface maps whose contours are called isopotential lines. Under anisotropic conditions (aquifer Properties dependent upon direction) orthogonality is not maintained, and other procedures are required to draw flow nets (Freeze and Cherry, 1979).

It is to be understood that water levels in wells penetrating individual units of the Midwest Bedrock Aquigroup represent the piezometric levels for those units, whereas water levels in multi-unit wells represent composite levels for the aquigroup as a collective unit. In constructing the piezometric maps shown in figures 26-29, these limitations were recognized and taken into consideration. In northeastern Illinois, for example, the piezometric surface map is a composite, whereas in western Illinois the predominance of data was from wells tapping the Calena-Platteville Unit and Ancell aquifer only. Elsewhere in the study area, the data were from both single- and multi-unit wells.

The exact configuration of the piezometric surface of the Midwest Bedrock Aquigroup at the time of initial development is not known. Suter et al. (1959) interpreted water level data presented by Anderson (1919) and Wiedman and Schultz (1915) in northeastern Illinois (see fig. 26). According to Suter et al., a groundwater ridge existed in parts of McHenry, Kane, and DeKalb Counties, and groundwater moved southeastward toward Chicago. Westward flow from the ridge moved toward the Rock River. Water level contours

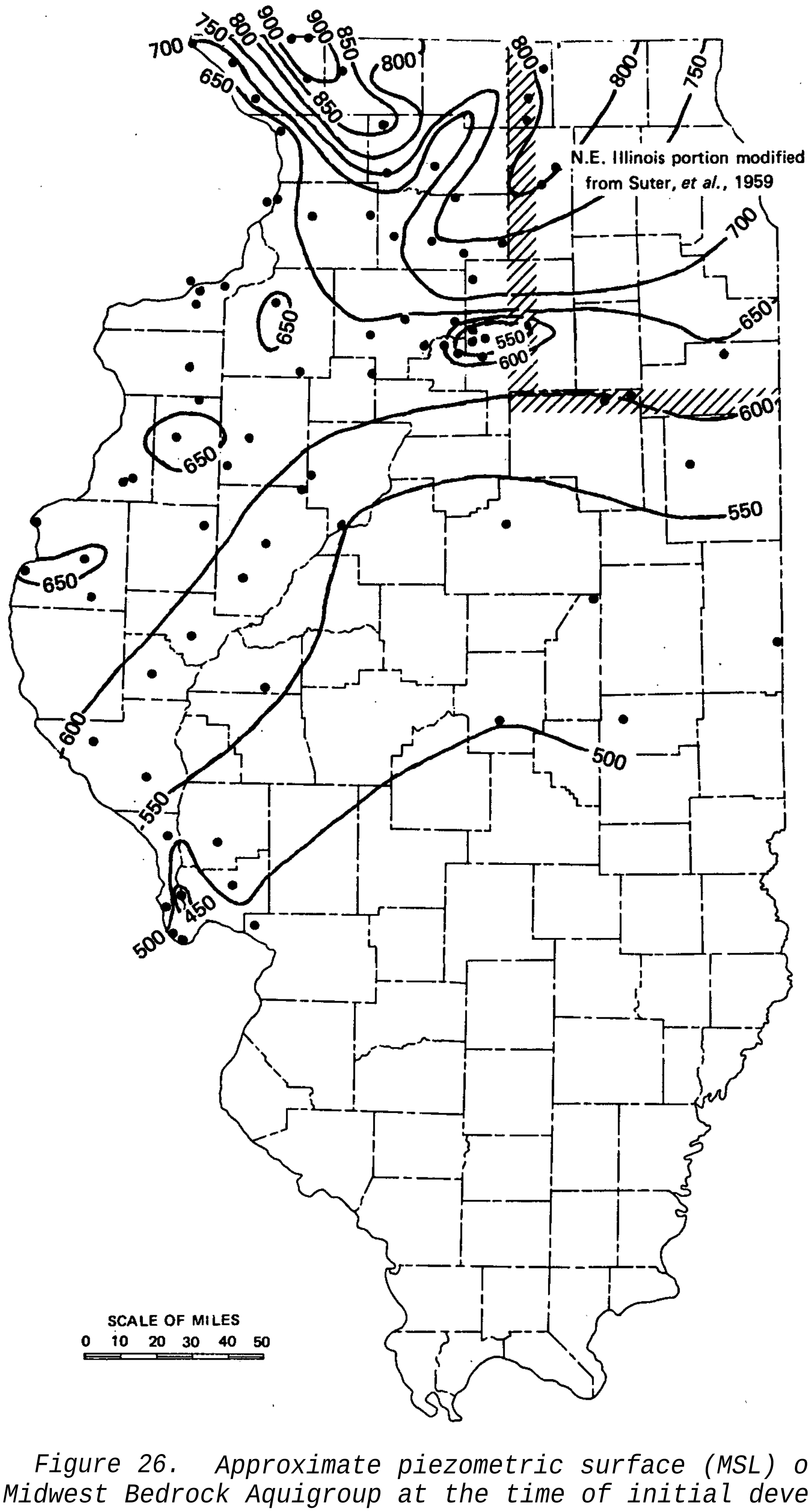


Figure 26. Approximate piezometric surface (MSL) of the Midwest Bedrock Aquigroup at the time of initial development

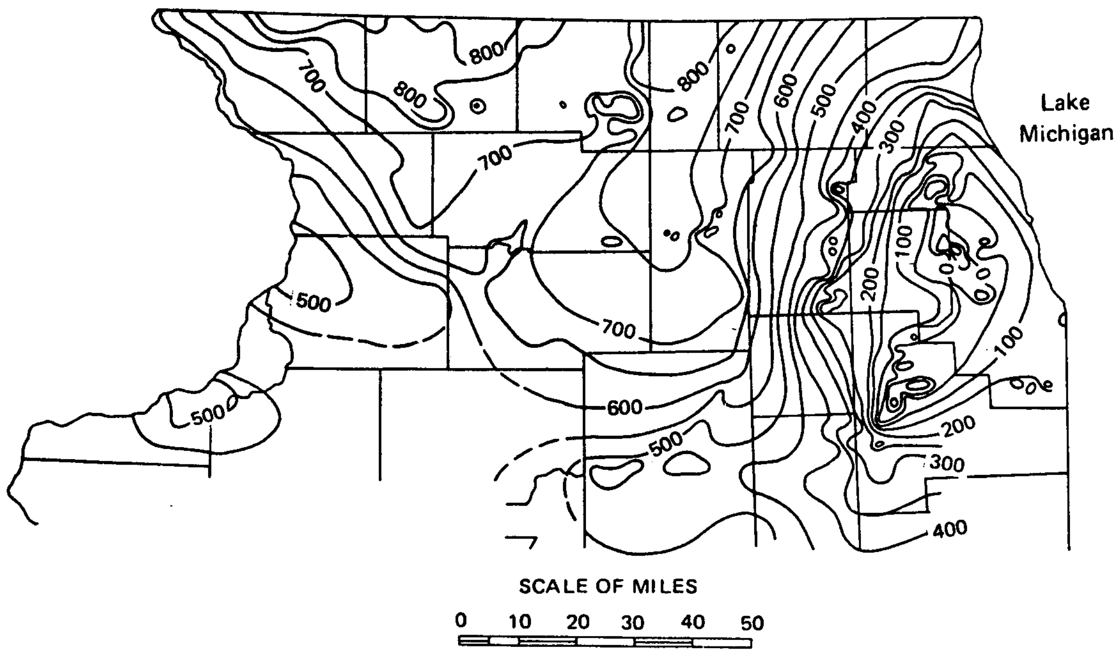
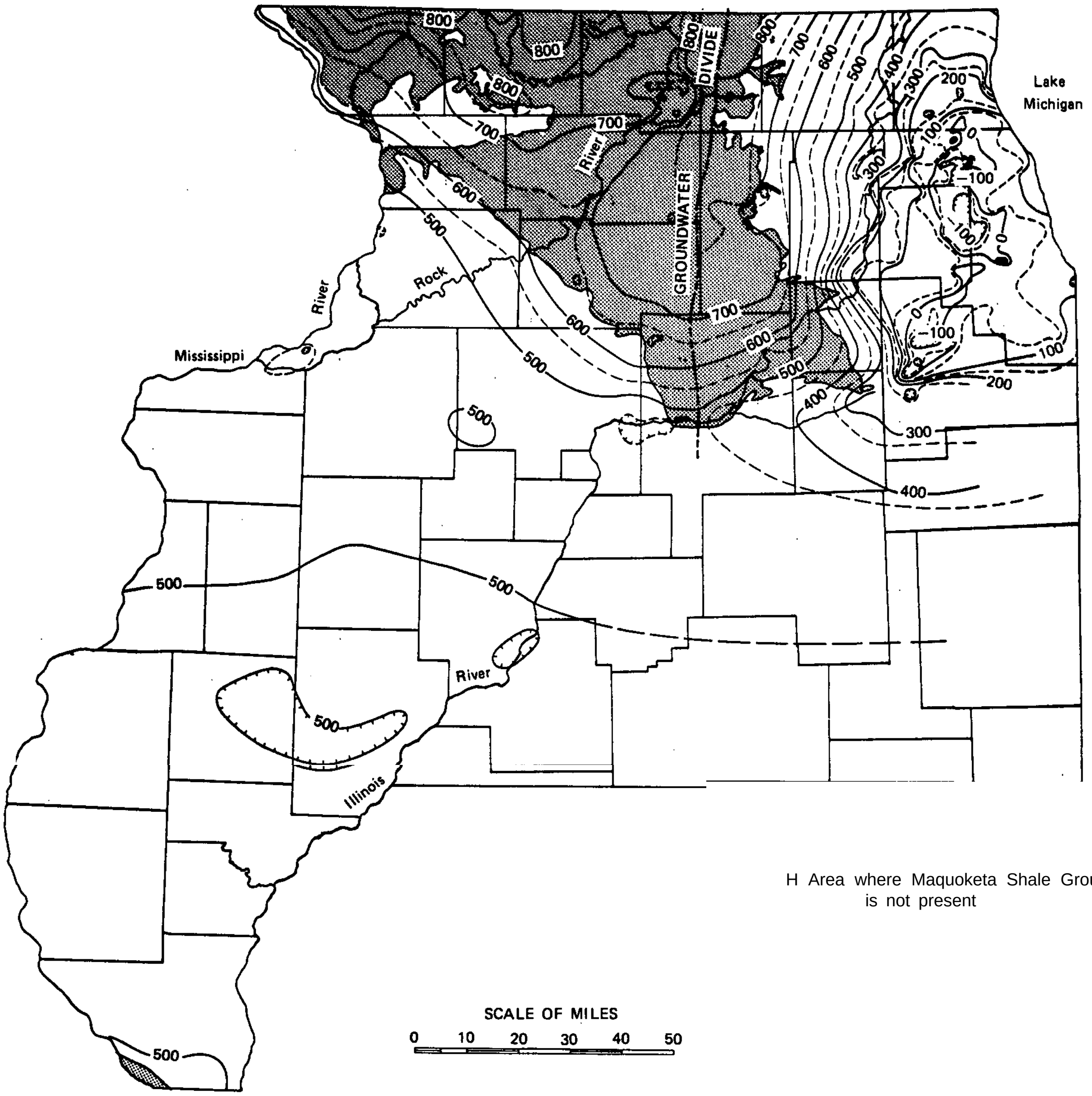


Figure 27. Piezometric surface (MSL) of the Midwest Bedrock Aquigroup in October 1971



H Area where Maquoketa Shale Group is not present

Figure 28. Piezometric surface (MSL) of the Midwest Bedrock Aquigroup in October 1980

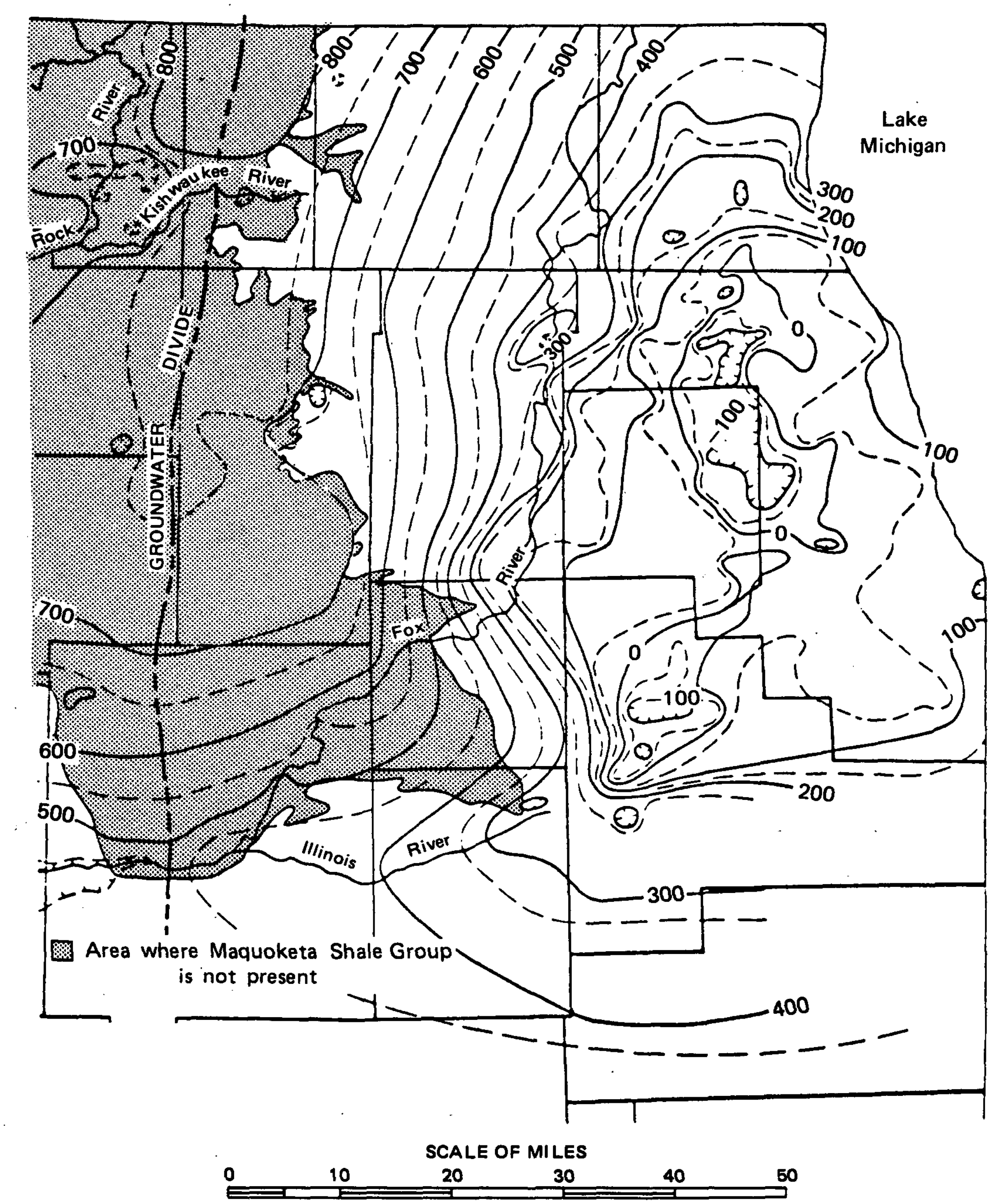


Figure 29. Piezometric surface (MSL) of the Midwest Bedrock Aquigroup, October 1980, northeastern Illinois

also indicate that groundwater moved toward discharge along the Illinois River in Grundy and LaSalle Counties.

Water level measurements on file at the State Water Survey for the northwestern, western, and southwestern portions of the study area in Illinois (taken prior to any significant effects of deep groundwater development) were used, along with geologic information, to construct water level contours in those areas and, in effect, extend Suter's piezometric surface map (with minor modification) over the entire study area (fig. 26). The contours indicate a groundwater ridge in portions of Jo Daviess, Stephenson, Carroll, and Ogle Counties in northwestern Illinois, an area which topographically is the highest in the state. Stream incisement, which is pronounced in the area, has exposed the Midwest Bedrock Aquigroup. Groundwater movement toward the Mississippi and Pecatonica Rivers can be inferred from the contours. Flow toward the other incised streams, such as the Galena and Apple Rivers, cannot be inferred from the historical data. It is evident in the 1980 data, however, and it is assumed to have occurred prior to significant pumpage.

Water level data from western Illinois and eastern Iowa (Norton, 1897) indicate that water flowed southeastward from Iowa under the Mississippi and Illinois Rivers toward the Illinois Basin. There is some evidence of a low, discontinuous groundwater ridge between the Mississippi and Illinois Rivers; hydrologic and stratigraphic information suggest that no discharge to these rivers occurs in western Illinois, except in the extreme southern portion of the Illinois River in Calhoun and Jersey Counties. Here, erosion has brought the aquifer close to the surface, and discharge takes place.

Suter et al. (1959) reported that hundreds of deep wells were drilled in Chicago and Joliet after 1864, and, as a result of heavy pumpage, considerable changes in the piezometric surface were noted as early as 1895. The 700-foot isopiestic line had migrated in a northwesterly direction about 22 miles since 1864, while the 550-foot contour had moved northwestward from northern Indiana and south of Kankakee, Illinois, to a position west of the Chicago centers of pumpage. No such early data are available elsewhere, but it is reported that the first high-capacity deep well in northwestern Illinois was drilled in 1875 (Sasman and Baker, 1966). The rate of growth in pumpage was not as rapid in northwestern Illinois, however, as in northeastern Illinois.

Although several piezometric surface maps were prepared for northeastern Illinois (Suter et al., 1959; Sasman et al., 1961, 1962, and 1967), it was not until 1971 that a comprehensive study was made of water levels in deep aquifers across northern Illinois. Sasman et al. (1973) summarized deep pumpage and prepared a 1971 piezometric surface map for a 20-county area (fig. 27). The general pattern of groundwater flow in 1971 was toward the deep cones of depression, primarily centered at Des Plaines, Elmhurst, Bellwood, and Joliet. Other large pumping centers west of the Chicago region, at Belvidere, Rockford, Rochelle, and DeKalb, were also diverting flow. In the Chicago region the average water level decline since 1864 was about 800 feet.

In the fall of 1980 water levels were measured in approximately 800 wells tapping the Midwest Bedrock Aquigroup. The area covered was northern Illinois and western Illinois south to Calhoun County. This is the largest area ever covered by a set of water level measurements in Illinois. Sasman et al. (1982) prepared a piezometric surface map from the data points (figs. 28 and 29). In the northeastern portion of the study area the cones of depression had deepened and grown considerably since 1971, as can be observed from a comparison of figures 27 and 29. Major growth of pumping centers can be observed in eastern DuPage County, west-central and northern Cook County, the Joliet area of Will County, and the Fox River valley centers in eastern Kane County. Declines of water levels since 1971 were as much as 183 feet in the Joliet area, 220 feet in the upper Cook County suburbs, 200 feet in eastern DuPage County, and 190 feet in the Fox Valley. As a result . of the rapid growth and deepening of the major pumping cones, large areas of dewatering have occurred in the upper permeable units of the Midwest Bedrock Aquigroup. The 1980 map was compared with the elevation of the tops of the Galena-Platteville Unit and the Ancell aquifer (from Suter et al., 1959) at several selected pumping centers to determine the amount of dewatering. The results are shown in table 3. For the most part, the groundwater divide for northeastern Illinois remained much the same as in 1971, moving slightly westward in Boone county and nearly out of Grundy County into LaSalle County.

Table 3. Units of Midwest Bedrock Aquigroup
Dewatered in Major Pumping Centers, Fall 1980

Pumping Center	Units Dewatered
Aurora	More than 2/3 of the Galena-Platteville
Elgin	More than 2/3 of the Galena-Platteville
E. DuPage-W. Cook Co.	All of Galena-Platteville and less thah 1/4 of Ancell
Joliet	All of Galena-Platteville and nearly 1/4 of Ancell
N. Cook Co.	All of Galena-Platteville and more than 1/3 of Ancell

Recharge and Movement of Groundwater

The predominant feature of the 1980 piezometric surface map of the Midwest Bedrock Aquigroup is the major pumping cones in the Chicago area. A second area of interest, however, is the recharge area of north-central and northwestern Illinois. Sasman et al. (1982) superposed on the 1980 piezometric surface map the major streams as well as the outline of the Maquoketa and Pennsylvanian shales which rim the recharge area and act as confining beds to the Midwest and Mississippi Valley Aquigroups. In the west, the Mississippi Valley Aquigroup overlies the Midwest Bedrock Aquigroup. A groundwater ridge along the major flow divide in north-central Illinois roughly marks the center of the recharge area of the Midwest Bedrock Aquigroup, with flow moving from the ridge principally to the east and south and, to a lesser extent to the west, toward the Rock River.

