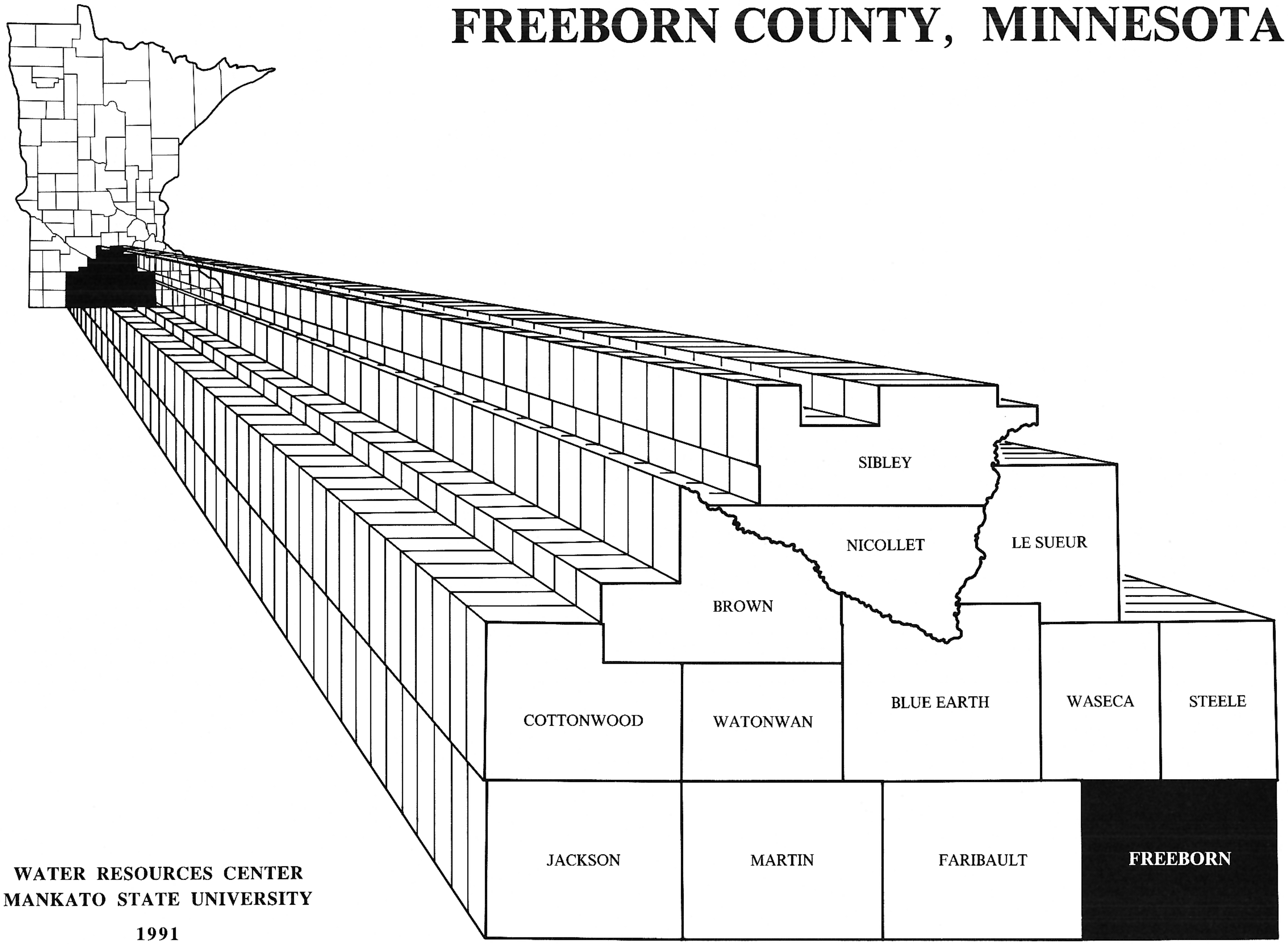
GEOLOGIC ATLAS

FREEBORN COUNTY, MINNESOTA



WATER RESOURCES CENTER
MANKATO STATE UNIVERSITY
1991

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JULY, 1991

The Freeborn County Geologic Atlas was prepared and published with the support of a grant from the Legislative Commission on Minnesota Resources and the Freeborn 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.

Cartography: Jesse Wohlfeil, Paul Vogel, Cis Berg, Chuck Broste, Quinto Lotti, Tom Kujawa and Eric Hendricksen.

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FREEBORN 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, 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 Freeborn 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 bedrock units in Freeborn County. This atlas is intended to be used as a guide to the subsurface geologic conditions and groundwater resources in Freeborn 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 and Bedrock Structure Maps were constructed independently; they were directly created from the data itself. These maps 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 Bedrock Structure Maps. 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 7) 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.

BEDROCK STRUCTURE MAPS (Page 9 thru 11) were directly created from geophysical logs. These maps show the structural configuration of key bedrock units and provide a means by which these bedrock units may be traced continuously over wide areas.

DEPTH TO BEDROCK MAP (Page 8) 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 6) combines the Bedrock Topography Map and Bedrock Structure Maps 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 13 thru 17) combine the Surface Topography, Bedrock Topography, and Bedrock Structure Maps to construct cross sectional profiles for Freeborn County. The cross section profiles are arranged as a grid system to provide county wide cross section coverage.

BEDROCK AQUIFER MAP (page 19) was developed directly from the data contained in the hydrologic portions of water well drillers' logs, including static water level and casing length.

GENERAL GEOLOGY

The characteristics of the present land surface in Freeborn 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 Freeborn 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 less than 50 feet to over 200 feet. Before glaciation, erosion of the bedrock surface produced valleys on the bedrock surface, all 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.

The bedrock that underlies Freeborn County is part of a sequence of Late Cambrian to Middle Devonian sedimentary rock which consists of three major rock types: sandstone, shale, and carbonates. The bedrock was deposited under tectonically stable geologic conditions in shallow marine waters that flooded southern Minnesota about 500 million years ago. The lithology of individual bedrock units is nearly uniform throughout Freeborn County due to the continuous nature of the geological processes that formed them. In Freeborn County, limestone forms the bedrock surface beneath the glacial drift. These limestones represent the youngest bedrock units that are underlain by progressively older shales and sandstones.

Structural faulting and uplift is known to have occurred in Minnesota during Precambrian time. The tectonic activity that contributed to the Precambrian faulting is thought to have ceased before Cambrian time. This interpretation suggests that the Cambrian and Ordovician aged bedrock sediments were deposited on top of inactive Precambrian aged fault blocks, and assumes that individual bedrock formations are not deformed internally. For the purpose of this study, each bedrock unit is treated as a continuous layer and mapped accordingly.

GROUNDWATER

INTRODUCTION

In Freeborn County, groundwater exists in unconsolidated glacial deposits and in the underlying bedrock. The possibility of developing adequate supplies of groundwater from the glacial deposits is generally poor. However, the bedrock aquifers are among the highest yielding in the United States. The groundwater supplies that are contained within the bedrock aquifers are adequate for present and foreseeable needs.

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 Freeborn 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.

BEDROCK AQUIFERS

Groundwater can be obtained from four bedrock aquifer systems in Freeborn County. They are the Cedar Valley-Maquoketa-Galena aquifer system, the St. Peter-Prairie du Chien-Jordan aquifer system, the Franconia-Ironton-Galesville aquifer system and the Mt.Simon-Hinckley aquifer system. The data suggest that there is good hydraulic connection between the bedrock units within each of the four bedrock aquifer systems.

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 act hydrologically as a single unit and are bound on the top and bottom by aquitards. Individual bedrock aquifers range from coarse-grained deposits such as sandstone to hard fractured sedimentary rocks such as limestone or dolomite.

In Freeborn County, most farm and domestic wells draw water from the uppermost bedrock aquifer that is locally available. Throughout most of Freeborn County the upper bedrock aquifer consists predominately of Cedar Valley, Maquoketa, and Galena limestones. Wells that require high pumping capacity are often drilled through two or more bedrock aquifers.

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 Freeborn County, the water pressure in bedrock aquifers is generally 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.

RECORD OF WATER WELL CONSTRUCTION

WELL NO.	: 218068
* COUNTY	: FREEBORN
* TOWNSHIP	: 101 NORTH
* RANGE	: 23 WEST
* SECTION	: 14/ACADDA
* QUADRANGLE	: CONGER
COMPLETED	: 08/72
DEPTH	: 313 FT.
* ELEVATION	: 1258 FT.
* WELL USE	: IRRIGATION

CASING	: 016 INCH TO 150 FEET
WATER LEVEL	: 37 FT. (EL. 1221 FT.)
DATE	: 08/72
AQUIFER (S)	: CEDAR VALLEY - ST. PETER

PUMPAGE TEST		TEST 1	TEST 2
HOURS	:	4 HRS.	----
RATE (GPM)	:	1800 GPM	----
PUMPING LEVEL	:	46 FT.	----

GEOLOGIC LOG

WELL DRILLER'S DESCRIPTION					INTERPRETATION
DEPTH (FEET) FROM	TO	LITHOLOGY	COLOR	HARD-NESS	STRATIGRAPHIC UNIT
0	3	TOP SOIL	BLACK	SOFT	RECENT
3	16	CLAY	YELLOW	SOFT	PLEISTOCENE
16	45	CLAY	BLUE	SOFT	PLEISTOCENE
45	55	GRAVEL	------	SOFT	PLEISTOCENE
55	80	CLAY	BLUE	SOFT	PLEISTOCENE
80	88	SAND	------	SOFT	PLEISTOCENE
88	98	CLAY & SAND	------	SOFT	PLEISTOCENE
98	117	CLAY	BLUE	MED	PLEISTOCENE
117	126	CLAY STICKY	BLUE	SOFT	PLEISTOCENE
126	132	SHALE	GRAY	SOFT	CEDAR VALLEY
132	165	LIMESTONE	WHITE	SOFT	CEDAR VALLEY
165	185	LIMESTONE	GRAY	MED	CEDAR VALLEY
185	190	SHALE	GREEN	MED	CEDAR VALLEY
190	225	LIMESTONE	LT.BROWN	HARD	CEDAR VALLEY
225	380	LIMESTONE	GRAY	HARD	CEDAR VALLEY
380	430	LIMESTONE	DARK	HARD	CEDAR VALLEY
430	450	BROKEN LIMESTONE	------	MED	MAQUOKETA
450	505	LIMESTONE & SHALE LAYERS	BROWN	SOFT	MAQUOKETA
505	580	LIMESTONE	LT.BROWN	MED	GALENA
580	640	LIMESTONE	GRAY	HARD	GALENA
640	730	LIMESTONE & SOME SHALE	------	HARD	GALENA
730	800	SHALE	GREEN	------	DECORAH
800	815	LIMESTONE	GRAY	------	PLATTEVILLE
815	830	SHALE & SANDSTONE	------	------	GLENWOOD
830	940	SANDSTONE	------	------	ST. PETER
940	945	LIMESTONE & SHALE	------	------	PRAIRIE DU CHIEN

* 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.

WATER WELL CONSTRUCTION

In Freeborn 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.

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.

DATA BASE MAP

By

John M. Rongstad and Quinto J. Lotti

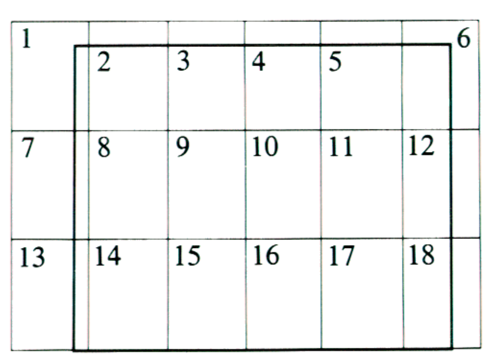
1991

The Data Base Map shows the location, distribution, and type of subsurface data used to develop this atlas. 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.

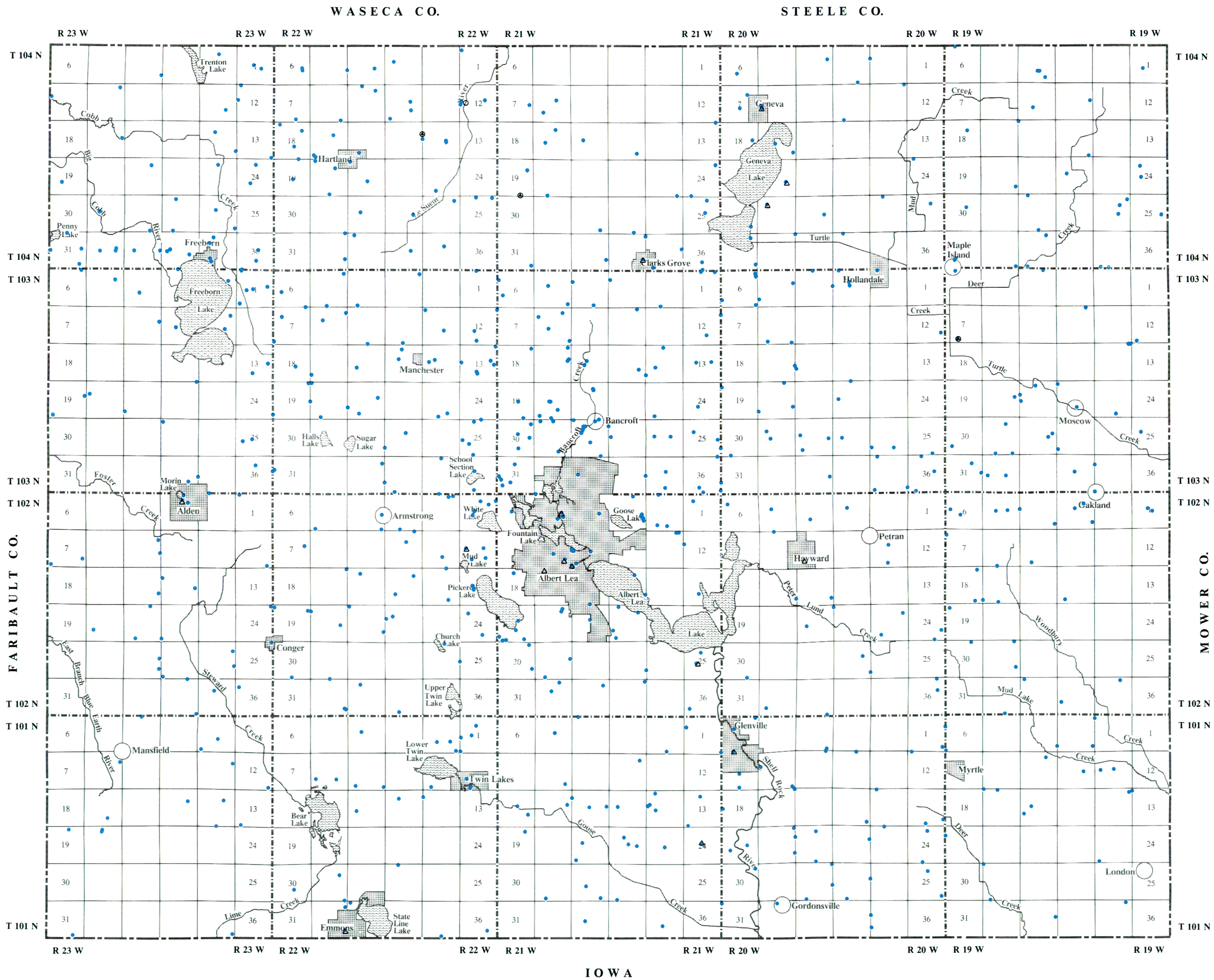
The subsurface data used to develop this atlas is a compilation of all water well drillers' logs, geophysical logs, and cutting sample logs that are currently available in the files of the Minnesota State Geological Survey. The water well drillers' logs contain the water well contractor's description 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, and the clean sandstone and carbonate units occupy areas of lowest gamma-ray values.



