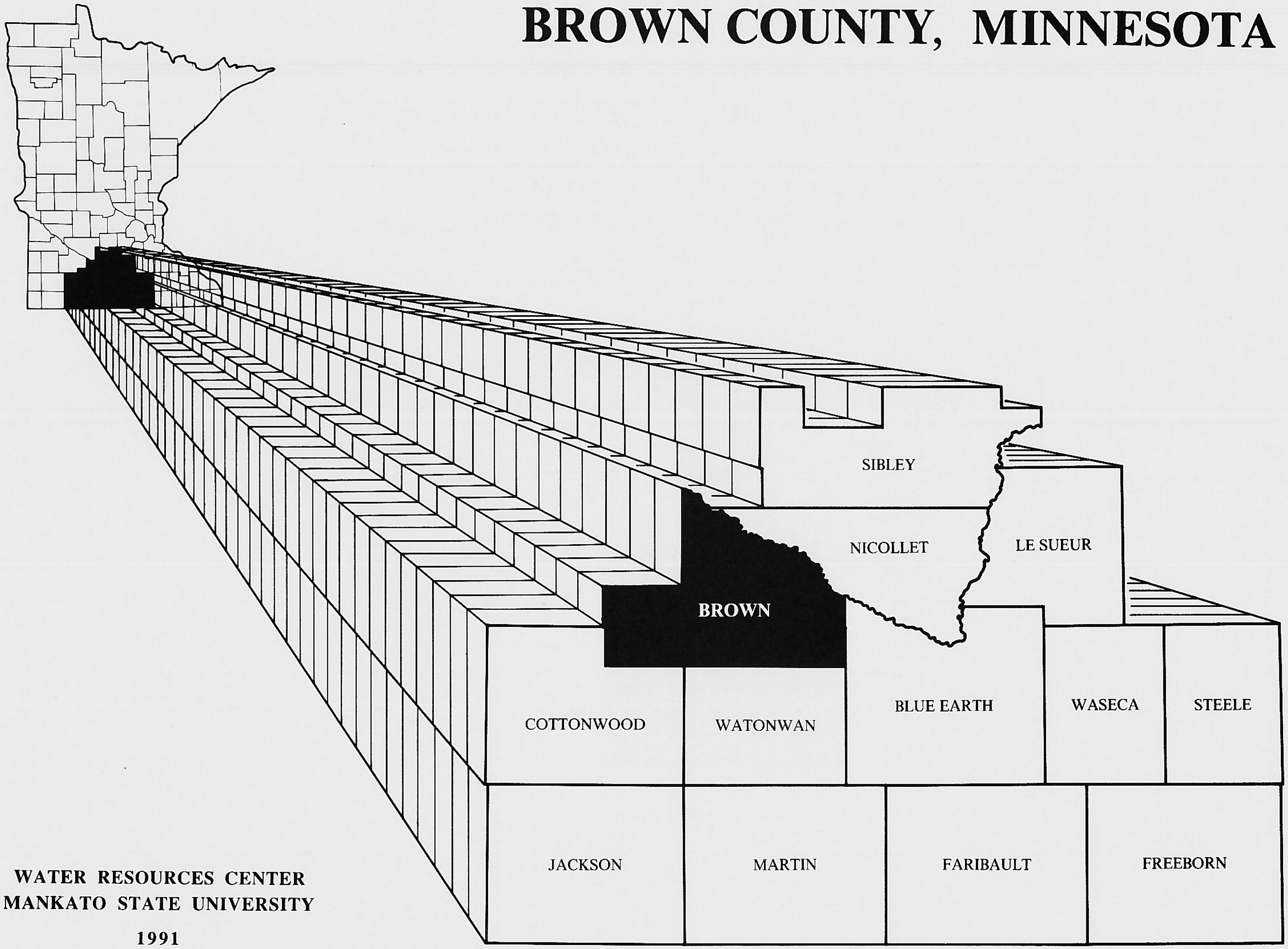
GEOLOGIC ATLAS

BROWN COUNTY, MINNESOTA



WATER RESOURCES CENTER
MANKATO STATE UNIVERSITY

1991

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JULY, 1991

The Brown County Geologic Atlas was prepared and published with the support of a grant from the Legislative Commission on Minnesota Resources and the Brown County Board of Commissioners. The project involves the production of county geologic atlases for each of the 13 counties of south central Minnesota and a computerized data base of available water well and groundwater data. Principal investigators for the project are Henry Quade and John Rongstad.

The following people and agencies have provided valuable assistance to this project by providing information, reviewing or contributing to the content, or by making helpful comments. While their contributions are acknowledged, the responsibility for errors or omissions rests with the principal authors.

The Minnesota Geological Survey for providing water well records and other subsurface geophysical data. Particular thanks to Bruce Olsen, Bruce Bloomgren, and Roman Kanivetsky for their guidance and support.

Mankato State University for providing work space and a variety of needed services. Personal thanks to James Zimmer for his guidance and encouraging remarks, and to the Biology Department for its close support. Special mention should be made of Phil Kelley and the Geography Department for use of its camera and darkroom facilities where most of the map reproduction and picture processing was done. Special thanks goes to Jean Spellacy, the secretary at the Water Resources Center.

The building of this atlas involved the contributions of a significant number of students at Mankato State University. The maps in this atlas are, in large part, the result of their loyal support.

Fieldwork: Paul Vogel, Kristen Vogel, Bruce Anderson, Chuck Peterson, and Charles Wohler, Jesse Wohfeil, Tom Kujawa, and Cis Berg.

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BROWN COUNTY GEOLOGIC ATLAS

INTRODUCTION

This is one of thirteen geologic atlases that were prepared for the South Central Minnesota Comprehensive County Water Planning Project consisting of Blue Earth, Brown, Cottonwood, Faribault, Freeborn, Jackson, LeSueur, Martin, Nicollet, Sibley, Steele, Waseca, and Watonwan Counties. The basic subsurface data for these atlases have been gathered over a period of years by the Minnesota Department of Health and the Minnesota State Geological Survey. Additional data pertaining to well location and elevation were gathered by the Water Resources Center at Mankato State University during preparation of the geologic mapping project. The subsurface geologic atlases are the first of two reports on the water resources of southcentral Minnesota. Surface water resources are the subject of a 13 county atlas series that is now in preparation.

The Brown County Geologic Atlas presents available subsurface geologic and hydrologic data in a descriptive form. The maps in this atlas present an interpretation of the subsurface data on a county wide scale. The scale (1:150,000), and hence the size of the atlas maps, was chosen because it shows both geologic and hydrogeologic interpretation at a manageable level, and it represents the size at which the atlas can be printed economically. Detailed, site specific, information cannot be shown on the maps presented in this atlas. The accompanying text is designed to present only general concepts.

The subsurface maps and cross sections that are presented in this atlas show both the vertical relationship and areal distribution of important water-yielding and non-water-yielding bedrock units in Brown County. The atlas is intended to be used as a guide to the subsurface geologic conditions and groundwater resources in Brown County. The amount of geologic information that is required for decision making will vary considerably. For this reason, more detailed site-specific information is available in readily accessible electronic files at the Water Resources Center, Mankato State University.

ATLAS MAPS

Preparation of the maps presented in this atlas required the evaluation of information concerning the present land surface and subsurface. The Bedrock Topography Map was constructed independently; it was directly created from the data itself. The Bedrock Topography Map and Geologic Cross Section profiles provided the necessary reference lines from which all succeeding geologic boundary lines were drawn. All other geologic maps in the atlas were derived through combinations of the Surface Topography, Bedrock Topography, and the Geologic Cross Sections that were prepared for this atlas. This sequence of atlas map construction is designed to present a consistent picture of the bedrock geology on a county wide scale.

SURFACE TOPOGRAPHY MAP was produced for each of 13 counties included in the South Central Minnesota Comprehensive County Water Planning Project. These maps were compiled from US Geological Survey 7.5 Minute Topographic Quadrangles. The USGS quadrangle maps were photographically reduced in scale from 1:24,000 to 1:62,500, and a photo mosaic was constructed to provide a county base surface topography map for each county. These maps provided a standard base from which the maps for all 13 county geologic atlases were developed.

DATA BASE MAP (Page 3) shows the location, distribution, and type of subsurface data used to develop this atlas. The Data Base Map is designed to be used as a guide to interpreting the accuracy of atlas maps.

BEDROCK TOPOGRAPHY MAP (Page 8) was directly created from the data contained in water well drillers' logs. The map provides a means by which the top of the bedrock can be traced continuously over the entire county.

DEPTH TO BEDROCK MAP (Page 9) combines the Surface Topography Map and Bedrock Topography Map to show variations in the thickness of sediments that cover the bedrock surface.

BEDROCK GEOLOGY MAP (Page 7) combines the Bedrock Topography Map,, and the Geologic Cross Sections to show the distribution of bedrock units, as they would appear, if the overlying sediments were removed and the bedrock exposed at the surface.

GEOLOGIC CROSS SECTIONS (Page 10 thru 13) combines information contained in water well drillers logs with Surface Topography Map and Bedrock Topography to construct cross sectional profiles for Brown County. The cross section profiles are arranged as a grid system to provide county wide cross section coverage.

BEDROCK AQUIFER MAP (Page 15) was developed directly from the data contained in the hydrologic portions of water well drillers' logs, including static water level and casing length.

GLACIAL DRIFT CROSS SECTIONS (Page 16 and 17) were developed directly from the data contained in the geologic portions of water well drillers' logs for water wells finished in the glacial drift.

GLACIAL DRIFT AQUIFER MAP (Page 18) was developed directly from the data contained in the hydrologic portions of water well drillers' logs, including static water level, casing length, and pumpage test.

GENERAL GEOLOGY

The characteristics of the present land surface in Brown County, including the topography and nature of surficial materials, are the result of the action of glacial ice and flowing water. The surficial materials are chiefly glacial deposits, collectively called drift, of the continental glaciers that covered Brown County during the last million years. The continental glaciers were centered over southern Canada and extended into southern Minnesota. These continental glaciers expanded and contracted several times and the interval between glacial episodes may have been sufficient to allow deep erosion and weathering of the drift and bedrock surfaces.

The glacial drift is composed mainly of glacial till, which is characterized by a matrix of sand, silt, and clay with scattered pebbles, cobbles, and some boulders. The drift deposits overlie the bedrock surface and range in thickness from slightly less than 50 feet to over 250 feet. Before glaciation, erosion of the bedrock surface produced deep valleys, most of which are now filled with glacial drift. The nature of thickening and thinning of the glacial deposits is largely influenced by buried bedrock valley cuts and present day river valley cuts.

The Paleozoic age bedrock that underlies eastern Brown County is part of a sequence of sedimentary rock which consists of three major rock types: sandstone, shale, and carbonates. The bedrock was deposited in a shallow depressional lowland, called the Hollandale Embayment, in shallow marine waters that flooded southern Minnesota about 500 million years ago. The Paleozoic age bedrock sediments, that underlie the eastern edge of Brown County and are common to the Hollandale Embayment, are entirely missing from the central portion and western half of Brown County and the transcontinental arch. The Paleozoic bedrock may have one day covered the entire county, but have since been worn down by erosion. The transcontinental arch consists mostly of Precambrian age igneous and metamorphic rocks, including granites and granitic gneisses that are capped in many areas with sioux quartzite.

The Cretaceous age bedrock sediments that underlie Brown County were deposited some 100 million years ago when the ocean invaded North America for the last time. The Cretaceous sea invaded Minnesota from the west, over an irregular terrain. The advancing sea was preceded by a humid subtropical climate that produced a deeply weathered bedrock zone. The vertical succession of Cretaceous age sediments generally consists of pre-Cretaceous weathered bedrock overlain by nonmarine stream or alluvial deposits which is overlain by shallow marine sands and clays. However, this vertical sedimentary sequence is not continuous and, thus, not present in all areas.

GROUNDWATER

INTRODUCTION

In Brown County, groundwater exists in unconsolidated glacial deposits and in the underlying bedrock. The possibility of developing adequate supplies of groundwater for farm and domestic use from the glacial deposits is extremely favorable throughout the county. The bedrock aquifers that underlie Brown County are the highest yielding aquifers in the county.

An aquifer is any geologic unit that is capable of storing and yielding fresh water in usable quantities. Groundwater is usually held in an aquifer, at significant pressure, by the presence of a confining bed above the aquifer. In most cases confined water is equivalent to artesian water. A flowing artesian well is a well that yields water at the land surface, under its own pressure, without pumping. In a non-flowing artesian well, the pressure is not sufficient to lift the groundwater above the land surface. In the bedrock aquifers that underlie Brown County, high groundwater pressure usually occurs in hydraulically isolated layers that are under high pressure. In bedrock aquifers that form the bedrock surface, high groundwater pressure is sometimes the result of continuous bedrock strata with recharge areas at higher elevations.

GLACIAL DRIFT AQUIFERS

The glacial drift includes all materials deposited directly by glacial ice or by meltwater streams flowing from the ice. Glacial meltwater streams laid down water-sorted sediments, called outwash deposits, along drainage channels that extended beyond the glacier's margins. Glacial outwash deposits are usually coarse-grained sands and gravels which form good aquifers in the drift. Many outwash deposits were laid down during the retreat of various ice sheets and were not destroyed by the advance of subsequent ice sheets. Interglacial erosion may have produced ancient glacial terrain valleys that contained sand and gravel deposits that are now buried and provide productive aquifers. Depending upon their extent, these deposits may be important local aquifers if they are extensive enough and the recharge is large enough. However, glacial outwash deposits probably form the most important aquifers in the glacial drift.

Materials of low permeability, such as thick clay layers, may suggest confined conditions in the glacial drift. However, clay layers may have a discontinuous areal distribution that make unconfined conditions possible. Confined flow may occur in hydraulically isolated lenses of sand and gravel, within the drift, under sufficiently high pressure. The water pressure in glacial aquifers with unconfined conditions will be influenced by the local topography.

BEDROCK AQUIFERS

Groundwater can be obtained from two Paleozoic bedrock aquifer systems, from the Cretaceous groundwater system, and from the hard Precambrian basement rock in Brown County. The two Paleozoic aquifer systems are the Franconia-Ironton-Galesville aquifer system and the Mt. Simon-Hinckley aquifer system. Within the Cretaceous groundwater system lie localized and regional aquifers that may provide significant amounts of groundwater. The main water-yielding unit of the Precambrian basement rock is the Sioux Quartzite.

A bedrock aquifer is a geologic formation or geologic unit that is capable of storing and yielding fresh water in usable quantities. A Paleozoic bedrock aquifer system is a multiaquifer system that is composed of two or more bedrock aquifers that act hydrologically as a single unit and are bound on the top and bottom by aquitards. Individual Paleozoic bedrock aquifers range from coarse-grained deposits such as sandstone to hard fractured sedimentary rocks such as limestone or dolomite. The Cretaceous groundwater system may be either a connected set of aquifers that act hydrologically as a single unit or a set of independent aquifers that act similarly. The Sioux Quartzite yields water through cracks and fractures.

In Brown County, the uppermost bedrock aquifer will often supply water for farm and domestic use. Throughout most of Brown County, the Cretaceous aquifer system occupies the uppermost bedrock aquifer position. In the western half of Brown County and along the Minnesota River, where the Cretaceous sediments have been removed by past erosion, the Precambrian granites, granitic gneiss, or Sioux Quartzite forms the bedrock surface. The Sioux Quartzite and granites may yield only small amounts of groundwater.

WATER WELL CONSTRUCTION

In Brown County, water well drilling and water well construction will vary from place to place, due to variations in bedrock geologic conditions. In 1974, implementation of the Minnesota water well code standardized water well construction practices. Since 1974, all water well drillers are required to be licensed by the Minnesota Department of Health. Licenses are issued on the basis of one's knowledge of the regulations governing well construction and proof of drilling experience. All water wells drilled since 1974 may use from only one aquifer, and each well must meet minimum standards of depth, minimum distances from possible sources of contamination, and have had a water sample analysis that confirms potability.

Before the Minnesota water well code was implemented in 1974, well construction practices were used that are no longer allowed. Water well casings were often not seated firmly into the bedrock and few were properly sealed to prevent the downward movement of groundwater between the well casing and the borehole. High-capacity wells were often cased only to the uppermost bedrock unit and left as an open borehole between two or more bedrock aquifers, sometimes crossing a confining bed. These wells interconnect aquifers and aquifer systems, allowing the movement of groundwater and serve as conduits for spreading pollution into otherwise unspoiled groundwater supplies.

Since 1974, all newly constructed wells must use standardized well construction materials and installation procedures. Each well casing should extend at least 15 feet into the bedrock aquifer being used with the casing grouted and seated firmly into the bedrock. Water wells that penetrate more than one bedrock aquifer or that penetrate a confining bed must have the entire casing grouted. If multiple strings of casings are used, the inner casing must be separated from the outer casing by at least two inches of space to accommodate cement grout between them. Grouting of the well casing is done to insure that the well does not interconnect aquifers along the space between two casings or between the well casing and the borehole into which it is set.

SUBSURFACE DATA

The subsurface data used to develop this atlas is a compilation of all water well drillers' logs, geophysical logs, and cutting sample logs that are currently available in the files of the Minnesota State Geological Survey. The water well drillers' logs contain the water well contractor's description of the geologic and hydrologic conditions encountered at a specific well site, and a description of the materials used to complete the well. A geophysical log can be an electrical log or gamma-ray log. An electric log records differences in the electrical resistance that is measured along the length of an open borehole. A gamma-ray log records the amounts of natural gamma radiation occurring in the strata of the earth. Cutting sample logs consist of drilling samples that were collected from selected well sites. Cutting samples provide physical examples of subsurface materials.

The gamma-ray logs are records of the measured amount of natural gamma radiation that is emitted by various rocks. The intensity of gamma radiation in sandstone, limestone, and dolomite is relatively low while clay, shale, and siltstone have the highest values. Probably the most important application of gamma-ray logs is to identify the amount of shale content in the bedrock sediments. Consequently, the upper and lower boundaries of shale units are identified and marked at the highest gamma-ray value, the shaley sandstone and carbonate units occupy positions of intermediate values, while the clean sandstone and carbonate units occupy areas of lowest gamma-ray values.

WATER WELL DRILLERS' LOGS

The largest source of information used to develop the geologic and hydrogeologic maps in this atlas are drillers' logs from water wells. The preparation of water well data, for mapping, was a two step process; first to verify the location and determine the elevation of each water well, and second to evaluate the geologic data contained in each water well drillers' log. The location of each water well was determined by visiting the well site and marking its position onto a USGS 7.5 minute topographic map. The position of each water well has been described by Public Land Survey coordinates to an accuracy of half an acre. The elevation at the top of each water well was determined, from USGS topographic maps, to an accuracy of five feet.

The two most difficult tasks a well driller performs during drilling operations are to record the physical characteristics of the penetrated rock and the depth at which these characteristics change significantly. Most of the geologic portions of well drillers' logs are only tolerably accurate; however, many can be re-evaluated by comparing them with more dependable subsurface data. The geologic portion of each well drillers' log was re-evaluated and adjusted by comparing them against the information contained in geophysical logs. The geophysical logs provided standardized data against which all well driller data was compared.

Information contained in each well drillers' log should include the following: a description of the main rock types encountered during drilling, their thickness and depth; a description of the well casing including diameter, length, and screened zones; hydrologic data, such as the static water level in a well after drilling is completed and a report of a production test; and the direction and distance to the nearest sources of possible contamination. In actuality, many of the drillers' logs have only a portion of the above information. An example of the information contained in a typical well drillers' log is given in FIGURE 1, together with interpretation.

RECORD OF WATER WELL CONSTRUCTION

WELL NO.	: 415179	CASING	: 005 INCH TO 263 FEET
* COUNTY	: BROWN	WATER LEVEL	: 95 FT. (EL. 897 FT.)
* TOWNSHIP	: 109 NORTH	DATE	: 5/16/86
* RANGE	: 31 WEST	AQUIFER (S)	: CRETACEOUS-CRETACEOUS
* SECTION	: 24/CCBCDD		
* QUADRANGLE	: LAKE HANSKA EAST		
COMPLETED	: 5/16/86		
DEPTH	: 330 FT.		
* ELEVATION	: 992 FT.		
* WELL USE	: DOMESTIC		

PUMPAGE TEST		TEST 1	TEST 2
HOURS	:	----	----
RATE (GPM)	:	40 + GPM	----
PUMPING LEVEL	:	DEVELOPED BY AIR	----

GEOLOGIC LOG

WELL DRILLER'S DESCRIPTION					INTERPRETATION
DEPTH (FEET) FROM	TO	LITHOLOGY	COLOR	HARD-NESS	STRATIGRAPHIC UNIT
0	2	TOPSOIL	BLACK	SOFT	RECENT
2	5	SAND	BROWN	SOFT	PLEISTOCENE
5	14	CLAY	YELLOW	SOFT	PLEISTOCENE
14	198	CLAY	BLUE	SOFT	PLEISTOCENE
198	232	SANDY CLAY	BLUE	SOFT	PLEISTOCENE
232	236	SHALE	RED	SOFT	PLEISTOCENE
236	242	SHALE	GREEN	FIRM	PLEISTOCENE
242	300	SHALE	WHITE	FIRM	CRETACEOUS
300	312	SHALE	RED	FIRM	CRETACEOUS
312	325	SANDSTONE	BROWN	HARD	CRETACEOUS
325	330	DECOMPOSED GRANITE	RED	FIRM	CRETACEOUS
330	-----	GRANITE	RED	HARD	SIOUX QUARTZITE

* Information that was verified or obtained from a field investigation at the well site.