Flow from a smaller groundwater high in Stephenson and Jo Daviess Counties divides into a southwesterly direction toward the Mississippi River and an east-southeasterly direction toward the Rock River. Water level contours also indicate flow toward the Fox, Apple, Galena, and Pecatonica Rivers. In areas where these major streams are underlain by drift and shale, the streams are not incised into the productive units of the Midwest Bedrock Aquigroup. Where the shales are missing, however, streams have cut into the upper permeable units (Galena-Platteville Unit or Ancell aquifer), and in these reaches of the streams groundwater discharge takes place.

In the southwestern part of the study area, the Midwest Bedrock Aquigroup is buried beneath the Mississippi Valley Aquigroup. Because it is not exposed at the surface, except in the extreme southern portion of the Illinois River Valley, no discharge to streams can be inferred from the map contours. Hydraulic gradients are quite low, and flow is sluggish. Slight remnants of a low groundwater ridge apparently are still present between the Illinois and Mississippi Rivers. In this area, the regional flow is generally southeastward toward the Illinois Basin.

Using flow-net analysis of the piezometric surface map for 1864, Walton (1960) determined that the recharge rate through the Maquoketa Confining Unit to the aquifers of the Midwest Bedrock Aquigroup in northeastern Illinois was about 1330 gpd/sq mi. He also calculated that by 1958 this recharge rate had increased to about 2100 gpd/sq mi under the influence of large head differentials created by pumpage. In a 1964 report, Walton estimated that the maximum amount of leakage that could take place through the Maquoketa would be about 12 mgd. Based on the area through which such leakage could occur (4000 sq mi), the maximum rate of leakage through the Maquoketa is about 3000 gpd/sq mi. There is also evidence that head differentials across the Basal Bedrock Aquitard have been produced by pumping in the Midwest Bedrock Aquigroup and that upward leakage of water from below the aquitard has resulted. Walton estimated that the maximum amount of upward leakage to the Midwest Aquigroup from the Basal Bedrock Aquigroup would be about 3 mgd.

Walton (1962) computed a recharge rate of 21,000 gpd/sq mi to the Midwest Bedrock Aquigroup in 1958 in an area west of the border of the Maquoketa Confining Unit. Hoover and Schicht (1967) calculated an average recharge rate in LaSalle County of 10,800 gpd/sq mi. As part of this study a flow-net analysis was made in the area west of the Maquoketa Confining Unit in north-central Illinois. Using the 1971 piezometric surface map (fig. 30), five flow channels were investigated. These flow channels were selected because they were not believed to be significantly influenced by groundwater pumpage. Recharge rates for each flow channel were determined by solving Darcy’s Law for the flow through each channel cross section and dividing this amount by the area within the flow channel. An average transmissivity of 20,000 gpd/ft was assumed in calculating flow through sections 1, 2, 3, and 5. Based on local data, a value of 17,000 gpd/ft was assumed for section 4. The results are summarized in table 4. An average recharge rate in 1971 for the area west of the Maquoketa boundary was 20,400 gpd/sq mi, close to the value Walton had determined earlier. In 1964 Walton estimated

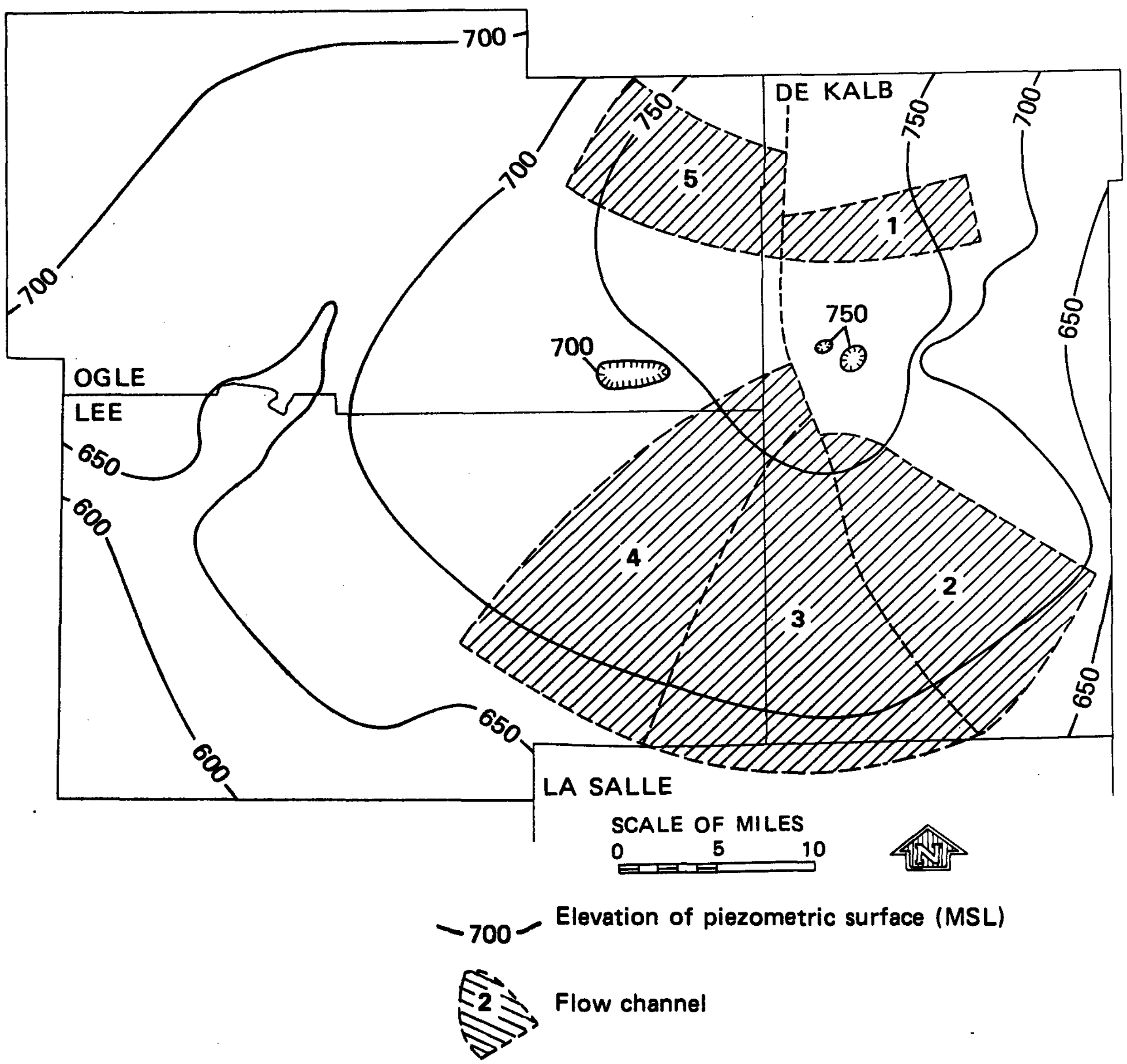


Figure 30. Flow-net analysis using 1971 piezometric surface map

that the maximum rate of recharge in the area west of the Maquoketa would be about 42,000 gpd/sq mi.

Table 4. Recharge Rates in North-Central Illinois in 1971

Flow Channel		Recharge Rate (gpd/sq mi)
1		22,000
2		22,400
3		19,000
4		11,300
5		27,400
	Average	20,400

Attempts at computing recharge rates in northwestern Illinois using the 1971 piezometric surface maps have been unsuccessful. Water level declines there have resulted in storage changes which are difficult to account for in a flow channel analysis due to the uncertainty in estimating a regional storage coefficient. Flow analysis on the piezometric map for the time of initial development (fig. 31) was reasonably successful, however. Three flow channels in portions of Stevenson, Carroll, Ogle, and Whiteside Counties were analyzed. Transmissivity values of 12,000, 10,000, and 12,000 gpd/ft were assumed for channels A, B, and C, respectively. Recharge rates for channels A, B, and C in figure 31 were calculated to be 16,900, 16,500, and 18,200 gpd/sq mi, respectively. The average rate was 17,200 gpd/sq mi, about 16% lower than the 1971 rate for north-central Illinois but nearly 13 times as large as the pre-development rate for northeastern Illinois.

Hydraulic gradients in western Illinois are very small and result in uncertainties in flow-net analysis. Recharge rates are probably extremely low, however, because of the thick sequence of strata overlying the Midwest Bedrock Aquigroup (the Maquoketa Confining Unit as well as the Mississippi Valley Aquigroup). On the basis of pre-development water level and transmissivity maps presented by Horick and Steinhilber (1978), recharge rates to the Jordan Aquifer in eastern Iowa were estimated. The results indicate that recharge to the Jordan is of the same order of magnitude as determined by Walton (1960) for the Chicago area (1330 gpd/sq mi).

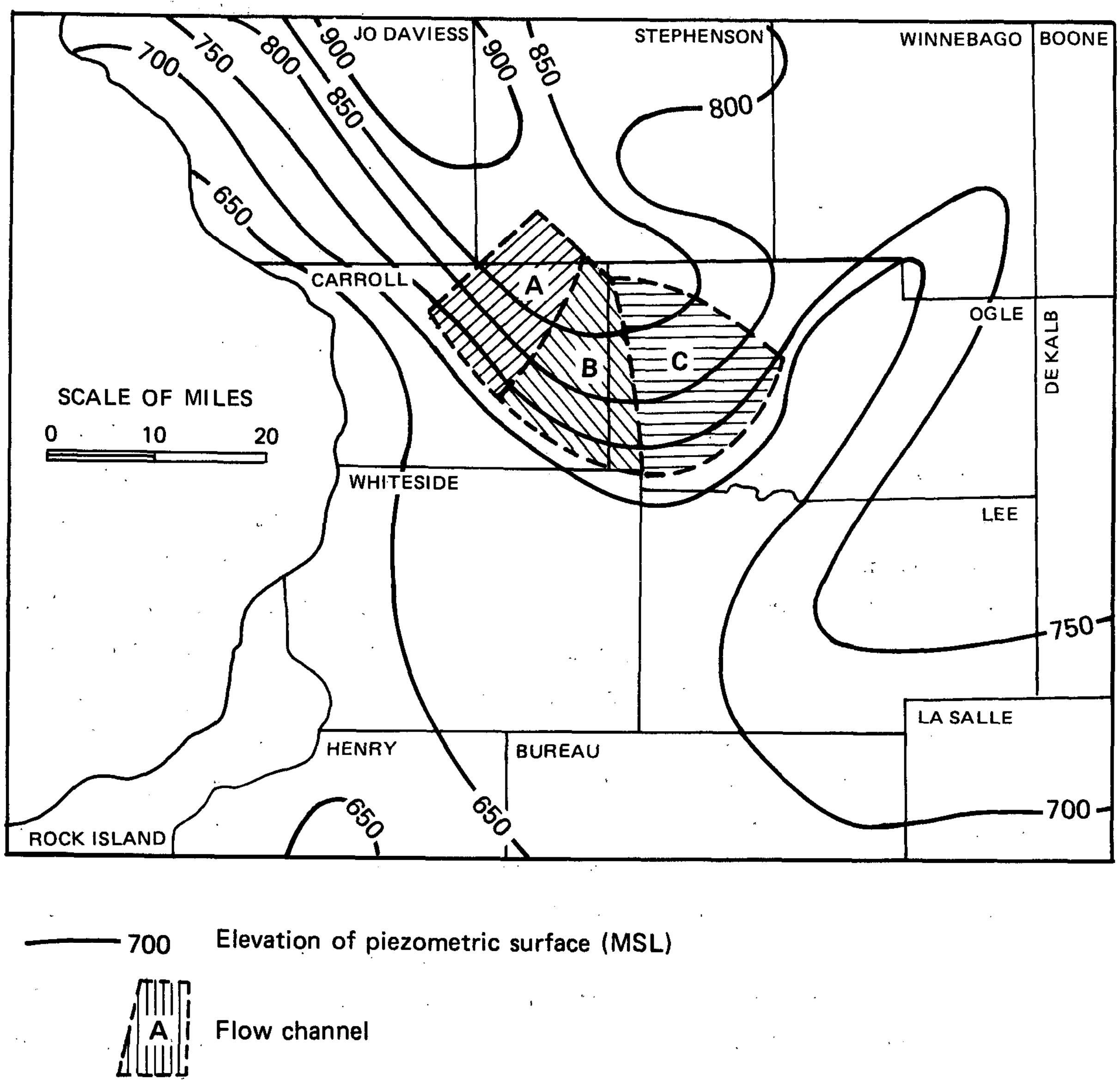


Figure 31. Flow-net analysis using piezometric surface map for the time of initial development

Historical Pumpage

Table 5 shows average groundwater pumpage from the Midwest Bedrock Aquigroup by county for 10-year periods beginning in 1861 and ending with 1980. Figure 32 shows the average pumpage for the entire area for the same 10-year periods. It also presents three regional pumpage-time distributions, aggregated from the data in table 5. All of the recorded pumpage from 1861 through 1880 was in Cook County. From 1881 through 1940 the 10-year average pumpage increased 1.57 million gallons per day (mgd) per year. Average pumpage continued to increase, at a rate of 2.90 mgd per year, from 1941 through 1960. The largest increase in pumpage was during 1961 through 1980 when average pumpage increased 6.15 mgd/yr. Total withdrawals from Cambrian and Ordovician aquifers averaged 278.6 mgd between 1971 and 1980. By 1980, however, the total had declined to 258.4 mgd, of which the largest withdrawals--67.2 mgd, 28.4 mgd, 27.7 mgd, and 23.7 mgd--occurred in Cook, DuPage, Kane, and Will Counties, respectively.

It should be noted that in the past, and to a lesser extent at present, pumpage from deep wells in northern (especially northeastern) Illinois has included pumpage from wells known to be open to both the Midwest Bedrock Aquigroup and the Basal Bedrock Aquigroup (Schicht et al., 1976). Some wells were also known to be open to both the Upper Bedrock Aquigroup and the Midwest Bedrock Aquigroup. In addition, many deep wells were improperly cased through the Upper Bedrock Aquigroup, and leakage down the well bore may have been significant. Suter et al. (1959) estimated the contributions to deep pumpage from these outside sources in northeastern Illinois to be as much as 43% of the total in 1958. There is evidence to indicate that this contribution declined to about 14% of the total in northeastern Illinois by 1975 (Visocky, 1982).

Most of the pumpage occurs in the northeast region, consisting of Cook, DuPage, Grundy, Kane, Kendall, Lake, McHenry, and Will Counties. Average pumpage has increased from 0.381 mgd during 1861 through 1870 to 165 mgd during 1971 through 1980. Pumpage in the northeast region has averaged 59% Of the total groundwater pumped from the Midwest Bedrock Aquigroup since 1881.

The data used in table 5 and figure 32 were compiled from several sources. Suter et al. (1959) presented a detailed discussion of the areal distribution of pumpage within the northeast region from 1864 through 1957.

Table 5. Average Pumpage form the Cambrian and Ordovician aquifers from 1861 through 1980 in mgd

		Pumping interval											
Region	County	1861-1870	1871-1880	1881-1890	1891-1900	1901-1910	1911-1920	1921-1930	1931-1940	1941-1950	1951-1960	1961-1970	1971-1980
Northeast	Cook	.381	3.301	7.539	15.40	21.33	28.19	32.20	29.25	30.70	41.59	51.13	62.883
	Du Page	0.000	0.000	0.000	.193	.218	.856	1.175	2.679	6.653	6.156	12.01	21.669
	Grundy	.000	.000	.126	.259	.386	.404	.481	1.921	2.153	2.786	3.450	9.763
	Kane	.000	.000	.218	1.958	4.203	7.555	9.158	12.45	16.43	21.12	25.42	28.851
	Kendall	.000	.000	.072	.072	.081	.081	.089	.123	.319	.764	1.493	2.102
	Lake	.000	.000	.024	.054	.106	.130	.162	1.186	1.777	1.945	3.770	8.483
	McHenry	.000	.000	.018	.018	.018	.018	.018	.484	.543	1.357	3.080	3.845
	Will	.000	.000	.376	1.040	1.791	4.517	7.544	7.170	9.172	14.90	25.38	27.430
<u>Subtotal</u>		.381	3.301	8.373	18.994	28.133	41.751	50.827	55.263	67.747	90.618	125.733	165.026
Northwest	Boone	0.000	0.000	0.030	0.259	0.577	0.792	0.916	1.163	2.061	1.918	4.193	5.004
	Carroll	.000	.000	.253	.397	.595	.686	1.486	1.978	1.635	1.905	3.456	3.396
	De Kalb	.000	.000	.349	.449	.889	1.605	2.478	3.058	3.557	4.448	7.078	9.180
	Jo Daviess	.000	.000	4.282	3.716	3.677	3.630	3.558	3.498	3.456	3.458	4.936	6.878
	La Salle	.000	.000	.000	.000	1.034	1.336	2.446	3.704	5.840	8.147	9.560	12.902
	Lee	.000	.000	.468	.798	.935	1.398	1.702	2.026	3.334	3.626	4.142	5.419
	Ogle	.000	.000	.465	.672	1.160	1.748	2.330	2.794	3.944	4.361	8.205	9.478
	Rock Island	.000	.000	.000	.004	.014	.061	.112	.179	.250	.410	4.588	5.545
	Stephenson	.000	.000	.465	.608	.724	.815	2.466	3.581	4.630	3.424	10.11	10.612
	Whiteside	.000	.000	.800	.804	1.804	2.356	2.320	2.048	2.602	3.106	5.185	5.264
	Winnebago	.000	.000	.986	2.766	5.402	8.101	12.18	13.72	22.10	20.99	26.06	29.564
<u>Subtotal</u>		.000	.000	8.098	10.509	16.847	22.523	31.994	37.749	53.409	55.793	87.513	103.242

Table 5. Concluded

Region	County	Pumping interval 1861-1870	1871-1880	1881-1890	1891-1900	1901-1910	1911-1920	1921-1930	1931-1940	1941-1950	1951-1960	1961-1970	1971-1980
Central	Bureau	0.000	0.000	0.000	0.000	0.000	0.000	0.028	0.108	.235	.359	.417	0.624
	Fulton	.000	.000	.000	.000	.000	.008	.112	.267	.412	.551	.656	0.712
	Henderson	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.001	0.010
	Henry	.000	.000	.000	.000	.000	.007	.032	.090	.649	1.287	1.693	3.011
	Kankakee	.000	.000	.000	.000	.000	.000	.000	.000	.000	.002	.002	0.004
	Knox	.000	.000	.000	.047	.553	1.200	1.851	2.502	3.167	3.790	.699	0.840
	Livingston	.000	.000	.000	.000	.012	.018	.030	.043	.055	.067	.079	0.097
	Marshall	.000	.000	.000	.000	.000	.000	.000	.000	.054	.203	.251	0.304
	McDonough	.000	.000	.000	.000	.000	.000	.092	.153	.214	.292	.385	0.402
	McLean	.000	.000	.000	.000	.000	.002	.007	.012	.022	.044	.075	0.113
	Mercer	.000	.000	.000	.000	.000	.002	.033	.116	.211	.273	.314	0.358
	Peoria	.000	.000	.000	.014	.032	.059	.091	.162	.296	.488	.683	0.882
	Putnam	.000	.000	.000	.000	.000	.016	.052	.066	.107	.117	.127	0.144
	Stark	.000	.000	.000	.003	.015	.025	.040	.053	.122	.191	.205	0.287
	Warren	.000	.000	.014	.156	.334	.464	.532	.590	.672	1.053	1.696	2.353
	Woodford	.000	.000	.000	.006	.027	.049	.071	.093	.114	.128	.138	0.164
Subtotal		.000	.000	.014	.226	.973	1.850	2.971	4.255	6.330	8.845	7.421	10.305
Total		0.381	3.301	16.485	29.729	45.953	66.124	85.792	97.267	127.486	155.256	220.667	278.573

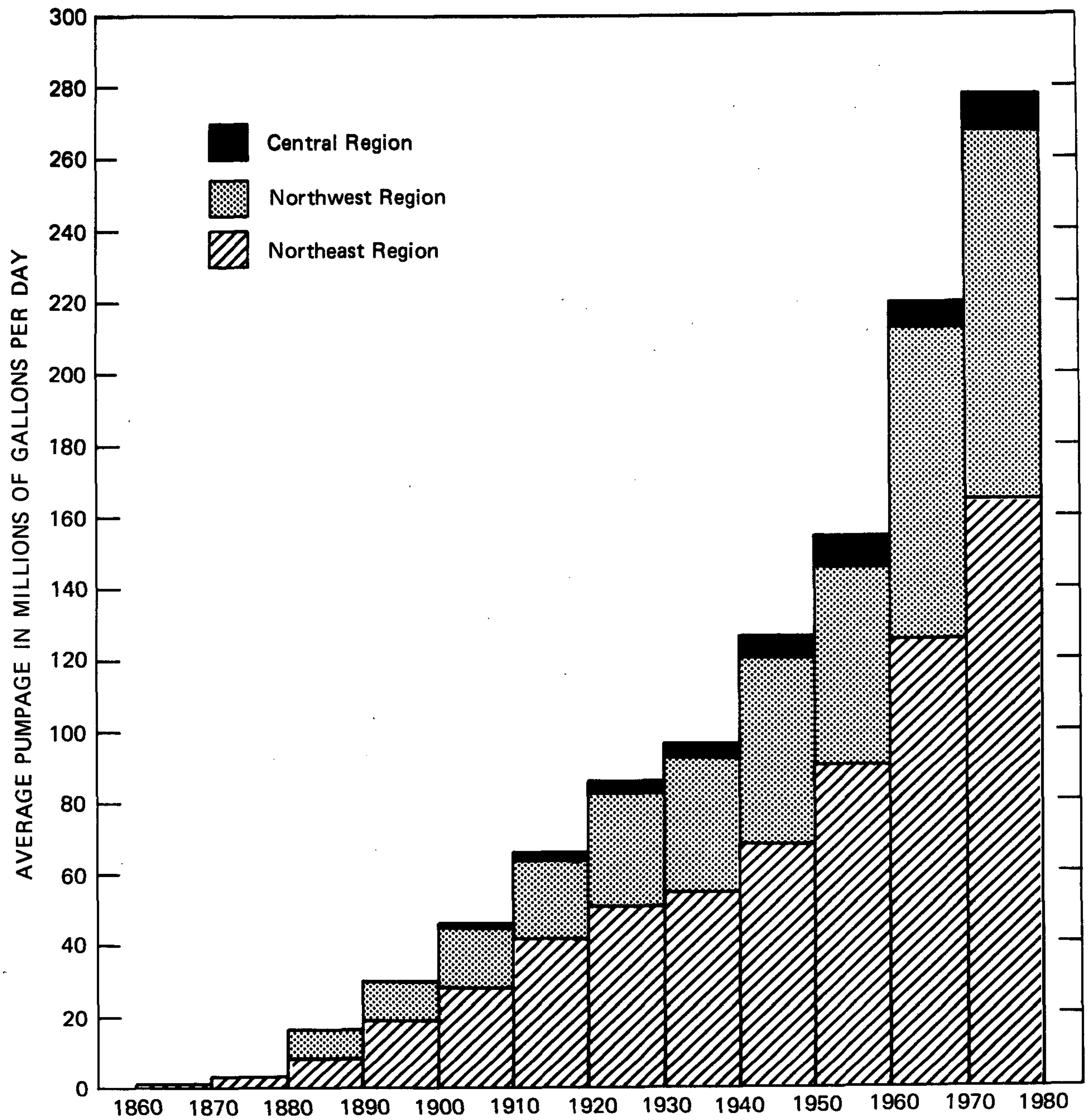


Figure 32. Pumpage growth in the Midwest Bedrock Aquigroup

They also classified pumpage in 1957 according to usage categories (public, industrial, rural, and irrigation). Sasman (1965) also summarized historical pumpages through 1962 for public, industrial, and domestic water supplies. Annual pumpage data for 1960 through 1975 were summarized by Sasman et al. (1967, 1973, 1974, 1977) and Schicht et al. (1976). The data are presented on an areal basis and by water use. Pumpage data for 1978 and 1980 were estimated from results of the Illinois Water Use Inventory presented by Kirk et al. (1979 and 1982).