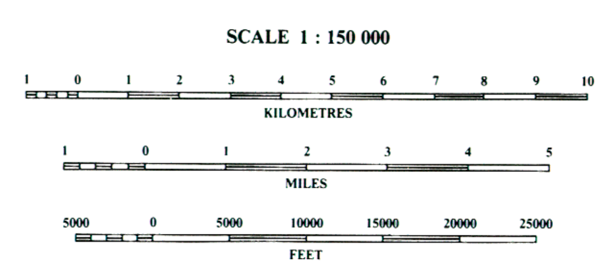
INDEX TO U.S. GEOLOGICAL SURVEY 1 : 24 000 - SCALE TOPOGRAPHIC MAPS

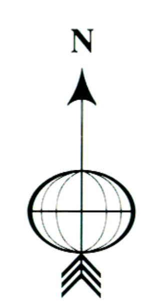
1. Matawan
2. Freeborn
3. Hartland
4. Ellendale
5. Hollandale
6. Blooming Prairie
7. Wells
8. Alden
9. Albert Lea W
10. Albert Lea E
11. Hayward
12. Austin W
13. Kiester
14. Conger
15. Emmons
16. Glenville
17. Myrtle
18. London

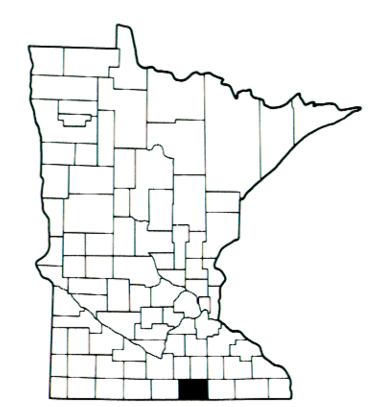


EXPLANATION

- • Record of water-well construction
- ○ Borehole (geophysical log)
- △ Cutting samples
- ⊛ Cutting samples and geophysical log







LOCATION DIAGRAM

BEDROCK GEOLOGY

GEOLOGIC HISTORY

The bedrock that underlies Freeborn County is 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 south.

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).

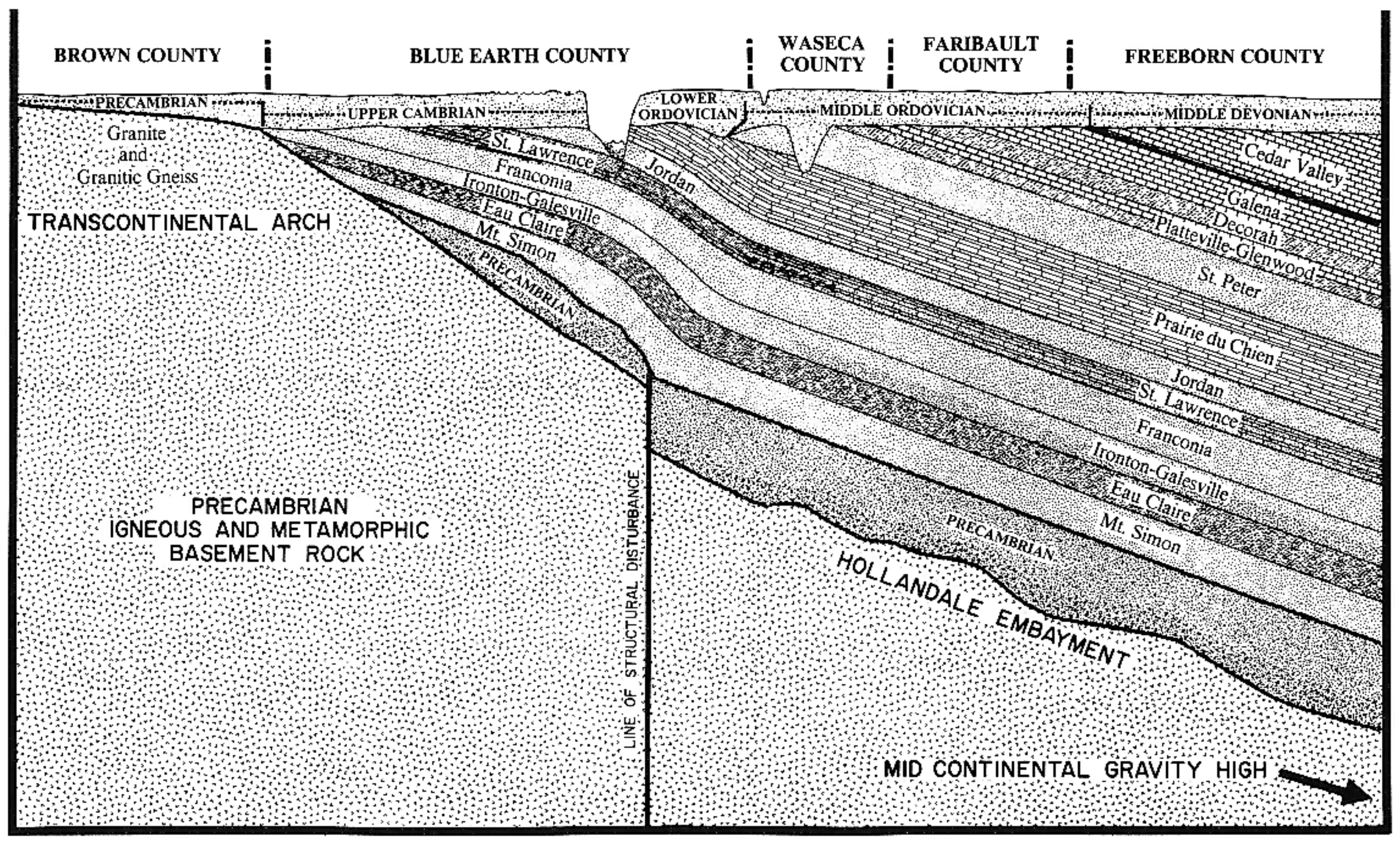


FIGURE 2. Highly generalized cross section showing the variation of subsurface conditions along a line extending from Brown County to Freeborn County Minnesota. The above diagram illustrates the lateral variations and distribution of sediments in the Hollandale Embayment. The geologic structure is much 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.

BEDROCK UNITS

The following descriptions of the bedrock units that underlie Freeborn 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-- is the lowest unit of bedrock presented in the atlas. Its thickness is unknown but probably attains several hundred feet. The Mt. Simon is usually characterized as a medium- to coarse-grained quartzose sandstone, however, in Freeborn County the well drillers' data for the Mt. Simon is sparse. The base of the Mt. Simon marks a major erosional surface with the underlying Precambrian age Hinckley sandstone. The Mt. Simon sandstone marks the advance of the Late Cambrian sea into southern Minnesota.

EAU CLAIRE FORMATION-- may exceed 100 feet in thickness. 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-- exceeds 60 feet in thickness, is generally characterized as a medium- to coarse-grained quartz sandstone. The Ironton and Galesville sandstones are classified as separate bedrock formations; however, both sandstone units are sources of groundwater. For the purpose of this study, the Ironton and Galesville sandstones are treated as a single geologic unit and for convenience called the Ironton-Galesville sandstone. The Ironton-Galesville sandstone may indicate the return to a higher energy nearshore or beach environment of sedimentation.

FRANCONIA FORMATION-- is generally about 120 feet thick. The Franconia is commonly characterized as a fine-grained, glauconitic sandstone. The upper part of the Franconia Formation may contain shale and dolomitic layers that are similar to those found in the overlying St.Lawrence Formation. The fine-grained glauconitic sandstone suggests a low-energy sedimentary environment. Glauconite forms on the sea floor in oxygen-poor water where the rate of sedimentation is very slow.

ST. LAWRENCE FORMATION-- is generally about 80 feet thick. The St. Lawrence may contain several rock types including dolomite, siltstone, shale, sandstone, and glauconite. It is usually characterized by layers of shale, siltstone, and dolomite. The dolomitic units of the St. Lawrence Formation would signify a low energy depositional environment; however, the interbedded clay, silt, and sand indicates an environment with fluctuating conditions.

JORDAN FORMATION-- is generally about 80 feet thick. The Jordan Formation is characterized as a medium- to coarse-grained quartzose sandstone. The base of the Jordan sandstone may contain minor amounts of shale. The Jordan sandstone indicates the return to a high-energy, nearshore sedimentary environment, perhaps a beach.

PRAIRIE DU CHIEN GROUP-- has been measured as thick as 350 feet. The Prairie du Chien consists primarily of dolomite and sandy dolomite with some thin shale layers and a few units of quartz sandstone. The massive nature of the Prairie du Chien dolomite indicates a low-energy sedimentary environment where carbonate deposition was the dominant rock forming process. Carbonate deposits were terminated when the shallow sea retreated from the continent, exposing the Prairie du Chien dolomite to the forces of erosion. Consequently, the top of the Prairie du Chien Group represents a major erosional surface and its thickness may vary greatly from place to place.

ST. PETER FORMATION-- is generally about 80 to 110 feet thick. The St. Peter Formation is primarily a medium-grained pure quartz sandstone. The lower part of the St. Peter may contain beds with varying amounts of silt or shale. The St. Peter sandstone marks the advance of the Middle Ordovician sea into southern Minnesota. The sandstone was deposited along the turbulent shoreline of the advancing sea. The St. Peter sandstone was deposited on top of the Prairie du Chien dolomite and its base marks a major erosional unconformity.

PLATTEVILLE-GLENWOOD FORMATIONS-- are generally about 35 feet thick. The Platteville and Glenwood Formations are classified as separate bedrock formations based on major differences in lithologic characteristics. Each of the formations is very thin and difficult to separate at the scale used in atlas map production. For the purpose of this study, the Platteville and Glenwood formations are treated as a single geologic unit and for convenience called the Platteville-Glenwood Formations. The Glenwood Formation is a 15 to 20 foot thick shaley unit that directly overlies the St. Peter sandstone. The Glenwood shale represents a low energy sedimentary environment, offshore from the beaches where the St. Peter sandstone was being deposited. The Platteville Formation is a 20 to 30 foot thick bed of limestone that contains thin shale partings at its top and base. The Platteville limestone represents a more seaward sedimentary environment of the Glenwood shale. The Platteville was probably deposited in a shallow marine environment, similar to the modern Bahama bank.

DECORAH FORMATION-- about 50 to 60 feet thick. The Decorah is primarily a uniform bed of gray-green shale. The top and bottom of the Decorah shale consists of alternating layers of limestone and shale that mark the transition between the underlying Platteville limestone and overlying Galena limestones. The Decorah shale indicates a quiet water sedimentary environment, probably shallow water tidal flats.

GALENA GROUP-- recorded as thick as 300 feet. The Galena is a carbonate unit that consists mostly of limestone and dolomite with some silty, sandy, and shaley units. During the Galena time period, carbonate rock forming processes dominated the sedimentary environment.

MAQUOKETA GROUP--may be as thick as 80 feet. The Maquoketa Group is a carbonate unit, composed of limestone and dolomite that is often shaley or contains shale layers. The high shale content of the Maquoketa Group distinguishes it from the underlying Galena or the overlying Cedar Valley groups in water well drillers' logs.

CEDAR VALLEY GROUP--may exceed 300 feet in thickness. The Cedar Valley is primarily a carbonate rock, fine-grained limestone or dolomite with some shale and shaley units. The Cedar Valley limestone was deposited during the Devonian age on top of Ordovician age Maquoketa and Galena limestones. Its base marks a major erosional unconformity with the underlying bedrock units..

AQUIFER CHARACTERISTICS OF SEDIMENTARY ROCK TYPES

INTRODUCTION

The most favorable geological structure for groundwater accumulation is found in stratified sedimentary rock like that underlying Freeborn 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. The lithology of the individual sedimentary bedrock units is nearly uniform throughout Freeborn County due to the continuous nature of the geological processes that formed them.

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

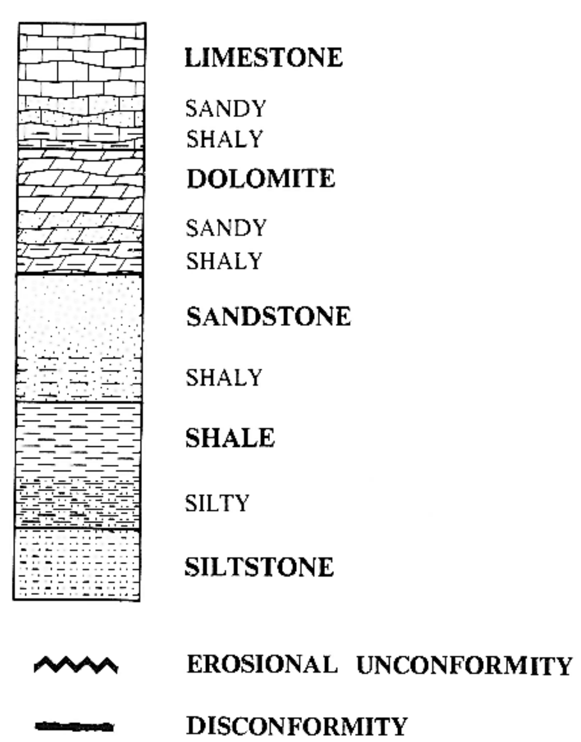
The carbonate aquifers are mostly composed of crystalline limestone and dolomite, with some quartz sand and shaley units. In carbonate rock, fractures along bedding planes and pores within the rock provide the primary routes for groundwater flow. The permeability of carbonate rocks depends upon their 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 which 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

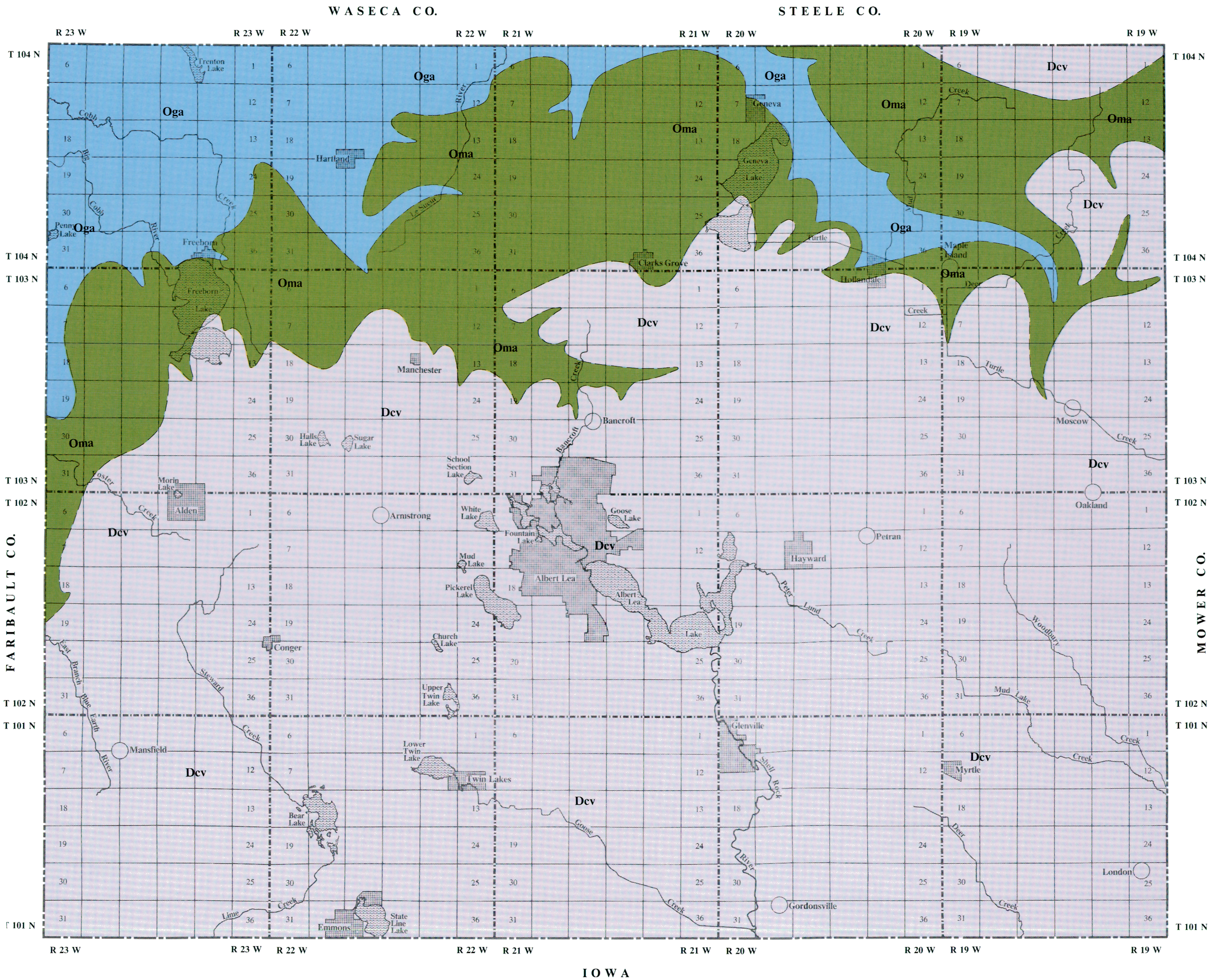
Shale and siltstone are composed of fine-grained particles that constitute the finest of the clastic sedimentary materials. The effective porosity of shale and siltstone result in a much more reduced permeability than that found in sandstone and carbonate bedrock units. Consequently, siltstone and shale 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.