Figure 1. The sample water well record shows information that was provided by the well contractor and information that was verified or obtained from a field investigation at the well site. The geologic portion of the water well record illustrates the sequence of paleozoic bedrock deposits and the unconsolidated nature of the overlying glacial deposits.

DATA BASE MAP

By

James P. Engfer and John M. Rongstad

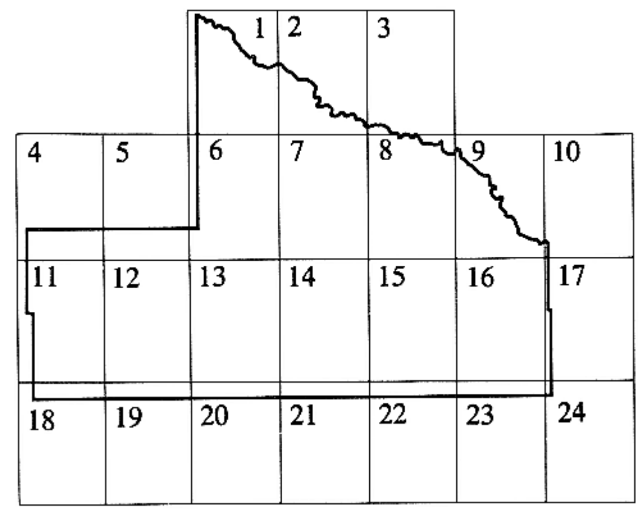
1991

The Data Base Map shows the location, distribution, and type of subsurface data used to develop this atlas. For the preparation of atlas maps every data point represents an area. This area is usually a circle, whose radius depends on the density of the data. When estimating the range of validity for individual atlas maps, it is important to take into account the uneven distribution of the data. The data quality and the depth penetrated by each control point will also affect the accuracy of each map. The Data Base Map is designed to be used as a guide to interpreting the accuracy of atlas maps.

The location of all points on the Data Base Map have been recorded onto USGS 7.5 minute quadrangle maps. The data for each point is stored in both manual and electronic files at the Water Resources Center, Mankato State University. Individual files can be accessed by Unique Well ID Number or by the Public Land Survey coordinates that correspond to individual well data points.

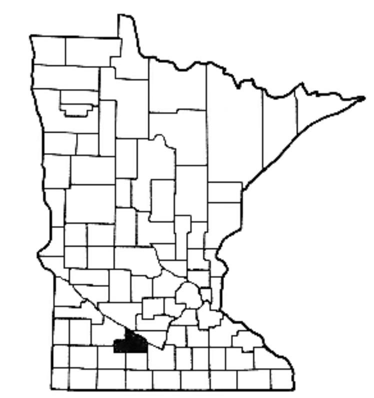
EXPLANATION

- ◦ Record of water-well construction
- ○ Borehole (geophysical log)
- △ Cutting samples
- ~ Bedrock exposure (outcropping)

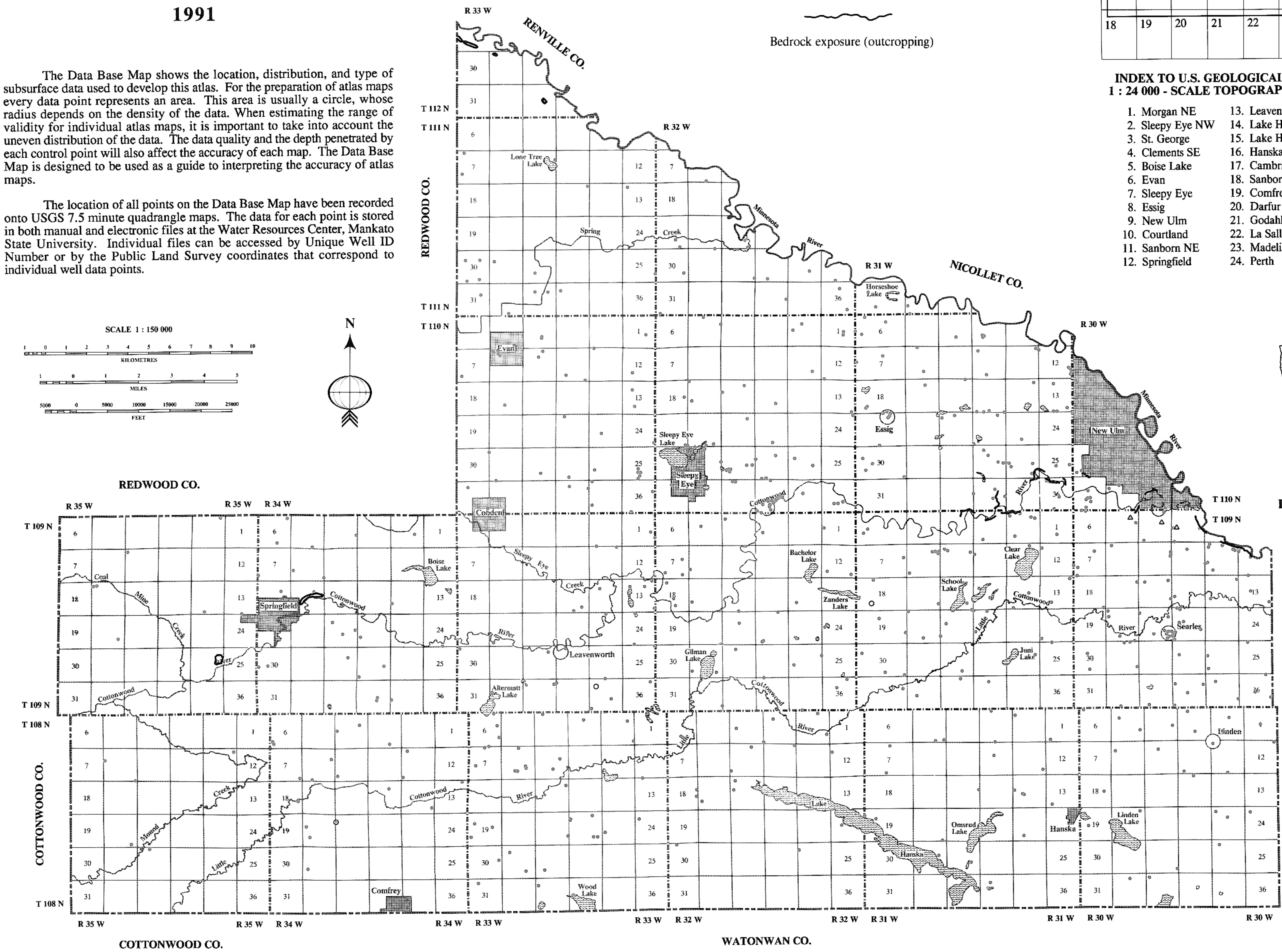


INDEX TO U.S. GEOLOGICAL SURVEY 1 : 24 000 - SCALE TOPOGRAPHIC MAPS

1. Morgan NE	13. Leavenworth
2. Sleepy Eye NW	14. Lake Hanska West
3. St. George	15. Lake Hanska East
4. Clements SE	16. Hanska
5. Boise Lake	17. Cambria
6. Evan	18. Sanborn SE
7. Sleepy Eye	19. Comfrey
8. Essig	20. Darfur
9. New Ulm	21. Godahl
10. Courtland	22. La Salle
11. Sanborn NE	23. Madelia
12. Springfield	24. Perth



LOCATION DIAGRAM



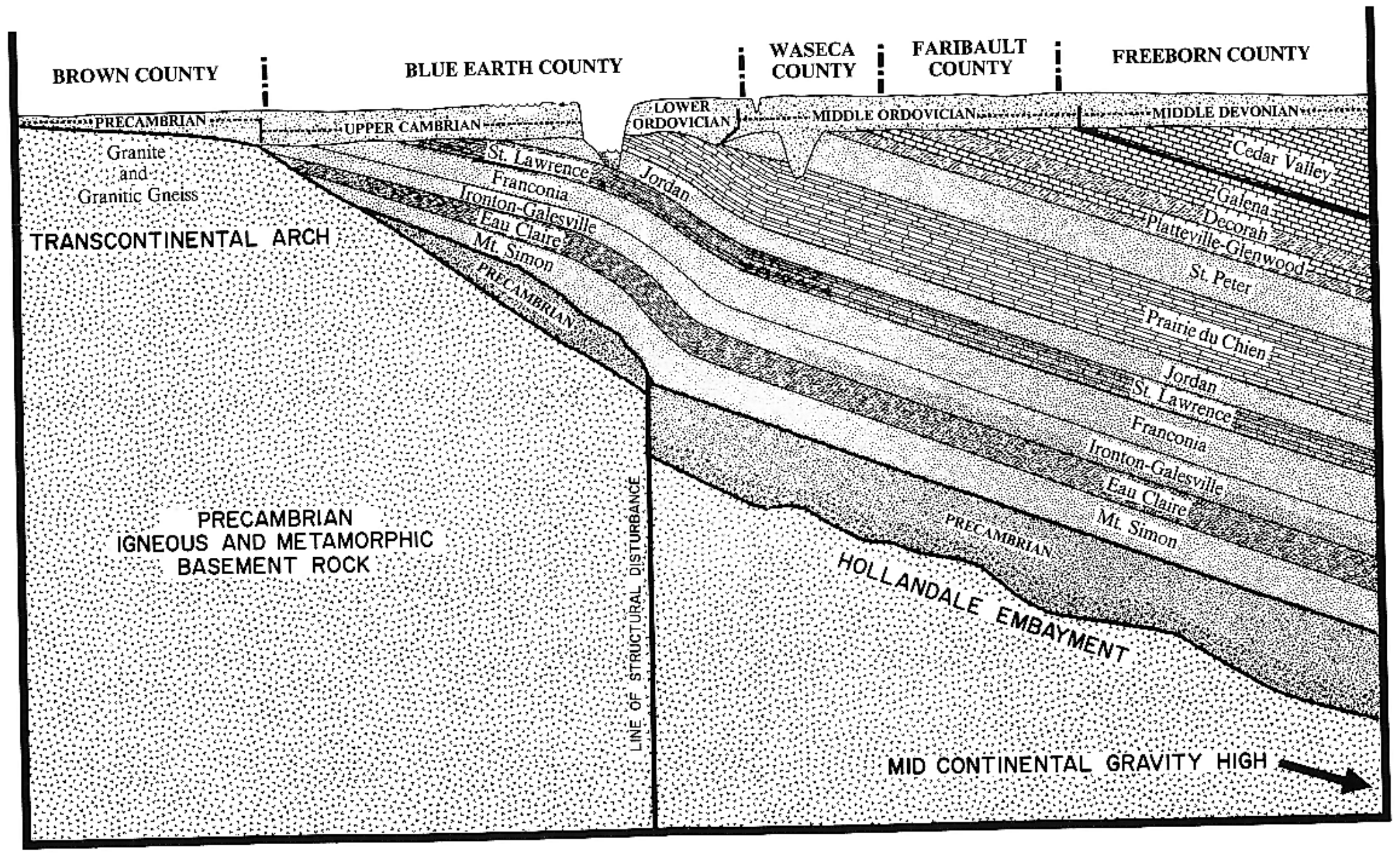


FIGURE 2. Highly generalized cross section showing the variation of subsurface conditions along a line extending from Brown County to Freeborn County Minnesota. The above diagram illustrates the lateral variations and distribution of sediments in the Hollandale Embayment. The geologic structure is much more complex than shown here. Note: the vertical scale is grossly exaggerated; if drawn at true scale the thickest part of the sedimentary basin would be 0.05 inches thick.

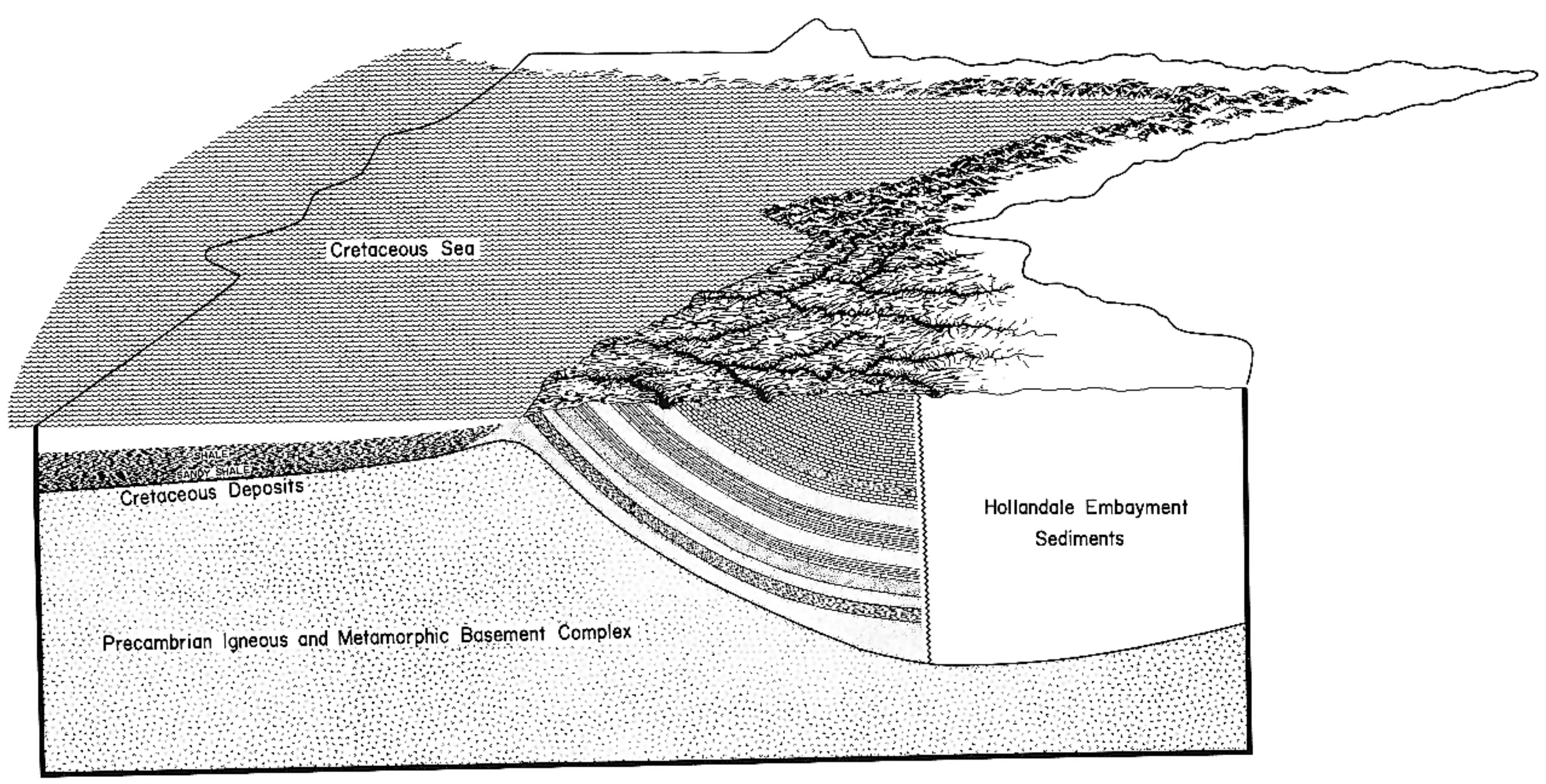


FIGURE 3. The above illustration shows the proposed position of the shoreline deposits that mark the maximum advance of the Cretaceous sea into Minnesota. The Cretaceous sediments in eastern Minnesota will be primarily non-marine, including lake, swamp, floodplain, or delta sediments. In western Minnesota, a shallow marine beach and offshore sedimentary sequence of the advancing sea will be present. The sedimentary bedrock units of the Hollandale Embayment underwent extensive weathering during Cretaceous time.

BEDROCK GEOLOGY

PALEOZOIC GEOLOGIC HISTORY

The Paleozoic bedrock units that underlie Brown County are part of a sequence of Late Cambrian to Early Ordovician sedimentary rock which consists of three major rock types: sandstone, shale, and carbonates. The bedrock was deposited layer upon layer in shallow marine waters that flooded southern Minnesota about 500 million years ago. The ancient intruding sea followed a shallow depressional lowland, now called the Hollandale Embayment, that extended into southern Minnesota from a larger basin to the southeast.

In a shallow marine environment, the material that is transported by water is sorted according to the weight and size of the individual particles. Because of different settling rates, coarse (heavy) materials are deposited in turbulent water while the finer (light weight) materials are transported by waves, currents, or winds and deposited in quiet waters.

The relationship between sandstone, shale, and carbonate deposits correspond to a seaward gradation of sediment size. Sand is deposited along the turbulent shoreline environment, where it becomes cemented into sandstone over time. Clay and silt are transported by wave and current action to a deeper, lower energy environment where they are deposited to form shale. Still farther off shore, where sand and clay are not transported by wave and current action, calcite is precipitated to form limestone.

The rise of sea level, during Late Cambrian time, resulted in a progressive overlap of sediment types. As the sea advanced landward, sandy beach deposits were overlain by offshore muds which were in turn overlain by carbonates. Thus, the advancing sea is recorded in bedrock layers by the sequence: sandstone overlain by shale overlain by carbonates. The lithologic character of the bedrock varies with such factors as sediment source, distance from the shore line, depth of the water, and the transporting agent (waves, currents, and winds).

CRETACEOUS GEOLOGIC HISTORY

The Cretaceous time period saw the rise of sea level from the west, which resulted in a different kind of progressive overlap than that recorded by the Paleozoic bedrock units. Sediments resulting from this overlap may be stream, lacustrine, and alluvial fan deposits as well as shallow marine sediments. The eastern portions of Brown County are thought to represent the eastern extent of the shoreline of the advancing Cretaceous sea.

When sediments are deposited on an erosional surface, the sediments are not likely to be laid down uniformly over a wide area. Actually, deposition will begin in a few favorable places and spread to other areas as the sea rises and deposits become thicker. As the land is submerged by the rise of the encroaching sea, the coarse debris of the land surface will commonly form a basal conglomerate, and there may be buried soils. Within the advancing sea, each depth is characterized by the weight and size of the individual particles that were transported and deposited by water. Because of different settling rates, coarse (heavy) materials are deposited in turbulent water while the finer (light weight) materials are transported by waves, currents, or winds and deposited in quiet waters.

Throughout eastern Brown County the Cretaceous age sediments overlie the much older Cambrian and Ordovician age bedrock units, and in the central and western half of the county the Cretaceous age sediments overlie Precambrian age igneous and metamorphic rocks. In eastern Brown County the Cretaceous sediments are viewed as shoreline or nearshore deposits of a shallow marine environment which may represent reworked Paleozoic bedrock sediments. In western Brown County the Cretaceous sediments are viewed as a combination of nearshore sands and offshore muds with isolated patches of loosely consolidated clays and sands that were primarily derived from the weathering of the underlying Precambrian bedrock surface.

PALEOZOIC BEDROCK UNITS

The following descriptions of the Paleozoic bedrock units that underlie Brown County are primarily derived from water well drillers' logs but supplemented by more detailed descriptions presented by Mossler (1987). For the purpose of this study, some of the stratigraphic units currently recognized as individual geologic units are combined.

MT. SIMON FORMATION-- may reach 200 hundred feet in thickness; is generally characterized as a medium to coarse-grained quartzose sandstone. The upper parts of the Mt. Simon contain varying amounts of siltstone and shale while the middle part is primarily quartzose sandstone. The Mt. Simon sandstone marks the advance of the Late Cambrian sea into southern Minnesota.

EAU CLAIRE FORMATION-- is generally about 100 feet thick. The Eau Claire consists primarily of shale and siltstone. Its contact with the underlying Mt.Simon sandstone is transitional. The fine-grained sediments of the Eau Claire Formation suggest a low energy environment of sedimentation, either relatively deep and quiet water or shallow water tidal flats.

IRONTON-GALESVILLE GROUP-- as thick as 60 feet, is characterized as a medium to coarse-grained quartz sandstone with some glauconite and minor amounts of silt. The Ironton-Galesville sandstone may indicate the return to a higher energy nearshore or beach environment of sedimentation.

CRETACEOUS BEDROCK SEDIMENTS

CRETACEOUS SANDSTONE-- Cretaceous sandstone is commonly white but may be brown, yellow, or red. White Cretaceous sandstone may be reworked Jordan or Ironton-Galesville sandstone that was deposited along the shoreline of the Cretaceous sea.