The first deep well in northern Illinois was drilled in Chicago in 1864. The well was probably finished in the Galena and Platteville Groups (Suter et al., 1959) and had an artesian flow estimated at 0.2 mgd. Cook County pumpage was more than 60% of the total pumpage in the northeast region for the period 1861 through 1930. Since 1930, the Cook County portion has declined to 38% or 62.88 mgd during 1971 through 1980.

Pumpage in DuPage, Kane and Will Counties has increased at a considerable rate since 1891. The combined three-county pumpage averaged 3.19 mgd or 17% of the regional total from 1891 through 1900. During 1971 through 1980 the pumpage in this same area totaled 77.95 mgd or 47% of the northeast region's total.

Boone, Carroll, DeKalb, Jo Daviess, La Salle, Lee, Ogle, Rock Island, Stephenson, Whiteside, and Winnebago Counties compose the northwest region. As shown in table 5, average pumpage has increased from 8.10 mgd during 1881 through 1890 to 103 mgd during 1971 through 1980. Pumpage in the northwest region has averaged 37% of the total pumpage from the Midwest Bedrock Aquigroup since 1881. Historic pumpage from 1881 through 1971 has been categorized on a county basis by water use in publications by Sasman and Baker (1966) and Sasman et al. (1973 and 1974). More detailed historical pumpage data for Winnebago and La Salle Counties have been published by Smith and Larson (1948) and Hoover and Schicht (1967), respectively.

Pumpage in Winnebago County is concentrated in the Rockford area and has been greater than twice the pumpage for any other county in the region except Jo Daviess County since 1891. During 1931 through 1950, Winnebago County accounted for more than 40% of the total regional pumpage. During the period 1971 through 1980, however, this amount decreased to 29% of the total.

Historically, pumpage has been distributed uniformly among the other counties except Winnebago and Jo Daviess Counties. In Jo Daviess County, more than 50% of the pre-1960 pumpage was for dewatering lead and zinc mines in the Galena and Platteville Groups.

The total pumpage in the 16 counties that comprise the central region (table 5) has averaged 3% of the total pumpage from the Cambrian and Ordovician aquifers since 1881. Total pumpage in the central region has increased uniformly from 0.014 mgd during 1881 through 1890 to 10.3 mgd during 1971 through 1980. Historical pumpages were estimated from data presented by Hanson (1950, 1958, and 1961) and Visocky et al. (1978). Additional information was obtained from publications by Woller et al. (1973 to date).

Prior to 1961, more than 68% of the central region pumpage was concentrated in Henry, Knox, and Warren Counties. All counties except Knox County have increased pumpages from the aquifers. Since 1961, Knox County has increased pumpage from sand and gravel sources (the Prairie Aquigroup) and decreased pumpage from the bedrock aquifers.

Potential Development of Midwest Bedrock Aquigroup

Practical Sustained Yield

Recharge to the Midwest Bedrock Aquigroup in northeastern Illinois, while due in part to downward leakage through the Maquoketa Confining Unit and upward leakage from the Basal Bedrock Aquigroup, comes primarily from lateral flow eastward from the major recharge area toward large pumping centers in Cook, DuPage, and Will Counties. Walton (1964) estimated that the maximum amount of water which could be safely pumped from the aquifers in northeastern Illinois (the practical sustained yield) consisted of three elements: 1) the rate at which groundwater could be induced to move laterally under maximum head gradients (estimated to be 50 mgd); 2) downward leakage from the Upper Bedrock Aquigroup (12 mgd); and 3) upward leakage from the Basal Bedrock Aquigroup (3 mgd). Maximum hydraulic gradients would occur when pumping levels reached the top of the Ironton-Galesville aquifer. The practical sustained yield could reach a maximum of 65 mgd if the number of pumping centers were increased, pumping centers were shifted westward, and wells were spaced at greater distances to minimize interference.

The practical sustained yield in north-central and northwestern Illinois is not as dependent on the establishment of large hydraulic gradients as is the case in the Chicago area where vertical recharge is limited. Thus, even if existing or new pumping centers in these areas were unable to develop hydraulic gradients as large as those suggested by Walton (1964) for the Chicago area, the substantially higher recharge rates west of the Maquoketa Confining Unit border should allow pumpage of comparably large quantities of water from the aquifers.

The practical sustained yield in western Illinois is limited by the same constraints as in the Chicago area, i.e., by the amount of lateral groundwater flow that can be induced toward pumping centers. Also, the Ironton-Galesville is thinner or absent in western Illinois. Currently there are no major pumping centers. In order to maximize the sustained yield in this area, controlled development will be necessary, including judicious placement of pumping centers in proximity to the recharge areas to the north and spacing of wells to minimize interference.

Well Yields

Yields of wells developed in the Midwest Bedrock Aquigroup vary considerably throughout the study area and depend upon the units penetrated as well as the geographic location. Several hundred deep wells in northern Illinois tap several units within the aquigroup. Walton (1962) concluded that the yields of the Ancell aquifer; the Prairie du Chien, Eminence-Potosi, and Franconia Formations; and the Ironton-Galesville aquifer constitute about 15, 35, and 50%, respectively, of the total yield of the Midwest Bedrock Aquigroup. The Ironton-Galesville aquifer is the principal source of groundwater for many municipal and industrial supplies because of its consistently high yield. Figure 33 shows observed well yields for the Midwest Bedrock Aquigroup in northern and western Illinois. Yields in northern Illinois usually exceed 500 gpm and, depending on the depth of penetration, may exceed 1000 gpm. In western Illinois, typical well yields are smaller, because wells in that area generally avoid the more mineralized units of the aquigroup and produce mainly from the Ancell aquifer.

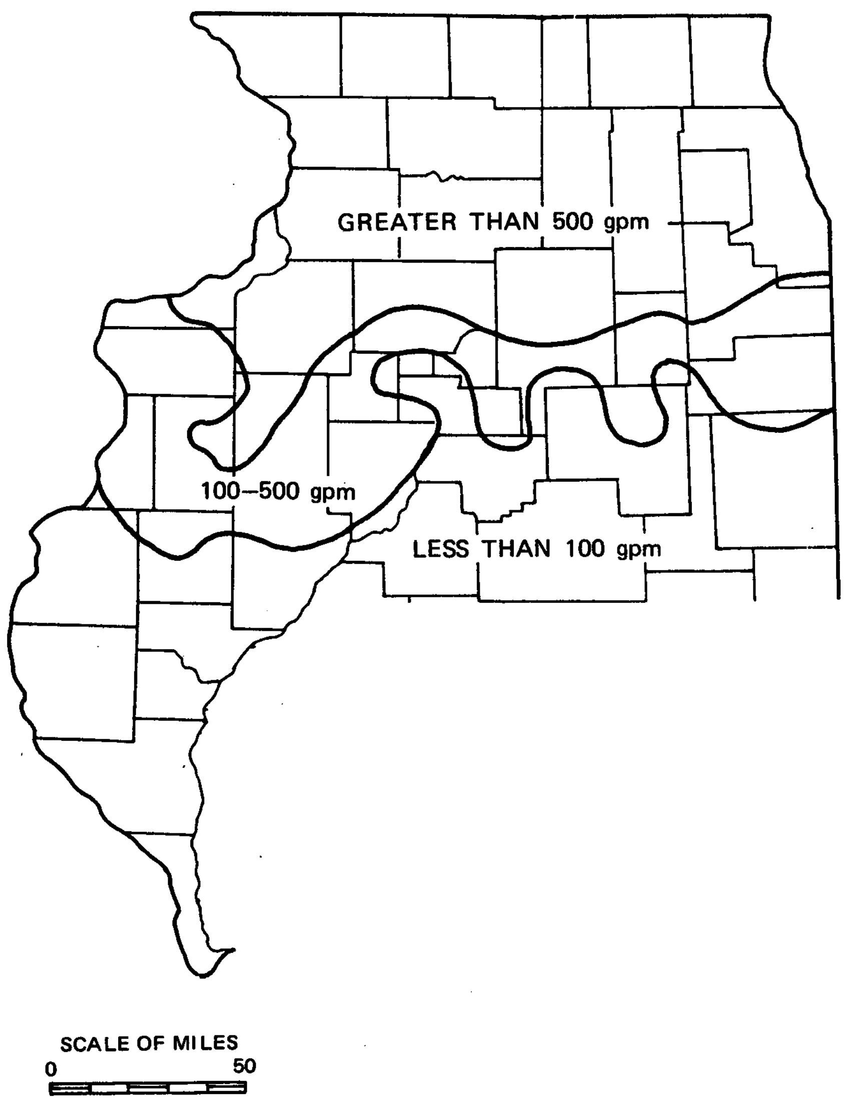


Figure 33. Observed yields of we wells in the Midwest Bedrock Aquigroup

GROUNDWATER QUALITY

Introduction

The water quality of the Cambrian and Ordovician aquifers was evaluated relative to the groundwater flow and geologic units. Geologic and well construction information for about 400 wells was obtained from ISGS and USGS files. Water quality analyses for about 300 wells were obtained from Illinois Environmental Protection Agency (IEPA) and ISWS files and from published reports. USGS additionally collected about 25 single-aquifer-unit water samples from individual wells or packer tests during the study. Four geological cross sections were constructed and water quality data were overlaid. (Cross sections are not necessarily oriented along present or past flow paths.) Concentrations of chemical constituents in water from wells on the cross sections were converted from milligrams per liter (mg/L) to percent milliequivalents per liter (% meq/L) and then plotted on trilinear diagrams (Hem, 1970) to show water types and changes (fig. 34).

It had become apparent during the study that groundwater quality within the aquifers of the Cambrian and Ordovician Systems had both similarities and differences that were related to regional flow systems. Therefore, the intent of this portion of the study was to characterize the water quality of individual aquifers (rather than of aquigroups) where possible. This approach would also provide data that is essential to the regional modeling of the Northern Midwest RASA, which is being carried out by the U.S. Geological Survey as part of its overall RASA report. As a result, it was decided that the most efficaceous manner of summarizing groundwater quality was to divide the study area into two general subareas: 1) the portion of north-central and northwestern Illinois in which the upper bedrock aquifers (within the Cambrian and Ordovician Systems) are not confined by shales and in which they become part of the Upper Bedrock Aquigroup (the stippled area of figure 28), which will be designated the "unconfined" area; and 2) the portions of northern and western Illinois that are confined by rocks of the Maquoketa Shale Group and/or rocks of Pennsylvanian or Devonian age. In these areas the upper aquifers of the Ordovician System are part of the Midwest Bedrock Aquigroup. These areas will collectively be called the confined area for purposes of this discussion.

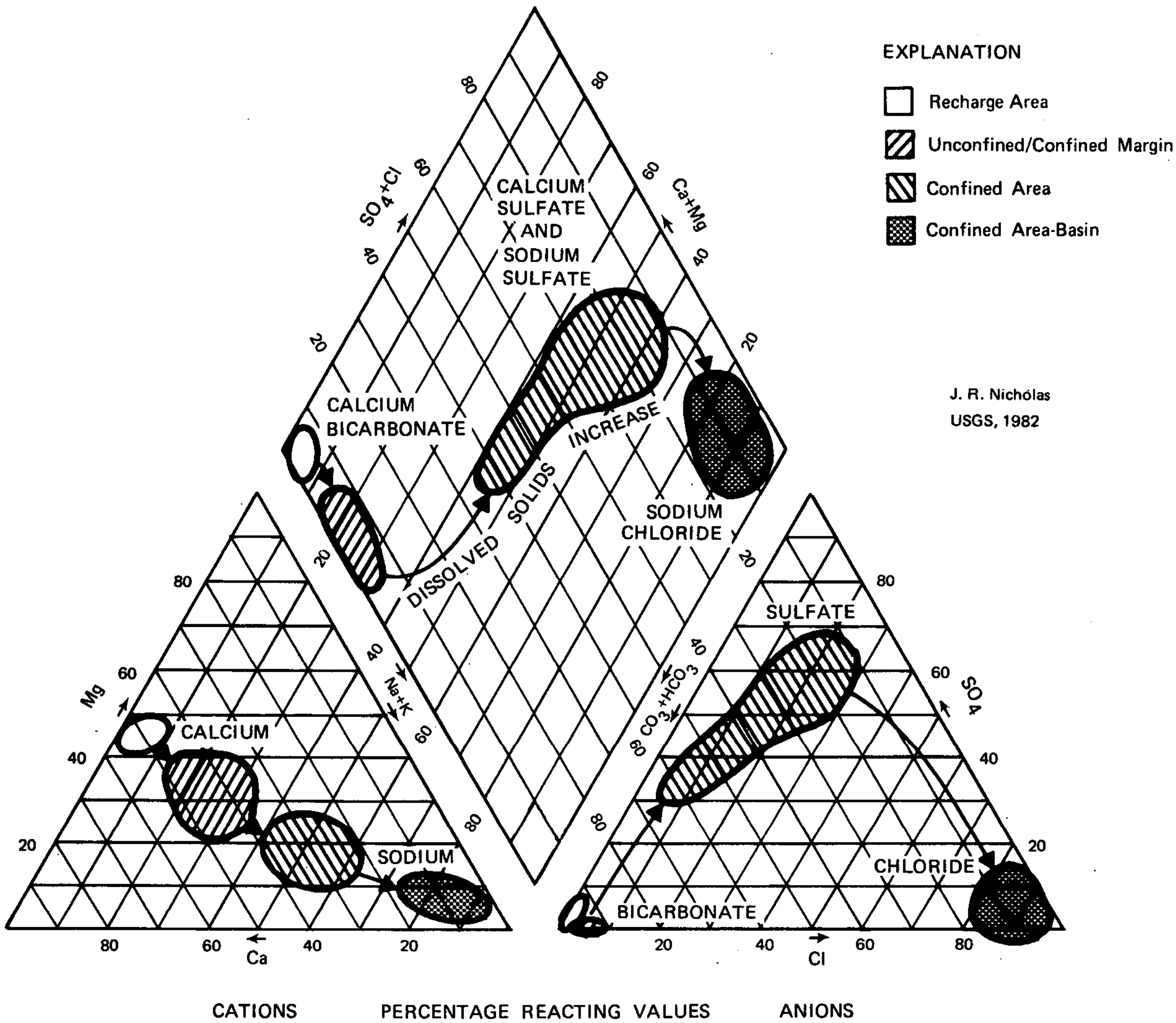


Figure 34. General changes in water type with increasing length of groundwater flow path

Water Quality of the "Unconfined" Area

The "unconfined" area of the Cambrian and Ordovician aquifers includes a large area of northern Illinois and represents a part of the recharge area of both shallow and deep flow systems (fig. 34). Local confining conditions, caused by fine-grained glacial deposits or dense strata of the Galena-Platteville Unit, are present in the regional "unconfined" area. Principal upper bedrock units are the Galena-Platteville Unit and the Ancell aquifer, with some older Cambrian rocks occurring locally in uplifted areas such as the Sandwich Fault Zone. The quality of groundwater in the "unconfined" area is influenced by local, intermediate, and regional flow systems; strong vertical gradients; and relatively rapid movement of groundwater. Faster movement of groundwater reduces the contact time between rocks and water and results in water with generally low concentrations of dissolved solids, indicating that only moderate changes in water quality occur from points of recharge. Flow systems contain water which is well-mixed vertically because of the strong vertical components of flow. Groundwater from individual rock Units in most of the "unconfined" area cannot be differentiated on the basis of major ion chemistry. A relatively homogeneous chemical system, dominated by calcium, magnesium, and bicarbonate ions, is present from the Basal Bedrock Aquigroup up through the Galena-Platteville Unit. An example of this vertical homogeneity in major ion chemistry is provided by a suite of analyses from packer tests in a deep well in Galena, Illinois (table 6). This well is a flowing well, situated in or near a discharge zone for a deep, intermediate, or regional flow system.

In the "unconfined" area, concentrations of dissolved solids usually range from 250 to 400 mg/L. The water is a calcium/magnesium bicarbonate type (fig. 34 and Creston sample, appendix C). Calcium is the dominant cation, representing greater than 50% meq/L (milliequivalents per liter). Magnesium represents 30-50% meq/L and sodium represents less than 5% meq/L. Bicarbonate is the dominant anion, representing 90% meq/L. Sulfate is generally less than 10% meq/L, and chloride represents less than 2% meq/L. The horizontal and vertical variations in water types are depicted on four cross sections (figs. 35 to 38).