EXPLANATION



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
MIDDLE DEVONIAN	CEDAR VALLEY GROUP	Dcv		Occurs only as present bedrock surface; recorded as thick as 300 feet	Carbonate rock, fine-grained; white, light-gray, and yellow; limestone, dolomitic limestone and shale partings. Wherever present its top forms the bedrock surface; its base marks a major erosional unconformity.	CEDAR VALLEY - MAQUOKETA - GALENA AQUIFER SYSTEM	CEDAR VALLEY LIMESTONE	Carbonate rock; comes in direct hydrogeologic connection with surficial glacial deposits. Wide zones of fractures, crevices, and solution cavities yield moderate to large quantities of water for domestic, commercial, and municipal supplies. Its base marks a major erosional unconformity.
MIDDLE ORDOVICIAN	MAQUOKETA GROUP	Oma		Uncertain; as thick as 80 feet	Carbonate rock, fine-grained; limestone, shaly-limestone and shale. Its base is gradational.		MAQUOKETA LIMESTONE	Carbonate rock; comes in direct hydrogeologic connection with surficial glacial deposits. Yields water for domestic and commercial use.
	GALENA GROUP	Oga		Upper contact is unconformal; recorded as thick as 300 feet	Carbonate rock, fine-grained; white, yellow, and yellowish gray; primarily limestone and dolomitic limestone, may contain some sandy, shaly or silty beds. Contact with overlying Maquoketa is gradational; elsewhere its top marks a major erosional unconformity.		GALENA LIMESTONE	Carbonate rock; comes in direct hydrogeologic connection with surficial glacial deposits. Yields water through solution cavities, fracture zones, and crevices. Provides water for domestic, commercial, and municipal supplies.
	DECORAH FORMATION	Odc		50 to 60 feet	Shale; greenish gray; uniform throughout; may include carbonate beds at the base.	CONFINING LAYER	DECORAH SHALE	Shales are generally not water yielding; act as confining bed at the base of the Cedar Valley-Maquoketa-Galena aquifer system.
	PLATTEVILLE & GLENWOOD FORMATIONS	Opg		25 to 30 feet	Carbonate rock over shale; data sparse.	NOT AN AQUIFER	PLATTEVILLE & GLENWOOD	Data sparse; generally considered part of the Decorah confining layer.
	ST. PETER FORMATION	Osp		80 to 100 feet	Quartzose sandstone; white or yellow; may be thin shale or siltstone beds in lower part of formation. Basal contact with Prairie du Chien is unconformal.	ST. PETER - PRAIRIE DU CHIEN - JORDAN AQUIFER SYSTEM	ST. PETER SANDSTONE	Highly permeable quartzose sandstone; has no direct hydrogeologic connection with surface and shallow groundwater systems. Yields large volumes of water for commercial, municipal and industrial use.
LOWER ORDOVICIAN	PRAIRIE DU CHIEN GROUP	Opc		Upper contact is unconformal; recorded as thick as 350 feet	Data sparse; mainly dolomite and sandy dolomite with some shale. The top of the Prairie du Chien marks a major erosional unconformity.		PRAIRIE DU CHIEN DOLOMITE	Carbonate rock, dolomite; data sparse; has no direct hydrogeologic connection with surface and shallow groundwater systems. Yields water from wide zones of fractures and crevices. Contributes water for commercial, municipal and industrial use.
UPPER CAMBRIAN	JORDAN FORMATION	Cj		Uncertain; about 80 feet	Quartzose sandstone; data sparse. Poorly cemented sandstone.		JORDAN SANDSTONE	Highly permeable quartzose sandstone; has no direct hydrogeologic contact with surface and shallow groundwater systems. Contributes water for municipal and industrial supplies.
	ST.LAWRENCE FORMATION	Csl		Uncertain; about 80 feet	Data sparse; primarily dolomite, siltstone, and shale. Transition with the underlying Franconia may be gradational.	CONFINING LAYER	ST.LAWRENCE DOLOMITE SILTSTONE	Rocks of low permeability; act as confining bed at the base of the St. Peter-Prairie du Chien-Jordan aquifer system.
	FRANCONIA FORMATION	Cfn		Uncertain; about 120 feet	Data sparse; mainly sandstone, glauconitic. Transition with overlying St. Lawrence is gradational.	FRANCONIA - IRONTON - GALESVILLE AQUIFER SYSTEM	FRANCONIA SANDSTONE	Franconia sandstone; data sparse; has no direct hydrogeologic connection with surface and shallow groundwater systems. Contributes water for commercial, municipal and industrial use.
	IRONTON & GALESVILLE FORMATIONS	Cig		Uncertain; about 60 feet	Quartzose sandstone; data sparse; poorly cemented sandstone.		IRONTON & GALESVILLE SANDSTONE	Highly permeable quartzose sandstone; has no direct hydrogeologic contact with surface and shallow groundwater systems. Contributes water for municipal and industrial supplies.
	EAU CLAIRE FORMATION	Cec		Data sparse, exceeds 100 feet	Data sparse; primarily shale and siltstone. Transition with the underlying Mt. Simon may be 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		Unknown; probably attains several hundred feet	Data sparse; primarily quartzose sandstone; its base marks a major erosional unconformity.	MT. SIMON - HINCKLEY AQUIFER SYSTEM	MT. SIMON SANDSTONE	Quartzose sandstone, data sparse; has no direct hydrogeologic contact with surface and shallow groundwater systems. Aquifer use is minimal.
PRECAMBRIAN	HINCKLEY & FOND DU LAC FORMATIONS	Pc		Unknown; may exceed 1000 feet	Driller data unavailable; other sources suggest mainly quartzose sandstone and shale. Its base marks a major disconformity.		HINCKLEY SANDSTONE	Data absent; water contribution for aquifer use is unknown.
	METAMORPHIC IGNEOUS	Pc		Unknown; several miles	Igneous and metamorphic rocks; undifferentiated.	BASEMENT ROCK	NOT AN AQUIFER	Not water bearing rock; represents the base of all aquifers and aquifer systems.

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). The descriptions of aquifer characteristics for the various bedrock units were derived from the hydrologic portions of well drillers' logs.



BEDROCK GEOLOGY

By

John M. Rongstad and Paul A. Vogel

1991

BEDROCK GEOLOGY MAP

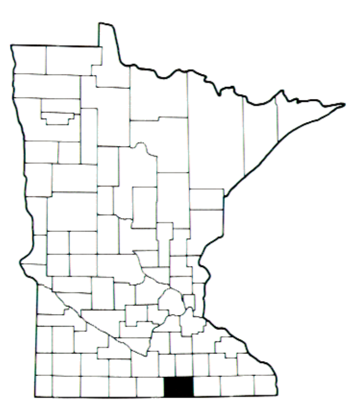
INTRODUCTION

In Freeborn County glacial deposits completely conceal the bedrock surface; thus, the nature of the bedrock surface is known entirely from subsurface data. The Geologic Map shows the distribution of bedrock units, as they would appear, if the bedrock were exposed throughout Freeborn County. The geologic boundary lines that separate individual bedrock units describe a change from one limestone group to another limestone group.

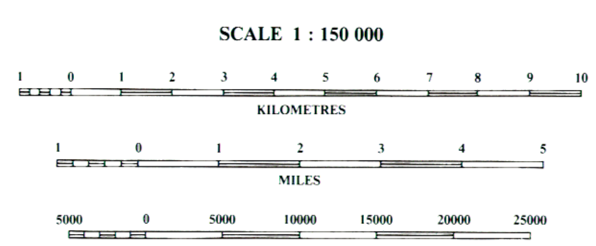
METHOD OF CONSTRUCTION

Several structural considerations controlled the construction of the geologic map. Among these were the character of the eroded bedrock surface and the relative thickness of individual bedrock units. The positioning of geologic boundary lines was accomplished by directly comparing the Bedrock Topography Map (Page 7) with the Decorah Structure Map (Page 11) and the geologic cross sections (Pages 13 thru 17).

The positioning of the geologic boundary line that separates the Galena and Maquoketa limestones was determined by applying a maximum thickness limit to the Galena limestone. The thickness limit for the Galena was projected onto the Decorah Structure Map and the Bedrock Topography Map was used as a guide for positioning the line. The boundary line that defines the extent of the Cedar Valley limestone was positioned through inferences made from the geologic cross sections that were prepared for this atlas. The boundary line is very generalized due to the nature of the unconformity that separates the Cedar Valley limestone from the underlying Maquoketa and Galena limestones. It is very difficult to distinguish the three limestone groups from information presented in water well drillers' logs.



LOCATION DIAGRAM



STRATIGRAPHIC CLASSIFICATION				DESCRIPTION OF ROCK UNITS	
SYSTEM /SERIES	GROUP OR FORMATION NAME	MAP SYMBOL	GRAPHIC COLUMN	THICKNESS	DOMINANT ROCK TYPES
MIDDLE DEVONIAN	CEDAR VALLEY GROUP	Dcv		Occurs only as present bedrock surface; recorded as thick as 300 feet	Carbonate rock, fine-grained; white, light-gray, and yellow; limestone, dolomitic limestone and shale partings. Wherever present its top forms the bedrock surface; its base marks a major erosional unconformity.
MIDDLE ORDOVICIAN	MAQUOKETA GROUP	Oma		Uncertain; as thick as 80 feet	Carbonate rock, fine-grained; limestone, shaly-limestone and shale. Its base is gradational.
	GALENA GROUP	Oga		Upper contact is unconformal; recorded as thick as 300 feet	Carbonate rock, fine-grained; white, yellow, and yellowish gray; primarily limestone and dolomitic limestone, may contain some sandy, shaly or silty beds. Contact with overlying Maquoketa is gradational; elsewhere its top marks a major erosional unconformity.

BEDROCK TOPOGRAPHY

By

John M. Rongstad and Jesse D. Wohlfeil

1991

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 Freeborn County the bedrock surface is completely covered by glacial deposits; thus, the nature of the bedrock surface is known entirely from subsurface data.

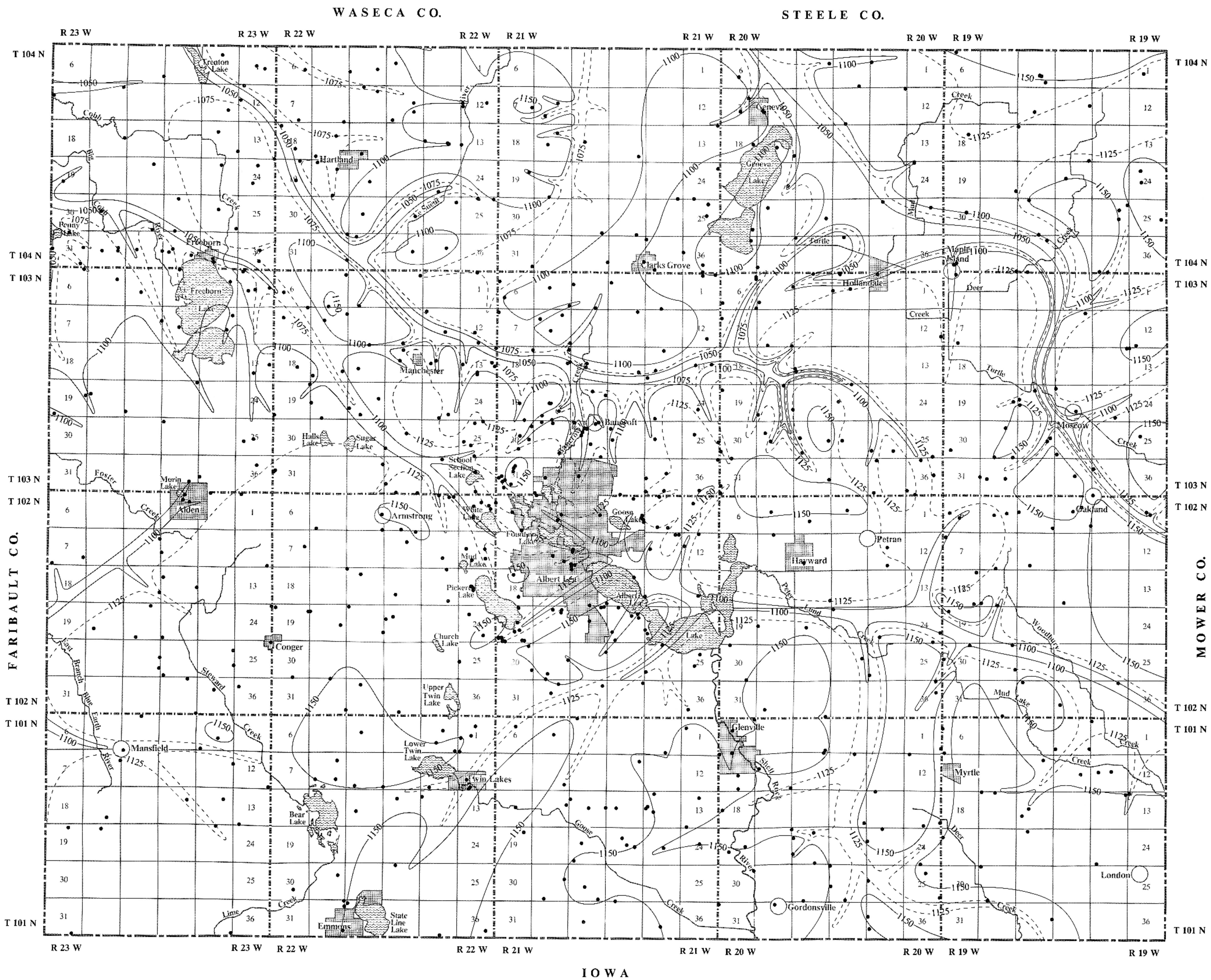
The configuration of the bedrock surface is a product of preglacial, glacial, and interglacial erosion of the bedrock strata. Preglacial erosion produced bedrock valley cuts that were excavated by river and stream erosion prior to continental glaciation, which began about 2 million years ago. Glacial 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. 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. This information was acquired from water well drillers' logs and is taken to be reliable. Where the data is dense, the map is more detailed; where the data is sparse, the map is more generalized. The location and distribution of these data points are shown on the Bedrock Topography Map.

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 and 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. In Freeborn county the bedrock surface is composed almost entirely of limestone or dolomite. Resistant rock types such as limestone or dolomite tend to form plateaus and steep valley walls.



EXPLANATION

Topographic contours in feet above sea level.