CRETACEOUS SHALE-- Cretaceous shale is commonly blue, green, or brown but may be white, yellow, or red. Thick layers of Cretaceous shales commonly represent shallow marine deposits or offshore muds.

CRETACEOUS DECOMPOSED-- May represent the weathering of the underlying bedrock or basement rock surface. Generally characterized by white, red, or brown clay with varying amounts of coarse-grained quartz particles.

PRECAMBRIAN ROCK

SIOUX QUARTZITE-- May be as thick as 400 feet; consists of pink, red, or purple hard silica-cemented quartzite that may contain thin localized beds of red mudstone.

GRANITE & GRANITIC GNEISS-- The rocks exposed along the Minnesota River Valley display an intertwined sequence of granitic gneiss and granite rock. Granite is a hard igneous rock; coarse-grained, that is chiefly composed of quartz, feldspars, and mica. Granitic gneiss is similar in composition to granite, however, gneiss is a banded metamorphic rock whose minerals are arranged in layers resembling a swirled pattern.

AQUIFER CHARACTERISTICS OF SEDIMENTARY ROCK TYPES

INTRODUCTION

The most favorable geological structure for groundwater accumulation is found in stratified sedimentary rock like that underlying Brown County. Sedimentary aquifers range from loose, coarse-grained deposits such as sandstone to hard fractured sedimentary rocks such as limestone or dolomite. A water bearing rock unit may vary locally in texture or composition, either vertically because of bedding planes or horizontally because of changes in sediment type.

SANDSTONE AQUIFERS

The sandstone bedrock units transmit water from between individual grains. The ability of sandstone to transmit water depends upon the size and amount of pore space between individual sand grains. Pore space is mostly a function of the amount of cementation that is holding the sand grains together. The cementing material consist of very small particles that partly or entirely fill the voids between sand grains. The most common cementing materials are clay minerals, calcite, and quartz. The hydraulic properties of any sandstone, as a whole, can be variable because the cementation may be localized.

CARBONATE AQUIFERS

The carbonate aquifers are mostly composed of crystalline limestone and dolomite with some quartz sand and shaley units. In carbonate rock, fractures along bedding planes and pores within the rock provide the primary routes for groundwater flow. The permeability of carbonate rocks depends upon their porosity, which is primarily due to the enlargement of fractures and other openings by erosion through water circulation.

The ability of dolomite to transmit water is usually lower than that of most limestone. The openings between the crystals in dolomite are small and the rate of erosion by solution is less than in limestone. Dolomite is a hard and very brittle rock and may have wide zones of fracturing that result in increased permeability. Limestone has a higher solubility than dolomite, which leads to more spacious fractures and much wider solution channels. Observations in quarries that are excavated in limestone or dolomite show that openings along bedding planes tend to remain open and transport water.

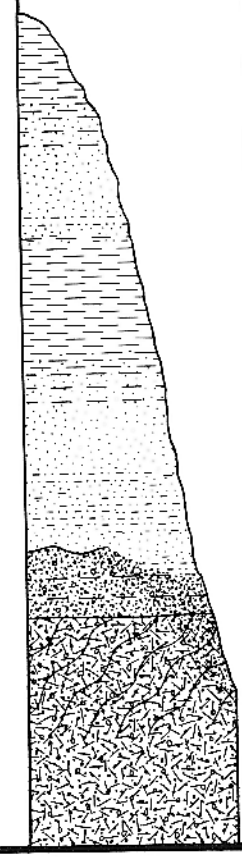
SHALE & SILTSTONE AQUITARDS

Shale and siltstone are composed of fine-grained particles that constitute the finest of the clastic sedimentary materials. The effective porosity of shale and siltstone result in a much more reduced permeability than that found in sandstone and carbonate bedrock units. Consequently, siltstone and shale yield little groundwater and function as aquitards in the sequence of bedrock sedimentary deposits. Although an aquitard may not yield water in usable quantities, it can hold appreciable amounts of water.

AQUIFER CHARACTERISTICS OF IGNEOUS AND METAMORPHIC ROCK TYPES

The hard Precambrian quartzite, granite, and granitic gneiss are generally impermeable. The permeability of these hard Precambrian rocks depends upon their porosity, which is primarily due to cracks and fractures. Decomposition, due to past weathering, may have increased the near-surface porosity of these rocks. In general, the permeability of the hard Precambrian bedrock will decrease with depth, as the cracks and fractures will tend to close at greater depths.

CRETACEOUS BEDROCK GEOLOGIC COLUMN

	SEDIMENT TYPES	MAP SYMBOL	GRAPHIC COLUMN	DISTRIBUTION AND LITHOLOGY OF THE CRETACEOUS SEDIMENTS	AQUIFER CHARACTERISTICS OF CRETACEOUS SEDIMENTS
CRETACEOUS SYSTEM	SHALE	Krt		The Cretaceous rocks in Brown County are loosely consolidated, flat laying sediments of varying lithologies. In extreme eastern Brown County the Cretaceous age sediments overlie the much older Cambrian age bedrock units and contain isolated patches of loosely consolidated white, red, or brown clays and sands that were primarily derived from the weathering of the underlying bedrock surface. In the central and western portions of Brown County the Cretaceous sediments are viewed as a sequence of shoreline, nearshore, or offshore deposits of a shallow marine environment: a combination of nearshore sands and offshore muds and sands.	The degree of consolidation of the Cretaceous bedrock sediments controls the manner and competence in which the sediments will store and transmit water. Semi-consolidated rock usually does not support open cracks or fractures, and its value as a productive aquifer depends upon the porosity of the original sediments. The semi-consolidated Cretaceous sandstones have sufficient porosity to transmit water.
	SANDY SHALE				The Cretaceous sandstone aquifers may be widespread, persisting for long distances, or they may grade into shales over very short distances. The shales will function as aquitards in the sequence of Cretaceous sedimentary deposits. The water-bearing Cretaceous sandstones may vary locally in texture and composition because of changes in sedimentary environments. Under favorable conditions a continuous blanket of sand may have been deposited over an entire region.
	SAND				Within the Cretaceous groundwater system lie localized and regional aquifers that may provide significant amounts of groundwater. The most productive Cretaceous aquifers are the uniform and continuous sandstone units that extend over wide areas. The Cretaceous groundwater system may be either a connected set of aquifers that act hydrologically as a single unit or a set of independent aquifers that act similarly.
	SILTY SAND				The hard Precambrian quartzite, granite, and granitic gneiss are generally impermeable. The permeability of these hard Precambrian rocks depends upon their porosity, which is primarily due to cracks and fractures. Decomposition, due to past weathering, may have increased the near-surface porosity of these rocks. In general, decomposed bedrock sediments will yield only small amounts of groundwater.
	SHALE				
	SANDY SHALE				
	SAND				
	SILTY SAND				
	SIOUX QUARTZITE DECOMPOSED			Throughout most of Brown County the Cretaceous sediments overlie the Precambrian age granites, granitic gneisses, and Sioux Quartzite. In these areas decomposed granite, granitic gneiss, and Sioux Quartzite have also been classified as Cretaceous age rock.	
	GRANITIC GNEISS DECOMPOSED				
	GRANITE DECOMPOSED				

PALEOZOIC AND PRECAMBRIAN BEDROCK GEOLOGIC COLUMN

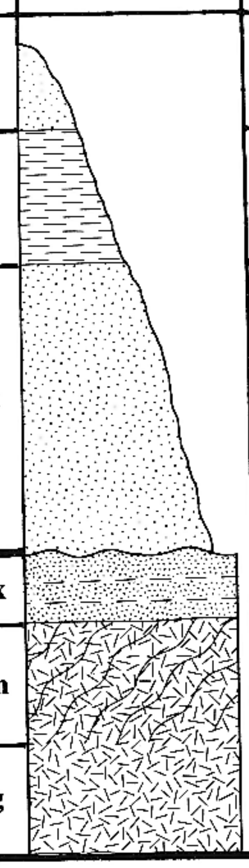
STRATIGRAPHIC CLASSIFICATION				DESCRIPTION OF ROCK UNITS		DESCRIPTION OF AQUIFERS		
SYSTEM/ SERIES	GROUP OR FORMATION NAME	MAP SYMBOL	GRAPHIC COLUMN	THICKNESS	DOMINANT ROCK TYPES	AQUIFER SYSTEM	AQUIFER	AQUIFER CHARACTERISTICS
UPPER CAMBRIAN	IRONTON & GALESVILLE FORMATIONS	Cig		Unknown	Quartzose sandstone; white, buff, or pink; may contain minor amounts of shale.	IRONTON - GALESVILLE AQUIFER SYSTEM	IRONTON & GALESVILLE SANDSTONE	Highly permeable quartzose sandstone; limited to erosional remnants in eastern part of the county; no record of aquifer use in Brown County.
	EAU CLAIRE FORMATION	Cec		May be as thick as 100 feet	Mainly shale and siltstone with some sandstone; transition with the underlying Mt. Simon is gradational.	CONFINING LAYER	EAU CLAIRE SHALE	Shales are generally not water yielding; act as confining bed at the base of the Franconia-Ironton-Galesville aquifer system.
	MT. SIMON FORMATION	Cmt		Uncertain; may attain several hundred feet	Quartzose sandstone; may contain shale and siltstone. Transition with the overlying Eau Claire is gradational; its base marks a major disconformity.	MT. SIMON AQUIFER SYSTEM	MT. SIMON SANDSTONES	Permeable quartzose sandstone; is limited to extreme eastern portions of the county. May yield large volumes of water; no record of aquifer use in Brown County.
PRECAMBRIAN	SIOUX QUARTZITE	Pysx		Several hundred feet	Orthoquartzitic sandstone and thin beds of mudstone.	PRECAMBRIAN AQUIFER SYSTEM	SIOUX QUARTZITE	Generally not water bearing rock; water contribution for aquifer use is low.
	GRANITIC GNEISS	Pcgn		Unknown	Banded metamorphic rock; similar composition as granite; minerals arranged in layers.		NOT AN AQUIFER	Generally not water bearing rock; represents the base of all aquifers and aquifer systems.
	GRANITE	Pcg		Unknown; several thousand feet	Hard igneous rock; coarse grained, chiefly of quartz, feldspars, and mica.			

FIGURE 3. Generalized stratigraphic column showing the relationship between individual bedrock units and corresponding water producing intervals. The descriptions of bedrock units, including thickness and rock type, were compiled from the geologic portions of water well drillers' logs and supplemented by more detailed descriptions presented by Mossler (1987), Southwick (1984) and Sloan (1964).

BEDROCK GEOLOGY MAP

INTRODUCTION

In Brown County glacial deposits almost completely conceal the bedrock surface; thus, the nature of the bedrock surface is known primarily from subsurface data. The Bedrock Geology Map shows the distribution of bedrock units, as they would appear, if the bedrock were exposed throughout Brown County. The Bedrock Geology Map presents a picture of the bedrock surface that supports a close relationship to the Bedrock Topography Map and Geologic Cross Sections that were prepared for this atlas. This method of geologic map construction is designed to present a consistent picture of the bedrock on a county wide scale.

Erosion of the bedrock surface before glaciation produced valley cuts in the bedrock surface. Because of past erosion, the thickness of the upper bedrock unit may change abruptly over short distances. The patterns displayed on the Bedrock Geology Map range from narrow bands to extended areas. The eroded bedrock valleys are often expressed as narrow bands of bedrock formations that follow along the bottom of these bedrock valleys. In places where a single bedrock formation occupies an extended area, the character of the bedrock surface will be flat and featureless if the formation is thin, but may be deeply eroded if the formation is thick.

Along the eastern portion of Brown County, Paleozoic age bedrock units underlie the Cretaceous age bedrock sediments. Within a small area in the southeastern corner of the county, Paleozoic age Ironton-Galesville sandstone forms the bedrock surface beneath the glacial drift. Elsewhere in Brown County, Cretaceous and Precambrian age bedrock units directly underlie the glacial drift.

METHOD OF CONSTRUCTION

Several structural considerations controlled the construction of the geologic map. Among these were the character of the eroded bedrock surface, the relative thickness of individual bedrock units, and the direction, rate, and degree of dip of the bedrock units. The boundary line separating the Cretaceous and Paleozoic bedrock units was located by projecting the average thickness and structural trend of the Paleozoic bedrock units from Blue Earth and Watonwan Counties, using the Bedrock Topography Map and Geologic Cross Sections as guides for positioning the lines. Information from water well drillers' logs were also used as guides for positioning the boundary lines that separate the individual bedrock units. The Bedrock Topography Map, Geologic Cross Sections, and information contained in water well drillers' logs were used as guides for positioning the boundary lines that separate the Cretaceous and Precambrian bedrock units.

BEDROCK TOPOGRAPHY MAP

INTRODUCTION

The bedrock topography map presents a three-dimensional picture of the bedrock surface by means of contour lines that connect points of equal elevation. The topographic rendition of the bedrock surface was designed to describe an ancient landscape characterized by broad uplands that are cut by a sinuous pattern of river and stream valleys. In Brown County the bedrock surface is completely covered by glacial deposits except along the Minnesota and Cottonwood Rivers, where the bedrock is exposed at the surface. Thus, the nature of the bedrock surface is known primarily from subsurface data.

The configuration of the bedrock surface is a product of preglacial, glacial, interglacial, and postglacial erosion of the bedrock strata. Preglacial erosion produced bedrock valley cuts that were excavated by river and stream erosion prior to continental glaciation, which began about 2 million years ago. Glacial erosion of the bedrock surface may have widened or deepened the bedrock valleys by ice scouring from advancing glaciers or by meltwater flows from retreating glaciers. Interglacial erosion may have modified the bedrock surface slightly; however, repeated ice advances gradually filled the bedrock valleys and covered the bedrock surface with glacial debris. Postglacial erosion of the bedrock surface occurred along the Minnesota and Cottonwood Rivers. In Brown County the majority of the bedrock channels are interpreted to have been eroded prior to glaciation of the region.

METHOD OF CONSTRUCTION

The Bedrock Topography Map is a compilation of all available data from wells that penetrated the glacial drift and reached bedrock. The location and distribution of these data points are shown on the Bedrock Topography Map. Wells that were drilled abnormally deep into the glacial drift, without reaching bedrock, influenced the positioning of the contours. Bedrock exposures along the Minnesota and Cottonwood River Valleys were used to guide the contours drawn in those areas. Where the bedrock data is dense, the Bedrock Topography Map is more detailed; where the data is sparse, the map is more generalized.

The elevation of the bedrock surface was calculated for each well drillers' log and the data plotted onto a map sheet. The map sheet was contoured to agree with the plotted elevations and to develop any distinctive landforms resulting from geomorphic processes that were wearing down the bedrock surface prior to recent continental glaciation. The placing of contours is intended to reveal a pattern of erosion much like that produced by present day river valleys and their tributaries. The map illustrates that only large valleys and tributaries are identifiable from existing data. In most instances, the valleys and their tributaries are probably not as straight nor wide as indicated.

On the Bedrock Topography Map, the closely spaced contours indicate steep slopes while widely spaced contours indicate flat or gently sloping areas. The spacing of contour lines and the nature of connecting or guiding each contour through elevation points is based upon factors concerning the type of bedrock sediments that underwent erosion. Resistant rock types such as granite or quartzite tend to form plateaus while softer rock such as shale and sandstone form gently sloping areas. The hard shales or sandstones may contribute to steep valley walls.

DEPTH TO BEDROCK MAP

INTRODUCTION

The characteristics of the present land surface in Brown County, including the topography and nature of surficial materials, is the result of the action of glacial ice and flowing water. The surficial materials are chiefly glacial deposits, collectively called drift, of the continental glaciers that covered Brown County during the last million years. The glacial deposits overlie the bedrock surface and range in thickness from less than 50 feet to over 250 feet except along the Minnesota and Cottonwood River Valleys where the glacial drift has been removed and the bedrock is exposed at the surface. In Brown County the nature of thickening and thinning of the glacial drift is largely influenced by buried bedrock valley cuts and present day river valley cuts.

The glacial drift is composed mainly of glacial till, which is characterized by a matrix of sand, silt, and clay with scattered pebbles, cobbles and boulders. The glacial till is interbedded with sand and gravel that was released by the melting glaciers. These sand and gravel units are scattered and discontinuous in the shallow drift; but thick deposits of sand and gravel can occur where the drift is thick.

The Depth to Bedrock Map, by means of isopach contours, shows variations in the thickness of glacial deposits. The topography of the bedrock surface has a direct bearing on the thickness of the glacial deposits. Where the elevation of the bedrock surface is low, as within major buried bedrock valleys, the glacial deposits are thick. Where the bedrock surface is high, the glacial deposits are generally thin. In the vicinity of buried bedrock valleys, the thickness of the glacial deposits may change abruptly over short distances. Valleys on the present land surface present irregularities in drift thickness.

METHOD OF CONSTRUCTION

The thickness of glacial deposits is shown on the Depth to Bedrock Map by isopach lines that connect points of equal thickness. The Depth to Bedrock Map was constructed by combining the Surface Topography Map and the Bedrock Topography Map. The Surface Topography Map was compiled from USGS 7.5 Minute Topographic Quadrangles. The Bedrock Topography Map was produced for this atlas and is somewhat generalized, and therefore limits the accuracy of the depth to bedrock mapping.

Construction of the Depth to Bedrock Map was accomplished by superimposing the Surface Topography Map onto the Bedrock Topography Map in order that the two could be directly compared. The isopach lines were drawn to agree with the difference in elevation between the two maps. The drift thickness was determined at any contour intersection by subtracting the lower value (bedrock elevation) from the higher value (surface elevation). The bedrock should be at or near the surface where the bedrock elevation and the surface elevation are equal.

The method of depth to bedrock map construction was designed to present a picture of drift thickness that is consistent with that suggested by the Surface Topography Map and Bedrock Topography Map prepared for this atlas. On the Depth to Bedrock Map, narrow bands of thick glacial deposits follow the buried bedrock valleys presented on the Bedrock Topography Map. This pattern illustrates the close relationship between drift thickness and the topography of the bedrock surface.

The scale of atlas maps and the generalized nature of the Bedrock Topography Map limits the amount of detail that can be shown on the Depth to Bedrock Map. When determining the nature of drift thickness for a small area at large scale, the original data base and staff at the Water Resources Center, Mankato State University, should be utilized.

BEDROCK GEOLOGY MAP

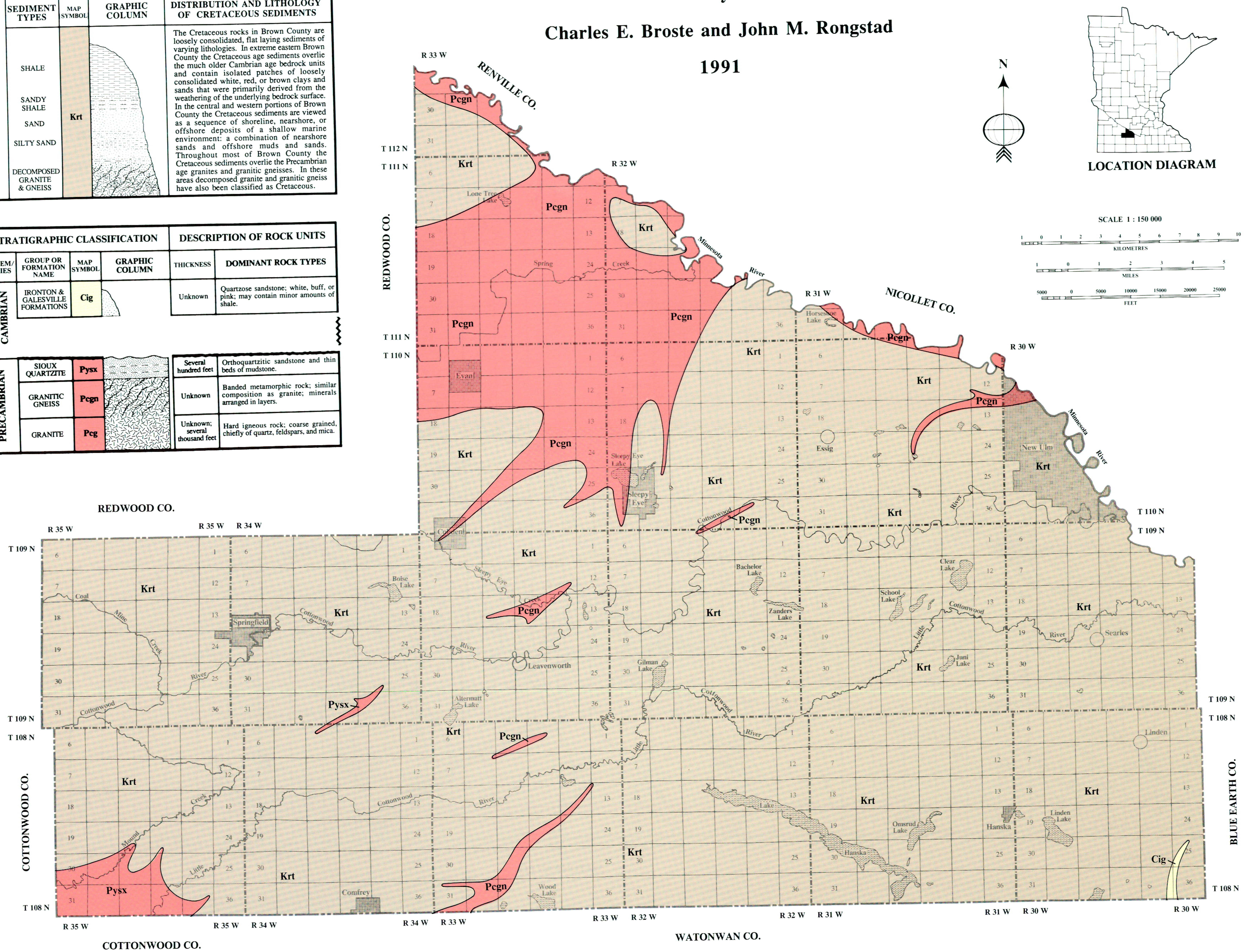
By

Charles E. Broste and John M. Rongstad

1991

	SEDIMENT TYPES	MAP SYMBOL	GRAPHIC COLUMN	DISTRIBUTION AND LITHOLOGY OF CRETACEOUS SEDIMENTS
CRETACEOUS SYSTEM	SHALE SANDY SHALE SAND SILTY SAND DECOMPOSED GRANITE & GNEISS	Krt		The Cretaceous rocks in Brown County are loosely consolidated, flat laying sediments of varying lithologies. In extreme eastern Brown County the Cretaceous age sediments overlie the much older Cambrian age bedrock units and contain isolated patches of loosely consolidated white, red, or brown clays and sands that were primarily derived from the weathering of the underlying bedrock surface. In the central and western portions of Brown County the Cretaceous sediments are viewed as a sequence of shoreline, nearshore, or offshore deposits of a shallow marine environment: a combination of nearshore sands and offshore muds and sands. Throughout most of Brown County the Cretaceous sediments overlie the Precambrian age granites and granitic gneisses. In these areas decomposed granite and granitic gneiss have also been classified as Cretaceous.