Table 6. Water-Quality Data from the Packer Tests in Limback Well in Galena, Illinois

JDV 28N1W-24.2b
Elev. 600' above msl
Total depth 1489 feet
Flowing well

Concentrations (mg/L)	Sampled unit* GPAN 81-346'	PEPF 412-587'	691-882'	EMS 981-1489'
Calcium	59	55	49	50
Magnesium	30	29	27	26
Sodium	1.8	1.7	1.3	1.3
Potassium	2.3	2.7	2.5	2.8
Chloride	1.8	1.3	3.2	1.3
Sulfate	21	8.4	8.7	5.9
Alkalinity (as $CaCO_3$)	280	270	240	230
TDS	294	269	245	235

*GPAN - Galena-Platteville/Ancell
PEPF - Prairie du Chien/Eminence-Potosi/Franconia
IG - Ironton-Galesville
EMS - Elmhurst/Mt. Simon

Although there is little vertical or areal variation in the water quality of the "unconfined" area, there are two exceptions. The first occurs along the eastern and southern edges of the "unconfined" area on sections B-B' and C-C' (figs. 36 and 37). This area contains water with low concentrations of dissolved solids, usually less than 300 mg/L (appendix C). Calcium is the dominant cation, ranging between 33 and 49% meq/L, but sodium increases to about 33% meq/L as shown in figure 34. Bicarbonate is the dominant anion and represents greater than 90% meq/L. Most significant is a reduction in the concentration of sulfate. This anion does not exceed 2% meq/L, with frequent zero values reported. On section B-B' (fig. 36) this area in Ogle and DeKalb Counties corresponds to a local reducing zone. The second exception to the general vertical and areal homogeneity of the "unconfined" area is found along the southern edge of the "unconfined" area as shown on section C-C' (fig. 37). Here, concentrations of dissolved solids increase from younger to older units. The Ironton-Galesville and Elmhurst-Mt. Simon aquifers contain water of higher dissolved solids concentrations than do the waters of the younger aquifers. Faults which appear on cross

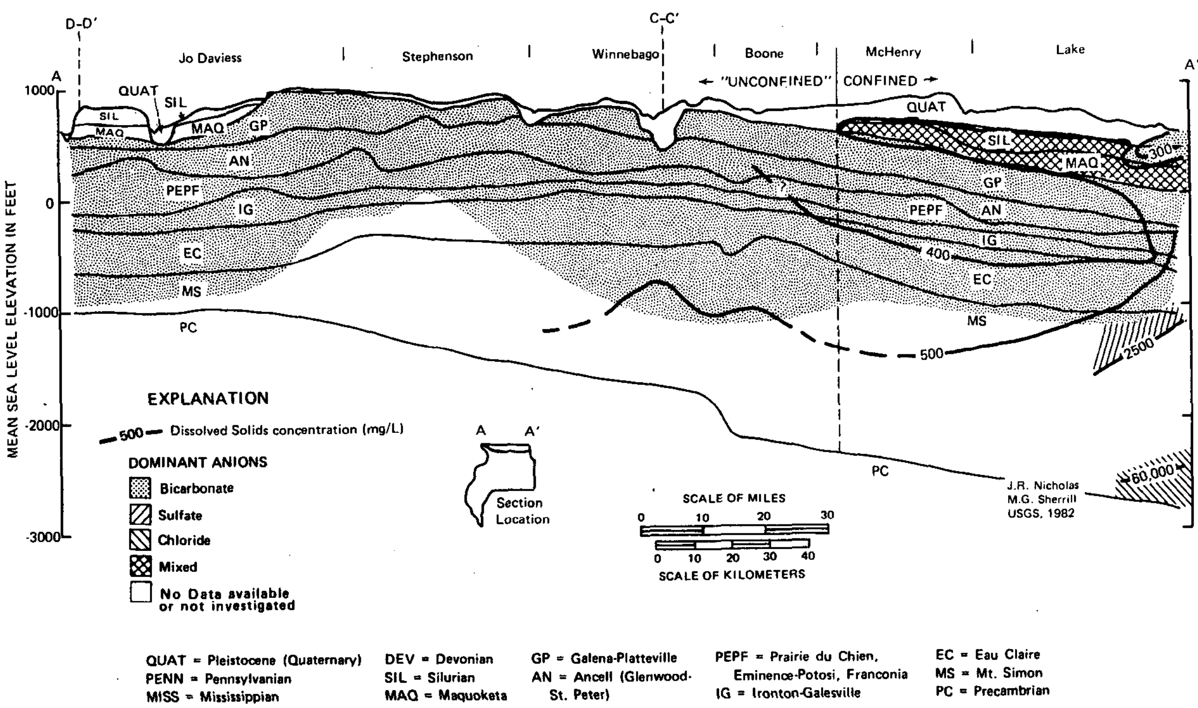


Figure 35. Cross section A-A' from Dubuque, Iowa, to Zion, Illinois, showing geology, dominant anions, and dissolved solids concentration

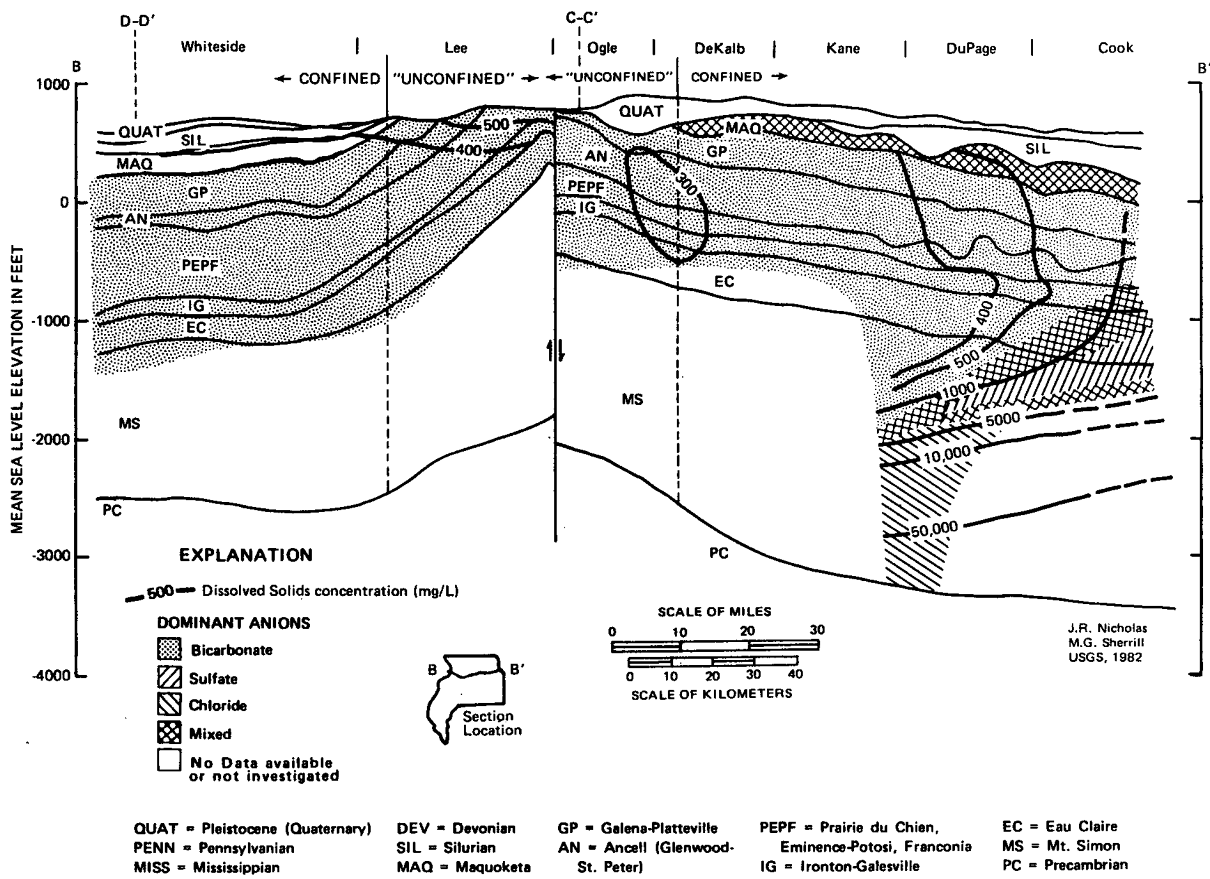


Figure 36. Cross section B-B' from Fulton, Illinois, to Chicago, Illinois, showing geology, dominant anions, and dissolved solids concentration

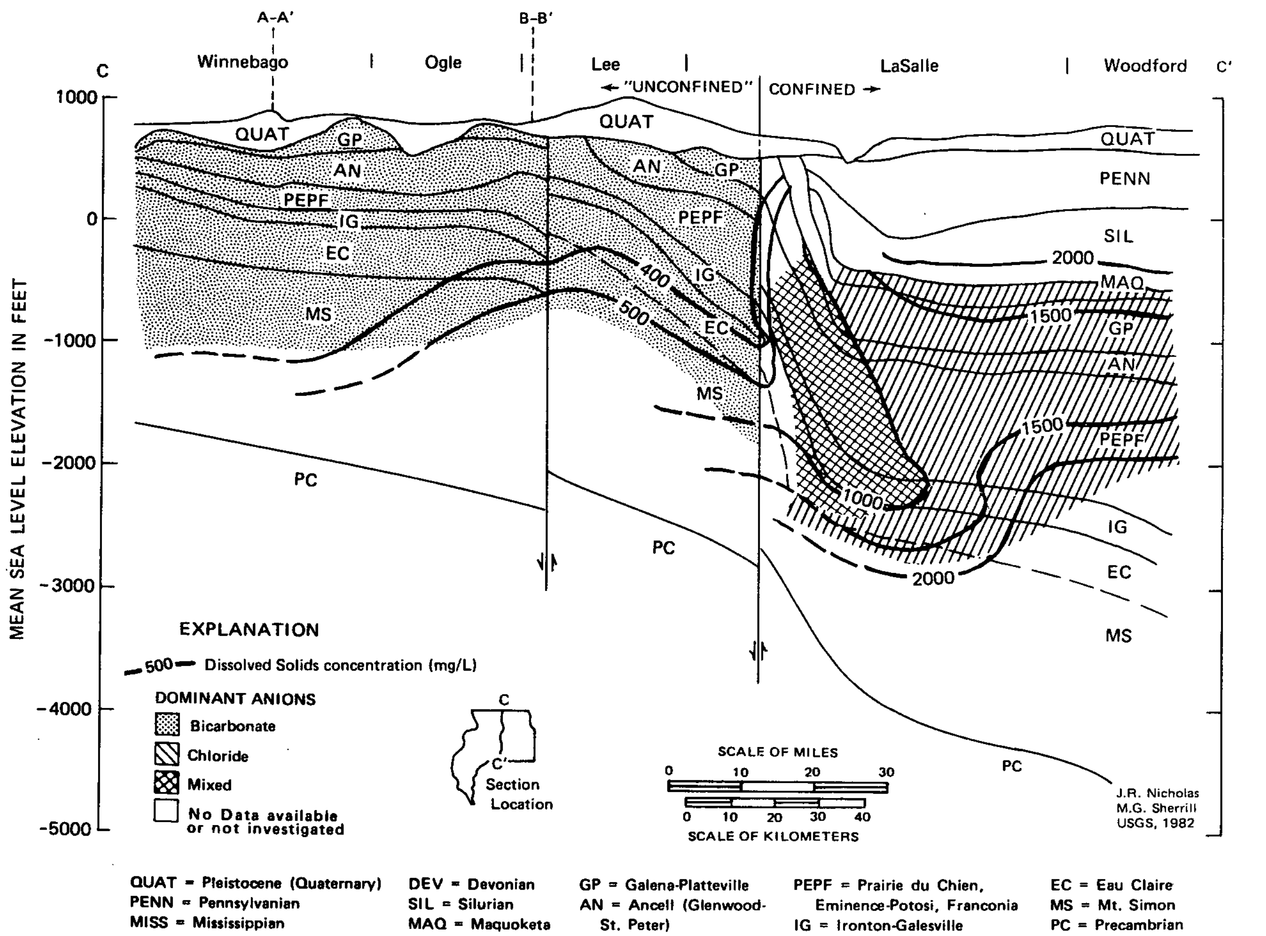


Figure 37. Cross section C-C' from South Beloit, Illinois, to Minonk, Illinois, showing geology, dominant anions, and dissolved solids concentration

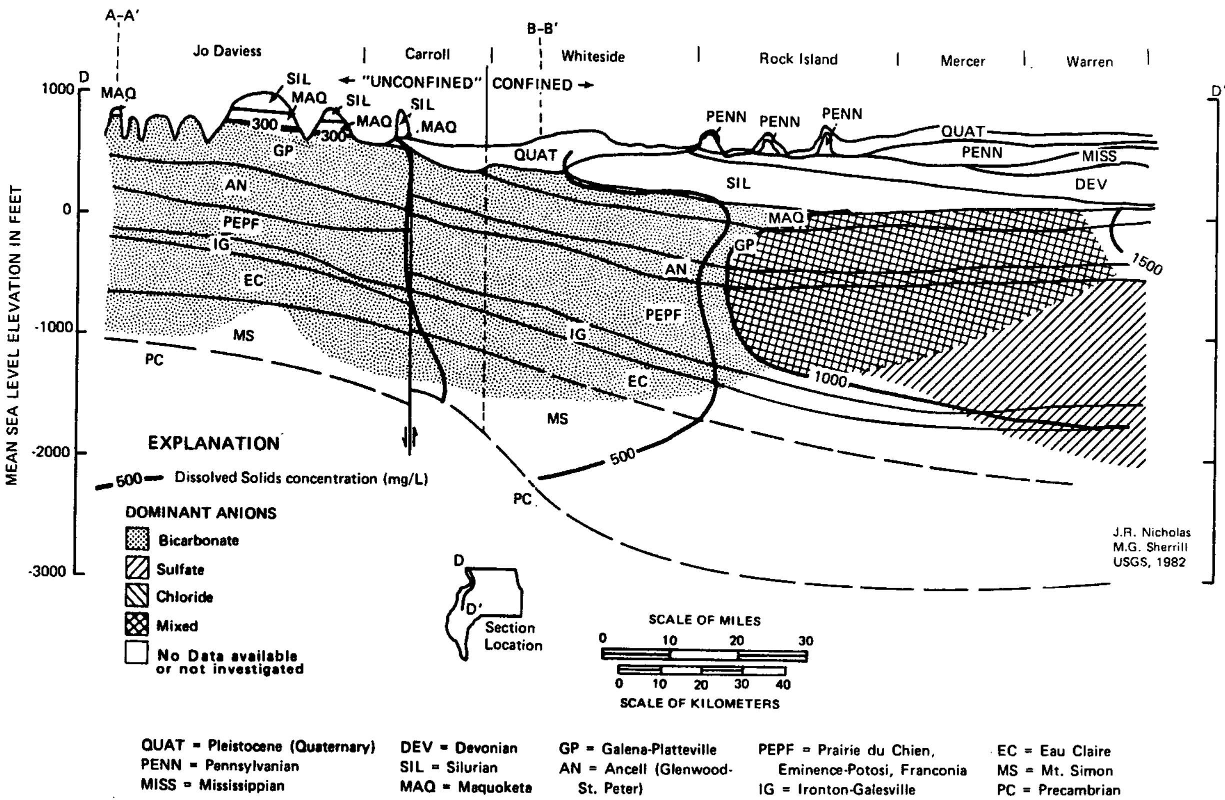


Figure 38. Cross section D-D' from Dubuque, Iowa, to Raritan, Illinois, showing geology, dominant anions, and dissolved solids concentration

sections B-B′, C-C′, and D-D′ (Pigs. 36-38, respectively) are not of major extent but are included for accuracy and completeness.

Water Quality of the Confined Area

In contrast to the "unconfined" area, significant vertical and areal changes in the chemical character of groundwater occur within the confined area of the Cambrian and Ordovician aquifers. Prior to heavy pumpage in northeastern Illinois, groundwater in the confined area traveled relatively longer flow paths at slower travel rates. The resultant longer time of contact between groundwater and rock units increased the dissolved solids concentration and more directly affected water types.

There are several water types between the calcium-magnesium bicarbonate water of the recharge area and the sodium chloride brines of the deep basin (Pig. 34). The cation evolution is from calcium-magnesium to calcium to sodium, with mixed waters occurring between dominant types. Anion evolution is from bicarbonate to sulfate to chloride, with mixed waters occurring between dominant types.

The pattern of evolution of water type from calcium magnesium bicarbonate to sodium chloride may be modified by geologic structures. Changes of water type across relatively short horizontal distances are associated with the steeply dipping bedrock near La Salle/Peru (fig. 37). Dissolved solids, sodium, and chloride increase significantly; however, there is no sulfate-dominant water type.

Within certain limitations, the general water quality and hydrology of the four units within the confined area of the Cambrian and Ordovician aquifers can be differentiated and discussed separately (fig. 39). The four units are the 1) Maquoketa Confining Unit (not shown in fig. 39), 2) Galena-Platteville and Ancell aquifers, 3) Ironton-Galesville aquifer, and 4) Basal Bedrock Aquigroup (Elmhurst-Mt. Simon aquifer). The limitations that affect area-wide characterization of units are:

1. Water-type changes occur down-dip within aquifer units.
2. Vertical components of flow cause mixing to occur between aquifer units.
3. Composite wells produce water from two or more aquifer units.
4. Data are non-uniformly distributed areally and vertically.

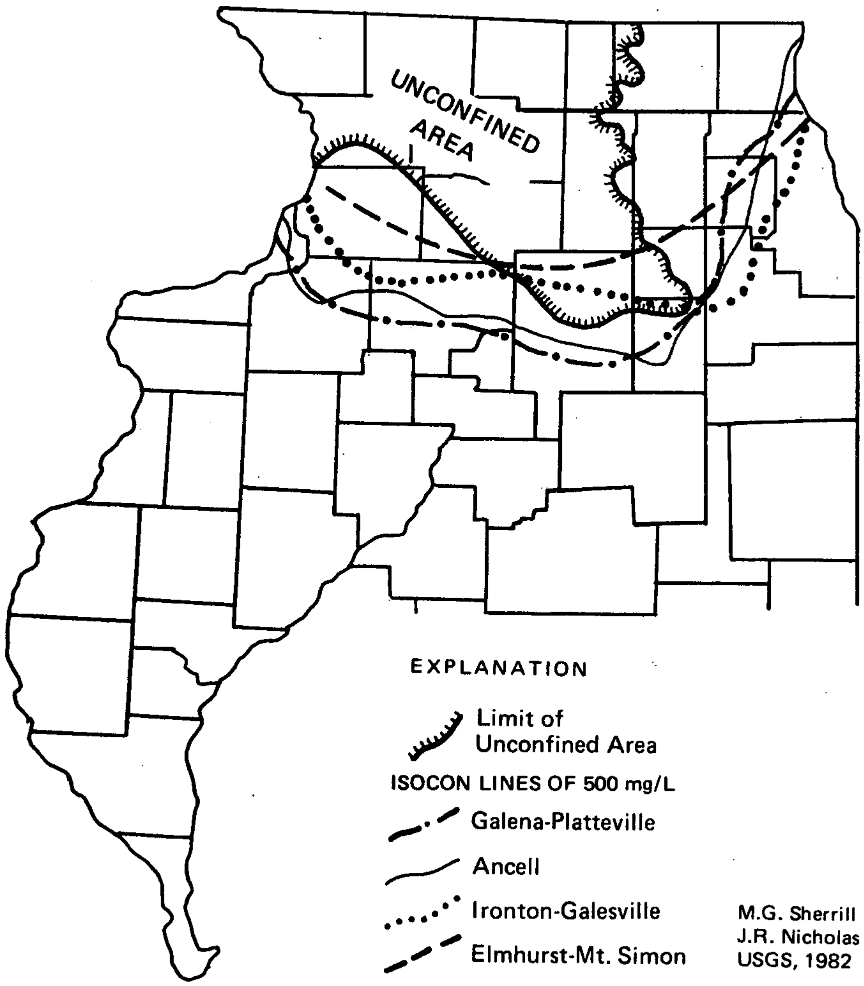


Figure 39. Map of 500 mg/L isocons of dissolved solids for major producing units

Unless otherwise noted, the following discussion is based on data from wells used in the preparation of cross sections A-A′ and B-B′ (figs. 35 and 36), where data are most abundant.

Maquoketa Confining Unit

The Maquoketa Confining Unit is the major confining unit of the Midwest Bedrock Aquigroup in northern Illinois but may yield small to moderate supplies of water where the unit is at the bedrock surface (fig. 19). Water from the few available single unit Maquoketa wells generally contains concentrations of dissolved solids of less than 500 mg/L. Calcium and magnesium are usually less than 10% meq/L, and chloride and sulfate are usually insignificant (figs. 34 and 35 and appendix C). Sodium and bicarbonate are both usually greater than 90% meq/L. Higher chloride and sulfate concentrations in some samples are caused by mixing with groundwater from overlying strata such as the glacial drift or Silurian dolomite.

Galena-Platteville and Ancell Aquifers

In the northeastern part of the confined area, water in the Galena-Platteville and Ancell (GP-AN) aquifers has a relatively low concentration of dissolved solids as shown in the Illinois Beach State Park test well (appendix C). Southeastward from the "unconfined" area there is a gradual increase in the concentration of dissolved solids (figs. 40 and 41), which is accompanied by a progression from calcium and magnesium to sodium as the dominant cation, and a progression from a bicarbonate to sulfate as the dominant anion.

South of the unconfined area, changes in the water quality occur rapidly over a short distance as the strata dip steeply toward the Illinois basin. In La Salle County, dissolved solids concentrations increase from 500 to 1500 mg/L in fewer than 20 miles (figs. 40 and 41). As shown on cross section C-C′ (fig. 37) the water type across a similar distance changes from a calcium-magnesium bicarbonate type to a sodium chloride type with no evidence of an intermediate sulfate type.