1150

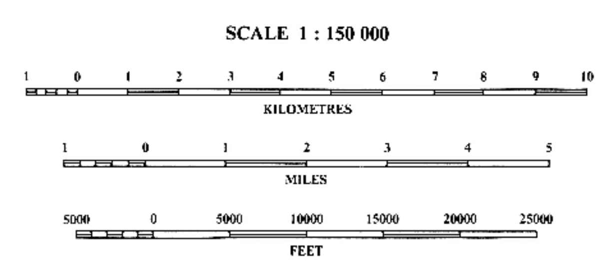
Contour interval 50 feet

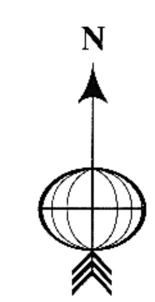
1075

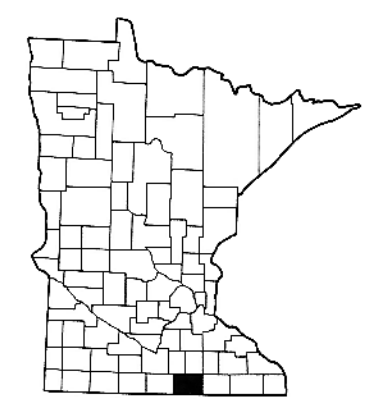
Contour interval 25 feet

•

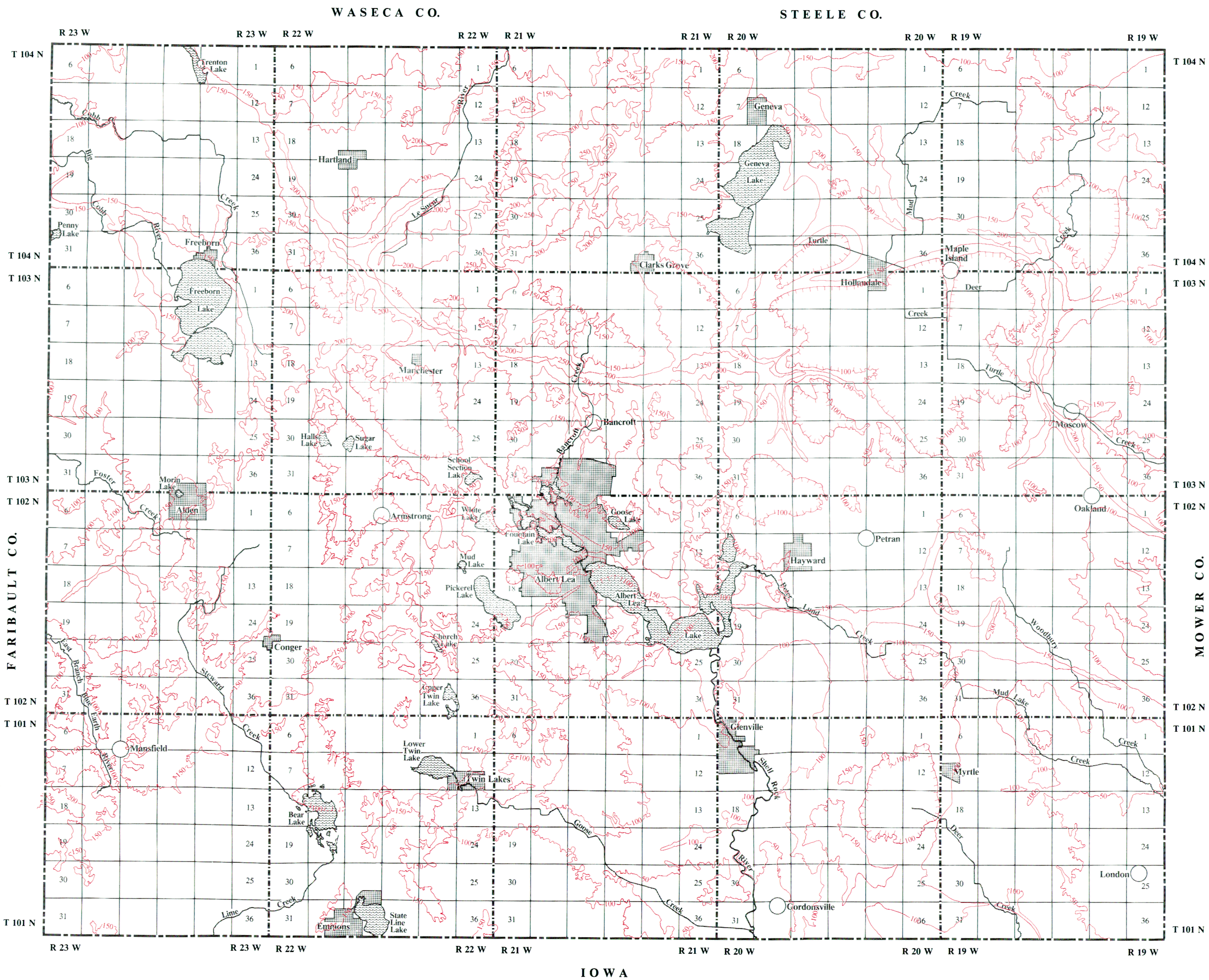
Datum Point

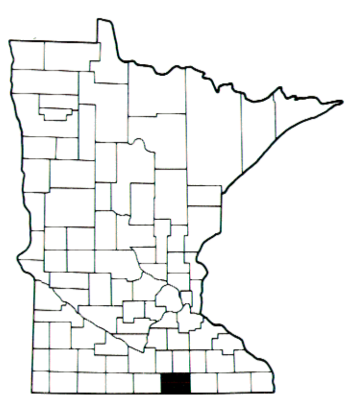




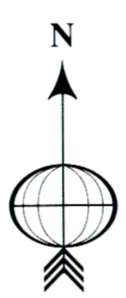


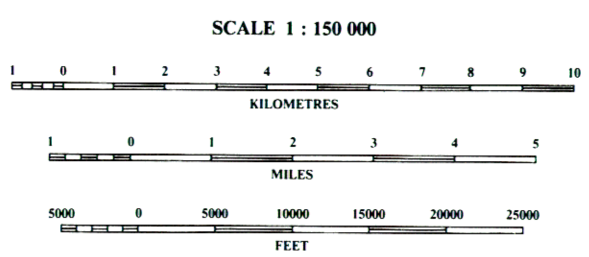
LOCATION DIAGRAM





LOCATION DIAGRAM





EXPLANATION

Isopach lines connect points of equal thickness
Contour interval 50 feet

Hachures show closed areas of less thickness

DEPTH TO BEDROCK

By

John M. Rongstad and Jesse D. Wohlfeil

1991

INTRODUCTION

The characteristics of the present land surface in Freeborn 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 Freeborn County during the last million years. The glacial deposits overlie the bedrock surface and range in thickness from less than 50 feet to over 200 feet The nature of thickening and thinning is largely influenced by buried bedrock valley cuts and bedrock uplands.

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 drift deposits. Where the elevation of the bedrock surface is low, as within major bedrock valleys, the glacial deposits are thick. Where the bedrock surface is high, the drift deposits are generally thin. In the vicinity of buried bedrock valleys, the thickness of the glacial deposits may change abruptly over short distances. Hills and valleys on the present land surface may present small 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 shown on page 7. The Bedrock Topography Map 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 drift thickness was determined at any contour intersection by subtracting the lower value (bedrock elevation) from the higher value (surface elevation). The isopach lines were drawn to agree with the difference in elevation between the two maps.

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 bedrock valleys while thinner glacial deposits correspond to bedrock upland areas. 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 STRUCTURE JORDAN FORMATION

By

John M. Rongstad and Paul A. Vogel

1991

JORDAN STRUCTURE MAP

INTRODUCTION

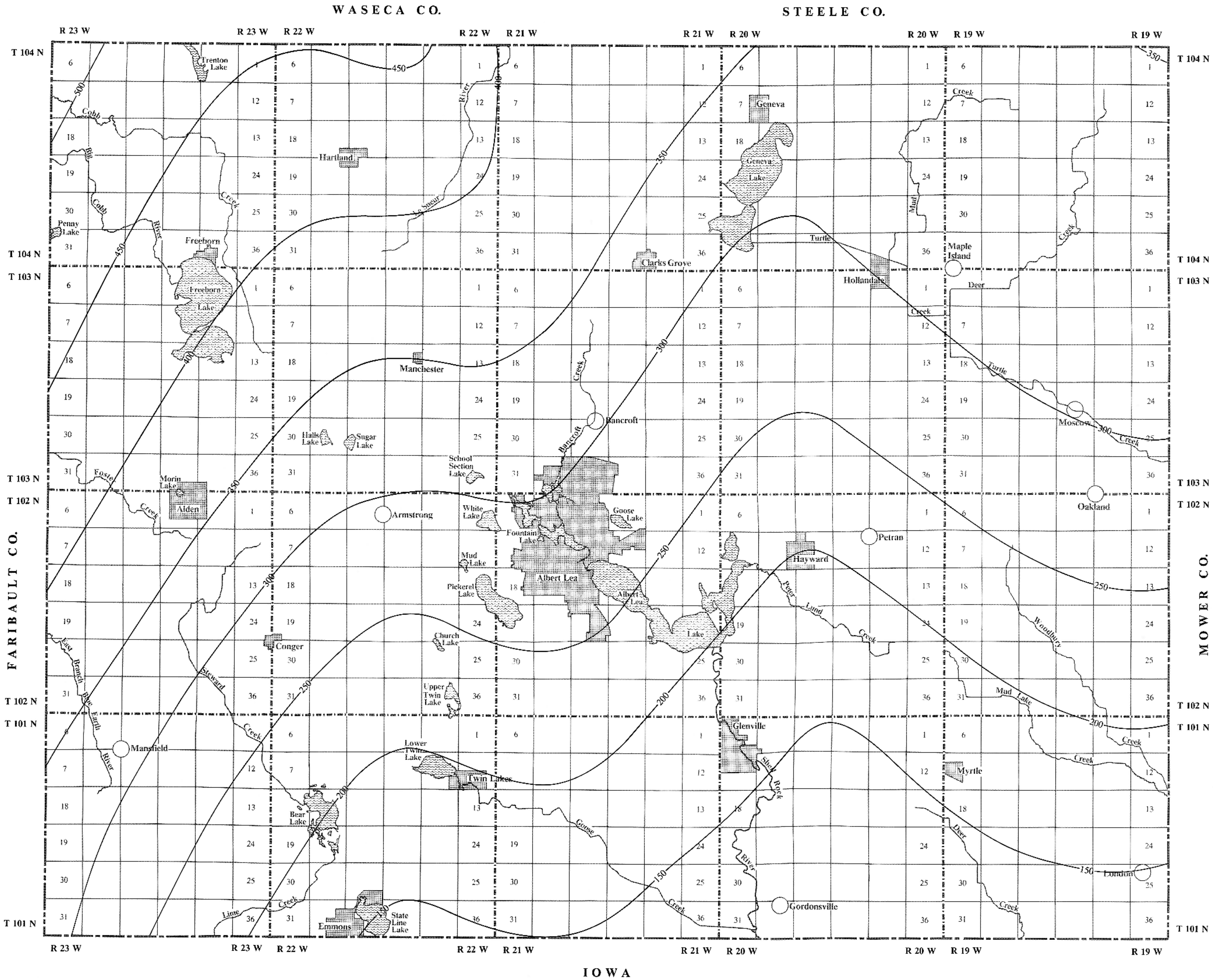
A structure map was constructed for the top of the Jordan Formation because the available data would support a generalized redition of the uneroded top of the Jordan sandstone. The Jordan structure contours were drawn solely on the basis of data supplied by the geophysical logs and cutting sample logs that are shown on the Data Base Map (Page 3). The structure map was contoured to convey the probable forms of any geologic structures that might be suggested by the data.

The structure map for the top of the Jordan Formation gives a complete view of the bedrock structure in Freeborn County. The bedrock that underlies Freeborn County was deposited in sheet-like layers under tectonically stable geologic conditions over a wide area in southern Minnesota. In Freeborn County, the bedrock structure generally dips toward the south-southeast and the center of the basin structure called the Hollandale Embayment. The Hollandale Embayment is the main regional stuctural feature in which the bedrock layers were deposited. Localized dip discordance occurs in the form of gentle anticlinal and synclinal structures. Deviations in the general direction of dip can be mapped only where subsurface information is adequate.

METHOD OF CONSTRUCTION

The Jordan structure contours were drawn solely on the basis of data contained in the geophysical logs and cutting sample logs shown on the Data Base Map (Page 3). The structure map was contoured to convey the probable forms of any geologic structures that might be suggested by the data. The positioning of the structure contours was influenced by Jordan Structure Maps that were constructed for the Faribault, Waseca, and Steele County geologic atlases. The top of the Jordan sandstone has not been exposed to the forces of erosion anywhere in Freeborn County.

The Jordan Structure Map was designed to act as a regional mapping horizon for the bedrock in Freeborn County. The structure map was used as a guide from which the top of the Jordan Formation was plotted onto each of the Geologic Cross Sections (Pages 13 - 17).

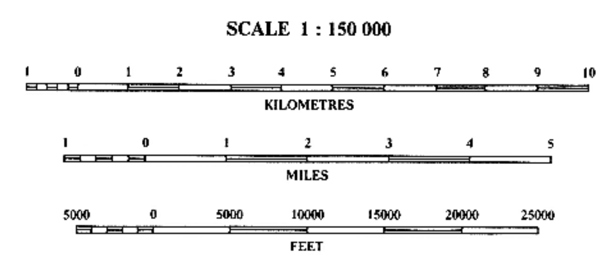


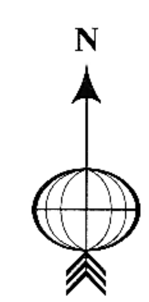
EXPLANATION

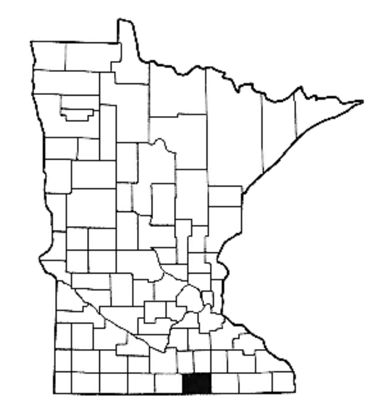
Structure contours in feet above sea level.

300

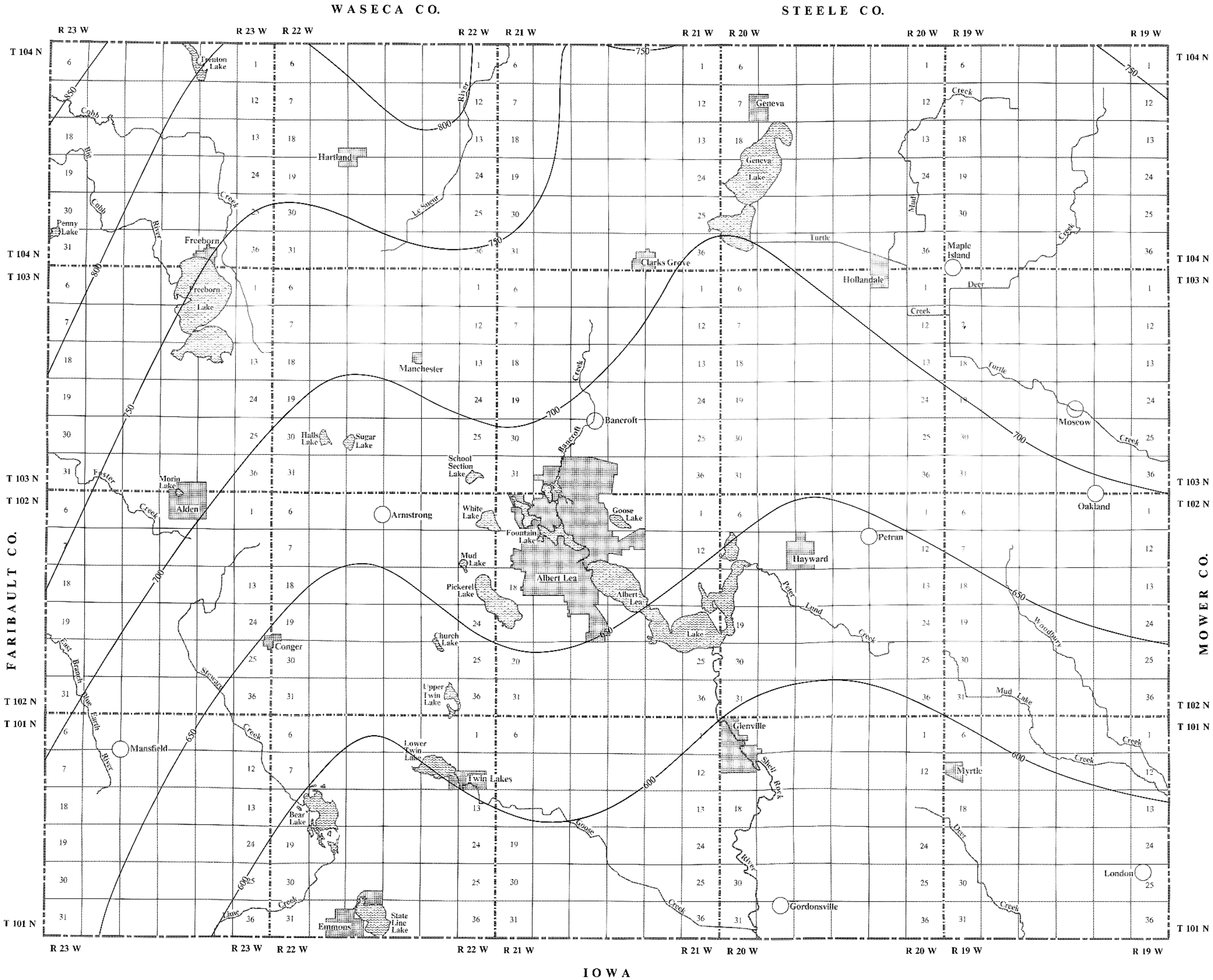
Contour interval 50 feet

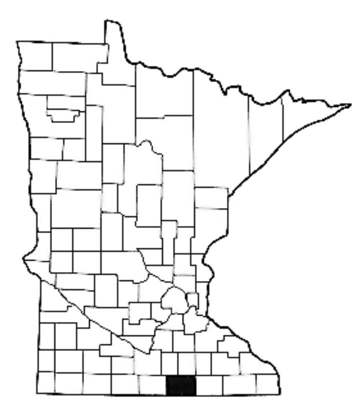






LOCATION DIAGRAM





LOCATION DIAGRAM

N

SCALE 1 : 150 000

KILOMETRES

MILES

FEET

EXPLANATION

Structure contours in feet above sea level.