STRATIGRAPHIC CLASSIFICATION				DESCRIPTION OF ROCK UNITS	
SYSTEM/ SERIES	GROUP OR FORMATION NAME	MAP SYMBOL	GRAPHIC COLUMN	THICKNESS	DOMINANT ROCK TYPES
UPPER CAMBRIAN	IRONTON & GALESVILLE FORMATIONS	Cig		Unknown	Quartzose sandstone; white, buff, or pink; may contain minor amounts of shale.
PRECAMBRIAN	SIOUX QUARTZITE	Pysx		Several hundred feet	Orthoquartzitic sandstone and thin beds of mudstone.
	GRANITIC GNEISS	Pcgn		Unknown	Banded metamorphic rock; similar composition as granite; minerals arranged in layers.
	GRANITE	Pcg		Unknown; several thousand feet	Hard igneous rock; coarse grained, chiefly of quartz, feldspars, and mica.



BEDROCK TOPOGRAPHY MAP

By

John M. Rongstad and Jesse D. Wohlfeil

1991

EXPLANATION

BEDROCK TOPOGRAPHY

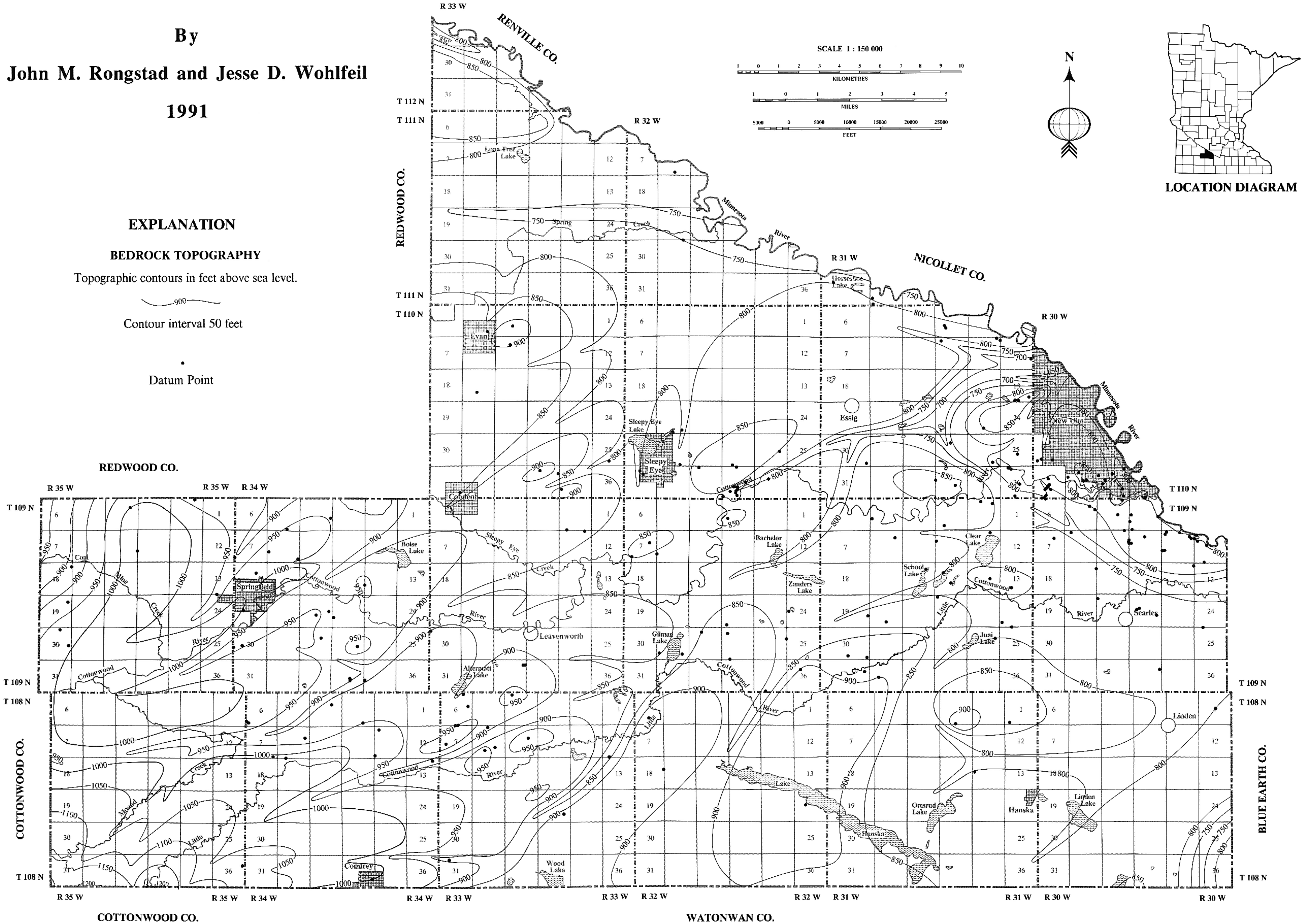
Topographic contours in feet above sea level.

900

Contour interval 50 feet

•

Datum Point



LOCATION DIAGRAM

DEPTH TO BEDROCK MAP

By

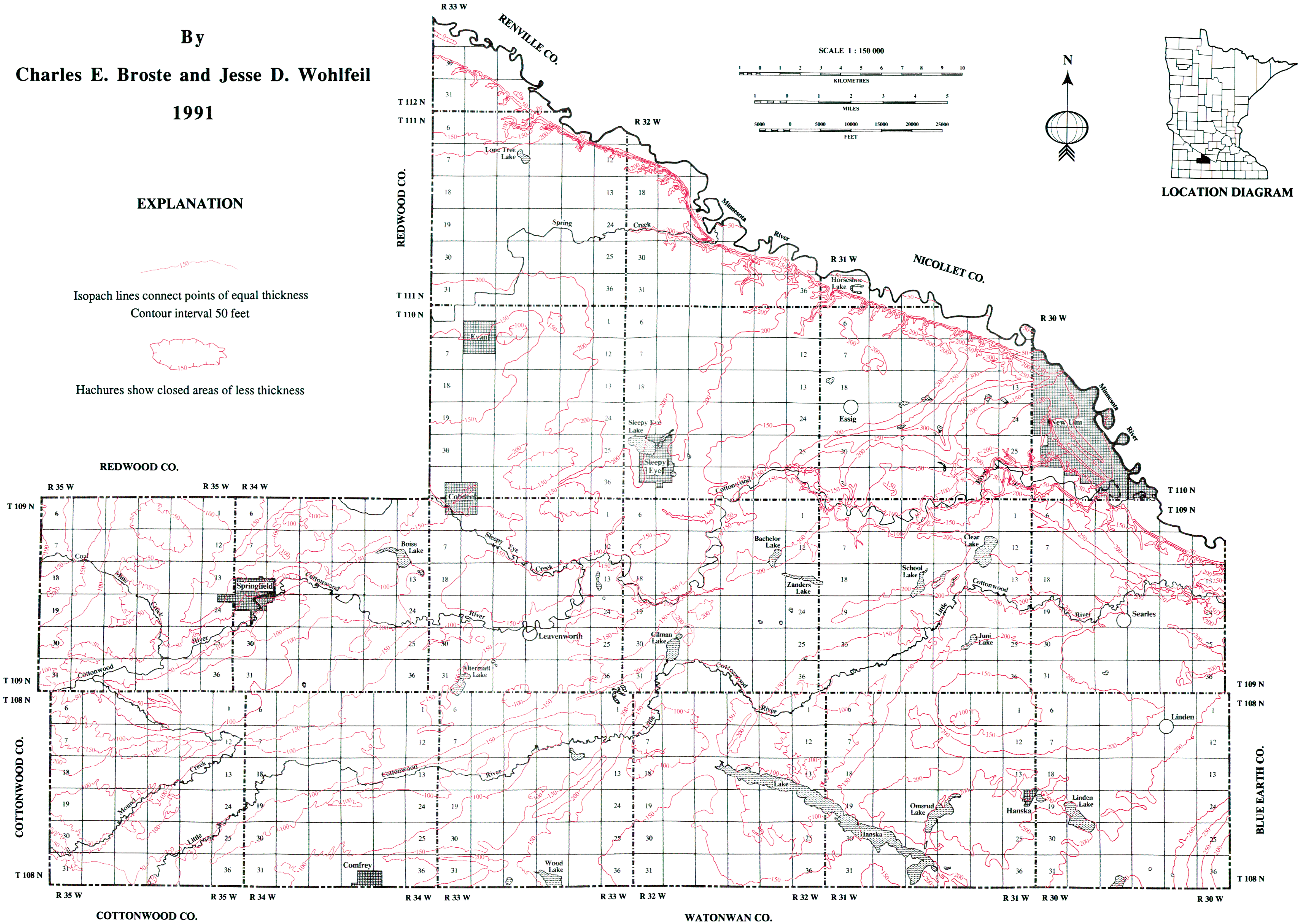
Charles E. Broste and Jesse D. Wohlfeil

1991

EXPLANATION

Isopach lines connect points of equal thickness
Contour interval 50 feet

Hachures show closed areas of less thickness



LOCATION DIAGRAM

GEOLOGIC CROSS SECTIONS A-A′ TO E-E′

The Geologic Cross Sections in this atlas combine the Surface Topography Map, Bedrock Topography Map, and information contained in the geologic portions of water well drillers' logs to develop cross section profiles of Brown County. The cross section profiles were prepared at three mile intervals; one set trending west-east and a second set trending north-south. The cross sections were constructed along each Township and Range line, and along section lines that pass through the center of each township (FIGURE 5). The cross section profiles are arranged as a grid system to provide county wide cross section coverage.

The cross section profiles of Brown County are arranged in stacks on pages 10 through 13 in this atlas. Those cross sections that trend from west to east are stacked and labeled from north to south (A-A' to I-I'). Those cross sections that trend from north to south, are stacked and labeled from east to west (J-J' to V-V'). On each cross section the location of intersecting cross sections and natural features such as rivers, streams, and lakes are labeled; the approximate location for cities and towns are also shown for reference. The individual bedrock units are separated by solid or dashed boundary lines and labeled with their respective names.

EXPLANATION

Unconsolidated surficial deposits, chiefly glacial drift: alluvial silts, sands, and gravels commonly present along streams.

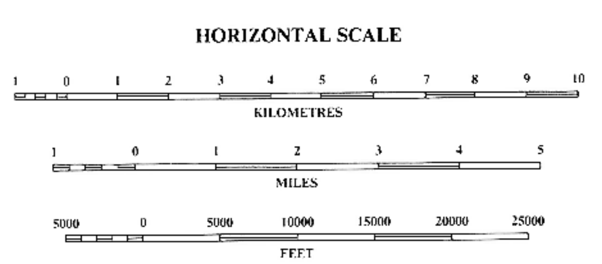
Confining layer, chiefly shale and siltstone: separates Paleozoic bedrock aquifer systems.

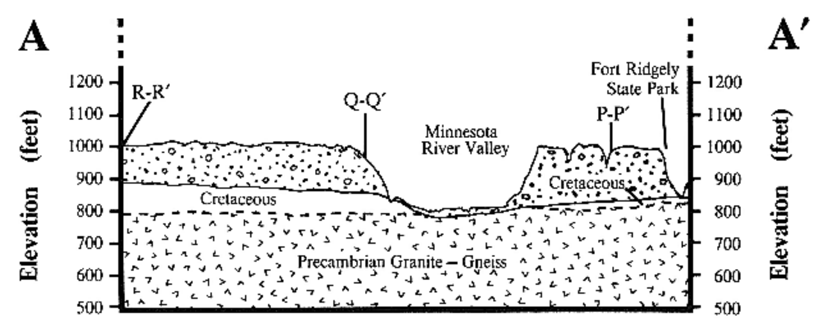
Paleozoic bedrock aquifers, chiefly sandstone: represent the water yielding units of a bedrock aquifer system. Additionally represents Cretaceous age sediments; primarily shale, sandy shale, and sandstone.

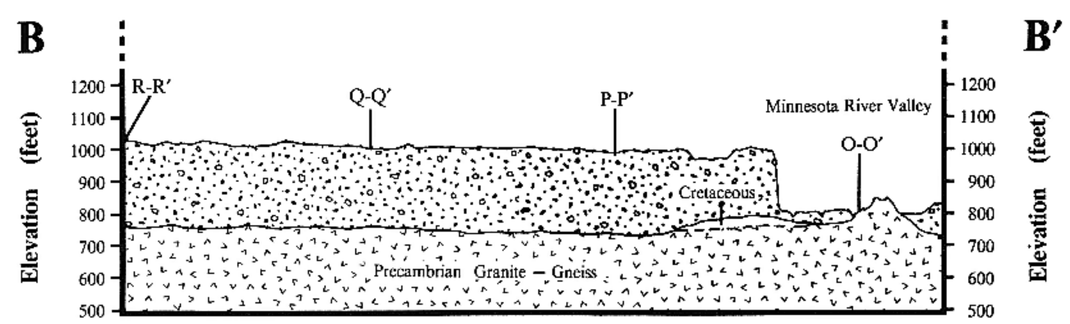
Precambrian basement rock, chiefly granitic gneiss, granite, and sioux quartzite; represents the base of all sedimentary bedrock units.

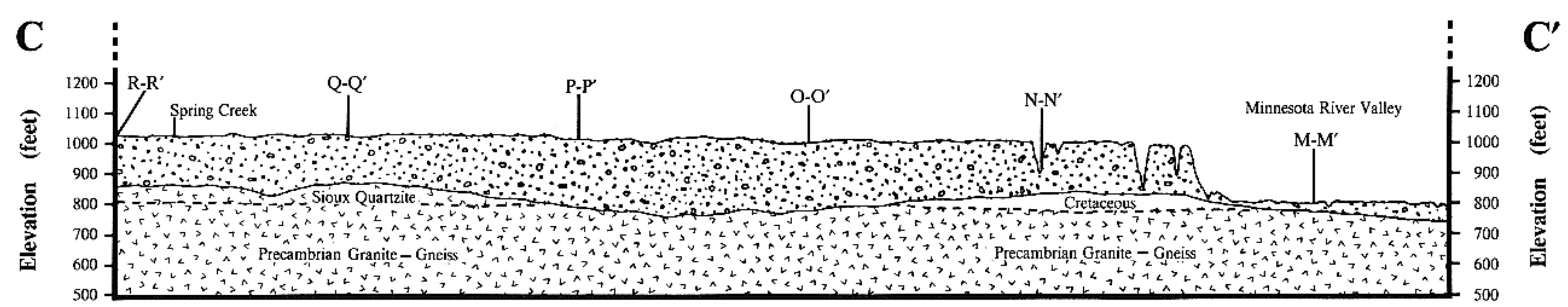
Contact between bedrock units is approximately located; dashed where inferred between lithologically similar units, erosional unconformities, or where contact is gradational.

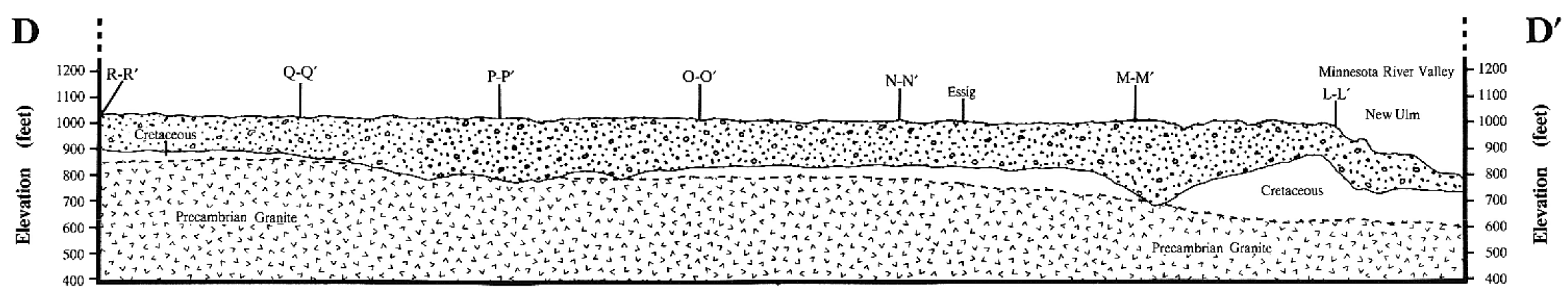
Contact line between Precambrian age basement rock and overlying sedimentary bedrock units or unconsolidated glacial deposits. Contact line is terminated where supporting data is absent.

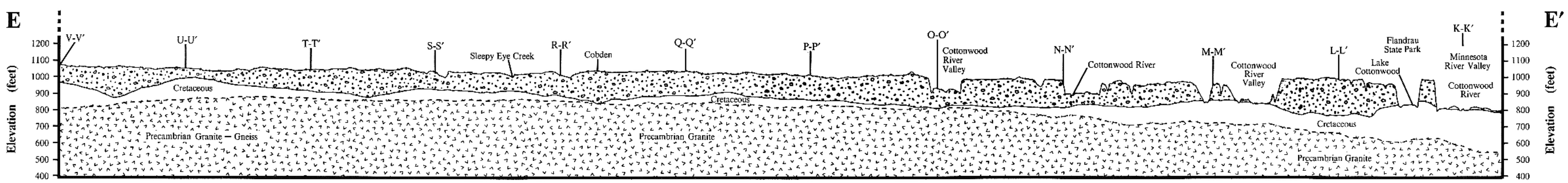












INDEX TO GEOLOGIC CROSS SECTIONS

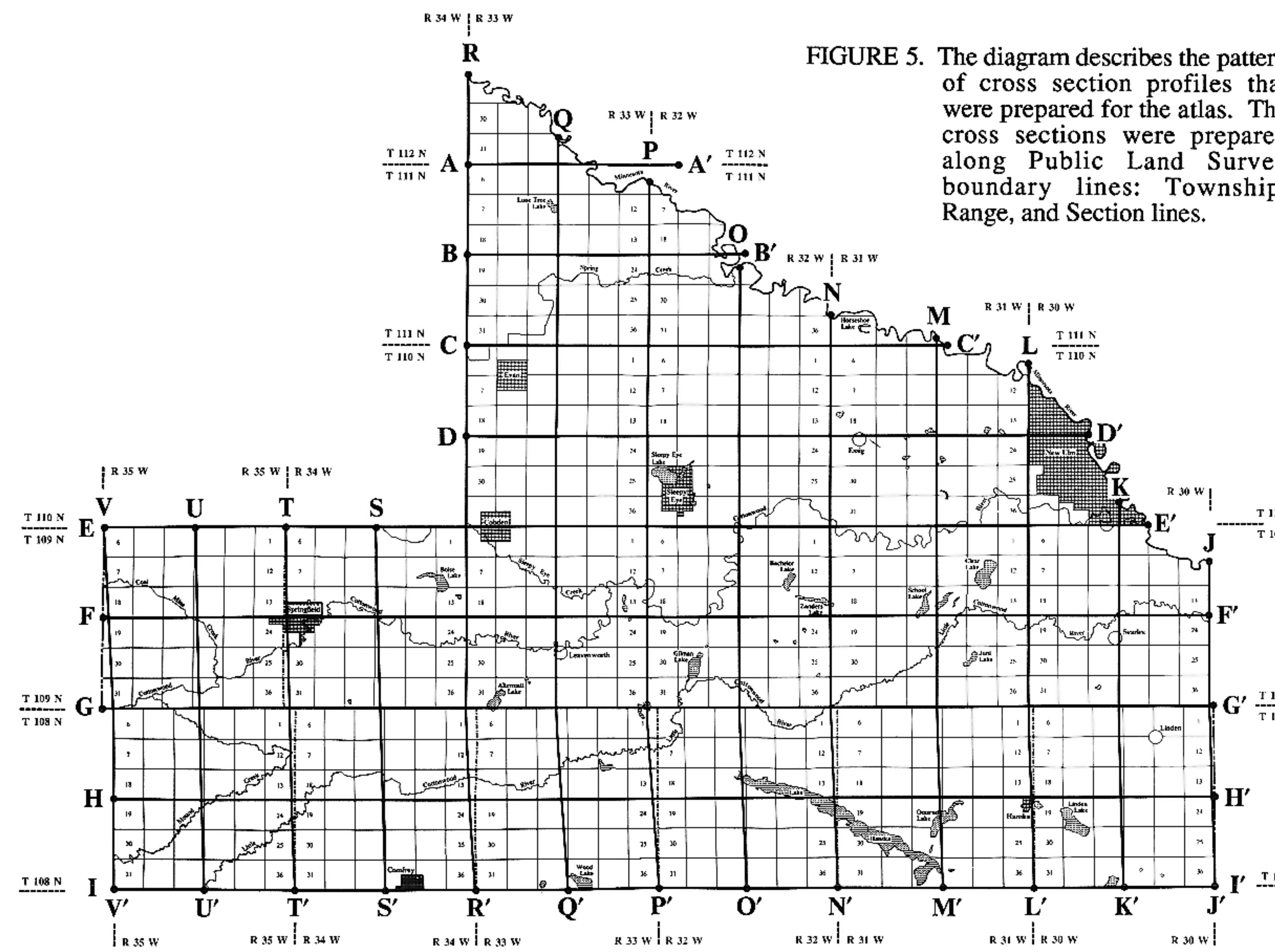


FIGURE 5. The diagram describes the pattern of cross section profiles that were prepared for the atlas. The cross sections were prepared along Public Land Survey boundary lines: Township, Range, and Section lines.