In western Illinois, no significant changes in water quality occur where the GP-AN aquifers are confined by only the Maquoketa Confining Unit. However, when the GP-AN aquifers are confined by the Pennsylvanian-age rocks as well, the water type changes from a calcium-magnesium bicarbonate to a sodium sulfate (cross section D-D′, fig. 38). Associated with the water-type

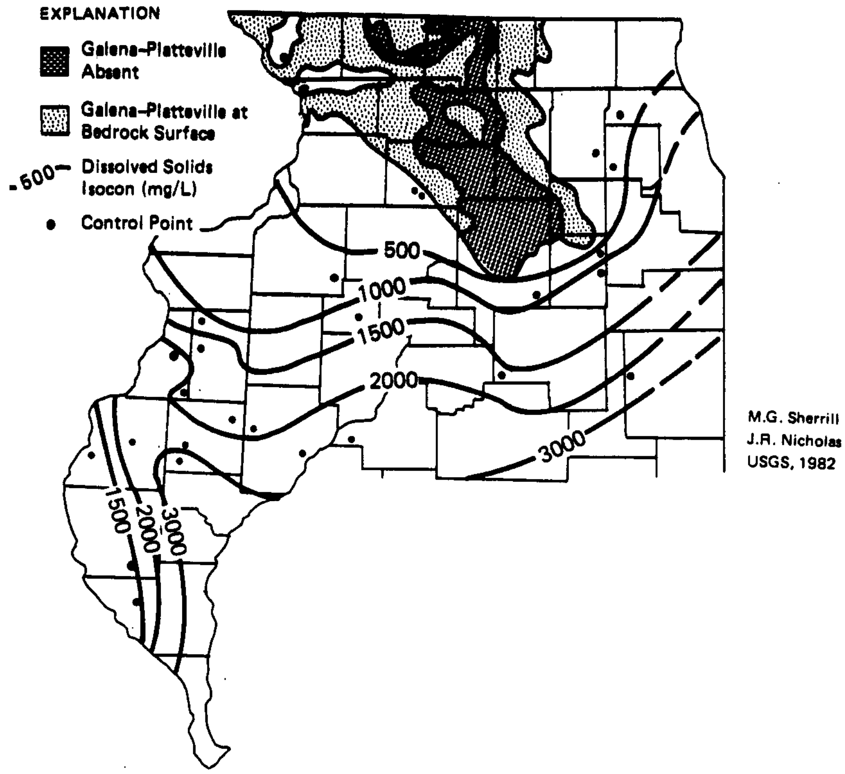


Figure 40. Generalized concentrations of dissolved solids in the Galena-Platteville aquifer

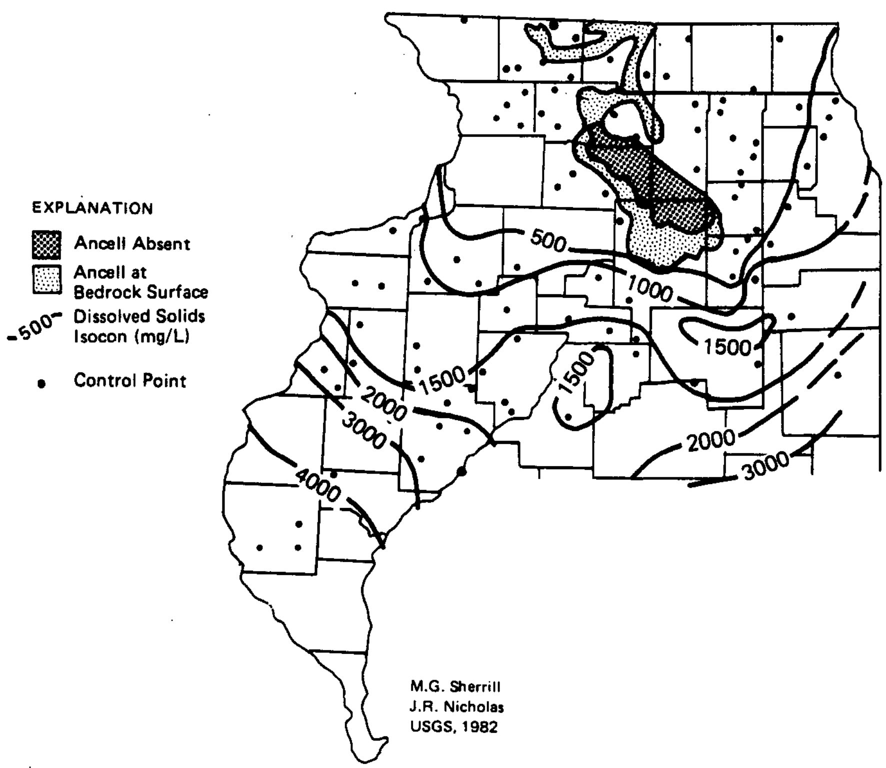


Figure 41. Generalized concentrations of dissolved solids in the Ancell aquifer

change is an increase in the dissolved solids concentrations. North of the Pennsylvanian outcrop, concentrations are less than 400 mg/L; under the Pennsylvanian concentrations exceed 1000 mg/L.

Ironton-Galesville Aquifer

In northeastern Illinois, the Ironton-Galesville aquifer is regionally the most permeable and most heavily pumped aquifer. High transmissivity reduces the travel time of water in this aquifer relative to travel times in aquifers above and below. In general, water in the Ironton-Galesville has the lowest concentrations of dissolved solids (fig. 42) in the Cambrian and Ordovician aquifers in northeastern Illinois. This may be seen by comparing figs. 40 to 43; it is also shown on cross section B-B′ (fig. 36) and in the water analysis for city well no. 8 in Bloomingdale (appendix C). The water type is calcium bicarbonate, with calcium exceeding 50% meq/L and bicarbonate exceeding 90% meq/L. Changes in water quality of the Ironton-Galesville occur in the easternmost portion of northeastern Illinois, as the bedrock units dip into the Michigan Basin (cross section B-B′; fig. 36). As water moves into the basin from the recharge area, the water type changes from calcium bicarbonate to sodium bicarbonate to sodium sulfate.

Very little water quality data is available to describe the Ironton-Galesville in central and west-central Illinois, although changes in water quality are probably similar to those in the other aquifers in the Midwest Bedrock Aquigroup in central Illinois.

Basal Bedrock Aquigroup

The water quality of the Basal Bedrock Aquigroup (Elmhurst-Mt. Simon aquifer) is highly variable; all water types present in the Cambrian and Ordovician aquifers are also present in this single aquifer. Water quality changes from a calcium-magnesium bicarbonate to a sodium-chloride type. The change in water type is associated with increasing depth of penetration into the Elmhurst-Mt. Simon and with southward and eastward movement from the unconfined area. Samples of water from the USGS test well near Zion, which penetrates the entire Mt. Simon, show that water quality changes with depth from sodium-sulfate to sodium chloride type (appendices A, B, and C).

High concentrations of dissolved solids and sodium chloride at depth restrict the use of water from the Basal Bedrock Aquigroup (figs. 43 and 44) for such uses as public and industrial water supplies. Concentrations of

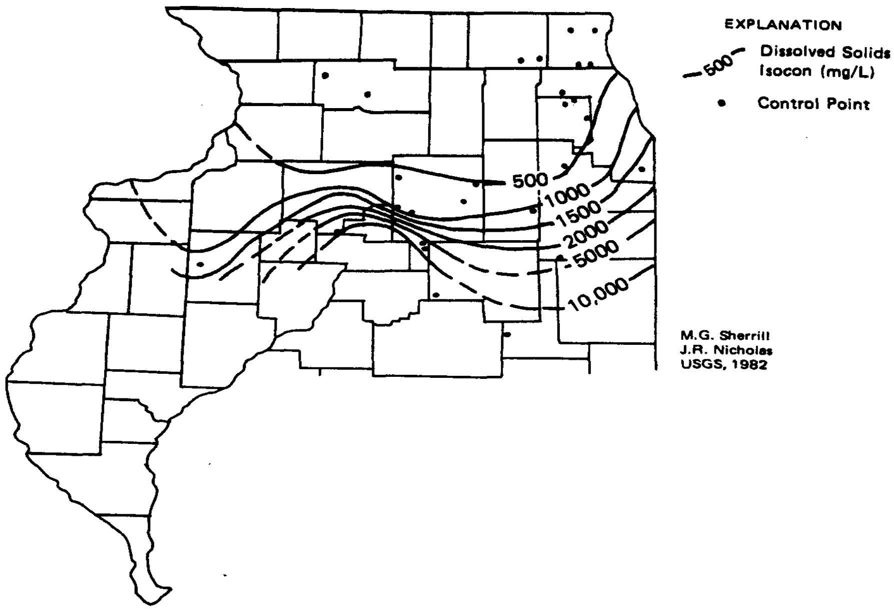


Figure 42. Generalized concentrations of dissolved solids in the Ironton-Galesville aquifer

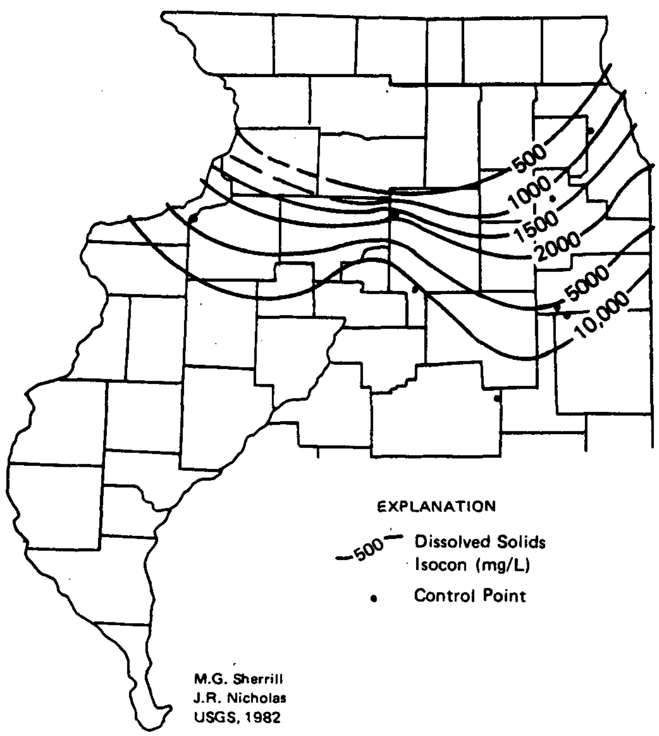


Figure 43. Generalized concentrations of dissolved solids in the upper part 1200-300 feet) of the Basal Bedrock Aquigroup

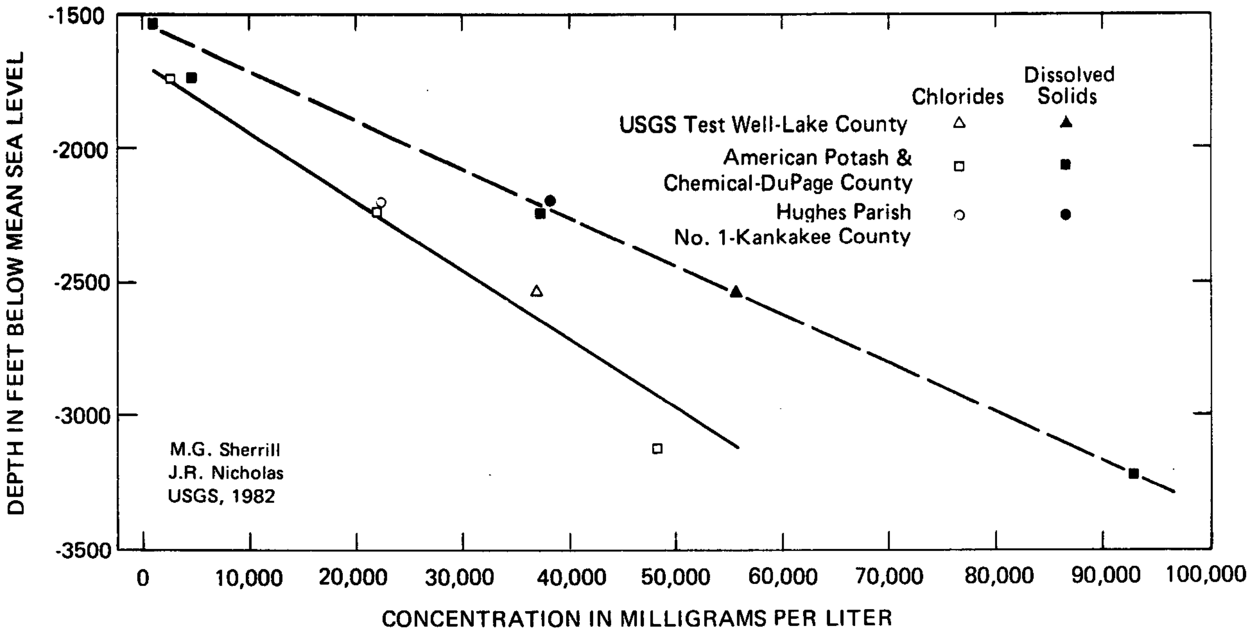


Figure 44. Concentration of chloride and dissolved solids versus altitude in the Basal Bedrock Aquigroup

chloride below an elevation of approximately -1600 feet MSL increase at a rate of about 1000 mg/L per 25 feet of penetration (fig. 44). Dissolved solids increase about 1400 mg/L per 25 feet of penetration (fig. 44). Temperature also increases with depth. Temperature logs from the Commonwealth Edison test well in Stephenson County (STE 28N6E-7.4d) and the U.S. Geological Survey test well in Lake County (LKE 46N12E-14.6g) (appendix A), both of which fully penetrate the Elmhurst-Mt. Simon, show an increase from 0.7 to 1.68 degrees Fahrenheit per 100 feet of penetration (fig. 45).

In the upper part of the Mt. Simon Sandstone, shale is interbedded with sandstone. These shale beds are important in confining highly mineralized water to the lower part of the Mt. Simon. At the USGS test well, chloride concentrations are two orders of magnitude higher beneath the shales than above them.

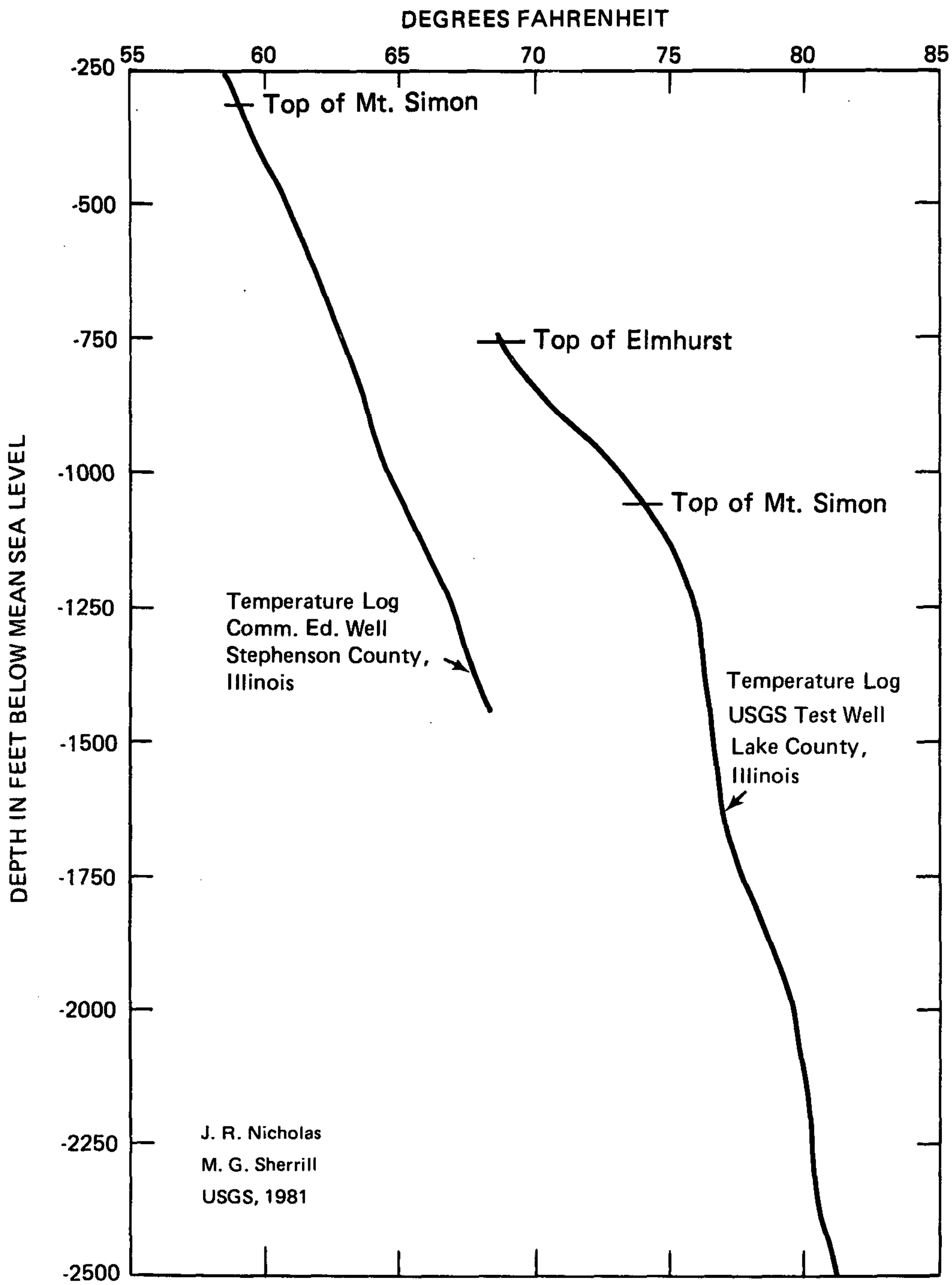


Figure 45. Temperature logs of two wells in northern Illinois

SUMMARY AND CONCLUSIONS

The Cambrian and Ordovician rocks include major aquifers throughout all of northern Illinois and are also tapped by wells as far south and west as Fulton and McDonough Counties. In northern Illinois approximately 250 municipalities as well as 150 industries derive at least a portion of their water requirements from these sources. This report incorporates both previously collected and reported data as well as data collected during the study. The updated information was used in the preparation of fifteen maps showing the thickness and surface configuration of geologic units. The report reflects the current state of understanding of the geologic, hydrologic, and water quality character of the aquifers. The scope of this understanding can be summarized by the following key conclusions:

1. Storage coefficients of the Midwest Bedrock Aquigroup under artesian conditions range from 1.6×10^{-4} to 6.8×10^{-4} and average 3.9×10^{-4}. Storage coefficients have not been evaluated where the system is now dewatered by pumpage. Storage coefficients in the Basal Bedrock Aquigroup range from 1.3×10^{-4} to 5.2×10^{-4}.
2. Transmissivities in the Midwest Bedrock Aquigroup range from 10,000 to 20,000 gpd/ft in northeastern Illinois and are generally increased by local or regional thickening of the Ancell and Ironton-Galesville aquifers. In north-central Illinois, where the Maquoketa Confining Unit is absent, the Galena-Platteville Unit contributes significantly to the transmissivity, and regional values generally exceed 20,000 gpd/ft. Transmissivities in the Basal Bedrock Aquigroup range from 980 to 10,600 gpd/ft.
3. Total withdrawals from wells finished in Cambrian and Ordovician rocks averaged 278.6 mgd between 1971 and 1980 but declined to 258.4 mgd in 1980. The largest withdrawals occur in Cook, DuPage, Kane, and Will Counties, where 1980 deep pumpages averaged 67.2 mgd, 28.4 mgd, 27.7 mgd, and 23.7 mgd, respectively.
4. Water level data suggest that, prior to development of the Midwest Aquigroup, a groundwater ridge existed in parts of McHenry, Kane, and DeKalb Counties, and groundwater moved southeastward toward Chicago and westward toward the Rock River. A second groundwater ridge existed in

portions of Jo Daviess, Stephenson, Carroll, and Ogle Counties. Groundwater discharge is believed to have occurred along portions of the Rock River; along the Illinois River in Grundy, LaSalle, Calhoun, and Jersey Counties; along the Mississippi River above Clinton, Iowa; and along the Pecatonica, Galena, -and Apple Rivers.

5. Groundwater withdrawals have caused water levels to decline as much as 900 feet in parts of Cook, DuPage, and Will Counties. Dewatering of the Galena-Platteville Unit is occurring at Aurora and Elgin, while at pumping centers at Joliet and in northern Cook County and eastern DuPage-western Cook Counties, all of the Galena-Platteville Unit and the upper part of the Ancell aquifer have been dewatered.
6. Maximum recharge rates, through the Maquoketa Confining Unit in northeastern Illinois and outside the area where the Maquoketa is present, have been estimated to be 3060 gpd/sq mi and 42,000 gpd/sq mi, respectively. Maximum recharge has probably- been reached in areas of heavy pumpage in the northeast, while in areas to the west of the Maquoketa, recharge is at about half of the maximum estimated rate.
7. The practical sustained yield of the Midwest Aquigroup, estimated by Walton (1964) to be 65 mgd for the eight-county northeastern Illinois areas, has been exceeded every year since about 1958. In north-central and northwestern Illinois, development has not exceeded the practical sustained yield, which is probably at least as great as that for northeastern Illinois. The potential for groundwater development in western Illinois is limited by the amount of lateral inflow which can be induced and also by poor water quality.
8. Wells in northern Illinois usually exceed 500 gpm in yield and may exceed 1000 gpm. In western Illinois, typical well yields are smaller because wells generally do not penetrate the more mineralized deeper units and tap only the Ancell aquifer.
9. Groundwater in the "unconfined" area of the Cambrian and Ordovician aquifers is chemically homogeneous and low in total dissolved solids. Concentrations of dissolved solids are generally between 250 and 400 milligrams per liter (mg/L). Water is a calcium-magnesium bicarbonate type, with calcium greater than 50% milliequivalents per liter (meq/L), magnesium between 30 and 50% meq/L, and bicarbonate about 90% meq/L.