650

Contour interval 50 feet

BEDROCK STRUCTURE ST. PETER FORMATION

By

John M. Rongstad and Paul A. Vogel

1991

ST. PETER STRUCTURE MAP

INTRODUCTION

The St. Peter Structure Map describes the present configuration and extent of the St. Peter sandstone in Freeborn County. A structure map was created for the top of the St.Peter Formation because of the abundance of available data, because of its importance as a regional aquifer, and because the contact between the St. Peter sandstone and the overlying Glenwood shale is usually abrupt and easily recognized in the geologic portions of water well drillers' logs.

The St.Peter sandstone was deposited under tectonically stable geologic conditions over a wide area in southern Minnesota. Where present, the St. Peter sandstone is nearly uniform due to the continuous nature of the geologic processes that formed it. The St. Peter sandstone forms a regional aquifer and is an important source of groundwater supplies for the city of Albert Lea.

The St. Peter Structure Map presents a slightly more subdued relief of the bedrock structure than does the Jordan Structure Map. The difference in structural relief may be due to the erosional unconformity that separates the Prairie du Chien dolomite from the overlying St.Peter sandstone. The erosion of the Prairie du Chien may have modified the bedrock surface prior to St. Peter deposition.

METHOD OF CONSTRUCTION

The St. Peter structure contours were drawn solely on the basis of data supplied by geophysical logs and cutting sample logs shown on the Data Base Map (Page 3). The structure map was contoured to convey the probable forms of any geologic structures that might be suggested by the data. The positioning of the structure contours was influenced by the St. Peter Structure Maps that were constructed for Faribault, Waseca, and Steele County geologic atlases.

The St. Peter Structure Map was designed to act as a regional mapping horizon for the bedrock in Freeborn County. The structure map was used as an aid in the interpretation of the geologic portions of water well drillers' logs. The St. Peter Structure Map was also used as a guide from which the top of the St. Peter was plotted onto each Geologic Cross Section (Pages 13 - 17).

BEDROCK STRUCTURE DECORAH FORMATION

By

John M. Rongstad and Paul A. Vogel

1991

DECORAH STRUCTURE MAP

INTRODUCTION

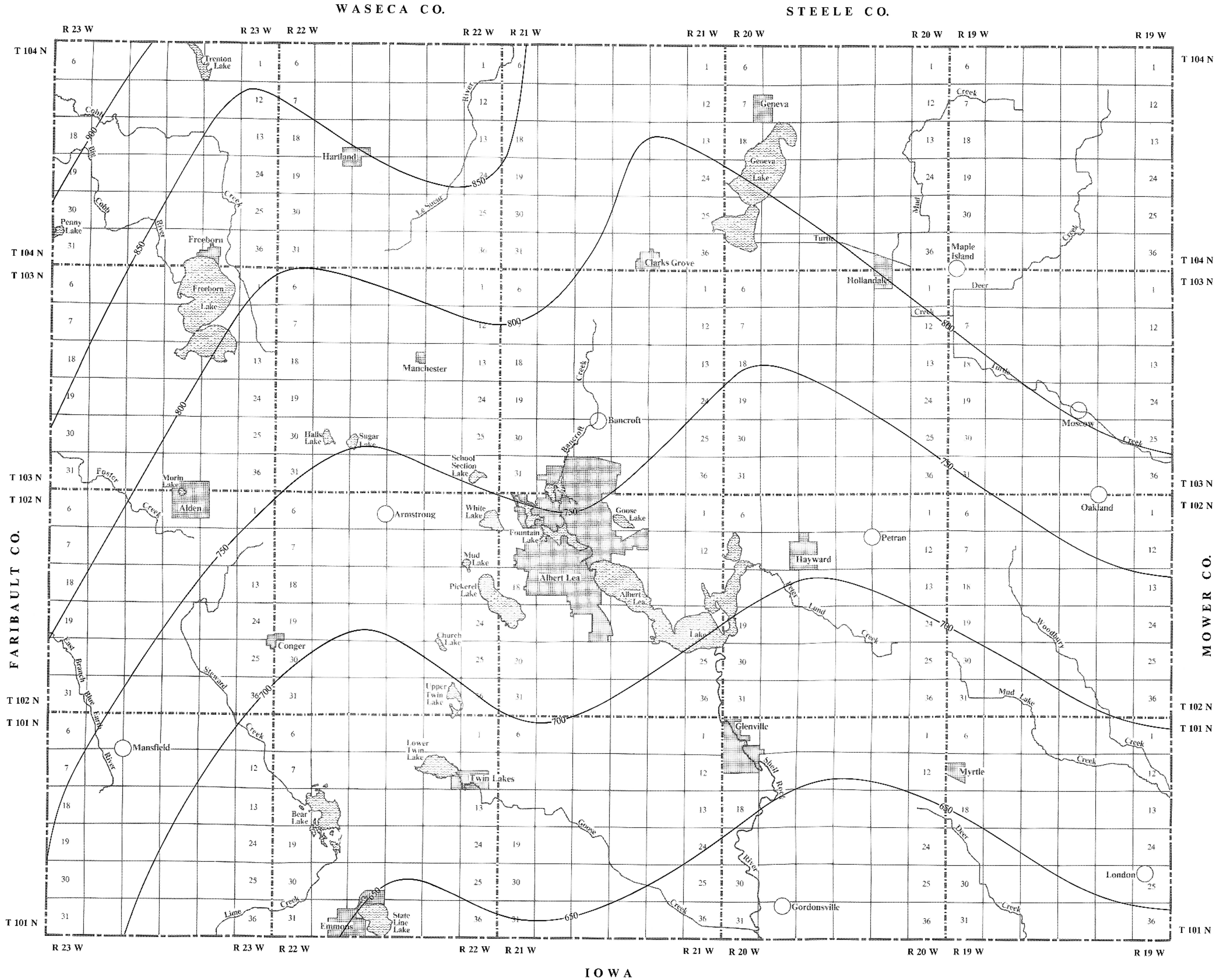
A structure map was constructed for the top of the Decorah Formation because of the abundance of available data, because of its importance as a regional confining layer, and because the contact between the Decorah shale and the overlying Galena limestone is usually abrupt and easily recognized in the geologic portions of water well drillers' logs. The Decorah shale forms a regional confining bed that hydrologically separates the Cedar Valley-Maquoketa-Galena aquifer system from the underlying St. Peter-Prairie du Chien-Jordan aquifer system.

The Decorah Structure Map describes the present configuration and extent of the Decorah shale in Freeborn County. The Decorah Shale was deposited under tectonically stable geologic conditions over a wide area. Contact between the Decorah shale and overlying Galena limestone is usually abrupt. Similarly, the Decorah shale grades quickly into the underlying Platteville limestone.

METHOD OF CONSTRUCTION

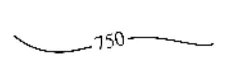
The Decorah structure contours were drawn solely on the basis of data contained in the geophysical logs and cutting sample logs shown on the Data Base Map (Page 3). The structure map was contoured to convey the probable forms of any geologic structures that might be suggested by the data. The positioning of the structure contours was influenced by the Decorah Structure Maps that were constructed for the Faribault, Waseca, and Steele County geologic atlases.

The Decorah Structure Map was designed to act as a regional mapping horizon for the bedrock in Freeborn County. The structure map was used as an aid in the interpretation of the geologic portions of water well drillers' logs. The Decorah Structure Map was also used as a guide from which the top of the Decorah was plotted onto each of the Geologic Cross Sections (Pages 13 - 17).

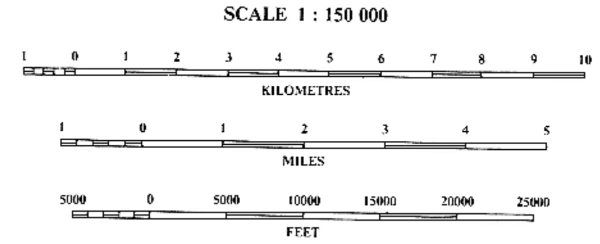


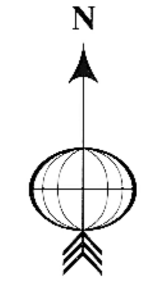
EXPLANATION

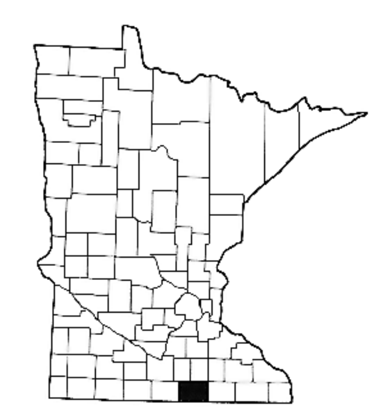
Structure contours in feet above sea level.



Contour interval 50 feet







LOCATION DIAGRAM

GEOLOGIC CROSS SECTIONS

INTRODUCTION

The Geologic Cross Sections in this atlas combine the Surface Topography Map, Bedrock Topography Map, and the Bedrock Structure Maps to develop cross section profiles of Freeborn 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 4). The cross section profiles are arranged as a grid system to provide county wide cross section coverage.

The cross section profiles of Freeborn County are arranged in stacks on pages 13 through 17 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 T-T'). 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.

INDEX TO GEOLOGIC CROSS SECTIONS

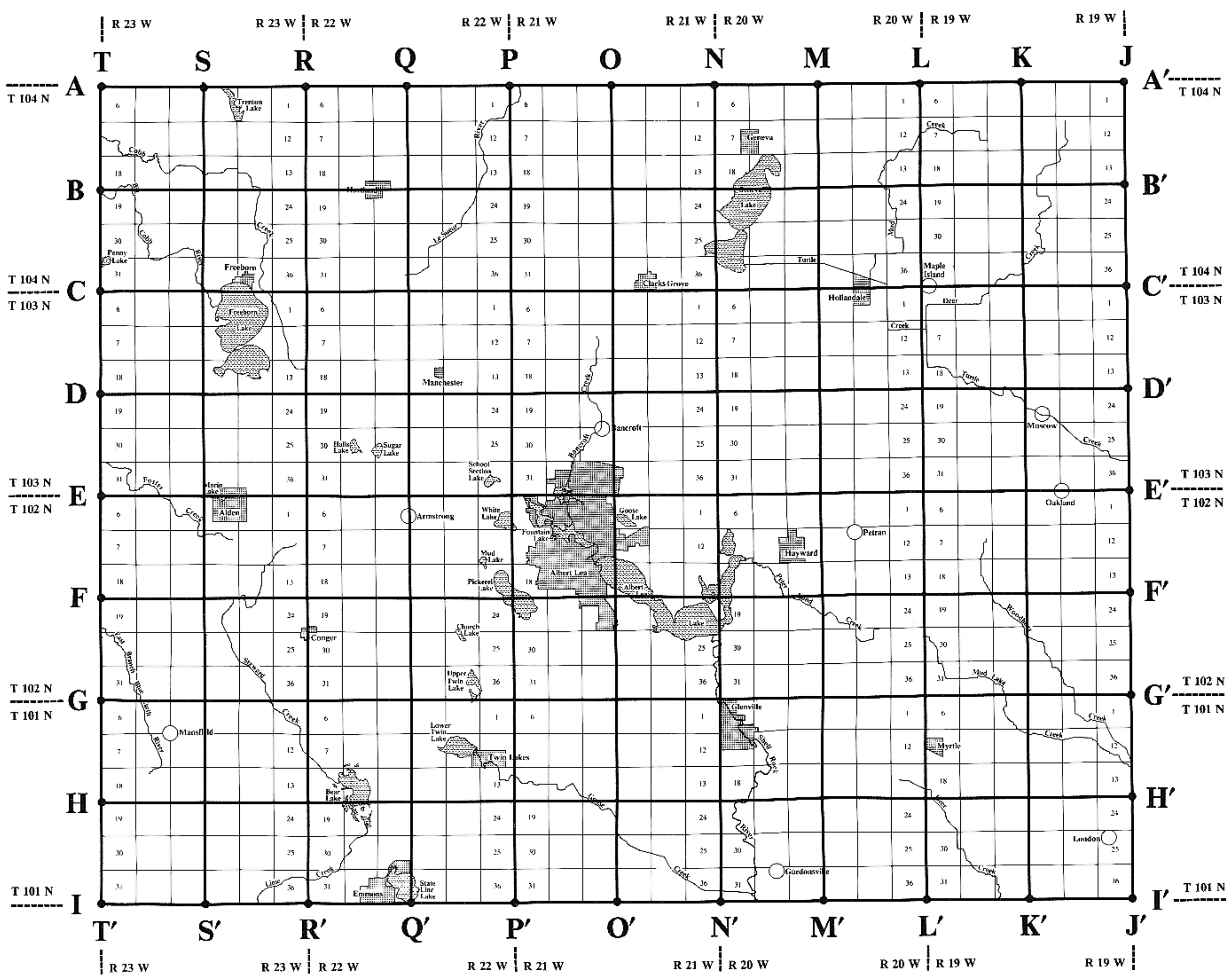


FIGURE 4. The above diagram describes the pattern of cross section profiles that were prepared for the atlas. The cross sections were prepared along Public Land Survey boundary lines: Township, Range, and Section lines.

The cross sections graphically illustrate the relationship between the thickness of glacial deposits and the location of hills and valleys on the land surface and buried bedrock valleys. The cross sections show that thicker glacial deposits are associated with surface uplands and bedrock lowlands while the thinnest glacial deposits occur over bedrock uplands or below surface lowlands. The buried bedrock valleys on the bedrock surface profiles are shown to present comparatively small irregularities in drift thickness.

The cross sections illustrate the relationship between individual bedrock units and bedrock aquifer systems. The four major bedrock aquifer systems and the individual bedrock aquifers that combine to form them are shown on the cross sections. The regional confining layers that separate bedrock aquifer systems have been filled with a distinguishing pattern to make them easy to recognize; the individual bedrock aquifers have been left clear or white.

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 Bedrock Structure Maps. 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 the contact between 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 Bedrock Structure Maps were used as guides to plot profiles for the top of the Decorah, St. Peter, and Jordan formations onto each of the cross sections. The geologic boundary lines for the Decorah, St. Peter, and Jordan formations provided structural reference lines from which the boundary lines of all other bedrock units were located onto the cross section profiles.

The positioning of the geologic boundary line that separates the Galena and Maquoketa limestone was determined by applying a maximum thickness limit to the Galena limestone. The boundary line was located by plotting the maximum thickness of the Galena Group above the top of the Decorah Formation. The thickness limit for the Galena was projected onto the Decorah Structure Map and the Bedrock Topography Map was used as a guide for positioning the line. The boundary line that defines the extent of the Cedar Valley limestone was positioned through inferences made from the available geophysical logs, cutting sample logs, and a few water well drillers' logs. The boundary line is very generalized due to the nature of the unconformity that separates the Cedar Valley limestone from the underlying Maquoketa and Galena limestones. The top of the Platteville-Glenwood Formation was located by plotting its average thickness above the top of the St. Peter Formation. The top of the Prairie du Chien Group was located by plotting the average thickness of the St. Peter Formation below its upper boundary. The boundaries of all other bedrock units were located by projecting the average thicknesses (accumulative) for each of the underlying bedrock units below the top of the Jordan Formation.

GROUNDWATER

The cross sections show the relationship between water producing intervals and bedrock formations. The sandstones and limestones function as aquifers while the shales and siltstones function as aquitards in the sequence of bedrock sedimentary deposits. The bedrock aquifers are shown to extend continuously and uniformly over extended areas beneath Freeborn County.

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 extent of bedrock aquifer materials and their connection with bedrock structure, bedrock topography, bedrock confining layers, and other factors that may control the movement of groundwater.

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.