SCALE

The horizontal scale of each cross section is identical to the horizontal scale on all other atlas maps (1:150,000). However, the vertical scale of each cross section has been exaggerated twenty times the horizontal scale. The vertical scale was magnified so that the thin bedrock units would have adequate dimension for mapping. Exaggeration of the vertical scale affects primarily the vertical dimensions of a bedrock formation but it also affects, in a certain way, the horizontal dimensions of a bedrock formation. In the vertical direction the bedrock formation is actually expanded; in the horizontal direction it is apparently contracted. Persons not accustomed to exaggerated cross sections are apt to forget the fact of exaggeration and will gain a mental picture of acute structural relief when, in fact, the structural relief may be very mild.

CONVERSION OF APPARENT DIP TO TRUE DIP
Vertical Exaggeration × 20

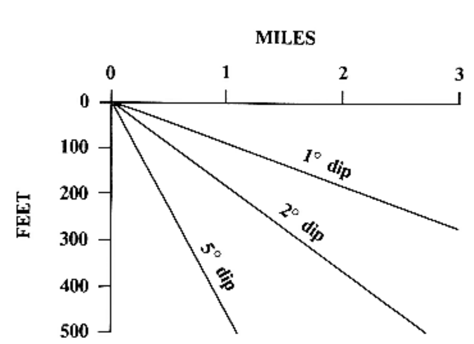


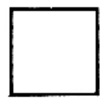
FIGURE 6. The above diagram illustrates the conversion of apparent dip to true dip. One is provided on each page of cross sections. The dip conversion diagram is designed to give the user a mental picture of the relief distortion that is caused by the vertical exaggeration.

GEOLOGIC CROSS SECTIONS
F-F′ TO I-I′

EXPLANATION

Unconsolidated surficial deposits, chiefly glacial drift: alluvial silts, sands, and gravels commonly present along streams.

Confining layer, chiefly shale and siltstone: separates Paleozoic bedrock aquifer systems.



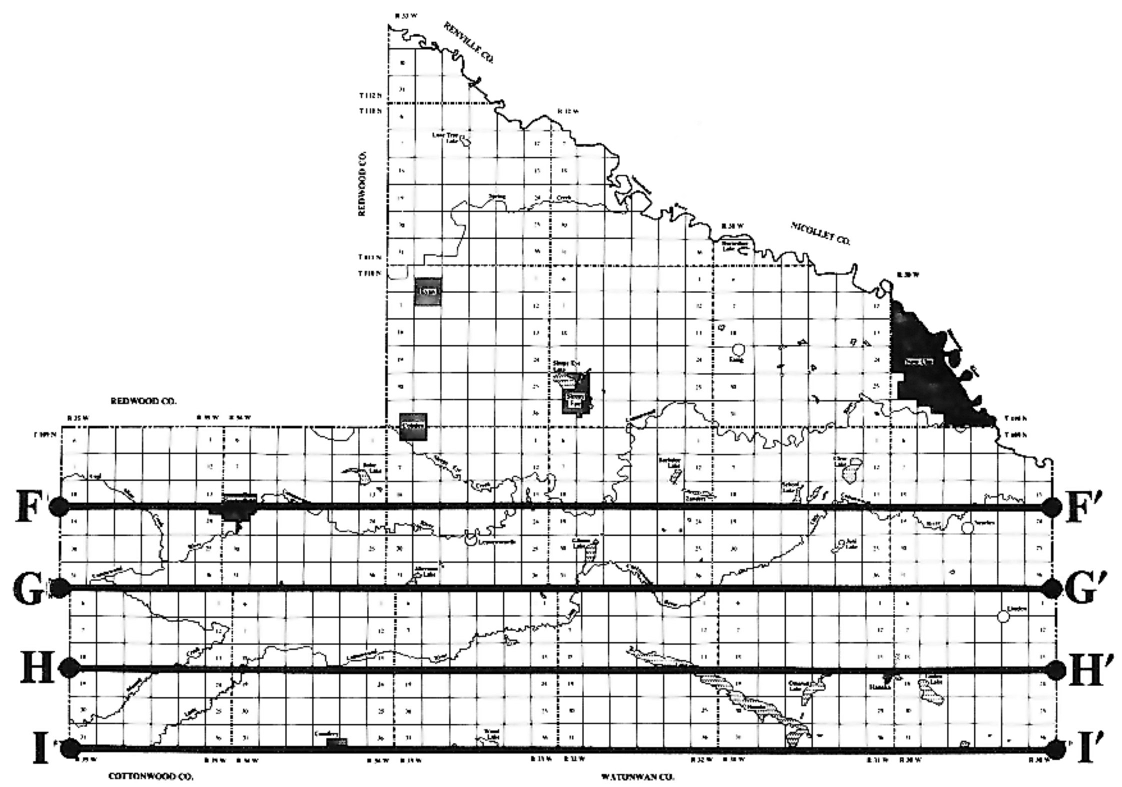
Paleozoic bedrock aquifers, chiefly sandstone: represent the water yielding units of a bedrock aquifer system. Additionally represents Cretaceous age sediments; primarily shale, sandy shale, and sandstone.

Precambrian basement rock, chiefly granitic gneiss, granite, and sioux quartzite; represents the base of all sedimentary bedrock units.

Contact between bedrock units is approximately located; dashed where inferred between lithologically similar units, erosional unconformities, or where contact is gradational.

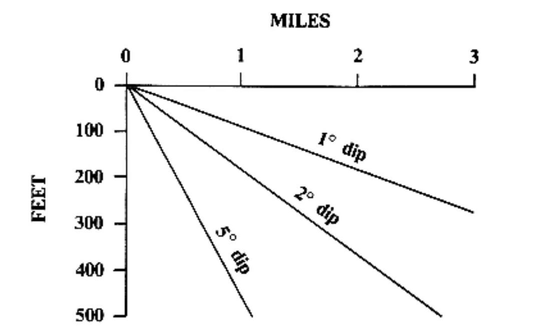
Contact line between Precambrian age basement rock and overlying sedimentary bedrock units or unconsolidated glacial deposits. Contact line is terminated where supporting data is absent.

INDEX TO GEOLOGIC CROSS SECTIONS

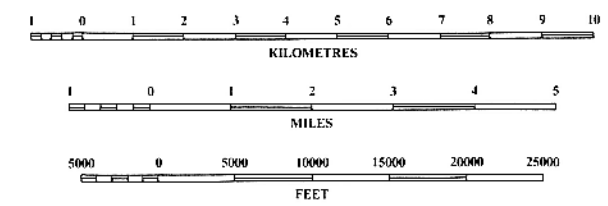


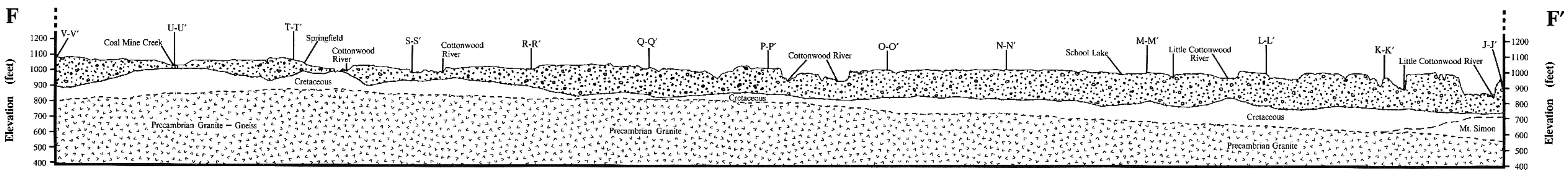
CONVERSION OF APPARENT DIP TO TRUE DIP

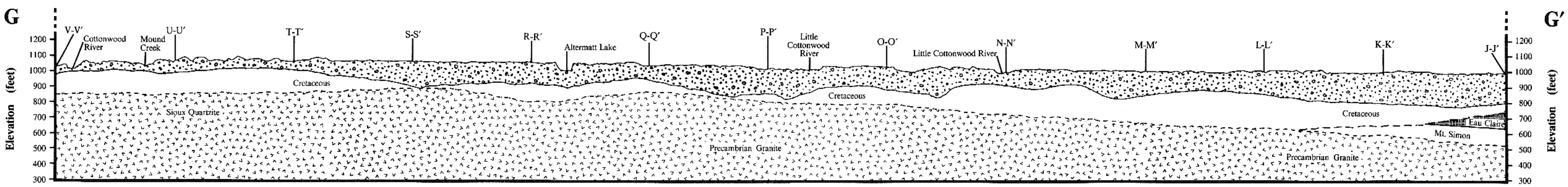
Vertical Exaggeration × 20

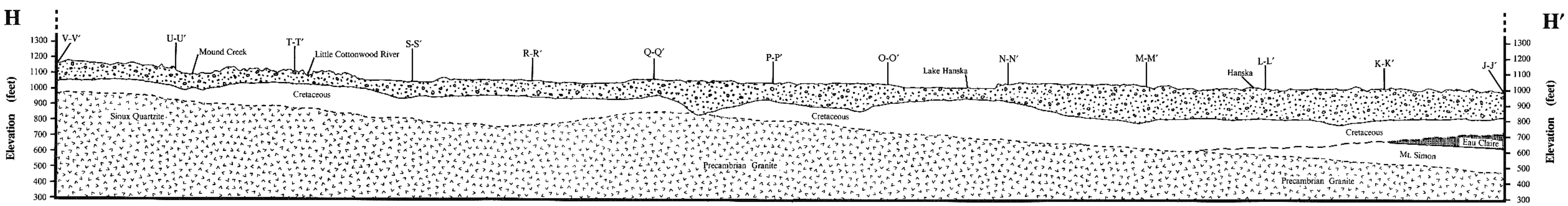


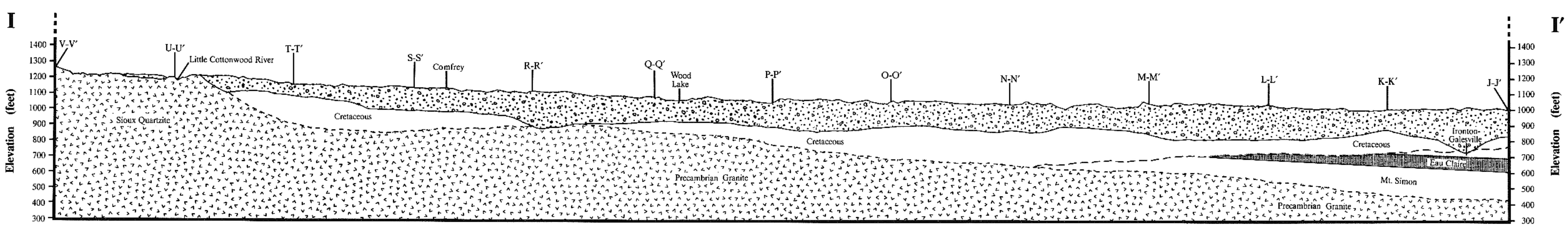
HORIZONTAL SCALE











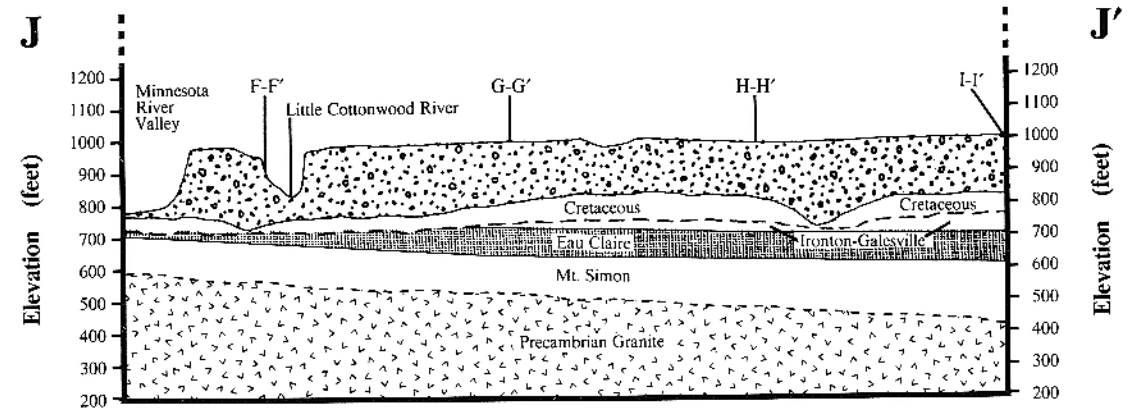
GEOLOGIC CROSS SECTIONS
J-J′ TO O-O′

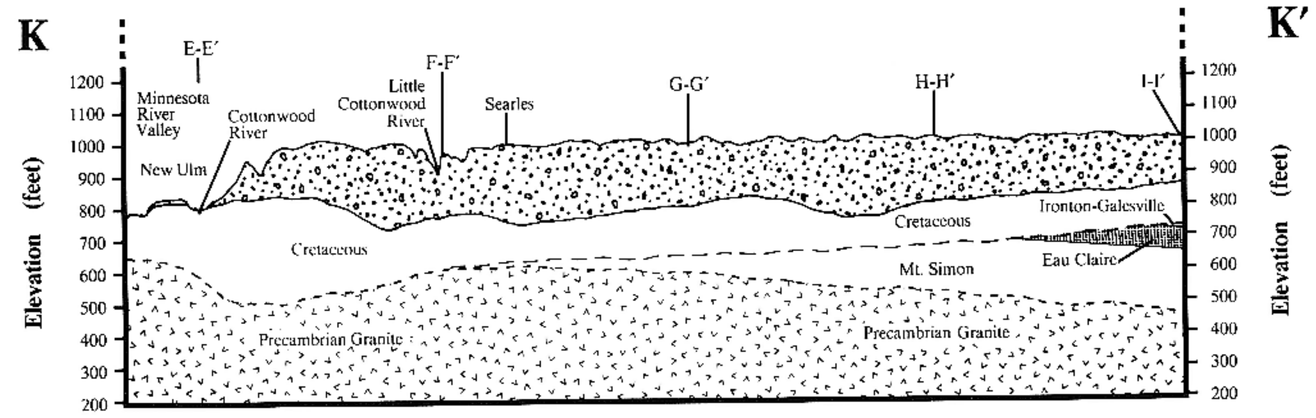
METHOD OF CONSTRUCTION

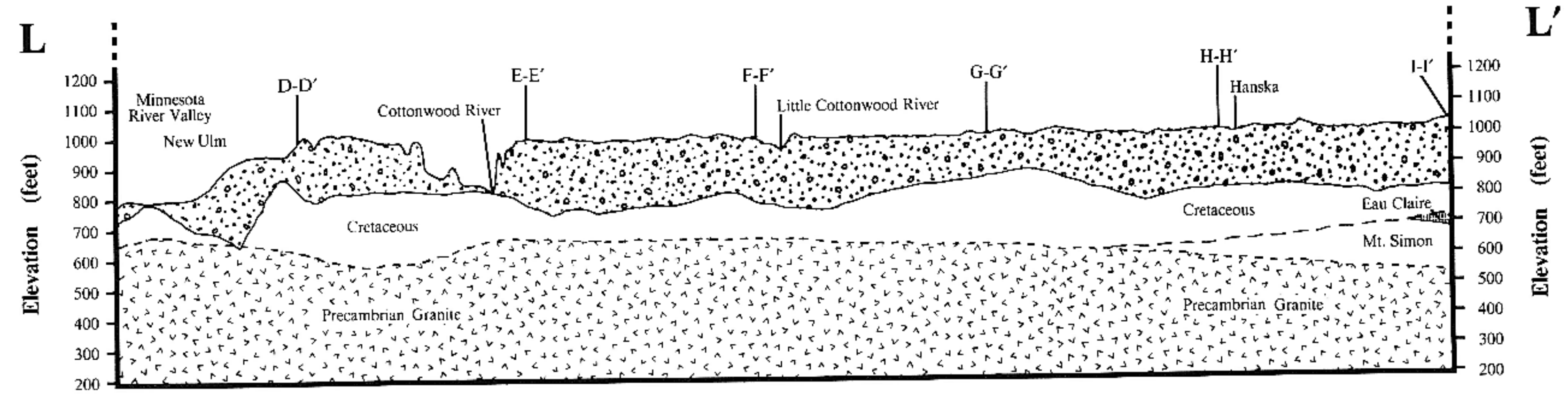
The positioning of boundary lines on each cross section was accomplished by transferring the elevation contour data from the Surface Topography Map, Bedrock Topography Map, and supplemented with information contained in the geologic portions of water well drillers' logs. The boundary lines that divide individual bedrock units may describe a gradual change over a few feet or tens of feet, from one rock type to another. Solid lines were used where contact between individual bedrock units is usually abrupt. Dashed lines were used where the contact between bedrock units represents an erosional unconformity or where the contact is gradational.

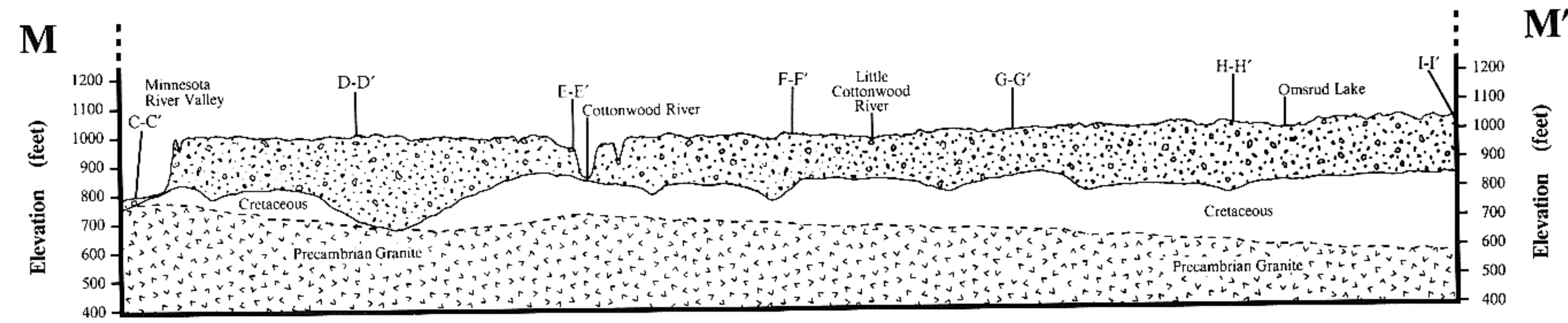
The surface profile for each cross section was constructed by using the Surface Topography Map as a guide. The profile for the top of the bedrock was constructed using the Bedrock Topography Map as a guide. The boundaries of all Paleozoic bedrock units were located by projecting the structural trend of the bedrock units from maps prepared for the Blue Earth County Geologic Atlas. The average thickness (accumulative) for each of the Paleozoic bedrock units was plotted and guided by existing water well driller data for wells that penetrated the Paleozoic bedrock units. The upper boundary of the Precambrian rock was plotted and guided by existing water well driller data and the general trend was projected into areas where driller data is sparse.