10. In contrast to the "unconfined" area, significant vertical and areal changes in the chemical character of groundwater occur in the confined area of the Cambrian and Ordovician aquifers. These changes are related to the longer Plow paths and travel times in the confined area. Cation evolution is Prom calcium-magnesium to calcium to sodium, and anion evolution is from bicarbonate to sulfate to chloride.

11. Hydraulic stress imposed by heavy pumpage of an aquifer modifies the pattern of chemical change evolution. For example, increased concentrations of sodium and chloride in the Ironton-Galesville aquifer are due at least in part to increasing head differences between this aquifer and the underlying, more saline, Elmhurst-Mt. Simon aquifer.

12. In northeastern Illinois the Ironton-Galesville aquifer generally has the lowest dissolved solids concentrations in the confined part of the Cambrian and Ordovician aquifers. The better quality of water from the Ironton-Galesville is probably attributable to its greater permeability and larger production, which result in reduced travel time for water moving from the recharge area.

13. In northeastern Illinois water from the upper 300 or 400 feet of the Basal Bedrock Aquigroup is normally of sufficient quality to be used for public or industrial supplies. Below an elevation of about -1600 feet MSL, concentrations of chlorides increase about 1000 mg/L per 25 feet of penetration. Concentrations of dissolved solids similarly increase about 1400 mg/L per 25 feet of penetration.

14. Temperature of groundwater also increases with depth in the Basal Aquigroup. Temperature logs from two wells fully penetrating this aquifer show increases of 0.7 and 1.68 degrees Fahrenheit per 100 feet of penetration.

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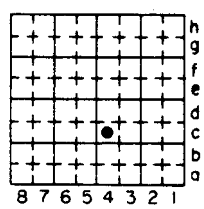
APPENDIX A

DATA FROM KEY WELLS

Wells listed below are key or essential wells used in preparing various parts of the text and/or illustrations or wells which are representative of the counties in which they are located. The well listing is by no means comprehensive and represents only a small portion of the Cambrian and Ordovician wells in the study area.

The well-numbering system used in the appendix is based on the location of the well, and uses the county, township, range, and section for identification. The well number consists of five parts: a three-letter county abbreviation, township, range, section, and coordinates within the section. Sections are divided into rows of one-eighth mile squares. Each one-eighth mile square contains 10 acres and corresponds to a quarter of a quarter of a quarter section. A normal section of one square mile contains eight rows of one-eighth-mile squares; an odd-size section contains more or fewer rows. Rows are numbered from east to west and lettered from south to north as shown below. Where there is more than one well in a 10-acre square, they are identified by arabic numbers after the lower case letter in the well number.



Will County
T35N, R10E
Section 5

The number of the well shown is WIL 35N10E–5.4c

County abbreviations used are:

ADM = Adams	IRO = Iroquois	OGL = Ogle
BNE = Boone	JDV = Jo Daviess	PEO = Peoria
BRN = Brown	KNE = Kane	PKE = Pike
BUR = Bureau	KNK = Kankakee	PUT = Putnam
CAL = Calhoun	KEN = Kendall	RIS = Rock Island
CAR = Carroll	KNX = Knox	SCH = Schuyler
COK = Cook	LKE = Lake	STK = Stark
DEK = DeKalb	LAS = LaSalle	STE = Stephenson
DUP = DuPage	LEE = Lee	TAZ = Tazewell
FRD = Ford	LIV = Livingston	VER = Vermilion
FUL = Fulton	MCD = McDonough	WAR = Warren
GRY = Grundy	MCH = McHenry	WIS = Whiteside
HAN = Hancock	MCL = McLean	WIL = Will
HND = Henderson	MRS = Marshall	WIN = Winnebago
HRY = Henry	MER = Mercer	WDF = Woodford
		WTS = Whiteside

Other abbreviations used in the report are:

P = Public Supply
I = Industrial Supply
R = Rural (non-irrigation) Supply
A = Abandoned
T = Test Well
QUAT = Pleistocene (Quaternary)
PENN = Pennslvanian
MISS = Mississippian
DEV = Devonian
SIL = Silurian
MAQ = Maquoketa
CO = Cambrian-Ordovician (Midwest Bedrock Aquigroup)
GP = Galena-Platteville
AN = Ancell (Glenwood-St. Peter)
PDC = Prairie du Chien
EP = Eminence-Potosi
FR = Franconia
PEPF = Prairie du Chien, Eminence-Potosi, Franconia
IG = Ironton-Galesville
EC = Eau Claire
MS = Mt. Simon
PC = Precambrian
DL = Driller's Log
SS = State Geological Survey, Sample Set Number
GPD/FT = Gallons per day per foot
MG/L = Milligrams per liter
CTY WELL = SGS designated county well number
W = State Water Survey, water quality analysis
E = Illinois EPA, water quality analysis
U = U.S. Geological Survey, water quality analysis

LOCATION	CTY WELL	OWNER	USE	YEAR DRILL	SURF ELEV (FT)	DEPTH (FT)	DEEP-EST FM	CASING DEPTH (FT)	CASING DIAM. (IN)	PRINC AQUIP	TYPE RECORD	WATER LEVEL (FT BELOW LAND)	YEAR MEAS-URED	TRANS-MISSIVITY (GPD/FT)	YEAR OF TEST	MINERAL ANALYSES NUMBER	YEAR OF TEST	TOTAL DISSOLVED SOLIDS (MG/L)	REMARKS
ADM 256W-19-1c	256	Bertha Phillips	T	1941	750	1,570	PDC				DL;SS 7053								Dry and Aband.
ADM 1S9W-16.4e	235	Hubbard, S.A.	T	1922	465	891	AN				DL;SS 280								
ADM 1N6W-34.3f	21166	Camp Point	P	1962	697	1,150	PDC	935	5	AN	DL								
BNE 43N3E-9.3h		Carlton #1	R			110	FP			GP	DL					U-251196	1980	439	Single unit GP
BNE 43N3R-25.4d	271	Elizabeth Taylor #1	T	1931	817	2,998	PC	110	20		DL;SS 1100	33	1931	17,500	1931				
BNE 44N3E-25.4d	296	Keene Belvid Canning #2	I	1942	780	550	AN	55	10	AN	DL;SS 8451	17	1942	19,900	1942				
BNE 44N3E-25.7c	343	Belvidere #2	P	1951	763	1,861	MS	50	12	CO,MS	DL	16	1951	41,170	1951	E-02973	1971	684	
BNE 44N3E-25.8b	292	Belevidere #3	P	1908	755	1,803	MS	55	15	CO,MS	DL	26	1951	11,000 (CO-MS) 42,560(CO)	1946 1951	E-029701	1971	738	
BNE 45N4E-11.7h		Capron #1	P	1900	912	880		90	10	CO	DL	7	1971	31,000	1946	E-00856	1971	360	No geological data
BNE 45N4E-22.8h	334	Gerald Seaver	R	1966	882	404	AN	390	5		DL;SS 52916	30	1966			U-248085	1979	375	Single unit AN
BNE 46N3E-33.7f	336	Krupke #1	T	1950	925	1,555	MS												
BRN 1S2W-33.1h	44	G. Cox #1	I		600	938	GP				DL;SS 312								
BRN 1S4W-22.6e	302		T	1964	705	1,045	GP	495	10		DL;SS 48780								Dry and Aband. 1964
BUR 15N6E-10.8b	164	Neponset #3	P	1955	820	1,640	AN	1,070	8	CO	DL;SS 25955	302	1956	17,000	1956	W-153664	1960	793	
BUR 15N6E-34.4c	165	Berry #1	P	1957	800	2,701	E	140	8.6		DL;SS 27725								Dry and Aband. Plugged 1957, borehole Logged
BUR 15N6E-34.6c	646	Buda #5	P	1968	770	1,601	AN	1,115	6	AN	DL	240	1968	5,650	1968	U-246125	1980	1,220	Single Unit AN
BUR 16N11E-10.8e	173	Joanna Western Mills #1	T	1960	630	1,643	PDC	1,170	10	CO	DL;SS 36332			1,720	1960				
BUR 16N11R-34.6h	21181	Spring Valley #11	P	1976	620	2,723	IG	1,158	18		DL;SS 60599	155	1976						
CAL 12S2W-9.5d	15	August Franke		1933	580	552	AN				DL;SS 1300								
CAL 10S3W-1.5c	42	Oettle #1		1969	535	485	GP	55	7		DL;SS 56406								
CAL 8S4W-6.3b	4	Fienup #1		1954	448	2,550	MS	310	8		DL;SS 24666								Dry and Aband.
CAR 23N5E-2.5f	88	Chadwick #2	P	1945	800	1,215		115	15	CO	DL;SS 12117	175	1964	3,000	1950	E-113906	1978	353	
CAR 24N3E-10.2e	118	Savanna #4	P	1935	610	1,309	EC	318	15.3	CO	DL;SS 1613	0	1935		1935	E-B00142	1976	297	
CAR 24N4E-12.7h3	2	Mt. Carroll #3	P	1955	740	1,453	MS	730	16	CO,MS	DL;SS 26039	120	1955	17,248 (CO)	1955	E-B49157	1978	376	
CAR 24N6E-5.5e	3	Lanark #3	P	1956	880	1,101	EC	340	14	CO	DL;SS 27454	175	1957	15,000	1957	E-B50658	1976	294	
CAR 25N3E-27.8b1	166	Miss. Palisades St.Pk	P	1951	655	560	GP	265	6	GP	DL;SS 1310	51	1951	1,175	1940	E-B48681	1978	288	Single Unit GP
CAR 25N7E-19.6f1		Shannon #1	P	1945	945	250	GP		6	CO	DL	58	1957	7,300	1957	E-01062	1971	420	
COK 35N13E-1.1d	2461	Flossmoor #2a	P	1973	674	1,764	EC	630	12	CO	DL;SS 58917			15,351	1973				
COK 35N14R-10.1g	958	Glenwood #5	P	1969	627	1,785		1,153	12	IG	DL;SS 56581			5,700	1969				
COK 37N12E-2.8h2	466	Orchard Hill Subd. #2	P	1962	680	1,610	EC	1,123	10	AN,IG	DL;Ss 42346			7,200	1962				Single Unit
COK 37N14E-22.1b	458	Sherwin Williams Co #1		1962	590	1,648		615	16.4	MAQ	DL;SS 43826			234	1962				Detailed Report filed.
COK 37N14E-27.6g	891	Chicago Sanit. Dist. DH-1	T	1968	591	1,696	EC				DL								
COK 39N13E-21.6g	2845	Kropp Forge Co		1955	610	1,635	EC		20	PEPG,IG EC				10,350	1966				
COK 37N14E-22.5a	3202	Chicago		1935	596	2,000	MS	1,810	6		DL;SS 1691								
COK 40N12E-31.4d	114	Automatic Elec.	I	1956	655	1,470	MS	73	30	CO	DL;SS 27117			23,223	1957				
COK 41N9E-36.3f	406	Hanover Park #1	P	1961	820	1,339			10	E,IG AN	DL;SS 39878	428	1961	18,640	1961				
COK 41N10E-15.4h	264	Hoffman Ests. 44 C	P	1959	775	1,380	E	1,019	12		DL;SS 33351	423	1959	22,000	1959	W-149556	1959	354	

LOCATION	CTY WELL	OWNER	USE	YEAR DRILL	SURF ELEV (FT)	DEPTH (FT)	DEEP-EST FM	CASING DEPTH (FT)	CASING DIAM. (IN)	PRINC AQUIP	TYPE RECORD	WATER LEVEL (FT BELOW LAND)	YEAR MEAS-URED	TRANS-MISSIVITY (GPD/FT)	YEAR OF TEST	MINERAL ANALYSES NUMBER	YEAR OF TEST	TOTAL DISSOLVED SOLIDS (MG/L)	REMARKS
COK 41N11E-13.4a	413	Des Plaines #5	P	1959	651	1,800	MS	1,030	18	CO,MS	DL;SS 34497	397		13,500	1959				
COK 41N13E-8.6d2	3512	Glenview Country Club	P	1958	650	2,050	PC	1,290	10	CO	DL;SS 628	338	1958	21,000	1958				
COK 42N10E-9.4b	24744	Palatine #9	P	1974	778	1,960	MS	1,018	16	PEPF IG,EC MS	DL;SS 59318	508		9,600	1974				
COK 42N11E-5.1g	139	Buffalo Grove #2	P	1957	685	1,342	EC	500	14	CO	DL; 30723	292	1958	11,250	1957	W-148334	1958	449	
COK 42N11E-27.1h		Mt. Prospect #17	P	1977	663	1,950	MS	1,030	20	IG,MS	DL	681							Borehole logged 1980
COK 42N11E-34.8f	3845	Mt. Prospect #5	P	1954	676	1,820	MS	442	16	IG,MS	DL;SS 25168	300	1955	12,830	1957	W-146788	1958	453	
DEK 3723W-22.1g	14	Structure Test P-2	T	1958	730	397	PEPF	90	5.5		DL;SS 32513								Plugged 1958
DEK 38N5E-15.2d	708	Hinckley	P	1913- 1914	740	708		120	12	AN	DL	16	1959	19,250	1913	W-112097	1947	325	
DEK 39N4E-32.7f	719	N.W. Mutual Ins	I	1940	900	400	AN				DL;SS 5252	760	1940						
DEK 40N3E-23.6e	730	Malta #2	P	1952	915	1,254	EC	530	14	CO	DL;SS2867	147	1952	15,050	1952	W130237	1952	245	
DEK 40N4E-21.3f	633	DeKalb #10	P	1966	880	1,316		640	20	AN, IG,PEPF	DL;SS 53204			23,020	1966				
DEK 41N5E-32.7g	723	Sycamore #6	P	1970	845	1,214		506	20	AN	DL;SS 57376	185	1970	19,860	1970				
DEK 42N3E-26.3h	792	Kirkland #1	P	1950	775	636	AN	152	8	AN	DL;SS 20714	10	1950		1950				
DEK 42N4E-22.7a	569	Kingston #3	P	1947	825	311		80	8	AN, PEPF	DL	35	1947	17,318	1958	W-112251	1947	417	
DEK 42N5E-20.7a	913	Genoa #4	P	1970		770			16	AN	DL;SS 57383	165	1970	15,600	1970				
DUO 38N10E-30.4d2	1294	Naperville #16	P	1967		1,245			16	CO	DL			18,174	1970				
DUP 38N11E-23.5e2	23733	Willowbrook #3	P	1974		1,620		1,704	18	CO	DL;SS 59050	675	1974	9,700	1974				Core Study, Plugged
DUP 39N9E-9.2a	1013	Am. Pot.& Chem. Waste Dept. #1	T	1967	741	4,043	PC	294	13.4		DL								Borehole logged Borehole logged
DUP 39N11E-10.1H	1563	Elmhurst #4	P	1928	665	2,205	MS		14	CO,MS	DL;SS 610			27,000	1953				
DUP 39N11E-10.3g2	1529	Wander Co. #11	I	1927	690	1,970	MS		16	CO,MS	DL;SS 722			23,300 24,000	1946 1956				
DUP 39N11E-27.6g	25210	Oak Brook #7	P	1977	710	1,522			18	PEPF, IG	DL;SS 61139			28,500	1977				
DUP 40N9E-11.	24149	Bartlett Vill.	P	1975	785	1,985	MS	1,044	16		DL;SS 59814	520	1975			U-177081	1980	512	Single unit IG
DUP 40N10E-20.4g		Bloomingdale #8	P	1980	770	1,400	IG			IG	DL	73	1980						Borehole logged 1980
DUP 40N10E-32.1c	24146	Carol Stream	P	1975	790	1,963	MS	1,074	18	IG,MS	DL;SS 59834								Borehole logged
DUP 40N11E-13.8e	1945	Bensenville #2	P	1929	676	1,442	EC	1,300	20	CO	DL;SS 55956	304	1944	23,000 21,600	1934 1950	W-110209	1947	378	
DUP 40N11E-26.3h1		Bensenville #6	P	1980	684	1,900	MS	1,271	20	IG,MS	DL	536	1980						Borehole logged
FRD 23N7E-36.5a	74	Helmick, Wil.#1		1940	725	1,631	AN				DL’Core 225 DL;SS 302414								
FRD 23N110E-36.8h	17	Workman #1		1957	737	1,449	GP	1,400	8.4										Dry and Aband. Plugged 1957
FRD 24N7E-19.4c	1	Erp, J #1		1940	840	4,250	EC	1,500	5		DL;SS 4717								Borehole logged
FRD 26N9E-33.5a	87	Fecht, W. J. #1		1943	741	2,237	PDC		10.8		DL;SS 10569 (Core #1196)								Dry and Aband. Dry and Aband.
FUL 4N2E-6.6b	10	Ipava	P	1915	650	1,324	AN	481	6	AN	DL	120	1948	3950	1948	W-113373	1948	2953	Single Unit AN
FUL 6N3E-20.6f	1286	Cuba #4	P	1951	683	1,380	GP		8	GP	DL;SS 22868			4500 7900	1951 1952				Single UniGp
FUL 7N4E-34		Canton #3	P	1924			AN			AN	DL			5300	1924				Single Unit AN
FUL 8N1E-19,4d	1577	Avon	P	1929	630	1,170	AN	829	8	AN	DL;SS 833	160							

LOCATION	CTY WELL	OWNER	USE	YEAR DRILL	SURF ELEV (FT)	DEPTH (FT)	DEEP-EST FM	CASING DEPTH (FT)	CASING DIAM. (IN)	PRINC AQUIP	TYPE RECORD	WATER LEVEL (FT BELOW LAND)	YEAR MEAS-URED	TRANS-MISSIVITY (GPD/FT)	YEAR OF TEST	MINERAL ANALYSES NUMBER	YEAR OF TEST	TOTAL DISSOLVED SOLIDS (MG/L)	REMARKS
FUL 8N3E-2.1f	703	Midland Elec. Coal		1933	700	2,777	IG	1,704	8		DL;SS 1329								
FUL 8N3E-33.5d	947	Fairview #1	P	1951	740	1,605	AN	1,605	6	AN	DL;SS 12872	225	1952	8,600	1951	W-127314	1952	1584	Single Unit AN
FUL 8N4E-11.1g	948	Farmington #2	P	1956	710	1,743	AN	1,280	12	AN	DL;SS27476	291	1952	1,900	1921	W-146687	1958	1965	Single Unit AN
GRY 31N8E-4.2b	698	Gardner	P	1925	588	973	AN	800	8	AN	DL;SS 435	63	1928	91	1951	W-61868	1928	980	Single Unit
GRY 31N6E-20.3c	1558	Babson Farms		1947	655	535	AN	450	6		DL	175	1947						
GRY 32N6E-29.4e	1053	E.I. DuPont #3		1940	520	1,545	EC	306	16	CO	DL;SS 4374			14,500	1943				
GRY 33N7E-4.4c	1080	Morris #5	P	1954	505	1,462	EC	800	16	IG	DL;SS 24398	46	1958	17,000 21,500	1958 1954	W-147974	1958	419	Borehole logged
GRY 33N7E-9.3h	1095	Morris #4	P	1938	518	1,501	EC	915	16	CO	DL;SS 2920	59	1955	10,500	1947	W-112558	1947	411	
GRY 33N8E-34.1d	22366	Coal City #5	P	1978	565	1,785			21	CO	DL;SS 61510	230		5,300	1978				
GRY 33N8E-1.3e	22239	Minooka #4	P	1973	613	725	AN	200	8	AN	DL;SS 58845	223	1973	5,900	1973				Single Unit AN
GRY 34N8E-35.1e	907	Dresden Nuclear #2		1957	530	1,500			26	CO	DL;SS 29050			2,830	1957				
HAN 3N7W-17.7e	157	M.D. Lafferty		1944	645	3,025	MS	233	10.8		DL;SS 11030								Dry and Aband. Borehole logged
HAN 4N5E-28.6g	200	Joe Rice		1941	614	2,085	PEPF	744	4.8		DL;SS 5672								Plugged back To 260 ft.
HAN 5N8W-6.8h		Camp Eastman	P	1958			AN		4	AN	DL			2,080	1957				Single Unit AN
HAN 6N9W-2.1h	46	Nauvoo Milk Prod.	I	1945	645	811	GP	65	8		DL								
HAN &N8W-2.2c	81	Chicago Bridge & Iron #1	I	1966		745		30	10	CO	DL;SS 53716	20	1966	2,840	1966				
HND 8N6W-2.5c	28	Evans		1964	533	802	AN	176	8		DL;SS 49972								Dry and Aband. Left open for Water well.
HND 9N5w-25.1e		Stronghurst #1	P	1925					8	AN	DL;SS 2713			2,080	1925				
HND 10N5W-34.2f	21	Dale McChesney		1950	675	675	GP	675	5.4	AN	DL	165	1950						
HND 11N5W-22.8b	196	G.C. Richmond #1		1942	520	900	AN				DL;SS 8791								Dry and Aband.
HRY 14N1E-21.1f	301	Alpha #2	P	1950	770	1,209	AN	1,209	16	CO	DL;SS 20014	256	1950	4,112	1950	W-120516	1950	754	
HRY 14N4E-27.8b	497	Galva #4	P	1933	845	1,687	PDC	1,040	20	AN	DL	304	1945	10,000 13,000 5,058	1934 1934 1970	W-112718	1947	898	
HRY 15N3E-7.3f	622	Cambridge #2	P	1913	800	1,377	AN	955	8	AN	DL			14,200	1944	W-109415	1946	640	Single Unit
HRY 15N5E-33.5h4	521	Kewanee #2	P	1927	848	2,430	EC		14	CO	DL;SS 613	304	1945	20,750 2,080	1927	W-108625	1938	1700	
HRY 15N5E-33.6g	515	Kewanee #3	P	1939	820	2,484	IG	1,525	10	AN CO CO CO	DL;SS	273	1944	2,250 22,000 36,000 23,000	1939 1939 1939 1939	W-8624	1939	1600	Single Unit
HRY 16N1E-30.8a	360	E. A. South	T	1961	803	3,863	PC				DL;SS 41427								Obsrv. Well
HRY 17N1E-5.6d		Silvis #6	P	1976	690	1,371	AN	312	12	Sil, CO	DL	206	1980						Plugged 1972 Borehole logged
HRY 17N3E-1.52a	587	Patten		1940	612	1,137	AN	820	8		DL;SS 4505								1980 Dry and Aband.
HRY 17N3E-35.1e	265	Midland Elec. Coal Corp. #2	I	1956	700	1,300	AN	548	16		DL;SS 28041	95	1956						Plugged
IRO 27N13W-31.8e	918	Harroun #1	T	1970	653	4,005	MS	4,000	5.5		DL;SS 56798								Borehole logged
IRO 26N13W-11.1h	46	V. Taden #1	T	1960	653	3,475	MS	3,466	5.5		DL;SS 35648								Borehole logged