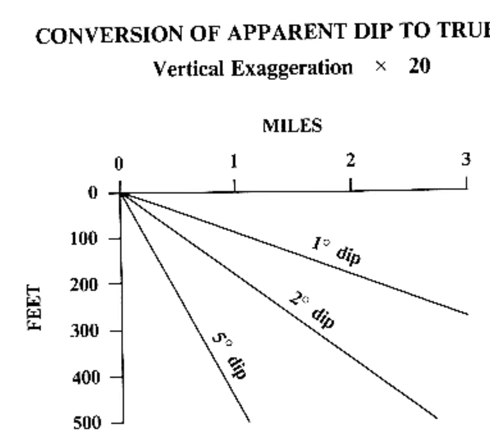


FIGURE 5. The above diagram illustrates the conversion of apparent dip to true dip. One is provided on each page of cross sections. The dip conversion diagram is designed to give the user a mental picture of the relief distortion that is caused by the vertical exaggeration.

GEOLOGIC CROSS SECTIONS A-A′ TO E-E′

EXPLANATION

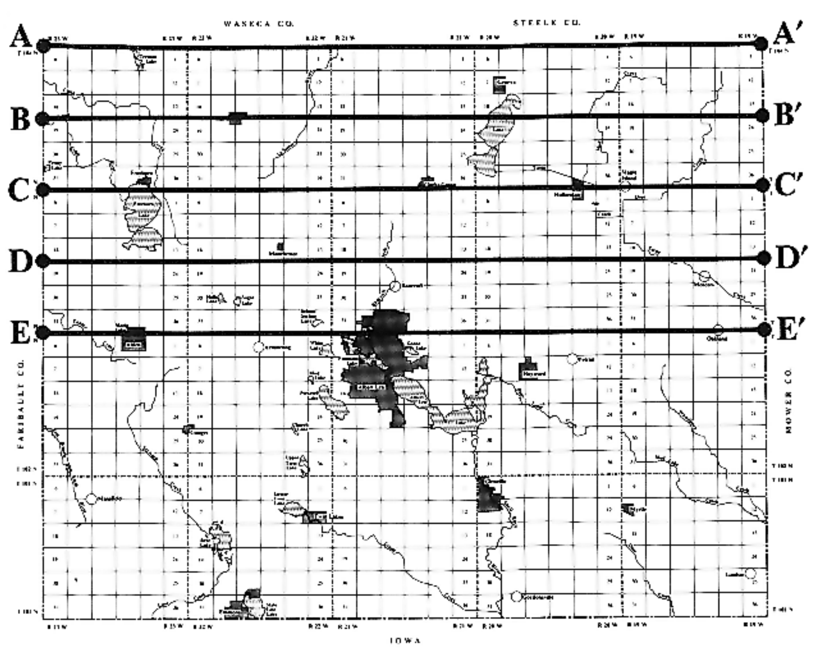
Unconsolidated surficial deposits, chiefly glacial drift; alluvial silts, sands, and gravels commonly present along streams.

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

Bedrock aquifer, chiefly sandstone, limestone, and dolomite; water yielding unit of an aquifer system.

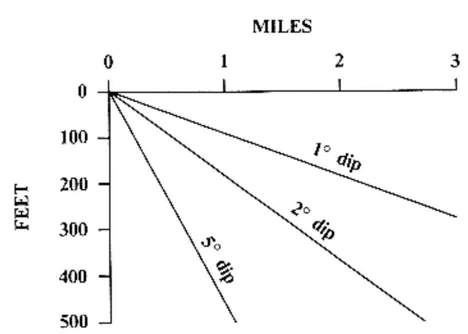
Contact between bedrock units is approximately located; dashed where inferred between lithologically similar units, erosional unconformities, or where contact is gradational.