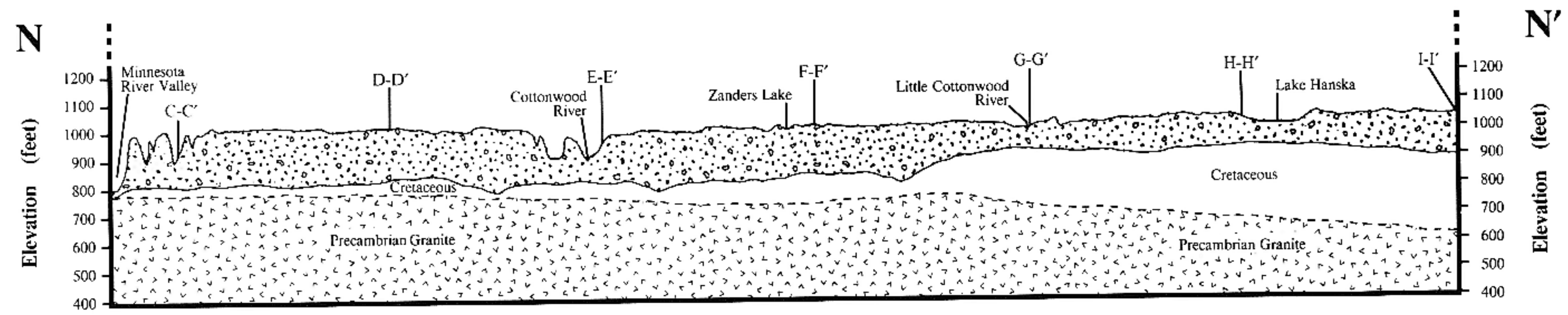
The cross sections illustrate the relationship between individual bedrock units and bedrock aquifer systems. The two major Paleozoic bedrock aquifer systems and the individual bedrock aquifers that combine to form them are shown on the cross sections J-J' to L-L'. The regional confining layer that separates the two Paleozoic bedrock aquifer systems has been filled with a distinguishing pattern to make it easy to recognize; the individual Paleozoic bedrock aquifers have been left clear or white. The Cretaceous age sediments have been left clear or white because individual aquifers and confining layers within these sediments are discontinuous or impossible to trace with existing data. The Precambrian basement rock have been filled in with a distinguishing pattern through areas where their presence can be traced with confidence. The cross sections show that thicker glacial deposits are associated with deep bedrock valleys while the thinnest glacial deposits occur over bedrock uplands and along present day river valleys.

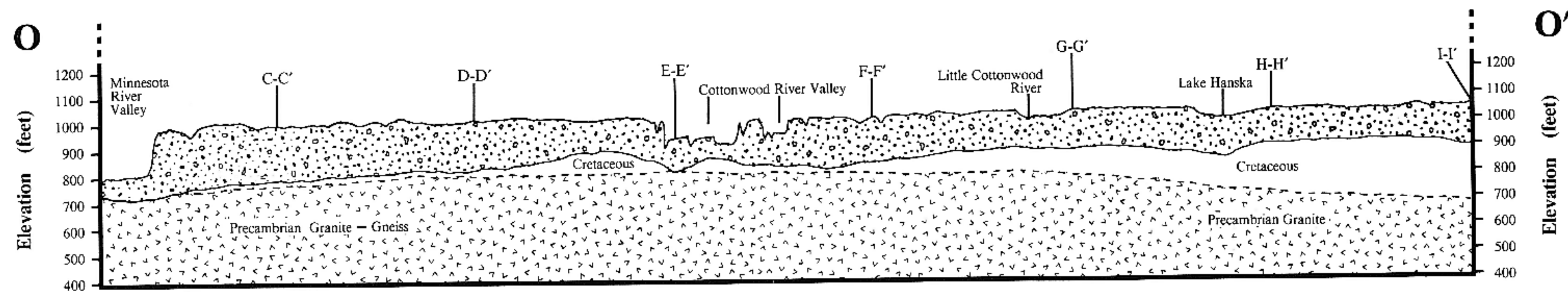












EXPLANATION

Unconsolidated surficial deposits, chiefly glacial drift: alluvial silts, sands, and gravels commonly present along streams.

Confining layer, chiefly shale and siltstone: separates Paleozoic bedrock aquifer systems.

Paleozoic bedrock aquifers, chiefly sandstone: represent the water yielding units of a bedrock aquifer system. Additionally represents Cretaceous age sediments; primarily shale, sandy shale, and sandstone.

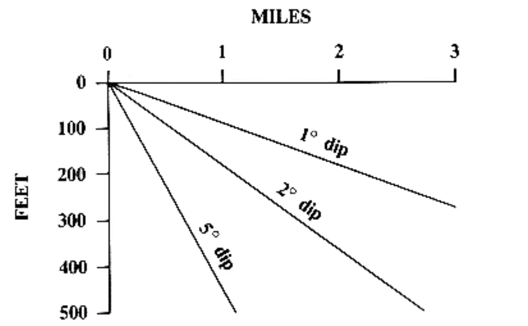
Precambrian basement rock, chiefly granitic gneiss, granite, and sioux quartzite; represents the base of all sedimentary bedrock units.

Contact between bedrock units is approximately located; dashed where inferred between lithologically similar units, erosional unconformities, or where contact is gradational.

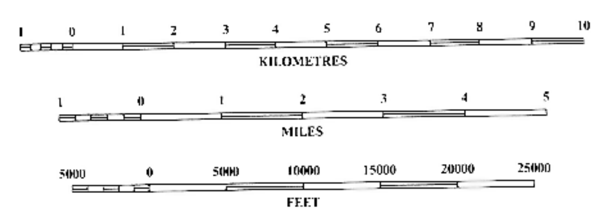
Contact line between Precambrian age basement rock and overlying sedimentary bedrock units or unconsolidated glacial deposits. Contact line is terminated where supporting data is absent.

CONVERSION OF APPARENT DIP TO TRUE DIP

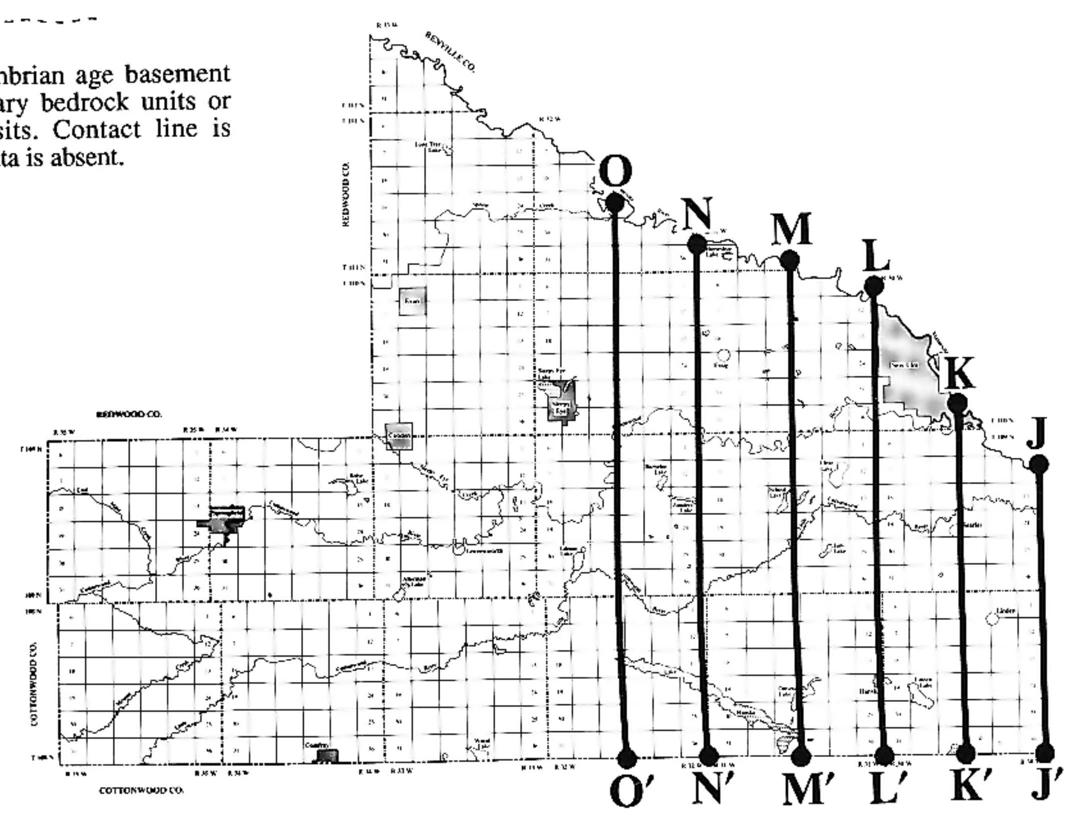
Vertical Exaggeration × 20



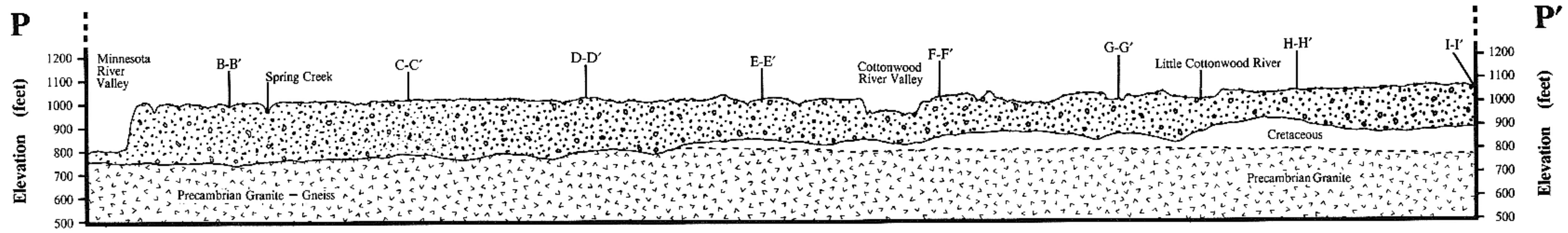
HORIZONTAL SCALE

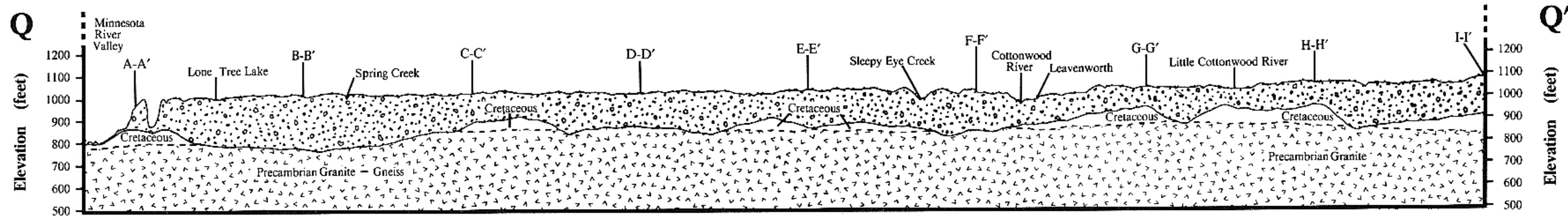


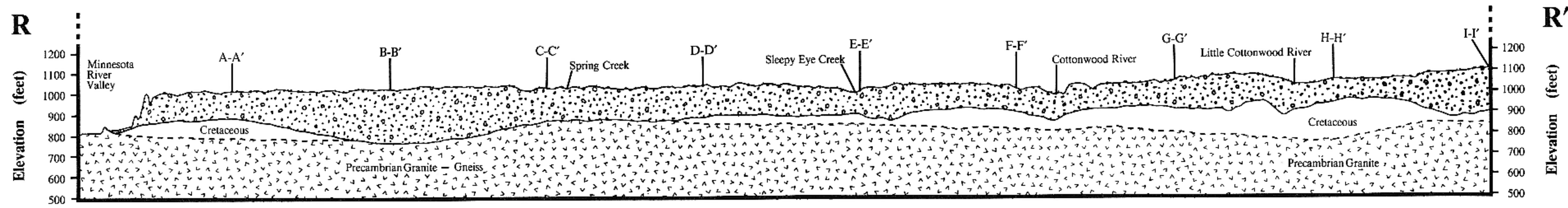
INDEX TO GEOLOGIC CROSS SECTIONS



GEOLOGIC CROSS SECTIONS P-P′ TO V-V′







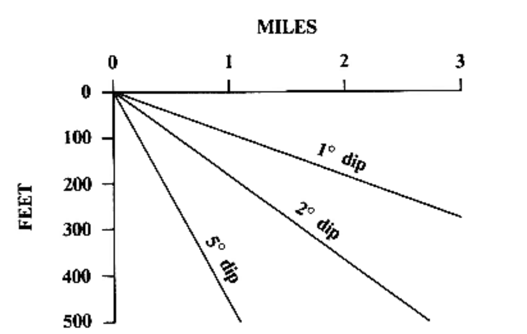
GROUNDWATER

The direction of groundwater movement cannot be shown on the cross sections in this atlas. Groundwater does not flow in a straight line and the direction of groundwater flow can change significantly over very short distances. For groundwater work, study area boundaries should be established and cross sections developed that are parallel and perpendicular to the direction of inferred groundwater flow.

The cross sections indicate the vertical and horizontal extent of Paleozoic bedrock aquifer materials and their connection with bedrock structure, bedrock topography, bedrock confining layers, and other factors that may control the movement of groundwater. Individual aquifers and confining layers within the Cretaceous sediments are not continuous or impossible to trace with existing data. In the vicinity of buried bedrock valleys, the emergence and subsequent termination of bedrock aquifer units may be abrupt. In these areas, bedrock aquifers may change from confined conditions to unconfined conditions over very short distances.

CONVERSION OF APPARENT DIP TO TRUE DIP

Vertical Exaggeration × 20



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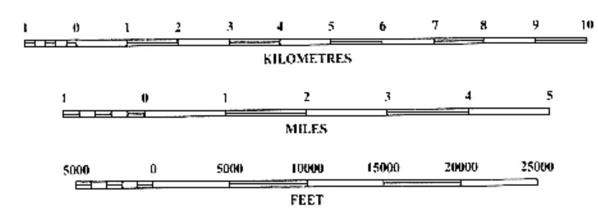
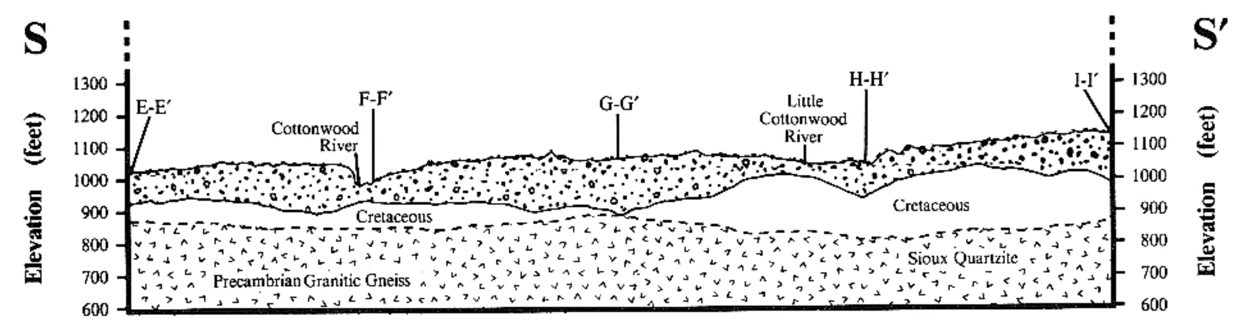
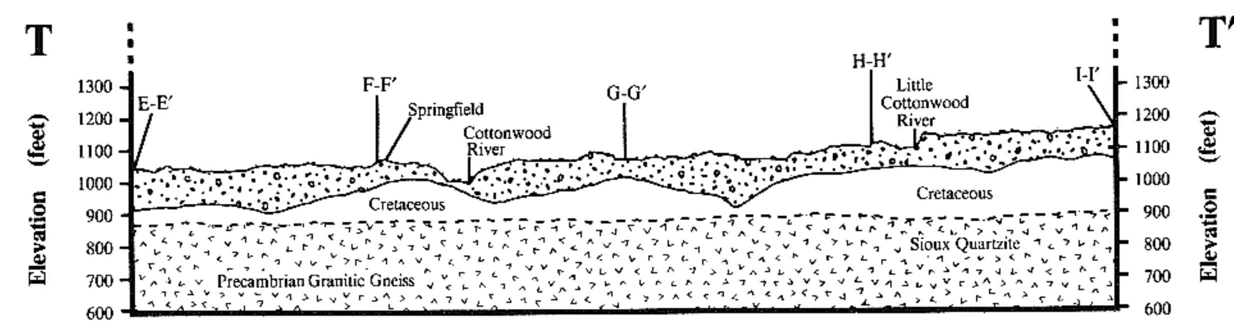
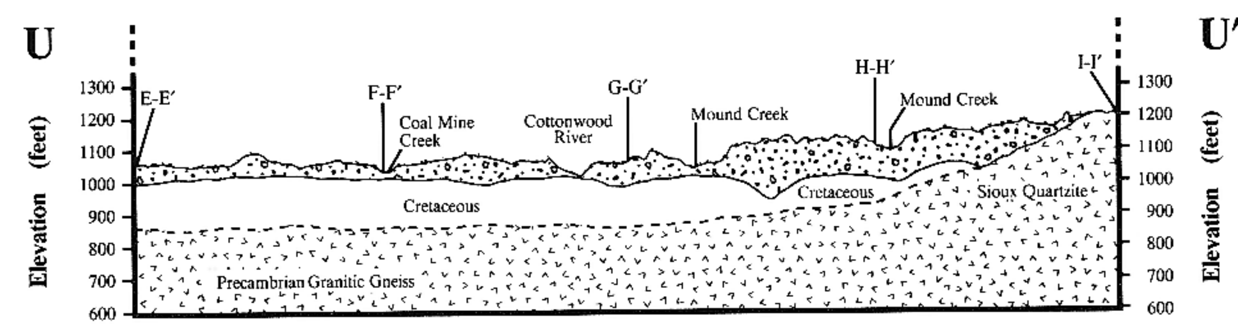
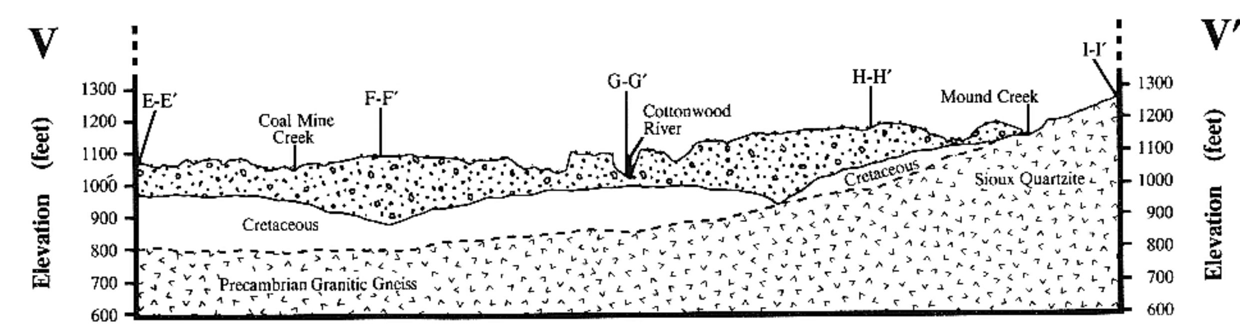


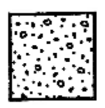








EXPLANATION



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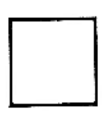

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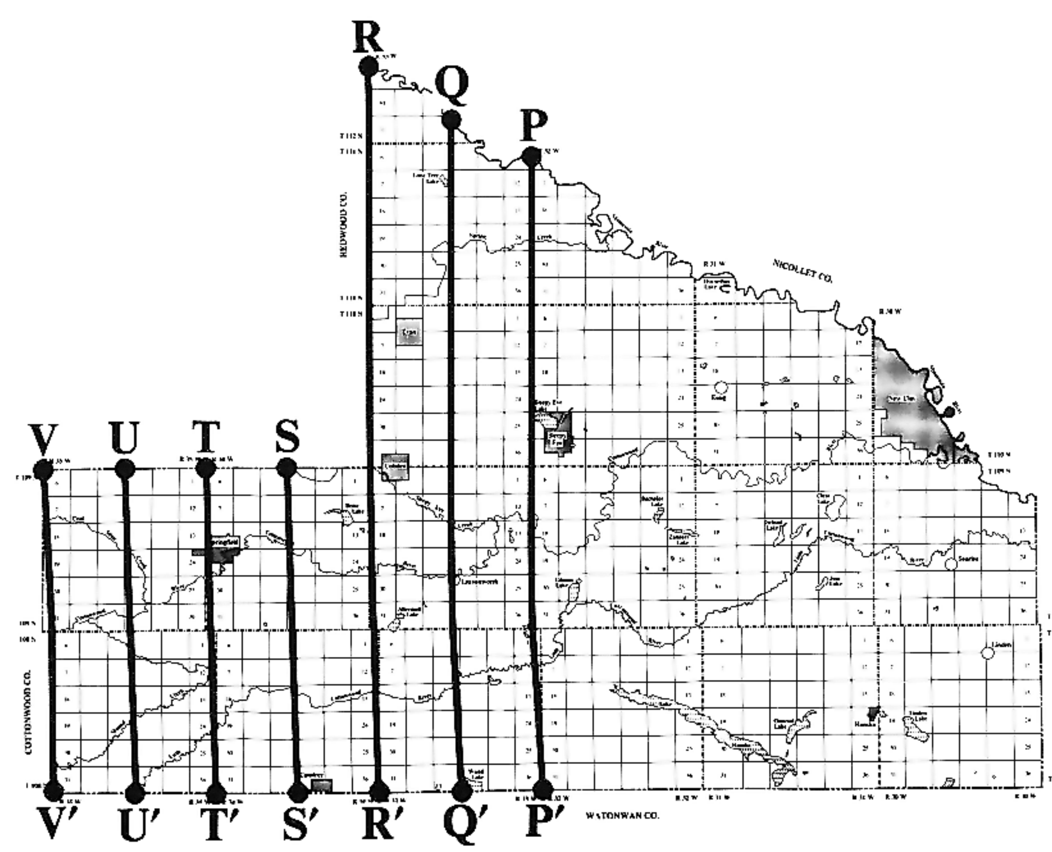


BEDROCK HYDROGEOLOGY

INTRODUCTION

The term bedrock is a relative term which is usually reserved for hard formations such as Precambrian granite and quartzite or the consolidated sandstones, shales, and carbonates of Cambrian and Ordovician age. In Brown County the term bedrock is also applied to the semi-consolidated Cretaceous sediments which are overlain by unconsolidated Pleistocene glacial deposits. Because most bedrock contains some water, the recognition or designation of any bedrock unit as an aquifer is as much a local economic decision as it is a hydrologic decision.