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IRO 26N12W-18.3a	914	NIG (Owing’s Farm)	T	1970	655	4,088	MS	4,081	5.5		DL;SS 56797								Borehole logged
JDV 26N2E-9.4b	60	Hanover #1	P	1922	638	1,090	EC	500	8	CO	DL;SS 1900	0	1937			W-108631	1946	263	
JDV 26N2E-18.1h	280	Stanley Coad	I	1948	930	245	GP				DL;SS 17900	95	1948						
JDV 27N2E-24.2c		Elizabeth #2	P	1900	790	317		200	5	GP	DL	130	1937	19,200	1937	W-108630	1946	361	Single Unit
JDV 27N2E-11.2d	242	Stockton #4	P	1938	1,000	1,277	EC	77	12.5	CO,EC	DL;SS 2343	143	1946	8,200	1946	W-108628	1946	305	
										CO,EC				7,000	1957				
										AN				1,900	1938				
										CO,EC				5,100	1938				
JDV 28N1W-24.2b		Limback (Galena)	T	1941	610	1,491	MS	80	12	GP,AN	DL	Flow-	1980	---	1980	U-299088	1980	294	Packed 81’-346' Borehole logged
										PEPF		ing		2,300	1980	U-299081	1980	269	Packed 412’-587’
										IG				12,800	1980	U-299085	1980	245	Packed 691’-882’
										EC,MS				6,000	1980	U-299087	1980	235	Packed 981’-1489’
JDV 28N1W-13.7g	3	Galena #5	P	1963	840	1,600	MS	370	20	CO	DL;SS 43568			43,200	1963				
JDV 28N3E-15.1h	699	Braniger Lake Properties #2		1970	915	1,825	MS		14	CO	DL			32,968	1970	W-108575	1946	272	
JDV 29N2W-20.8a	413	East Dubuque #1	P	1937	615	1,502	PC	723	6	PEPF, IG,MS	DL;SS 2390	16	1946	35,500	1938				
KNE 38N7E-24.6h	1434	Aurora #21	P	1972	670	1,447	AN	656	22	CO	DL;SS 58157	243	1972	16,203	1972	E-C006208	1977	344	
KNE 38N8E-3.6g	24389	N. Aurora #5	P	1978		1,330		231	12	IG	DL;SS 61817	491	1978	13,253	1978				
KNE 38N8E-8.3e	22562	Aurora #25	P	1974	695	1,460	EC	667	22	CO	DL;SS 59813	227	1974			E-C006210	1977	376	
KNE 38N8E-15.3h	666	Aurora #12a	P	1935	670	2,251	MS	32	18	CO,MS	DL;SS 1690	172	1949	20,000	1936	E-03720	1972	780	
KNE 38N8E-3.8g	721	Geneva #3	P	1941	758	2,300	MS	320	16	CO	DL;SS 970	256	1954	11,250	1941	E-C003809	1973	334	
KNE 38N8E-22.3e	19	Batavia #3	P	1941	667	2,200	MS	1,606	16	CO,MS	DL	250	1975	25,000	1941	W-199253	1975	459	
KNE 40N7E-32.8b	1204	Elburn #3	P	1971	900	1,393		352	12	CO	DL;SS 57638	362	1971	5,490	1971	W-186387	1971	311	
KNE 40N8E-34.6e	825	St. Charles #6	P	1956	766	2,249	MS	1,172	20	CO	DL;SS 25360	420	1975	21,500	1955	W-200023	1975	367	Plugged to 150 ft in 1974
KNE 41N6E-9.1g	196	Burlington #2	P	1960	930	1,105	AN	343	10	CO	DL;SS 35440	269	1960	6,424	1960	W-B32682	1976	304	
KNE 41N8E-11.3f	846	Elgin #5	P	1949	725	1,225	EC	129	22	CO	DL;SS 20946	307	1960			E-B20294	1976	347	
KNE 41N8E-14.8b	782	Elgin-Schuler St. Well	P	1931	821	1,940	MS	1,463	8	CO,MS MS	DL;SS 1098	180	1946			W-69718	1931	395	Borehole logged USG 1980
KNE 41N8E-23.6b	785	Elgin State Hosp. #2	P	1947	760	2,000	MS	1,010	16	IG	DL;SS 21248	314	1964	23,500	1951	E-A15004	1976	280	
KNE 42N6E-21.4b		Hampshire #3	P	1943	905	514		455	8	MAG, GP	DL	61	1958			W-148811	1958	315	
KNE 42N8E-27.1e	106	West Dundee #1	P	1957	760	1,239	EC	596	16	CO	DL;SS 27887	405	1972	18,501	1970	E-B32680	1976	329	
KNK 29N10E-4.8h	540	Natural Gas Pipeline Co	T	1966	704	2,640	MS	2,621	7		DL;SS 54391								Borehole logged
KNK 30N9E-6.8a		Reddick	P	1954					8	AN	DL			495	1954				
KNK 30N10E-29.2d		Herscher	P	1945					6	AN	DL			1,725	1945				
KNK 30N13W-8.	412	State Insane Hosp	P	1908	615	1,090			8	CO	DL			8,800	1934				
KNK 31N9E-29.8h	489	Natural Gas Pipeline Co.	T	1965	600	2,450	MS	2,445	5.5		DL $S 52149								
KNK 31N12E-29.6f		Bradley	P	1934					10	AN	DL			1,350	1934				
KNK 31N13E-24.8d	400	Hughes-Parish #1	T	1930	622	5,050	MS				DL;SS 997								
KNK 32N12E-15.7b		Manteno	P	1934					10	AN	DL			6,000	1934				
KEN 35N6E-5.5b	224	Nils, Nilson	R	1941	670	225	AN	218	4.5	AN	DL;SS 6870	88	1941						Single Unit AN
KEN 35N6E-32.7h	238	Paul DeLucia	R	1950	655	920	FR	152	13.5		DL;SS 20192	21	1949						
KEN 35N8E-16.7f	188			1965	585	411	AN				DL;SS 51501								Borehole logged
KEN 36N6E-5.8e	692	Wisc-Mich Pipeline	I	1949	648	630	FR				DL;SS 19443								
KEN 37N6E-4.4d		Chicago YWCA	P	1934	675	425			6	AN				3,950	1934				

LOCATION	CTY WELL	OWNER	USE	YEAR DRILL	SURF ELEV (FT)	DEPTH (FT)	DEEP-EST FM	CASING DEPTH (FT)	CASING DIAM. (IN)	PRINC AQUIP	TYPE RECORD	WATER LEVEL (FT BELOW LAND)	YEAR MEAS-URED	TRANS-MISSIVITY (GPD/FT)	YEAR OF TEST	MINERAL ANALYSES NUMBER	YEAR OF TEST	TOTAL DISSOLVED SOLIDS (MG/L)	REMARKS
KEN 37N7R-28.8b	21328	Yorkville #4	P	1976	628	1,393	EC	476	22	AN,IG PEPF	DL;SS 60068	245	1976	8,000	1976				
KEN 37N7R-35.4g		Farm Colony Sub #1	P	1978						AN		212	1980			U-246027	1980	387	Single Unit AN
KEN 37N8E-5.8e	12	Caterpillar Tractor	P	1957	665	1,380	IG	547	16	CO	DL;SS 27627	231		19,000	1957				
KEN 37N8E-20.8h	152	Oswego #3	P	1957	640	1,378	EC	520	20	CO	DL;SS 30474	190	1957	20,000	1957	E-00817	1971	472	
KNX 10N1E-33.5b2	585	Abingdon #2	P	1927	740	2,583	IG	1,441	10	IG, PEPF	DL;SS 703	578	1927	86,300	1958				Wall Packer At 2380
KNX 11N1E-14.7e	6	Galesburg	P	1944	785	2,450	EC	1,260	12	IG, PEPF.EC	DL;SS 90	525	1943	62,000	1944				Brook St. Well
KNX 11N1E-16.1a	577	Galesburg #5	P	1950	780	2,750	MS	2,637	24	PEPF,				1,030	1950				Plugged back
KNX 11N2E-28.5d	203	Knoxville #2	P	1934	780	2,400	IG	1,485	10		DL;SS 1487			34,500 2,250	1934 1934				CO AN-Single Unit
KNX 12N1E-14.6c	610	Henderson #1	P	1966	800	705		447	8	GP		497	1966	27,250	1944				Co
KNX 12N3E-36.4d	248	Little John Coal Co. #2	I	1941	756	1,490	PDC	978	10	AN	DL;SS 6740	6,000	1941	4,267	1966				
KNX 43N10E-14.7d	3070	Kemper Insur.	I	1970	760	1,400	EC	1,086	8		DL;SS 57491	500	1970	19,412					
LKE 43N10E-21.5e	3455	Lake Zurich #7	P	1971	850	1,333	EC	525	22	GP,AN PEPF,IG	DL;SS 57779	570	1971	13,130	1971	W-187004	1971	361	
LKE 43N12E-30.7e	2396	Riverwoods	P	1962	675	1,370	EC	1,220	10	IG	DL;SS 41801	335	1962	3,200	1962	E-03583	1972	438	Single Unit IG
LKE 44N09E-24.5d		Wauconda #4	P	1973	792	1,264	EC	537	14	GP,AN PEPF,IG	DL	398	1973			E-C006451	1976	345	
LKE 44N10E-12.8a	2872	Mundelein #9	P	1969	828	1,380	EC	600	18	GP,AN PEPF,OG	DL;SS 56252	450	1969	13,820	1969	E-02852	1971	356	
LKE 44N12E-20.1f	2372	Lake Bluff #3	P	1956	685	1,828	MS	1,693	20	GP,AN IG,MS	DL;SS 27858	210	1956	19,175	1956	W-148037	1958	510	
LKE 45N10E-15.7e	3522	Round Lake Beach #6	P	1972	790	1,287	EC	1,067	16	PEPF,IG, EC	DL	387	1972	5,884	1972	E-B110116	1973	376	
LKE 45N11E-14-5a	241	Gurnee #1	P	1959	663	1,517	EC	1,143	10	IG,EC	DL;SS 35007	320	1975		1972	W-197919	1975	443	
LKE 46N12E-14.6f		IL Beach Pk. Test USGS	T	1981	585	3,460	PC	600	10	AN MS MS	DL;SS	218 214 163	1981	---		U-246077 U-351038 U-19041	1951	507 2,570 55,800	896-1,040’ 1,775-1,932’ 3,120’
LKE 46N12E-8.1d	2997	Winthrop Harbor #6	P	1969	689	1,500	EC	644	16	GP,PEPF IG,EC	DL;SS 56948	208	1970			E-B108570	1973	575	
LAS 31N3E-22.8h	1416	Kangley #1	P	1958	635	542	AN	351	10	AN	DL;SS 34249	147	1958	1,900	1958	W-148369	1958	1,401	Single Unit AN
LAS 33N1E-8.2f	22533	Peru #8	P	1974	643	2,764	EC	1,191	16	CO	DL;SS 59534	179	1974	17,500	1974				
LAS 33N3E-1.7a		Ottawa #1	P	1932	489	1,180		272	16	CO	DL	4	1932	32,000	1959	W-102916	1945	537	
LAS 33N3E-3.3c		Ottawa #8 (Am. Hoechst Co)	P					275		AN	DL					U-246028	1980	387	Single Unit AN
LAS 33N5E-24.8c		Seneca #2			511	704	AN	135								U-246029	1980	522	Single Unit AN
LAS 35N1E-32.3a	1037	P. Mathesius		1958	677	3,356	PC	1,570	8.6	DL									Dry and abandoned gas input well
LAS 35N3E-11.5b	2111	Harding #1	P	1939			AN	100	6	AN	DL	30		2,700	1973				Single Unit AN
LAS 36N1E-33.3h	901	Mendota #3	P	1944	740	1,380	EC		12	AB	DL;SS 13054			5,300 9,219	1945 1952				AN, CO
LAS 36N3E-18.4d	926	Earlville	P	1959	679	650			12		DL	18	1959	1,800	1959				
LAS 36N4E-1.2f	300	R. W. Lawinger		1957	681	3,659	PC				DL;SS 30734								
LAS 36N5E-1.4e	1026	Swanson #1		1957	659	3,725	PC												
LEE 19N11E-9.1a	28	Sublette #2	P	1961	925	771	AN	457	10	CO	DL;SS 42128	237	1961	6,800	1961				
LEE 20N8E-14.1d		Harmon	P	1916					5	AN				1,000	1916				Single Unit AN
LEE 20N10E-22.2g	4	Amboy #3	P	1958	750	1,105	EC	235	16	CO	DL;SS 30888	44	1958	11,140	1958	W-153626	1960	389	
LEE 20N10E-22.3g	180	Amboy #1	P	1928	714	3,772	PC				DL;SS 3772								
LEE 20N10E-35.2g	277	H. Carr		1949	812	3,653	PC				DL;SS 17942								
LEE 219E-5.5a	25	Dixon #7	P	1961	740	1,865	MS		16	CO	DL;SS 38500			39,790	1961				
LEE 22N11E-27.5C		Ashton #1	P	1915	810	545		180	12	EP,FR IG	DL	39	1948	4,150 3,400	1941	W113129	1948	470	

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LEE 37N1E-8.7e	182	West Brooklyn #3	P	1948	945	650	AN	492	10	AN	DL	229	1948	6,000	1948	W-113672	1948	295	
LEE 37N2E-10.2b		Paw Paw	P	1895	928	1,018	EC	454	10	PEPF,	DL	202	1938	19,750	1938	W-113131	1948	238	
LIV 27N4E-2.5g	1113	Northern Ill. Gas Co.		1972	670	2,975					DL;SS 58251								
LIV 28N6E-33.	739	Feinhold #1		1965	730	2,485	MS	329	16		DL;SS 50590 DL;SS CA636								
LIV 28N6E-10.7f2		Odell #3	P	1951					8	AN,PDC EP				61,000	1951				
LIV 30N3E-27.8a	272	Fehr #1		1962	665	2,890	MS	2,897	5.5		DL;SS 42596								
LIV 30N6E-1.1a	36	St. Reforma-Tory for women #2	P	1948	649	1,201	AN	510	10	AN	DL;SS 18231	1900	1948			W-115872	1948	1278	Single Unit AN
MCD 6N3W-5.3g	20815	Cntrl Ill. Power	T	1975	752	2,806	MS	2,804	5.5		DL								
MCD 7N1W-33.4e3	440	Bushnell #3	P	1945	651	1,510	POC	909	12	AN	DL;SS 12057	123	1945	3,200	1948	W-113769	1948	1874	
MCH 43N8E-5.4g	782	Crystal Lake City #2	P	1930	915	2,000	MS	964	20	CO ecpt AN,MS	DL;SS 902	388	1961	15,300	1957	W-188639	1972	280	
MCH 43N8E-6.4a	340	Crystal Lake City #6	P	1963	892	1,294		1,023	16	IG	DL;SS 46792	332	1963	4,924	1963	E-C001054	1975	274	Single Unit IG
MCH 43N8E-3.4b	23460	Algonquin #4	P	1977		955	AN	425	16	AN	DL;SS 61589			5,850	1977				Single Unit AN
MCH 44N5E-35.3g	890	Marengo City #3	P	1953	817	1,028	EC	538	12	CO	DL;SS 21477	145	1976	9,400	1951	W-201080	1976	373	
MCH 45N8E-15.8h		Modine Mfg. Co.	I	1968					12	AN,FR IG				11,151	1968				
MCH 46NSE-33.8b	545	Dean Milk	I	1946	870	1,783	MS	292	16		DL;SS 14396								
MCL 24N2E-15.1b	616	Northern Ill. Gas Co.	T	1968	843	4,277	MS	4,277	5.5		DL;SS 55761								
MCL 24N4E-10.8h	974	Northern Ill. Gas Co.	T	1972	975	3,990	EP	3,041	8.6		DL;SS 58258								
MCL 26N2E-19.5e	535	Northern Ill. Gas Co.	T	1967	764	3,988	MS	3,987	5.5		DL;SS 54982								
MCL 26N4E-2.2c	3	Chenoa City	P	1911	722	2,035	PDC	478	8		DL	186	1945			W-105205	1946	1314	
MRS 12N9E-27.5a	5	Hopewell Estates #5	P	1977	654	1,773	AN	1,309	10		DL;SS 61026	167	1977						
MRS 13N10E-16.3b	110	Henry City	P	1886	460	1,355					DL;SS 195								
MRS 30N1W-28.2d	125	Varna City #1	P	1949	660	1,870		654	8		DL;SS 19287								
MRS 29N1E-5.5a	112	Toluca City #2	P	1951	695	1,874	AN	1,358	12		DL;SS 21633	187	1951			W-153666	1960	1550	
MRS 30N1E-24.2f	15	Wenona City #3	P	1937	695	1,865		1,343	8		DL;SS 2074								
MER 13N1W-26.8g		North Hender-son #1	P	1957	775	710	MAQ	343	8	DEV,SIL, MAQ	DL	257	1957	11,389	1957	W-145801	1957	777	
MER 13N4W-19.3d	172	Fullerton #1	P	1958	578	3,716	PC		8.6		DL;SS 30473								Dry and Aband.
MER 14N2W-15.1b	224	Viola Vill. #1	P	1915	790	1,281	AN		10	AN	DL	197	1925	6,200	1915	W-108243	1946	1104	Single Unit
MER 14N3W-17.4a	84	Aledo City #1	P	1894	736	3,113	PC		8		DL	130	1924			W-71846	1932	1673	Backfilled to 1450’
MER 14N3W-17.4a	173	Aledo City #2	P	1925	736	1,131		325	8		DL;SS 535	243	1980			W-108244	1946	1158	Borehole logged
MER 15N1W-24.5g		Swedona Vill. #1	P	1957	715	534		281	6	CO	DL	184	1957			W-144064	1957	462	
OGL 23N8E-9.4c1	684	Polo City #1	P	1891	830	2100	MS	43	10	CO,MS	DL	114	1931	1,720	1931	W-112657	1947	337	