INDEX TO GEOLOGIC CROSS SECTIONS

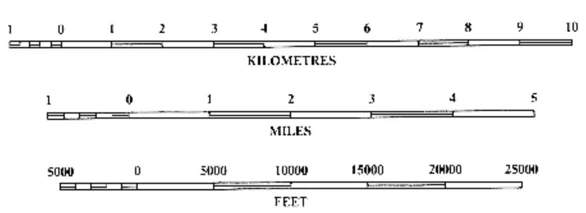


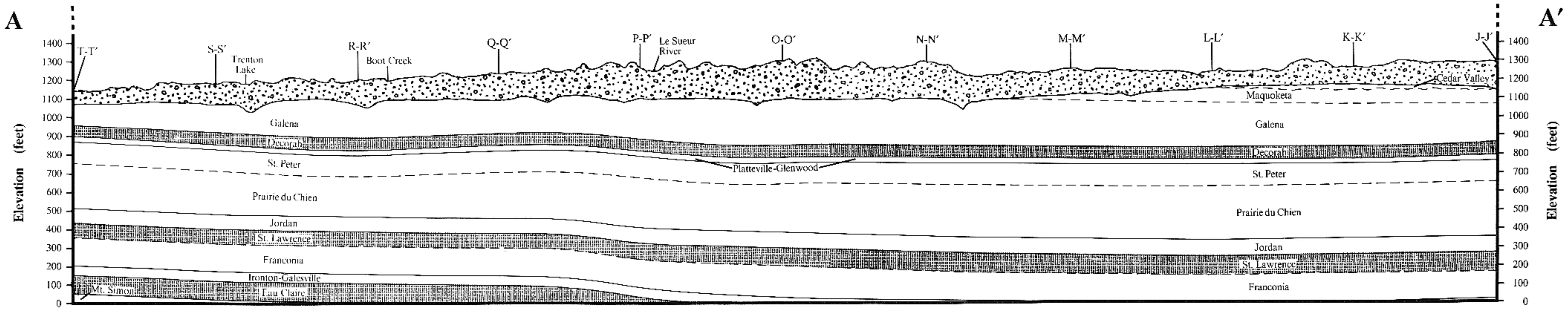
CONVERSION OF APPARENT DIP TO TRUE DIP

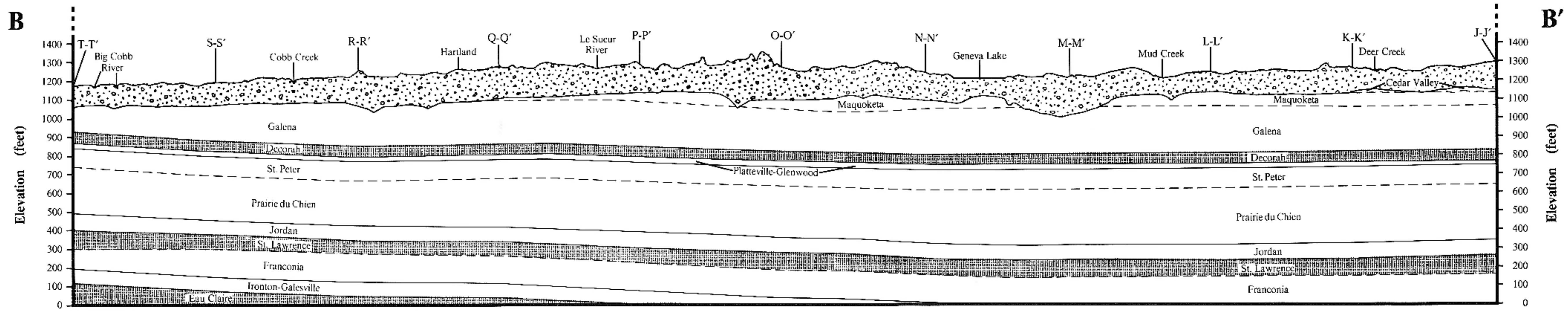
Vertical Exaggeration × 20

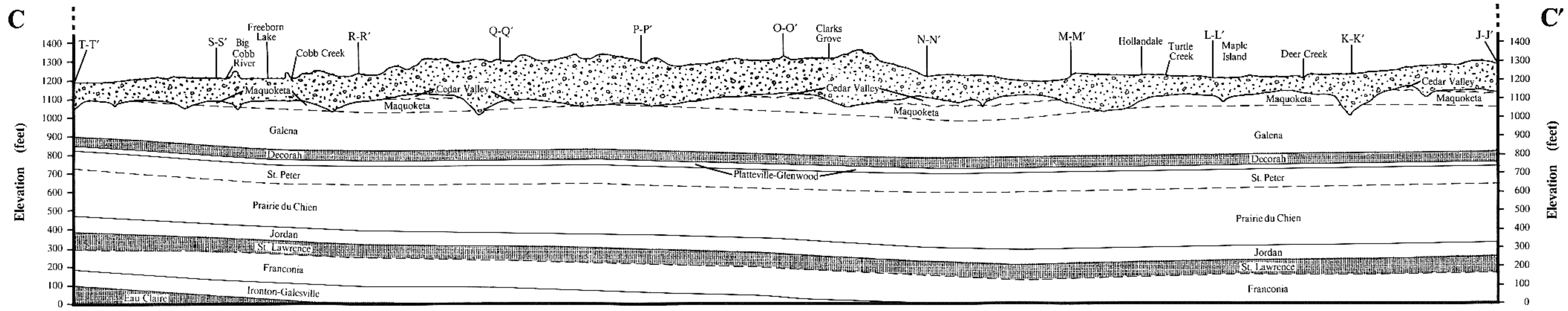


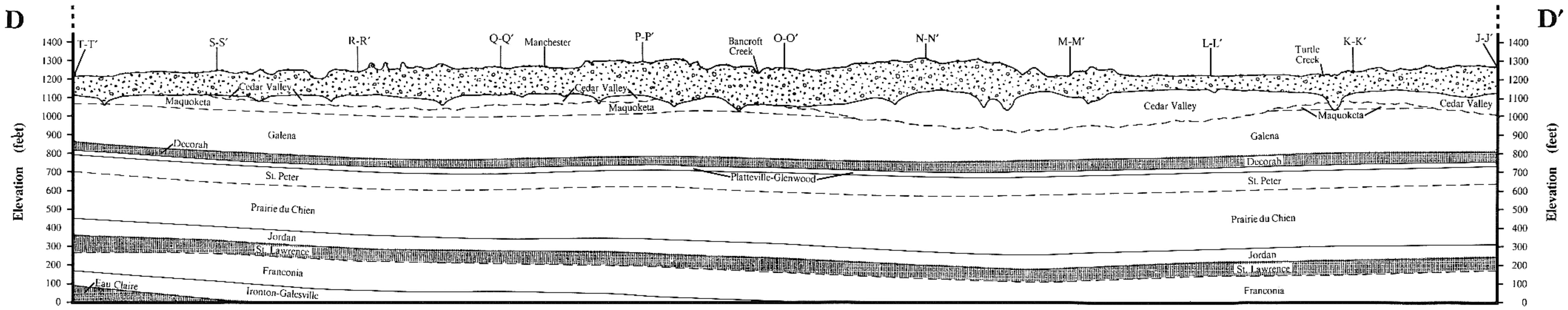
HORIZONTAL SCALE

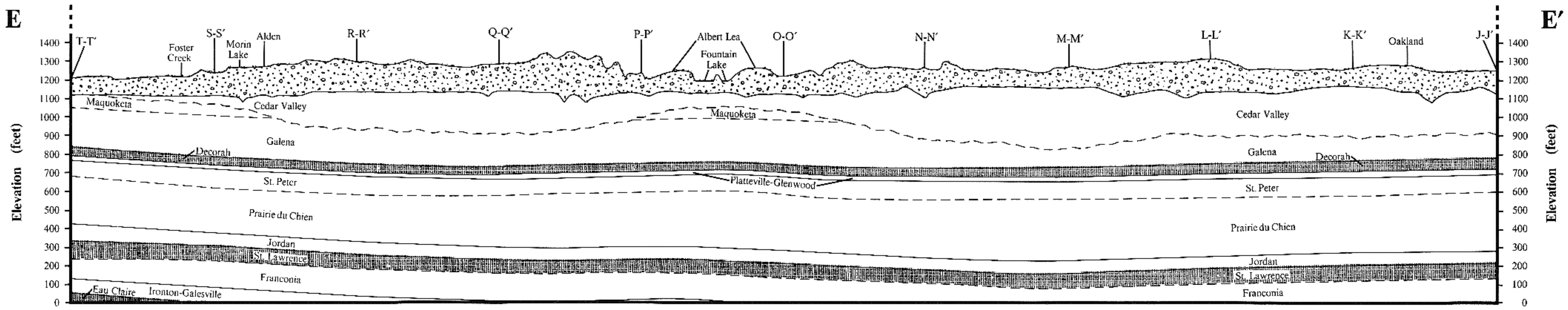




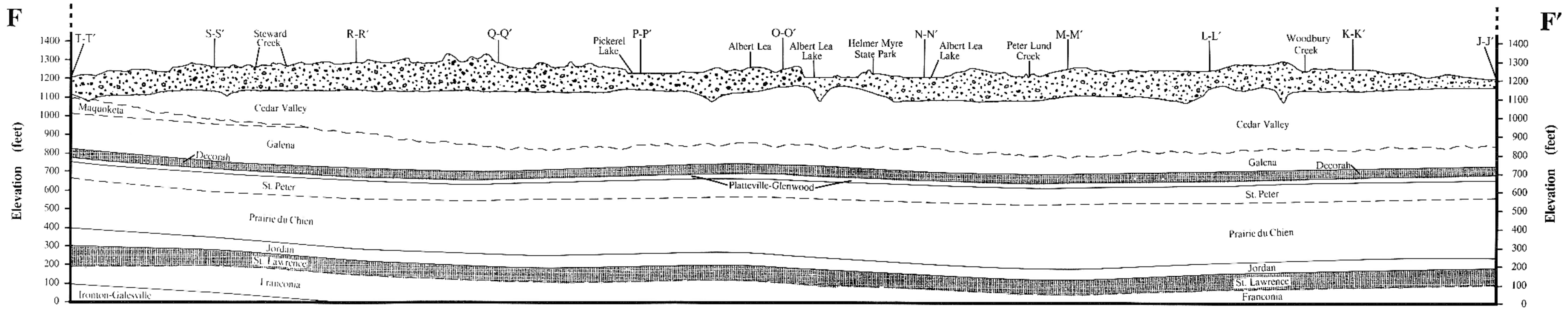


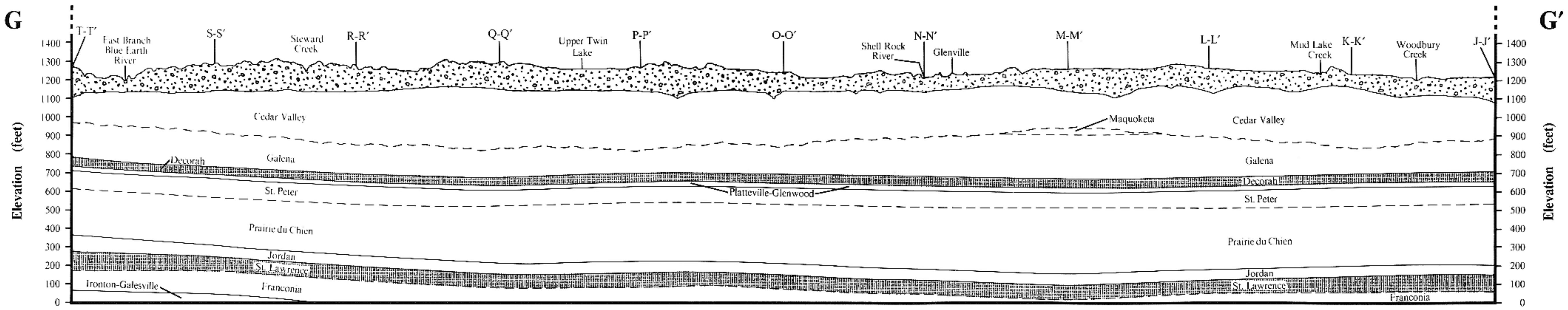


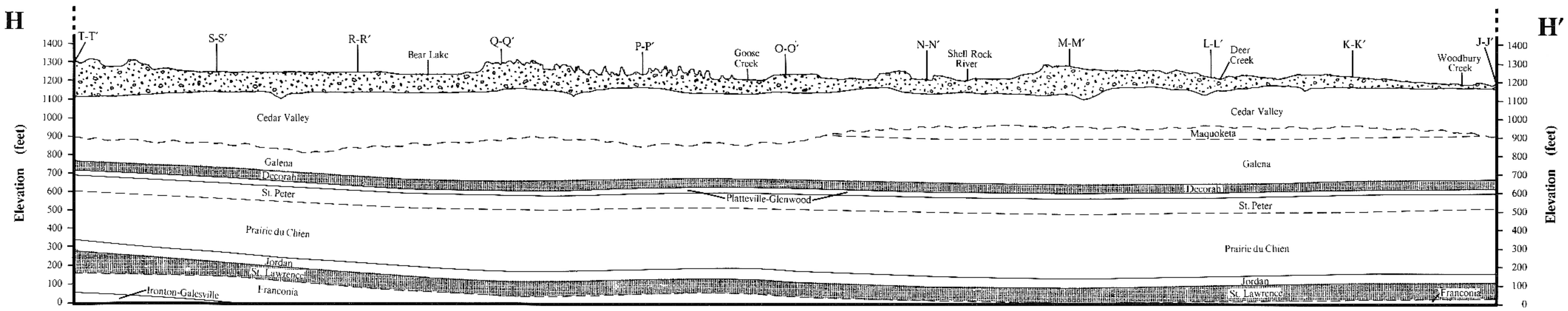


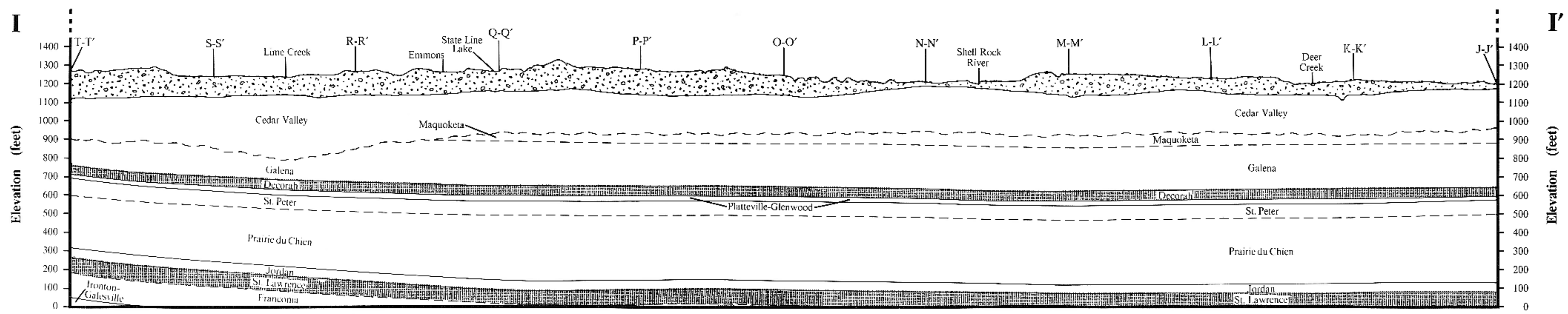


GEOLOGIC CROSS SECTIONS F-F′ TO I-I′









EXPLANATION

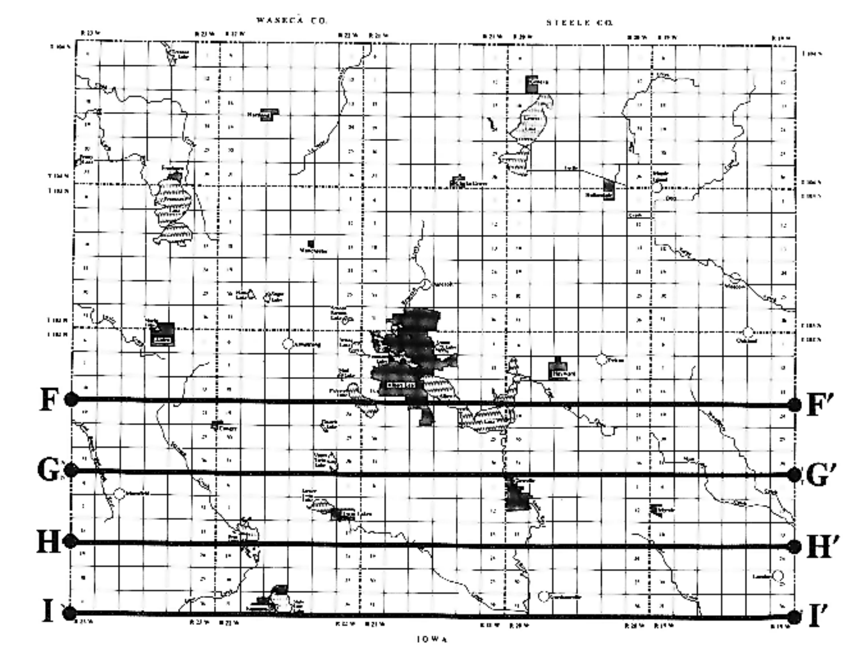
Unconsolidated surficial deposits, chiefly glacial drift; alluvial silts, sands, and gravels commonly present along streams.

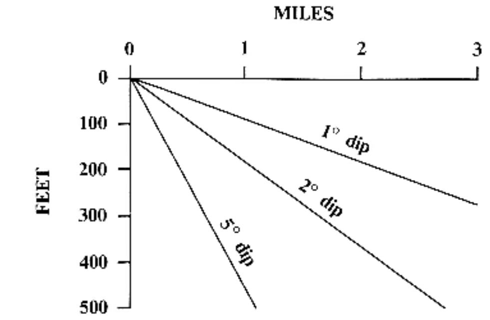
Confining layer, chiefly shale and siltstone; separates bedrock aquifer systems.

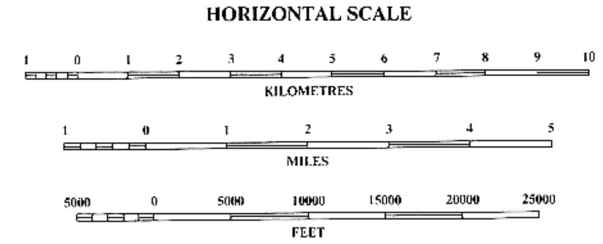
Bedrock aquifer, chiefly sandstone, limestone, and dolomite; water yielding unit of an aquifer system.

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

INDEX TO GEOLOGIC CROSS SECTIONS







GEOLOGIC CROSS SECTIONS
J-J′ TO M-M′

EXPLANATION

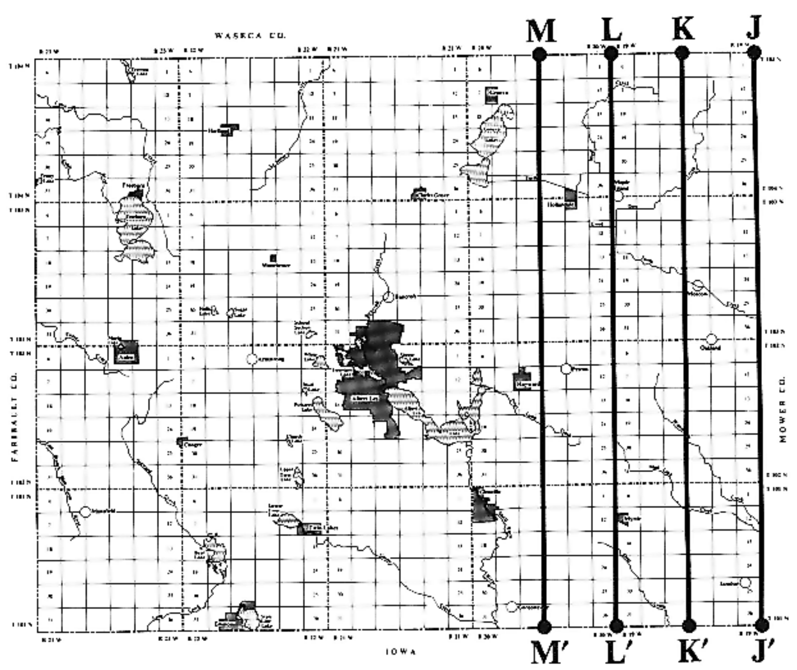
Unconsolidated surficial deposits, chiefly glacial drift; alluvial silts, sands, and gravels commonly present along streams.

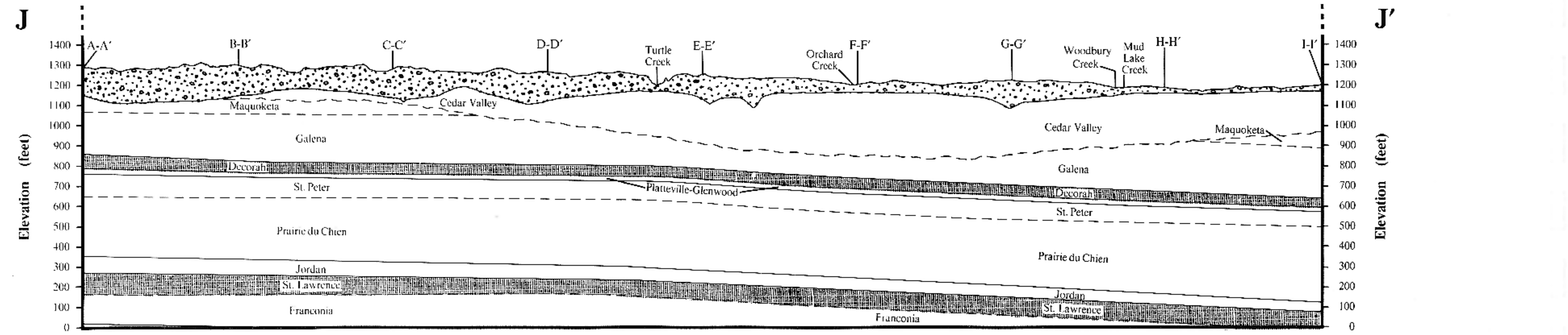
Confining layer, chiefly shale and siltstone; separates bedrock aquifer systems.

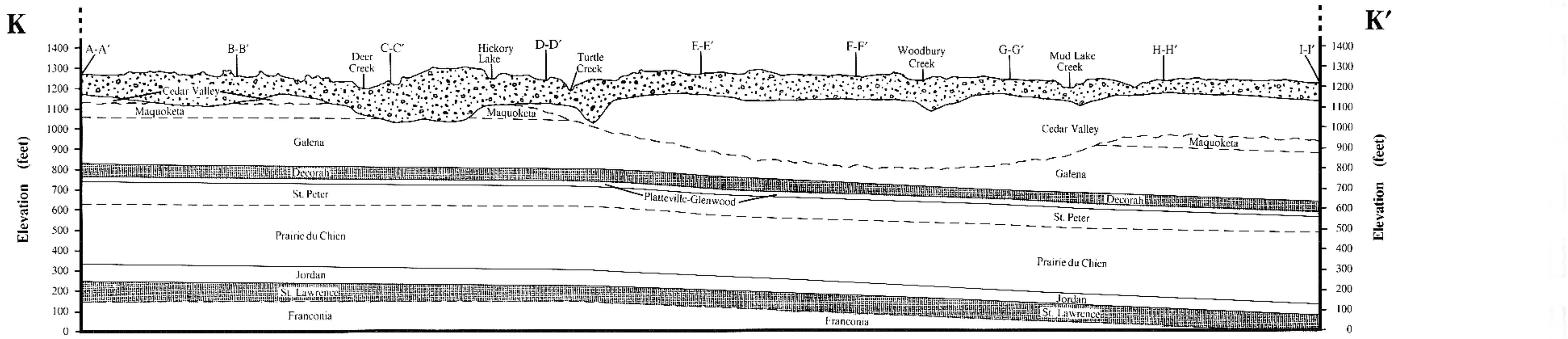
Bedrock aquifer, chiefly sandstone, limestone, and dolomite; water yielding unit of an aquifer system.

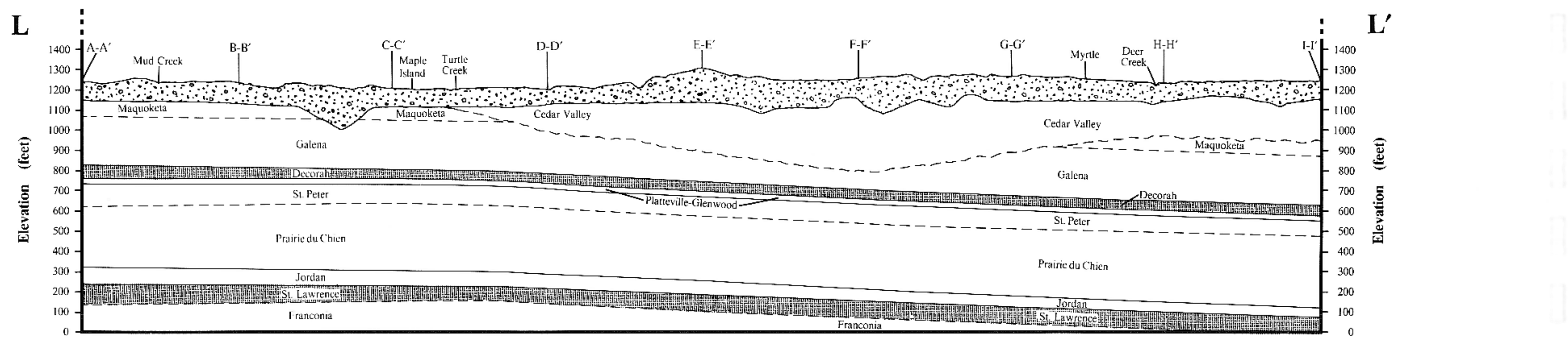
Contact between bedrock units is approximately located; dashed where inferred between lithologically similar units, erosional unconformities, or where contact is gradational.

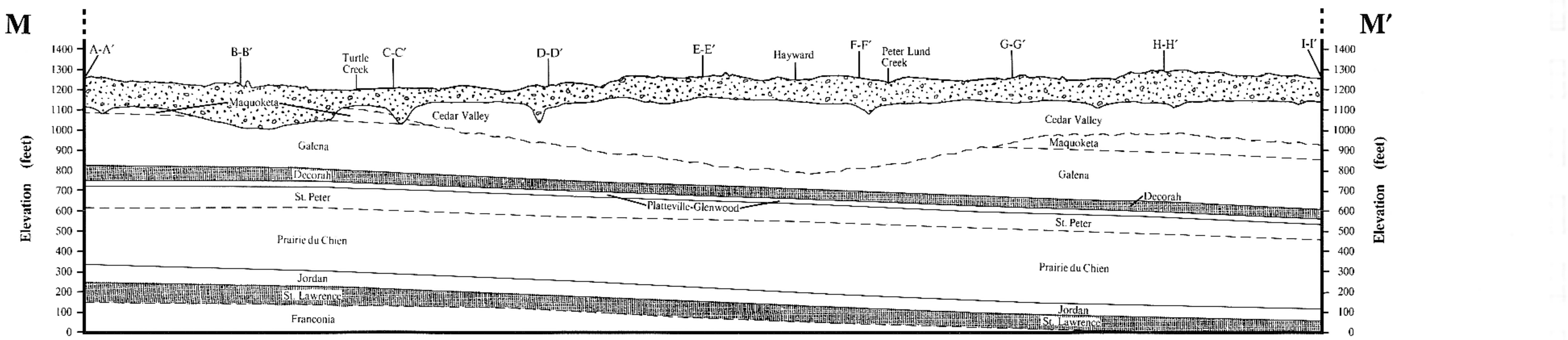
INDEX TO GEOLOGIC CROSS SECTIONS



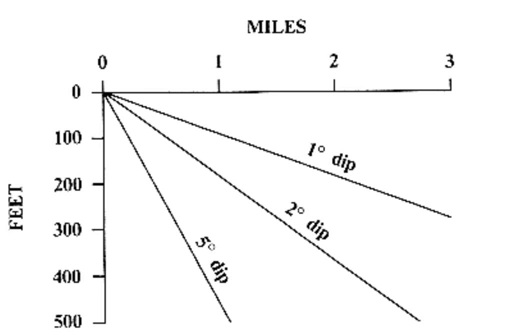




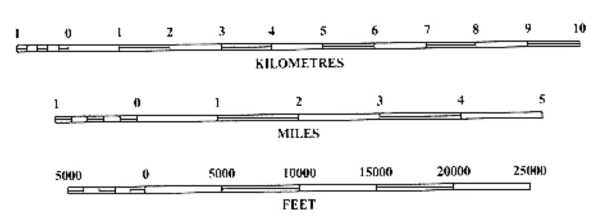




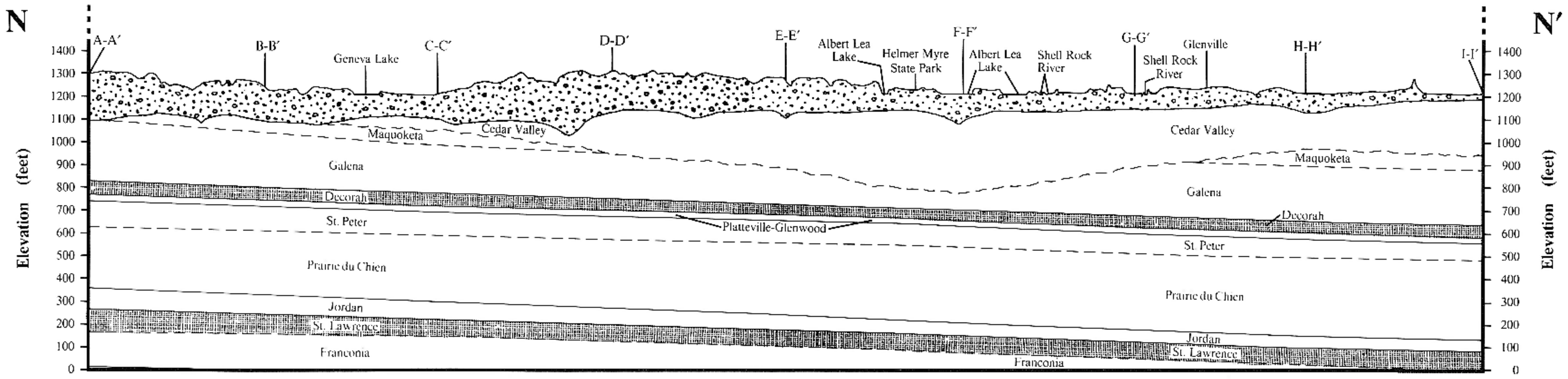
CONVERSION OF APPARENT DIP TO TRUE DIP
Vertical Exaggeration × 20