A bedrock aquifer is a geologic formation that is capable of storing and yielding fresh water in usable quantities. A bedrock aquifer system is a multiaquifer system that is composed of two or more bedrock aquifers that are bound on the top and bottom by aquitards. Individual bedrock aquifers range from coarse-grained deposits such as sandstone to sedimentary rock such as limestone or dolomite to hard fractured igneous and metamorphic rock such as granite or quartzite. A bedrock aquifer system is a connected set of individual bedrock aquifers that act hydrologically as a single unit.

Groundwater may be obtained from four bedrock aquifer systems in Brown County: the Cretaceous bedrock aquifer system, two Paleozoic bedrock aquifer systems, and the hard Precambrian basement rock. The main water-yielding units in the Cretaceous bedrock aquifer system are the Cretaceous sandstones; the main water-yielding units of the Paleozoic aquifer systems are the Ironton-Galesville sandstones and the Mt. Simon sandstone; the main water yielding unit of the Precambrian basement rock is the Sioux Quartzite.

SHALLOW BEDROCK AQUIFERS

The shallow bedrock aquifers consist of those bedrock units that commonly directly underlie the glacial drift and are recharged locally. The shallow bedrock aquifers are a primary source of groundwater due to their proximity to the land surface. Ease of drilling and lower drilling and operating costs are advantages of using from the shallow bedrock aquifers. The shallow bedrock has the advantage of local and rapid recharge, particularly in areas where the overlying drift is thin, or where there are permeable materials within the drift that are in direct hydrologic connection with the bedrock and will permit the downward movement of water into the bedrock. The disadvantages of the shallow bedrock aquifers include the susceptibility to contamination from waste disposal and other sources. Variability in the quality of the water may limit the use of a shallow bedrock aquifer when the aquifer is near the surface.

CRETACEOUS AQUIFERS

The degree of consolidation of the semi-consolidated Cretaceous bedrock sediments controls the manner and competence in which the sediments store and transmit water. Semi-consolidated rock usually does not support open cracks or fractures, and its value as a productive aquifer depends upon the porosity of the original sediments. The semi-consolidated Cretaceous sandstones have sufficient porosity to transmit water.

The Cretaceous sandstone aquifers may be widespread, persisting for long distances, or they may grade into shales over very short distances. The shales will function as aquitards in the sequence of Cretaceous sedimentary deposits. The water-bearing Cretaceous sandstones may vary locally in texture and composition because of changes in sedimentary environments due to shifting of the Cretaceous shoreline. Under favorable conditions a continuous blanket of sand may have been deposited over an entire region due to the continuous nature of the depositional environment; e.g. one direction shifting of the Cretaceous shoreline under uniform conditions.

Within the Cretaceous groundwater system lie local and regional aquifers that provide significant amounts of groundwater. The most productive Cretaceous aquifers are the uniform and continuous sandstone units that extend over wide areas. The density and distribution of water well driller data is sufficient to draw only localized correlation between the Cretaceous sandstone units encountered by water well drillers. Thus, the continuous extent of these sandstone units cannot be mapped with confidence on a county wide scale.

PALEOZOIC BEDROCK AQUIFER SYSTEMS

The Paleozoic bedrock aquifers are limited to the extreme eastern portions of Brown County. The areal extent of the Paleozoic bedrock aquifers in Brown County is unknown. Although the Paleozoic bedrock aquifers are present in Brown County, they are generally not utilized as a source of groundwater due to their proximity to the land surface. The Paleozoic bedrock units are overlain by thick glacial and Cretaceous deposits, each containing productive aquifers. Well drilling will stop when an adequate groundwater supply is encountered. Water well drillers' records are not available for the Paleozoic bedrock aquifer system in Brown County, therefore no hydrologic or geologic information is available for the Paleozoic aquifers.

The Franconia-Ironton-Galesville aquifer system is the uppermost of the two Paleozoic bedrock aquifer systems. The upper bedrock aquifer unit in the Franconia-Ironton-Galesville aquifer system is the Franconia glauconitic sandstone; the Franconia aquifer is not present in Brown County. The lower bedrock aquifer unit is the Ironton-Galesville sandstones which is generally a more productive aquifer than the overlying Franconia; the Ironton-Galesville sandstone is limited to erosional remnants along the eastern border of Brown County. Rock of low permeability of the Eau Claire Formation directly underlie the Ironton-Galesville sandstone and separate it from the underlying Mt. Simon aquifer system. The Mt.Simon aquifer system is deepest of the two Paleozoic aquifer systems in Brown County.

PRECAMBRIAN IGNEOUS-METAMORPHIC AQUIFER

The hard Precambrian quartzite, granite, and granitic gneiss are generally impermeable. The permeability of these hard Precambrian rocks depends upon their porosity, which is primarily due to cracks and fractures. Decomposition, due to past weathering, may have increased the near-surface porosity of these rocks. In general, the permeability of the hard Precambrian bedrock will decrease with depth, as the cracks and fractures will tend to close at greater depths.

The main water-yielding units of the Precambrian basement rock is the Sioux Quartzite. Groundwater in the Sioux Quartzite is primarily stored in cracks and fracture zones that are mostly closed, allowing the groundwater to flow slowly through them. The minimal water that is stored in and transmitted through these fracture zones is corroborated by pumping tests made by area well drillers. The utilization of the Sioux Quartzite as an aquifer is a local economic decision, as it is only used as a last resort when other sources of groundwater are unavailable.

STATIC WATER LEVELS

Groundwater is usually held in a bedrock aquifer, at significant pressure, by the presence of a confining bed above the aquifer. High water pressure is sometimes the result of continuous bedrock strata with recharge areas at higher elevations. Water pressure will change in response to varying patterns of recharge, discharge, and pumping. In Brown County, the water pressure in bedrock aquifers is not sufficient to lift the water above land surface.

In water well drillers' logs, groundwater pressure is recorded as static water level measurements that represent the non-pumping water level in a well. These water well records represent data that has been collected over many years through every season. The data is usually a one time measurement of the static water level that was made during well installation. To precisely map water levels in the bedrock aquifers, static water level data would have to be collected at about the same time of the year from many control points. When data points are few and unequally spaced, only limited confidence can be placed in the resulting map.

BEDROCK AQUIFER MAP

One bedrock aquifer map was constructed from the bedrock hydrologic data contained in water well drillers' logs for Brown County. Throughout Brown County the Cretaceous aquifer system commonly forms the bedrock surface and represents the shallow bedrock aquifers. The Cretaceous sediments are the primary source of bedrock groundwater due to their proximity to the land surface. No hydrologic data is available for the Paleozoic bedrock aquifers in Brown County because the Paleozoic bedrock is limited to the extreme eastern edge of the county and is commonly overlain by the Cretaceous bedrock sediments. Few wells need to penetrate the Cretaceous sediments because Cretaceous aquifers provide adequate water supplies. In areas where Cretaceous sediments are not present, the Precambrian bedrock is utilized as an aquifer only when the overlying glacial deposits cannot supply adequate water supplies.

The Bedrock Aquifer Map was developed from the data contained in hydrologic portions of water well drillers' logs. On the bedrock aquifer map, static water levels are shown by means of contours. The static water level contours are drawn on the basis of data contained in the hydrologic portions of water well drillers' logs for which static water levels have been recorded. The static water level elevation contours represent a water level surface which describes the hydraulic gradient expressed as the decrease in water level elevation over horizontal distance. The static water level surface is not a simple plane but changes in response to varying patterns of discharge, pumping, and recharge. The general direction of regional groundwater movement is approximately perpendicular to the static water level contours in the direction of decreasing elevation. In Brown County, current water well driller data are only sufficient to demonstrate the regional groundwater movement is toward the north and northeast.

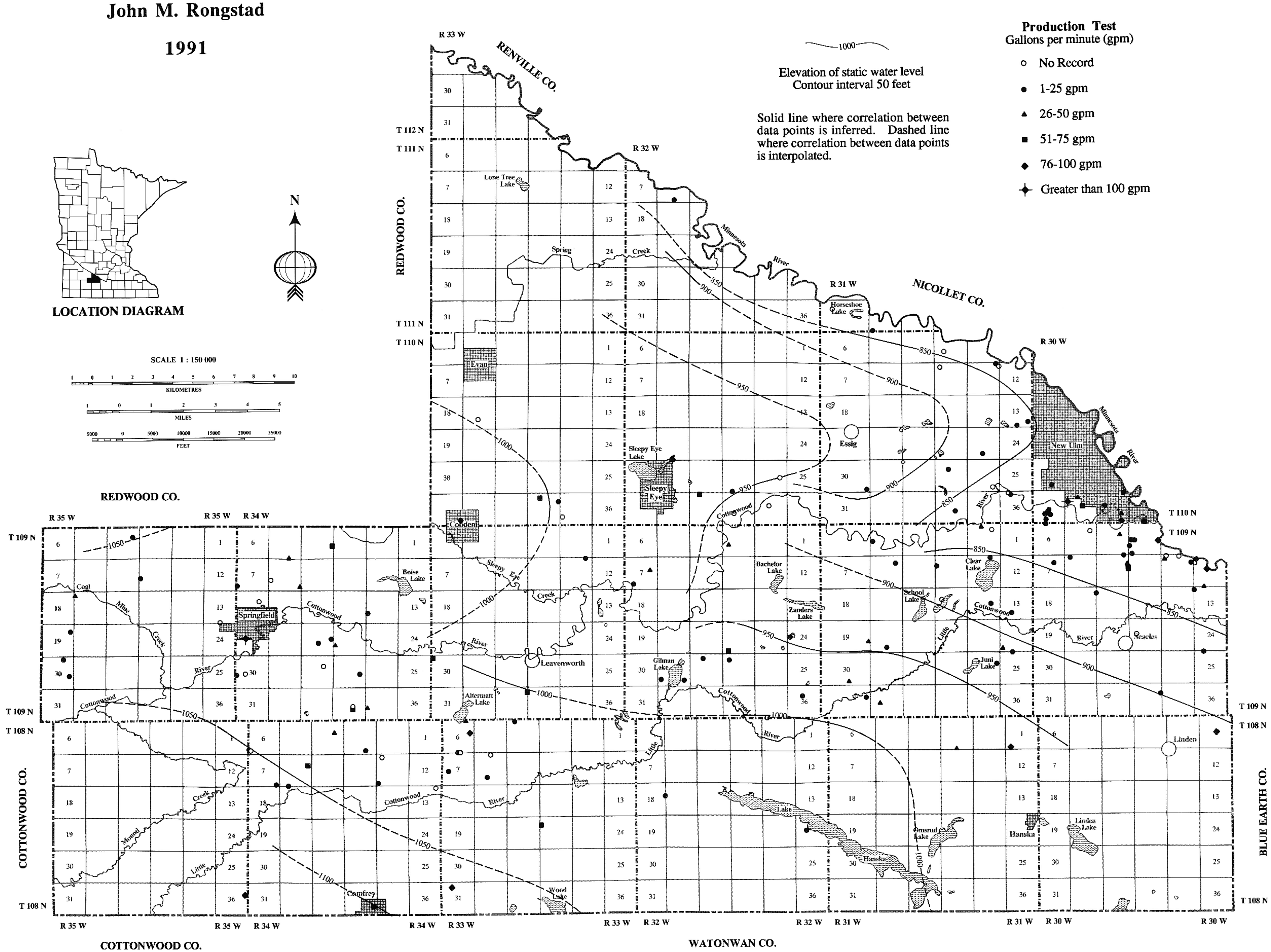
Hydrologic portions of water well driller data for all bedrock aquifers in Brown County were used to construct the static water level contours on the Bedrock Aquifer Map. When water level surface is prepared from measured static water levels in more than one bedrock aquifer, the resulting contoured map will usually reveal a complex surface which would indicate the existence of a mutiaquifer system separated by aquitards. However, the water level contours on the Bedrock Aquifer Map for Brown County describe a relatively smooth surface. Thus, the various bedrock aquifer systems presented on the Bedrock Aquifer Map may be either a connected set of aquifers that act hydrologically as a single unit or a set of independent aquifers that act similarly.

BEDROCK AQUIFER MAP

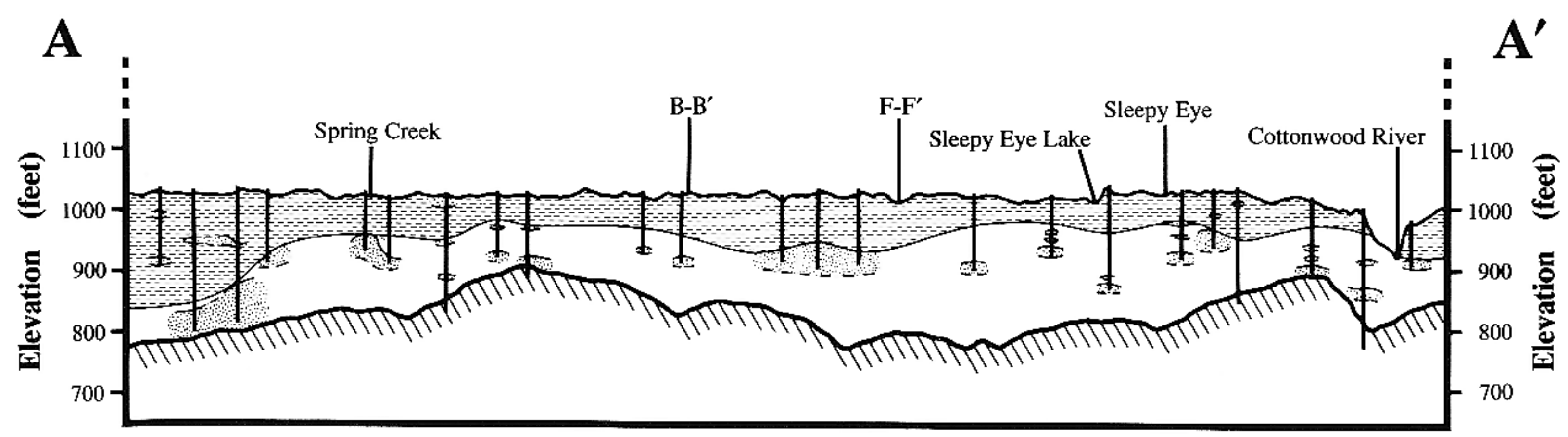
By

John M. Rongstad

1991



GLACIAL DRIFT CROSS SECTIONS



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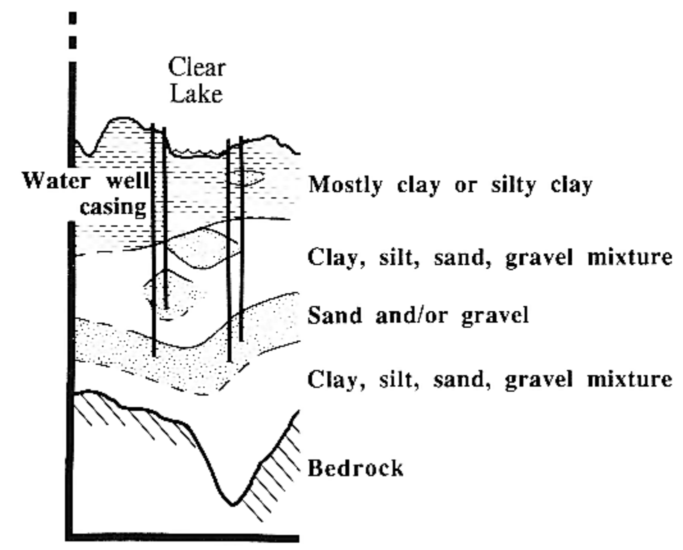

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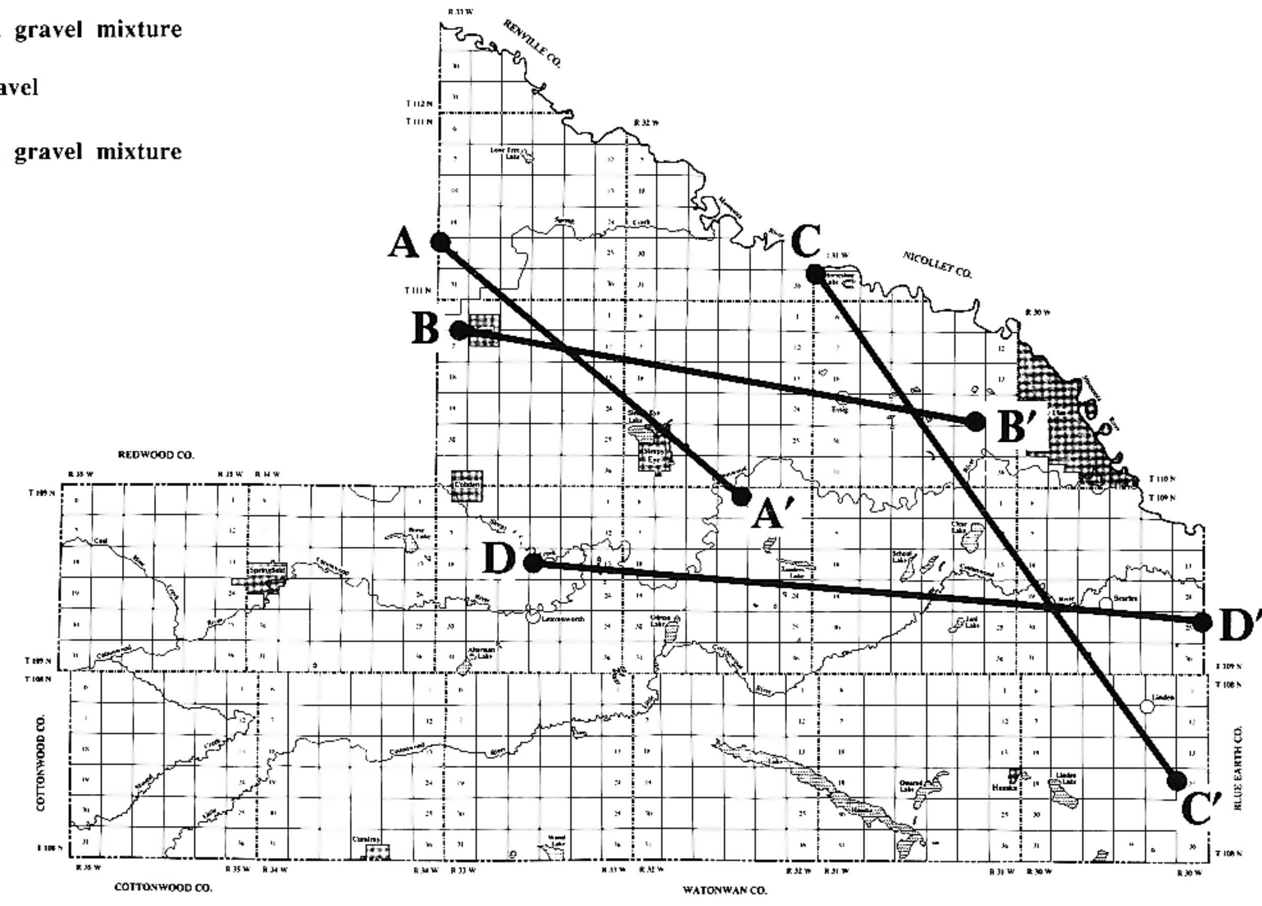