LOCATION	CTY WELL	OWNER	USE	YEAR DRILL	SURF ELEV (FT)	DEPTH (FT)	DEEP-EST FM	CASING DEPTH (FT)	CASING DIAM. (IN)	PRINC AQUIP	TYPE RECORD	WATER LEVEL (FT BELOW LAND)	YEAR MEAS-URED	TRANS-MISSIVITY (GPD/FT)	YEAR OF TEST	MINERAL ANALYSES NUMBER	YEAR OF TEST	TOTAL DISSOLVED SOLIDS (MG/L)	REMARKS
OGL 23N10E-3.6g	759	Oregon City #2	P	1948	707	1,200	MS	358	14 FR,IG MS	FR,IG	DL;SS 17940	31	1948 1948	5,500 1,000		W-115403	1948	320	Prod. Test made When drilling Stopped at depth Of 962’
OGL 24N10E-24.2h	27143	Commonwealth Edison		1974	860	853	FR	20	CO		DL;SS 60074	24,500	1974						
OGL 24N11E-1.7b		Stillman Valley	P	1938	725	300	AN	161	8	AN	DL	30	1938	7,200	1938	W-112797	1947	310	Single Unit
OGL 25N8E-33.4e		Forreston #2	P	1952	920	1,002	EC	254	12	CO,EC	DL	158	1952	62,000	1952	W-153353	1960	286	
OGL 25N11E-32.6g		Byron City #3	P	1969					16	AN,IG				24,288	1969				
OGL 40N1E-36.2h	290	Rochelle City #10	P	1966	783	920		203	20	CO	DL;SS 52614	103	1980	26,030	1966				Borehole logged-USGS, 1980
PEO 7N6E-22.8d	1640	Glasford Vill	P	1971	610	1,790	AN	1385	10		DL;SS 57655	+3	1971						Plugged back to 1618
PEO 8N6E-10.1f	704	Hanna City Vill. #1	P	1952	722	1,848		1340	8	AN	DL;SS 21553	200	1952	3,180	1952	W-127945	1952	1,543	
PEO 9N5E-7.6d	833	Elmwood City #3	P	1951	640	1,572	PDC	1121	10		DL;SS 21073	115	1951			W-125277	1951	1,513	
PEO 10N7E-11.7b	1286	Dunlap Vill #1	P	1964		1,691		800	8	MAQ,AN	DL	225	1964						
PEO 11N6E-13.1a2	375	Princeville Vill. #2	P	1938	745	1,342	GP	1091	12	GP	DL;SS 3001	190	1947	5,100	1943	W-109020	1947	1,604	Single Unit GP
PKE 4S5W-15.7h	189	Byron A. Campbell		1944	716	3,207	PC		10.8		DL;SS 10940 DL;SS 27228								Dry and Aband. Plugged 1959
PKE 5S4W-21.5h	205	Mumford		1948	810	2,226	PC	1765	10.8		DL;SS 17625								Dry and Aband. Plugged 1948
PKE 5S4W-24.	324	Pittsfield City	P	1922		835	AN				DL								
PUT 32N1W-11.1e	20224	Standard Vill.	P	1976	683	1,802	PDC	1304	6		DL;SS 60215	213	1976						Single Unit
PUT 32N1W-9.1e	75	Granville Vill. #2	P	1948	680	1,793	AN	1298	8	AN	DL;SS 18902	170	1948	4,700	1948	E-B0024119	1972	1,014	Single Unit
PUT 32N2W-3.7a	104	Jones & Laughlin		1966	527	4,877	PC	2703	9.8										
RIS 17N2W-36.6h		Milan #5	P	1970					14	CO				86,013	1970				
RIS 18N1E-32.7g	54	Silvis City #3	P	1956	580	1,675	EP	672	18	CO	DL;SS 26286	118	1957	5,461	1956	W-149561	1959	1,456	
RIS 19N1E-25.5e	341	Port Byron City	P	1943	584	1,597	EP	1077	8	AN,PDC EP	DL;SS 8649	43	1947	25,100	1953	W-112242	1947	2,410	
RIS 20N2E-18.1h	474	Commonwealth Edison		1968	608	1,800	EC	495	26		DL								
							FM												
SCH 151W-7.5a	358	T.R. Mills		1966	433	2,765	PDC	1530	5.5		DL;SS 52657								
SCH 2N1W-30.1e	113	Rushville City	P	1902	650	1,510	AN				DL					W-10421	1902	4,285	Aband. Due to High mineral Content in 1916
SCH 3N2W-9.4f	147	Applegate	P	1940	682	981	GP				DL;SS 5213								Dry and Aband.
STK 12N6E-1.7h	60	Wyoming City #1	P	1902	705	1,557	AN	1197	10	AN	DL	158	1943			E-B110824	1973	1,193	
STK 13N5E-11.1c	225	Witte #1		1971	758	2,822	MS	2808	5.5		DL;SS C-2940								Observation well
STK 14N7E-23.1a	32	Bradford City #2	P	1936	800	2,052	PDC	1439	12	MAQ,QN PDC	DL	268	1952			E-01626	1971	1,512	
STE 26N6E-9.8f2	38	Dean Milk Co. #2		1937	820	1,036	EC	112	10	CO	DL;SS 2144	54	1937	50,000	1937				

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STE 26N7E-30.2g		Donald Johnson #1				550	AN	469		AN						U-246123	1980	327	Single Unit AN
STE 26N9E-1.1b		Dorn Meldorf				150	GP			GP						U-239001	1980	531	Single Unit GP
STE 26N9E-32.8g	20917	German Valley Vill. #1	P	1971	900	560		382	10	AN	DL;SS 59533	170	1971	11,160	1971	E-B15548	1975	322	Single Unit AN
STE 27N8E-30.6b	336	Freeport City #3	P	1921	764	502	TR	150	16	AN,TR	DL;SS 225	20	1921	39,000 32,300 43,000	1921 1934 1949	W-185658	1971	508	
STE 28N6E-7.4d	UAH#3	Commonwealth Edison	T	1980	995	5,272	PC	2,177	3.4		DL;SS								No core from 30’ to PC, borehole logged
STE 28N6E-33.8e	489	Lena City #2	P	1931	965	998	IG	107	12.5	CO	DL;SS 1099	175	1975	21,500 3,750	1931 1947	E-B111090	1973	454	
STE 28N7E-8.3f		McConnel Methodist	P				AN	85		AN						U-246124	1980	293	Single Unit AN
STE 28N8E-36.5h	4	Dakota Vill #1	P	1957	940	516	AN	249	10	AN	DL;SS 30259	138	1957	5,492	1957	E-B16842	1975	279	
TAZ 23N6w-8.2b	261	Central Ill. Light Co.	A	1939	498	1,602	AN	134	10		DL;SS 34951								Dry and Aband.
TAZ 25N3W-24.8C	7	Mathis		1943	785	2,235	AN				DL;SS 8243								
TAZ 26N3W-29.3d	197	V. Zuercher	A	1954	788	1,825	AN	566	5		DL;SS 24691								Dry and Aband. plugged 1954
VER 19N11W-12.7e	1814	Allied Chem. Corp.	T	1972	662	6,684	MS	5,252			DL;SS 58118								
WAR 10N3W-8.5h		Kirkwood Vill. #4	P	1948	740	1,069	GP	945	5.2	GP	DL	219	1952			W-115995	1948	2,201	Single Unit GP
WAR-11N2W-19.1a	117	Monmouth City #7	P	1965	758	2,448		814	20	CO	DL;SS 52394	264	1974	12,029	1965	E-B117078	1974	1,283	
WAR 12N3W-20.3a		Little York Vill. #3	P	1969	623	872	GP	223	8	DEV,SIL GP	DL	107	1969	3,540	1969	E-B118039	1974	1,387	
WTS 19N4E-22.6h	23	Hannis #1		1952	607	1,548	EP				DL;SS 22342								
WTS 19N7E-28.2h	30	Carle Shedon		1941	647	1,500		1,188	6.6		DL;SS 5952								Dry and Aband. Plugged 1941
WTS 21N5E-18.8c1	2	Morrison West Well #2	P	1957	629	2,020	EC		7	CO,MS	DL;SS 30099			14,710	1957				
WTS 21N5E-22.1e		Nothern Ill Water Co (Sterling #2)	P	1947	650	1,725	MS	128	12	CO,MS	DL	95	1980						Borehole logged, USGS
WTS 21N7E-28.2h	95	Lawrence Bros. Mfg.		1947	640	1,588	EC		8	AN	DL;SS 7583			5,900	1947				Single Unit
WTS 22N3E-28.5d	103	Fulton #3	P	1931	600	1,943	MS	357	16		DL;SS 179	45	1947			W-83702	1938	333	
WIL 32N10E-36.2c	1230	Kankakee St. Boys Camp #2	P	1962	587	751	AN	278	8	AN	DL;SS 43822	182	1962	1,730 3,000	1962 1970				Single Unit
WIL 33N9E-12-1g	680	Kankakee Ordnance Works		1942	575	1,644	EC		15	CO	DL;SS 7995			25,700	1942				
WIL 33N14E-157a	600	D. D. VanVoorh		1933	682	1,625	EP	1,238	6.6		DL;SS 1314								
WIL 35N9E-20.6g	1303	McCoy		1963	625	4,300	PC	595	20		DL;SS 45073								
WIL 35N10E-14.6h	694	Joliet City Washing. St.	P	1937	560	1,608	EC	67	18		DL	420	1957	17,100	1937				
WIL 35N10E-30.1e	1259	Blockson Chem. Co. #2	I	1941	545	1,510	EC	527	12	IG	DL;SS 6133			6,800	1941				
WIL 35N12E-25.3e	1270	J. R. McGlasham		1934	738	2,700	MS				DL;SS 6133								
WIL 36N9E-10.8d	249	Plainfield City	P		615	1,481	IG				DL;SS 26207								
WIL 36N10E-21.4a	1334	Stateville Pen. #6	P	1966	642	1,611	EC	446	16	CO	DL;SS 52350	528	1966	2,650	1966				

LOCATION	CTY WELL	OWNER	USE	YEAR DRILL	SURF ELEV (FT)	DEPTH (FT)	DEEP-EST FM	CASING DEPTH (FT)	CASING DIAM. (IN)	PRINC AQUIP	TYPE RECORD	WATER LEVEL (FT BELOW LAND)	YEAR MEAS-URED	TRANS-MISSIVITY (GPD/FT)	YEAR OF TEST	MINERAL ANALYSES NUMBER	YEAR OF TEST	TOTAL DISSOLVED SOLIDS (MG/L)	REMARKS
WIL 36N11E-31.8b	1299	Joliet City #3	P	1950	642	1,659	EC	577	20	CO	DL;SS 19943 449 1950	10,500	1950						
WIN 26N11E-9.7g	877	Winnebago Village #3	P	1968	885	835	IG	313	16	IG	DL;SS 57008	160	1968	14,900	1968				
WIN 27N10E-29.1d	28	Pecatonica Village #2	P	1946	783	750	EC	145	12.5		DL;SS 14395	34	1946	11,700	1946				
														5,800	1956				
WIN 27N11E-27.1f		Marvin Johnson	P			320	AN			AN						U-248084	1979	282	Single Unit AN
WIN 28N10E-10.4b	23431	Durand City #3	P	1975	770	585	EC	60	18		DL;SS 59623	7	1975	18,390	1975				
WIN 28N10E-2.5f		Tom Koch	R			150	AN			AN		46	1980			U-248087	1979	395	Single Unit AN
WIN 43N1E-33.8h		C. W. Condon #1	R			145	GP	139		GP						U-251193	1980	253	Single Unit GP
WIN 42N2E-20.1h	1445	Cherry Valley Fire Dist #1		1970	850	635	EP	80	8		DL;SS 57016	130	1970	7,940	1970				
WIN 43N2E-25.3d		Blackmere #1	R			300	AN	284		AN						U-251199	1980	261	Single Unit An
WIN 44N1E-21.1e	640	Rockford City #15	P	1959	755	1,355	MS	260	20		DL;SS 34995	155	1959	40,000	1959				
WIN 44N1E-34.6h	304	Rockford Unit Well #4	P	1948	730	1,219	MS	193	20	GP,AN	DL;SS 18130	61	1980	23,600	1980	U-251197	1980	646	Packed 193'-420'
										PEPF		--	---	13,000	1980	U-251198	1980	658	Packed 420'-567'
										PEPF		64	1980	13,000	1980	U-251194	1980	665	Packed 435'-582'
										IG		65	1980	15,000	1980	U-251195	1980	706	Packed 572'-719'
										EC-MS		67	1980	11,300	1980	U-256090	1980	624	Packed 820'-1219'
										MS		69	1980	1,500	1980	U-256089	1980	695	Packed 1136'-1219'
WIN 44N2E-24.8g	646	Seele #1	T	1962	872	3,385	PC				DL;SS 20109								
WIN 44N2E-31.7f	367	Rockford Unit Well #6	P		790	1,376	MS	186	20		DL			69,800	1941				
WIN 46N1E-24.8a	1056	Rockton Vill	P	1969	840	728	IG	200											
		#5									DL	100	1969	19,000	1969				
WIN 46N2E-5.7d		S. Beloit City	P	1937	745	1,200	MS	230	18										
		#3										0	1937	34,500	1937	W-112321	1947	311	
WDF 26N1E-31.4d	60	Moreland	P	1940	740	2,175	PDC	832	8		DL;SS 5001								Dry and Aband. Plugged
WDF 28N2E-7.5c	184	Minonk City	P	1922	758	2,005	PDC	526	12			325	1947			W-109530	1947	1,703	

APPENDIX B

DRILLING AND TESTING

New data collected for this report include data from the drilling of a deep test well to Precambrian bedrock in Lake County, select packer tests in this test well plus two other deep wells, and borehole logging of the three packed wells plus several other representative Cambrian and Ordovician wells.

Illinois Beach Park Test Well (LKE 46N12E-14.6f)

This is a 10-inch well, located in the Camp Logan part of Illinois Beach State Park, and was drilled to a depth of 3460 feet into Precambrian bedrock as a part of this study (Nicholas et al., 1984). The Ancell, Ironton-Galesville, and Elmhurst-Mt. Simon aquifers were packed off, tested, and sampled during the period December 1980 to September 1981 (see appendix A). The following borehole logs were run in this well: spontaneous potential, resistivity, natural gamma, caliper, fluid conductivity, temperature, density, and porosity. Upon completion, piezometers were installed in the lower and upper Elmhurst-Mt. Simon and Ironton-Galesville aquifers, with open-hole completion into the Galena-Platteville unit and Ancell aquifer.

See appendices A and C for additional information on this well.

City of Rockford Unit Well #4 (WIN 44N1E-34.6h)

This 20-inch diameter, 1219-foot deep well is part of Rockford’s municipal water supply system and was tested during a down period in September, 1980. Six packer tests in five different zones were conducted and water samples were taken (appendix A). Natural gamma, spontaneous potential, resistivity, caliper, and fluid conductivity borehole logs were run.

Limback Well in the City of Galena (JDV 28NlW-13.78)

This is a privately-owned, 12-inch diameter, flowing well, 1491 feet deep. Four zones were packed and tested (appendices A and C). Several geophysical borehole logs were also run: natural gamma, spontaneous potential, resistivity, caliper, fluid conductivity, temperature, and flow meter tests.

Additional Borehole Geophysical Logging

The following Cambrian-Ordovician wells were borehole logged during this investigation:

Aledo City Well #2 (MER 14N3W-17.4a): gamma, spontaneous potential, resistivity

Bensenville City Well #6 (DUP 40N11E-26.3h1): gamma, spontaneous potential, resistivity, caliper, fluid conductivity, temperature

Carol Stream City Well #4 (DUP 40N10E-32.1c): gamma, spontaneous potential, resistivity, caliper, fluid conductivity, temperature

Elgin-Schuler St. Well (KNE 41N8E-14.8b): gamma, spontaneous potential, resistivity, caliper, fluid conductivity, temperature, flow meter

Mt. Prospect City Well #17 (COK 42N11E-27.1h): gamma, spontaneous potential, caliper, temperature

Rochelle City Well #10 (OGL 40N1E-36.2h): gamma, spontaneous potential, resistivity, caliper, fluid conductivity, temperature

Sterling City Well #2 (WTS 21N5E-22.1e): gamma, spontaneous potential, resistivity, caliper, fluid conductivity

Silvis City, Well #6 (RIS 17N1E-5.6d1): gamma, spontaneous potential, resistivity, caliper, fluid conductivity, temperature, flow meter

APPENDIX C

SELECTED CHEMICAL ANALYSES

Seven analyses are shown. Five of these are representative of water from single aquifer units and two are representative of a mixture of water from the aquifer units. The Maquoketa Shale Group, although generally considered an aquitard rather than an aquifer, does yield small supplies, so a typical sample from this unit is included.

"Unconfined" Area - Elmhurst-Mt. Simon Aquifer

An Elmhurst-Mt. Simon aquifer water sample was collected from the Limback well in the Village of Galena in Jo Daviess County (JDV 28N1W-24.2b). This is a 1491-foot flowing well. The well was packer-tested and sampled in four zones with this analysis representing the Elmhurst-Mt Simon aquifer between 981 feet and the bottom of the hole. This analysis is generally representative of the recharge area and, as such, is similar to the analyses for overlying aquifers.

USGS Lab Number 299087

		mg/L	me/L
Calcium	Ca	50.	2.50
Magnesium	Mg	26.	2.14
Sodium	Na	1.3	0.006
Potassium	K	2.8	0.007
Chloride	Cl	1.3	0.004
Sulfate	SO_4	5.9	0.12
Alkalinity	ALK	230.	4.60
Total Dissolved Solids		235.	

Reducing Zone - Galena-Platteville and Ancell Aquifers

A water sample was collected from a well in the Village of Creston in Ogle County (OGL4ON2E-23.1f). This is a 585-foot well cased to 417 feet and open to the Galena-Platteville and Ancell aquifers. The sample is typical of the reducing zone mentioned in the water quality section.

IEPA Lab No. B0019553

		mg/L	me/L
Calcium	Ca	39.	1.95
Magnesium	Mg	27.	2.22
Sodium	Na	34.	1.48
Potassium	K	1.6	0.004
Chloride	Cl	0.0	0.00
Sulfate	SO_4	0.0	0.00
Alkalinity	ALK	280.	5.83
Total Dissolved Solids		292.	

Maquoketa "Aquifer"

A water sample was collected from a well in the Turnberry Subdivision about 1-1/2 miles south of Lakewood in McHenry County (MCH 43N7E-11.4f). This is a 12-inch well, 395 feet deep with a surface elevation of 920 feet. The well is cased to the dolomitic part of the Maquoketa. The well is located in the outer edge of the confined area where the Maquoketa yields small supplies of water.

ISWS Lab No. 195667

		mg/L	me/L
Calcium	Ca	2.7	0.13
Magnesium	Mg	1.2	0.10
Sodium	Na	169.	7.35
Potassium	K	2.5	0.06
Chloride	Cl	6.0	0.17
Sulfate	SO_4	1.2	0.02
Alkalinity	ALK (as $CaCO_3$)	366.	7.32
Total Dissolved Solids		432.	

Discharge Area - Ancell Aquifer

A water sample was collected from the Ancell aquifer in the USGS test well in Illinois Beach State Park (Camp Logan Campground) in northeastern Lake County (LKE 46N2E-14.6g). This is a 3460-foot deep test well penetrating Precambrian bedrock. The land surface is 586 feet and the well is cased with 600 feet of steel casing down to the top of the Calena Group. This well was packer-tested and sampled in several zones. This analysis is from the Ancell aquifer between 896 feet and 1046 feet in depth.

USGS Lab No. 246077

		mg/L	me/L
Calcium	Ca	94.	4.69
Magnesium	Mg	23.	1.89
Sodium	Na	41.	1.78
Potassium	K	11.	0.28
Chloride	Cl	13.	0.37
Sulfate	SO_4	150.	3.12
Alkalinity	ALK	260.	5.20
Total Dissolved Solids		507	

Discharge Area - Ironton-Galesville Aquifer

A water sample was collected from the Ironton-Galesville aquifer from Bloomingdale Well No. 8 in DuPage County (DUP 40N10E-20.4g1). This is a 1,400-foot well drilled to the top of the Eau Claire confining unit. It is cased with 16-inch steel casing to 1174 feet down to the Franconia Formation. For practical purposes the well can be considered to be single-unit Ironton-Galesville.

IEPA Lab No. B42608

		mg/L	me/L
Calcium	Ca	65.0	3.24
Magnesium	Mg	18.	1.48
Sodium	Na	20.	0.87
Potassium	K	13.	0.33
Chloride	Cl	3.5	0.10
Sulfate	SO_4	16.	0.33
Alkalinity	ALK	271.	5.41
Total Dissolved Solids		298.	

Discharge Area - Elmhurst - Upper Mt. Simon Aquifer

This water sample is from a packer test in the upper Mt. Simon aquifer from 1355 feet to 1920 feet in the USGS test well (LKE 46N12E-14.6g) described above.

USGS Lab No. 351038

		mg/L	me/L
Calcium	Ca	230.	11.48
Magnesium	Mg	29.	2.39
Sodium	Na	190.	8.27
Potassium	K	22.	0.56
Chloride	Cl	140.	3.95
Sulfate	SO_4	840.	17.49
Alkalinity	ALK	210.	
Total Dissolved Solids		1600.	

Discharge Area - Lower Mt. Simon Aquifer

This is a point sample from the lower Mt. Simon aquifer at a depth of 3120 feet in the USGS test well (LKE 46N12E-14.6g) described above.

USGS Lab No. 19041

		mg/L	me/L
Calcium	Ca	1000.	49.90
Magnesium	Mg	930.	76.50
Sodium	Na	15000.	652.50
Potassium	K	270.	6.90
Chloride	Cl	37000.	1043.77
Sulfate	SO_4	1400.	29.15
Alkalinity	ALK	120.	2.40
Total Dissolved Solids		55800.	