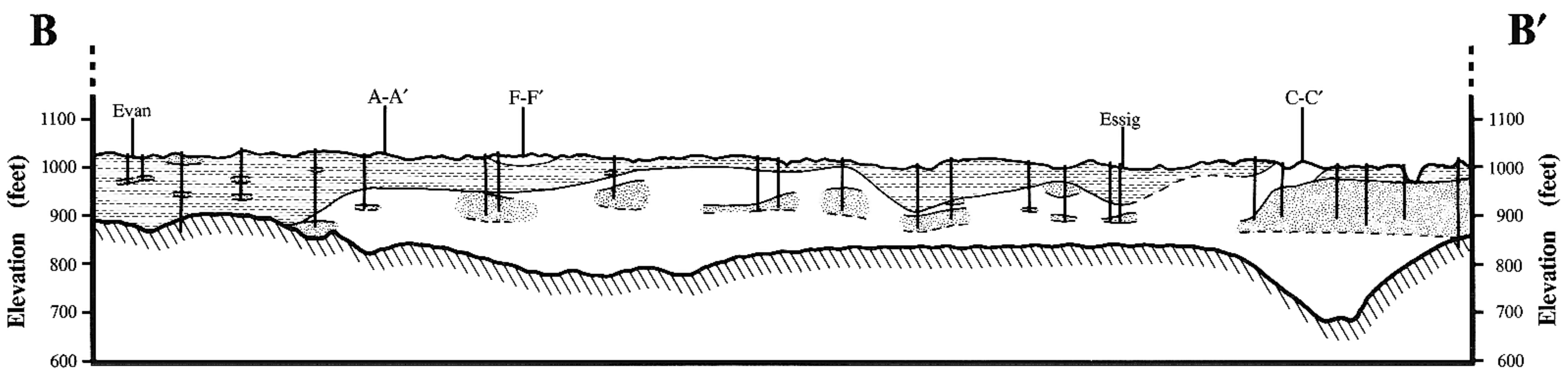

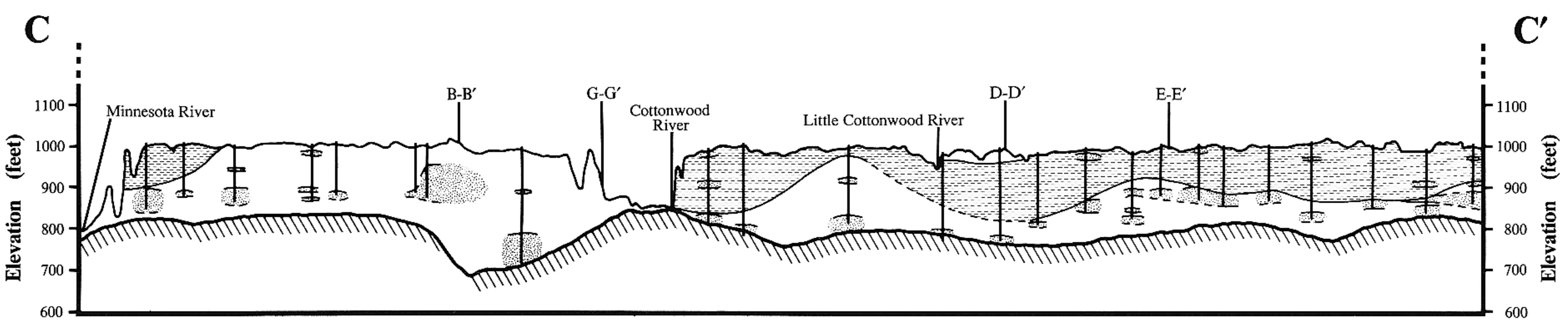

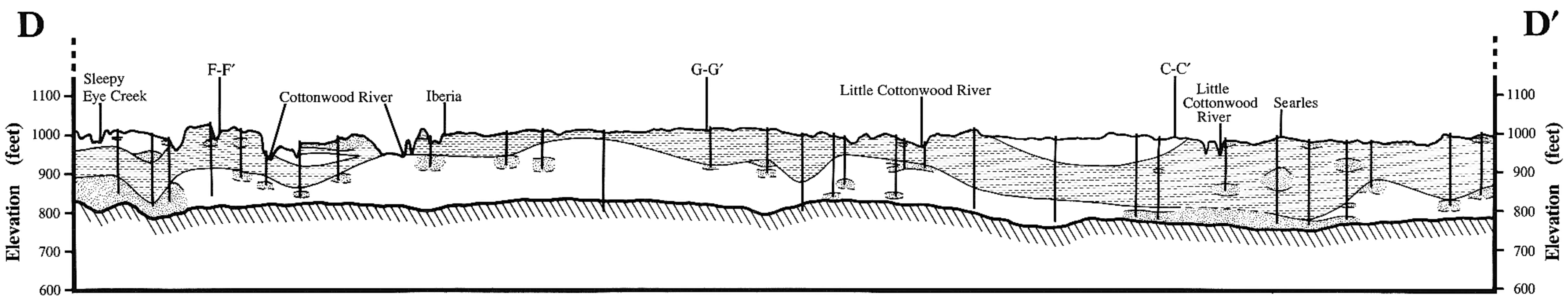

GLACIAL DRIFT CROSS SECTIONS

The cross sections illustrate that the uppermost till zone is commonly composed mostly of clay and silty clay which is neither as permeable nor as productive as the till zone beneath. The lower till zone is composed of a matrix of clay, silt, sand, and gravel. This lower till zone contains thin localized lenses of permeable sand and gravel deposits that may be used for small groundwater supplies. Thick linear deposits of permeable sand and gravel within the till zone may constitute a source of large groundwater supplies.

To identify and define the large permeable deposits within the glacial till, it is necessary to determine the three-dimensional distribution of the sand and gravel units. Water well drilling will stop when an adequate supply of groundwater is encountered by the well driller. Therefore, the borehole will seldom penetrate the total thickness of a sand or gravel aquifer and the total thickness of an aquifer with the glacial drift is seldom known.

The glacial till will generally yield little water over short time intervals, thus recharge is slow and low pumping rates are associated with small sand and gravel aquifers that are interbedded or enclosed by relatively impermeable till material. Where sand and gravel deposits extend to the bedrock surface, recharge rates are commonly fast and the pumping capacity is large. Occasionally, permeable sand deposits are reported by drillers as occurring just above the bedrock and may signify only the presence of weathered bedrock.

GLACIAL DRIFT AQUIFERS

INTRODUCTION

The possibility of developing small supplies of groundwater for farm and domestic use from wells finished in the glacial drift of Brown County is generally good. The potential for development of moderate to large groundwater supplies from the glacial drift ranges from poor, as in the southwestern parts of Brown County, to favorable in the central and eastern portions of the county.

Glacial deposits include all material deposited directly by ice or by meltwater streams derived from the ice. The term glacial drift refers to all types of glacial deposits, regardless of the manner in which they were deposited. The materials deposited directly by ice are called glacial till. Sediments deposited by glacial meltwater are referred to as glacial outwash, glacial fluvial deposits, or other similar terms.

In general, glacial till forms aquitards. The till is less permeable than outwash deposits because it is poorly sorted and rich in silt and clay. Fine silt and clay materials have been washed out by meltwater, leaving only the coarse texture materials which create good local aquifers. Outwash deposits were deposited by running water and have the hydraulic characteristics of stream sediments. However, outwash deposits are usually coarser grained than stream deposits because glaciers provided large volumes of water continuously.

A study of the geologic portions of water well drillers' logs resulted in the recognition of three general hydrostratigraphic units that were used to construct a geologic framework for describing the hydrologic system within the glacial drift. The glacial drift is considered to consist of alternating layers of impermeable, semi-impermeable, and permeable materials, forming a series of aquitards and aquifers. The three hydrostratigraphic units defined here have different properties in relation to the occurrence and movement of groundwater through the glacial drift. Mostly clay and silty clay deposits are fine-grained sediments and considered to be impermeable. A heterogeneous mixture of clay, silt, sand, and gravel are considered to be semi-impermeable. Sand and gravel bodies within the glacial till are considered to be permeable.

Few of the water wells that are finished within the glacial deposits draw water directly from till; most obtain water from sand and gravel bodies within the till. Generally, the glacial tills have low permeabilities and, in many places, the till is sufficiently impermeable that it forms an aquitard between productive sand and gravel aquifers. Groundwater supplies generally occur in sand and gravel deposits under semi-confined or confined conditions within the glacial till. Therefore, the water-yielding deposits are considered to represent an artesian condition and the water level rises above the level at which it was first encountered.

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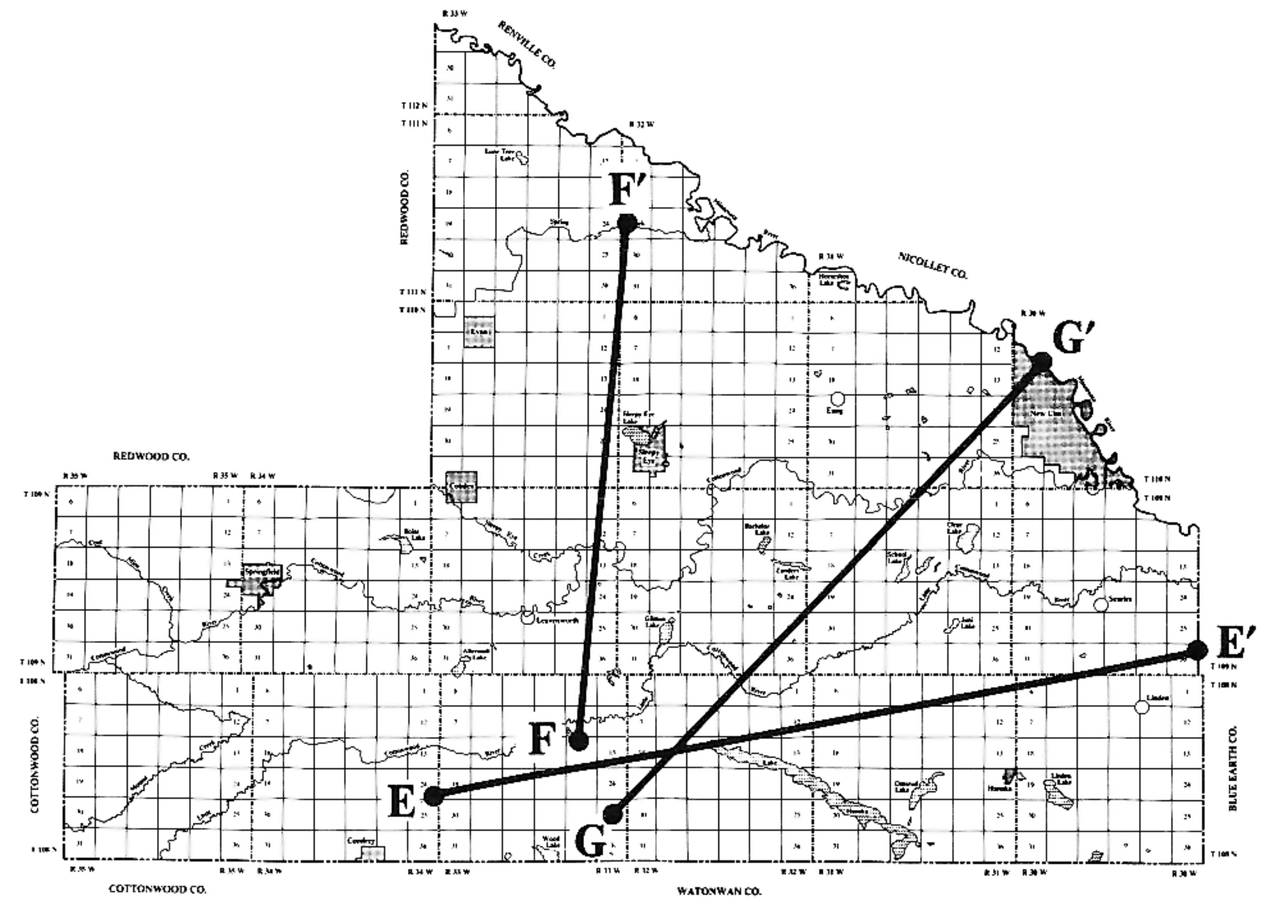

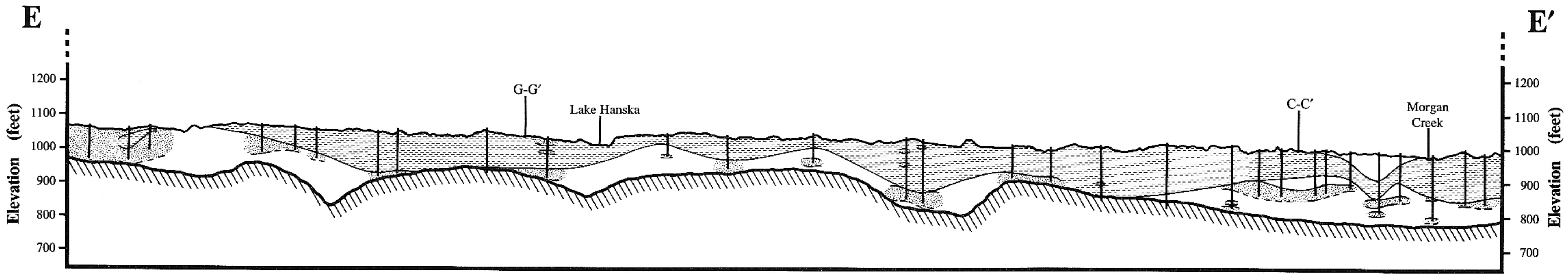

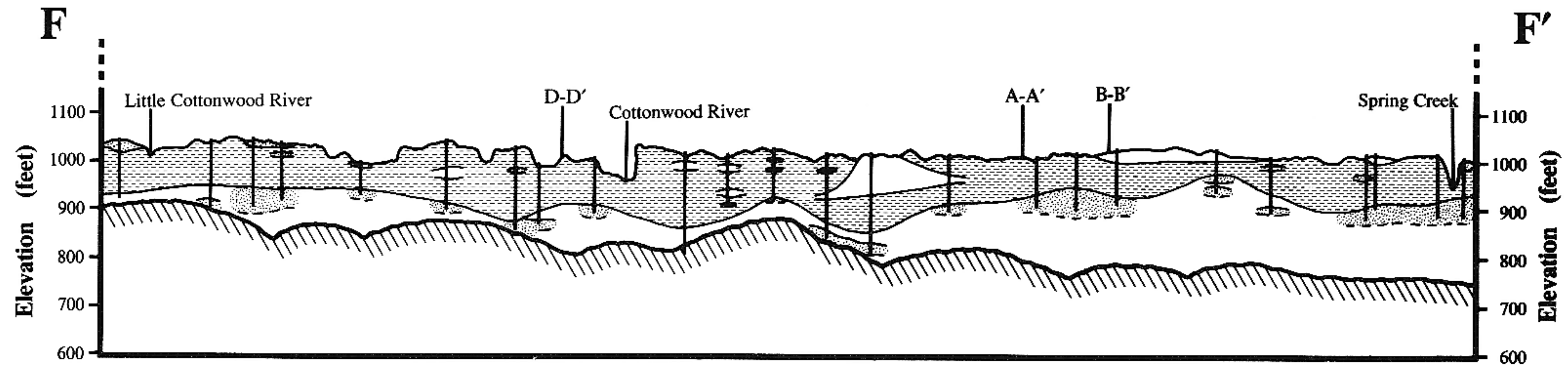

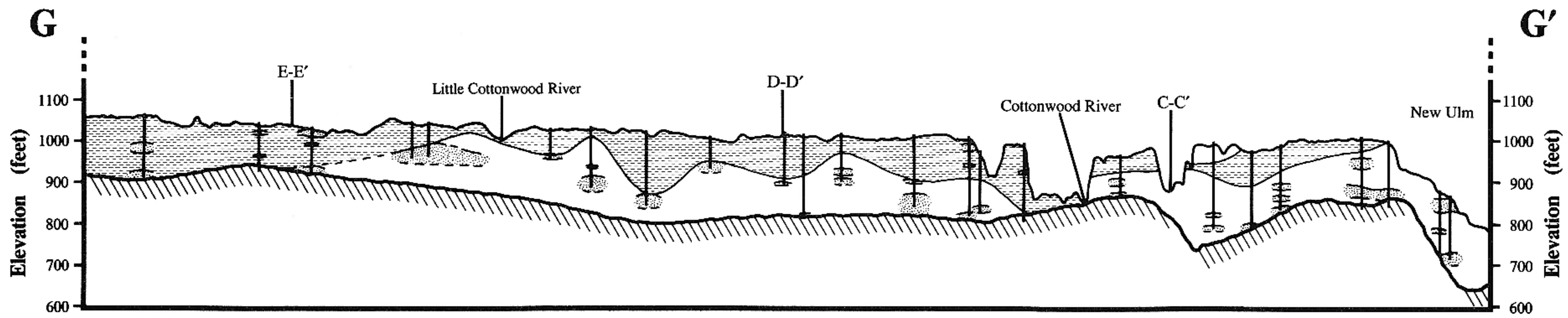

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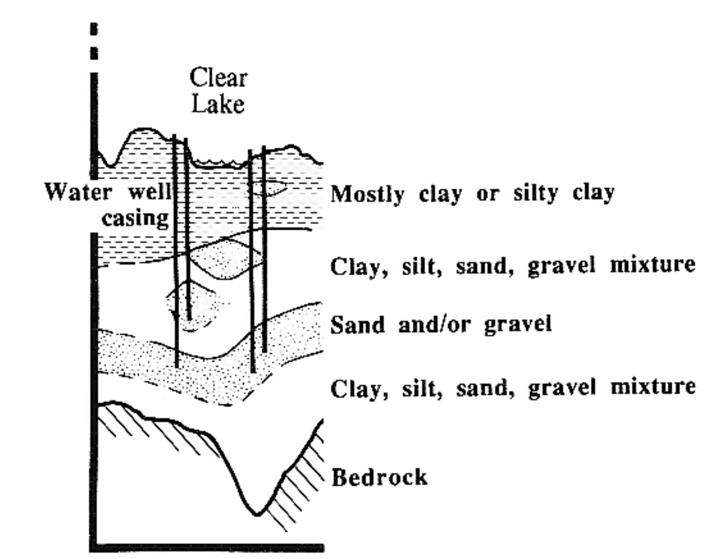


GLACIAL AQUIFER MAP

By

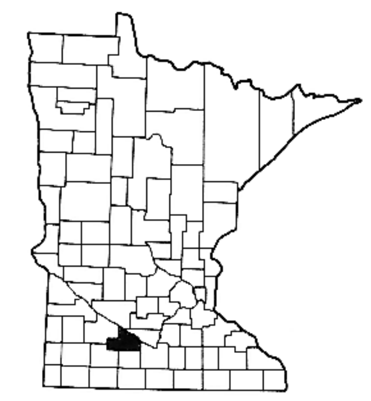
Thomas E. Kujawa
Cis A. Berg and John M. Rongstad

1991

The Glacial Drift Aquifer Map defines regions within Brown County that have the greatest potential for the development of groundwater supplies from the glacial drift. The map shows whether a test hole in a given area may encounter favorable conditions for groundwater supplies and at what elevation these conditions might be expected to exist.

The Glacial Drift Aquifer Map was developed directly from the data contained in the hydrologic portions of water well drillers' logs for wells finished in the glacial drift. The static water levels, presented on the map, are based solely on the data recorded in water well drillers' logs and represent the non-pumping levels in a well. The records of well casing were used to determine the elevation from which the reported static water levels are derived.

The static water level data was plotted onto the Glacial Drift Aquifer Map by means of elevation contour lines. The static water level surface is based on elevations to which the confined water rises. The elevation of static water levels may vary as much as 70 feet between neighboring wells whose casings extend to vastly different elevations. Therefore, it is impossible to determine the groundwater flow characteristics from the static water level data reported in water well drillers' logs. Well casings that extend to lower elevations in the glacial drift are usually associated with lower static water levels.



LOCATION DIAGRAM

EXPLANATION

Production Test
Gallons per minute (gpm)

- ○ No record
- ● 1-25 gpm
- ▲ 26-50 gpm
- ■ 51-75 gpm
- ◆ 76-100 gpm
- ✦ Greater than 100 gpm

900 — Elevation at bottom of well casing. Contour interval 50 feet

950 — Elevation of static water level. Contour interval 50 feet

Solid line where correlation between data points is inferred. Dashed line where correlation between data points is interpolated.