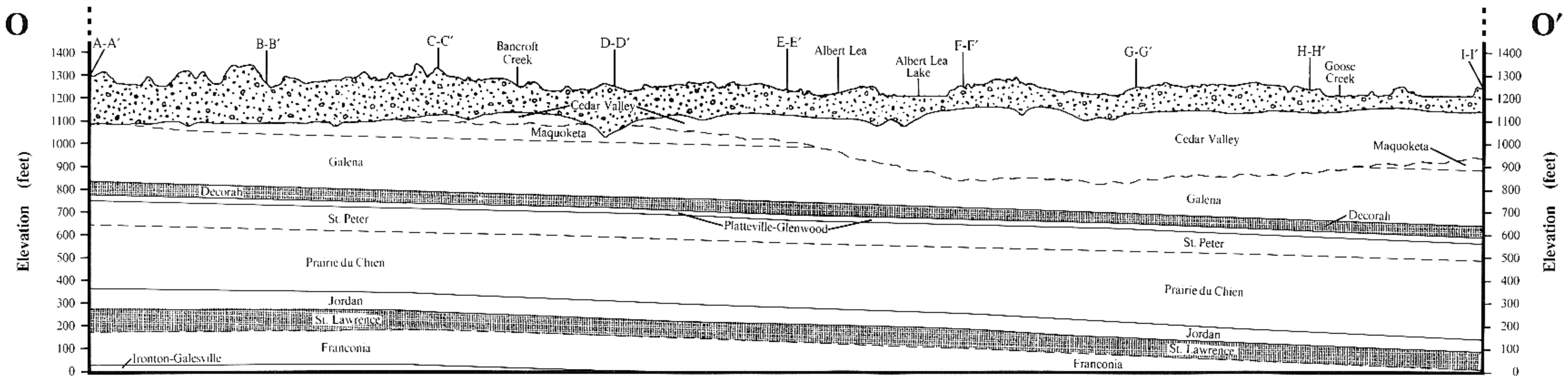


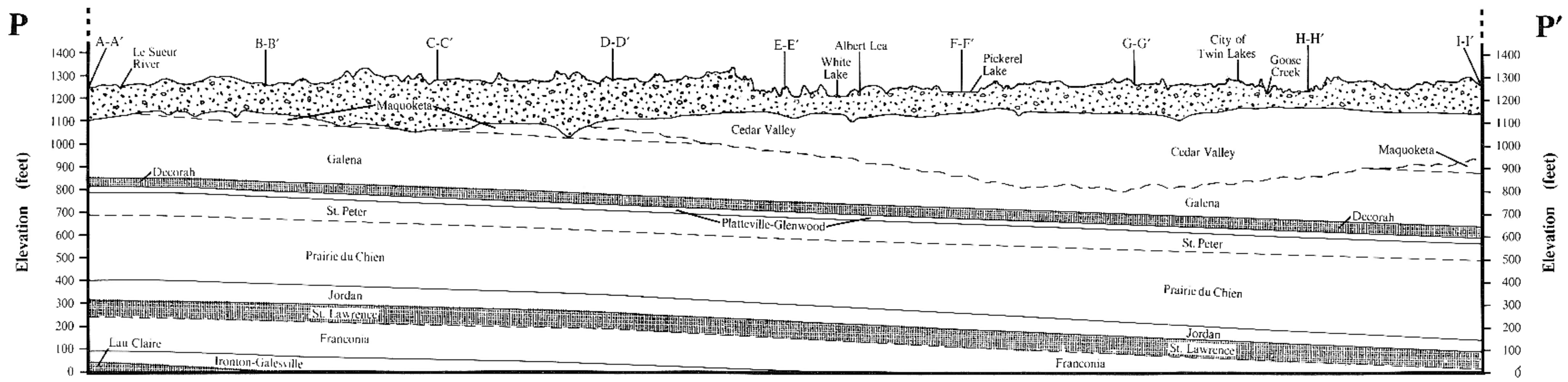
HORIZONTAL SCALE

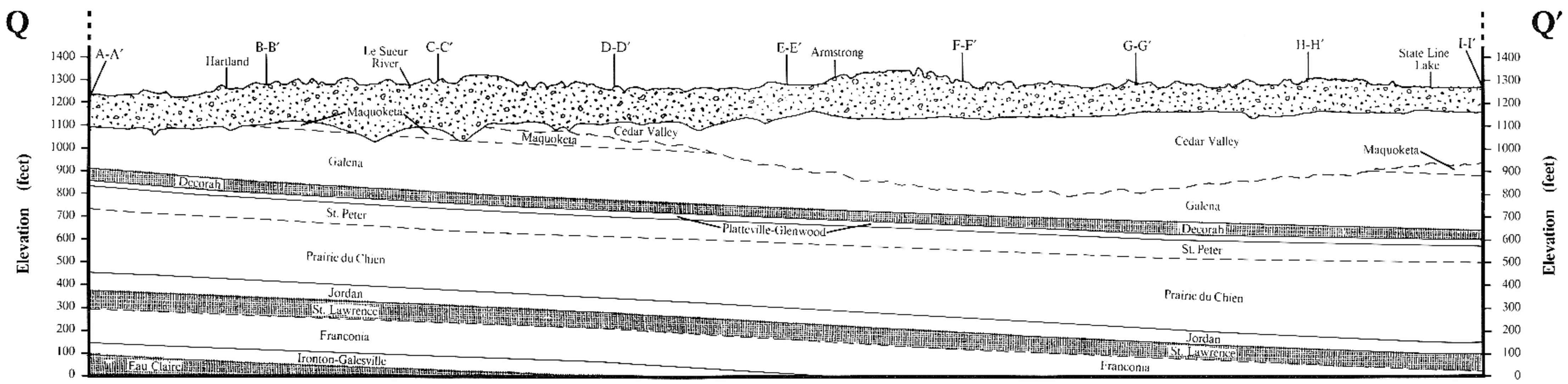


GEOLOGIC CROSS SECTIONS N-N′ TO Q-Q′

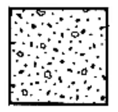




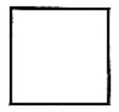




EXPLANATION

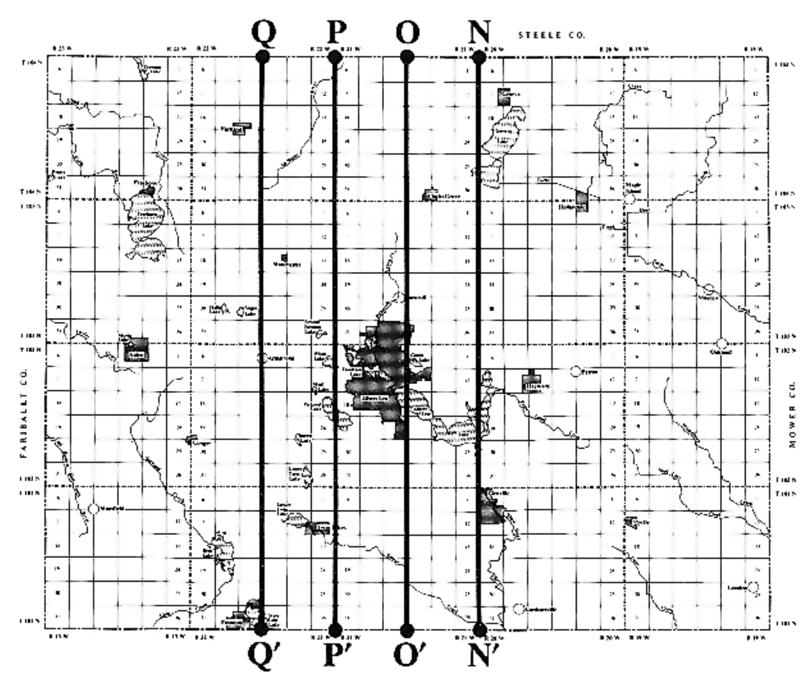

Unconsolidated surficial deposits, chiefly glacial drift; alluvial silts, sands, and gravels commonly present along streams.


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

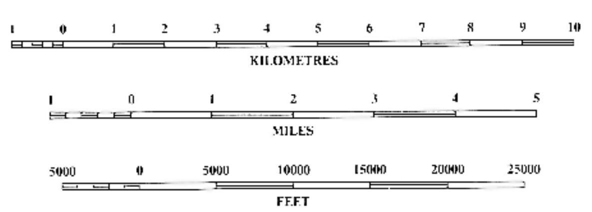

Bedrock aquifer, chiefly sandstone, limestone, and dolomite; water yielding unit of an aquifer system.

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

INDEX TO GEOLOGIC CROSS SECTIONS

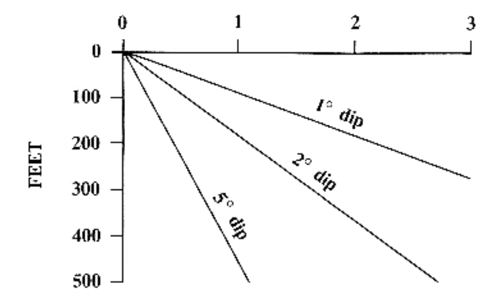


HORIZONTAL SCALE

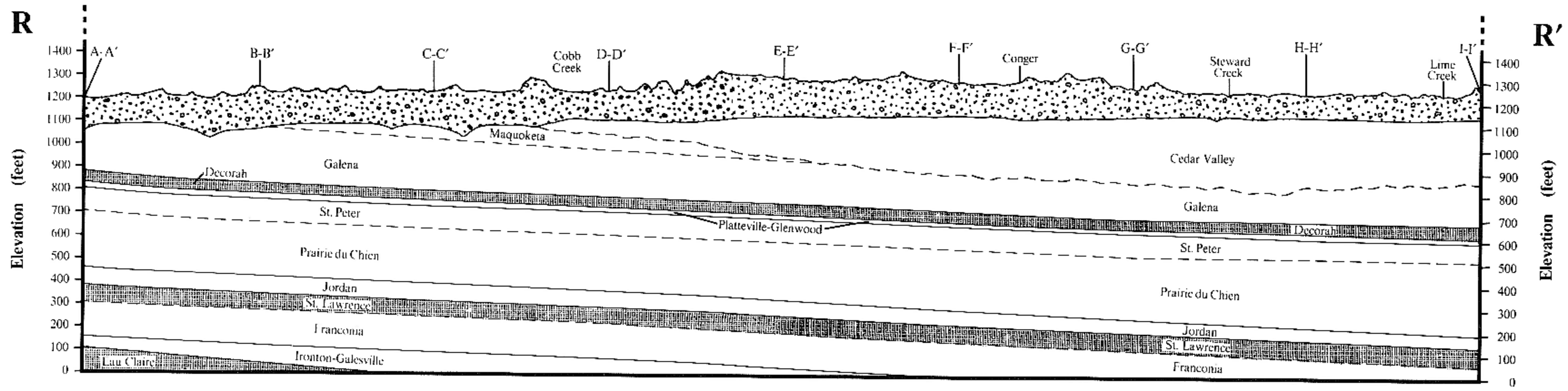


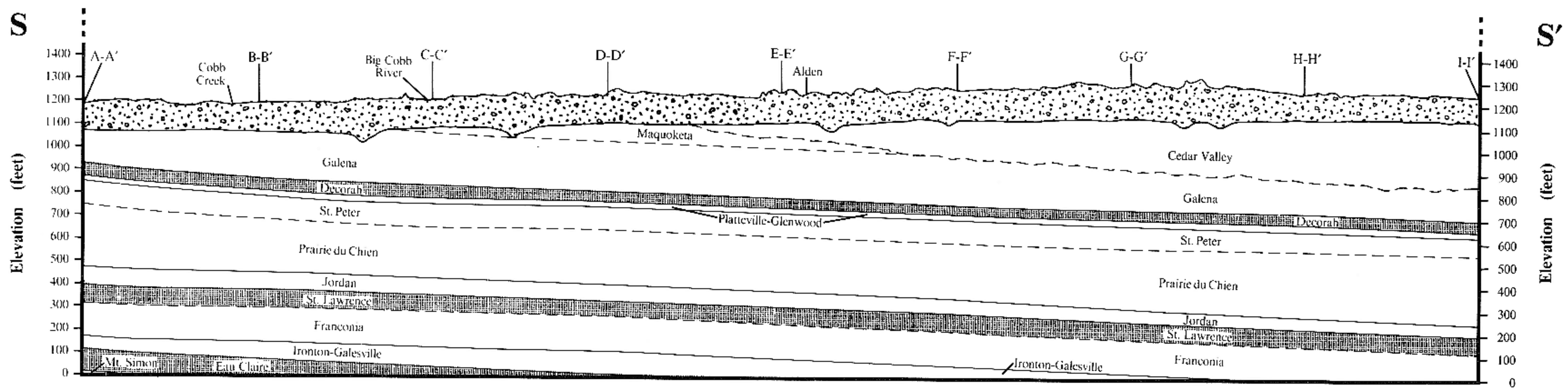
CONVERSION OF APPARENT DIP TO TRUE DIP

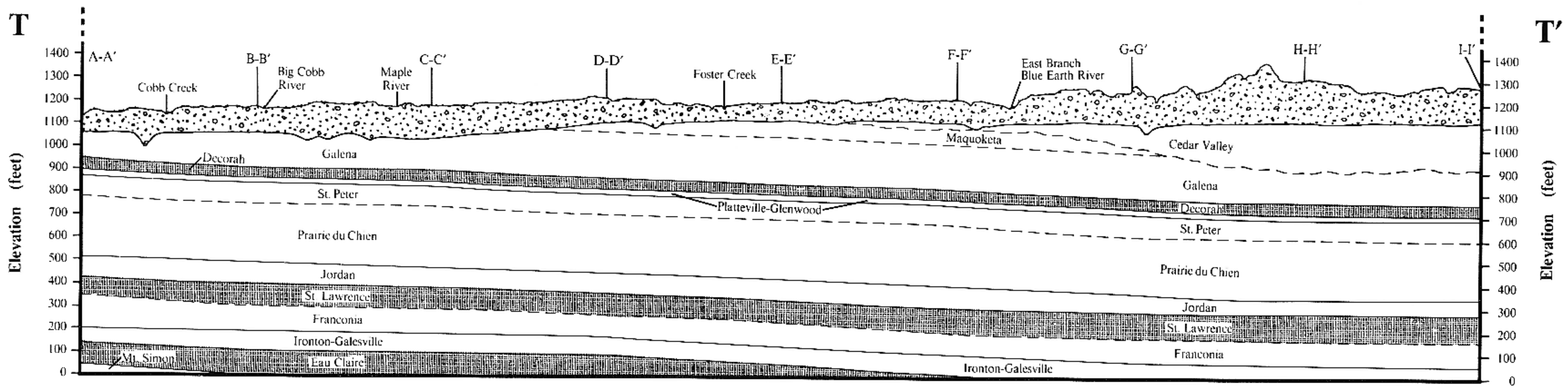
Vertical Exaggeration × 20



GEOLOGIC CROSS SECTIONS R-R′ TO T-T′







CROSS SECTIONS R-R' TO T-T'

Cross sections R-R' to T-T' trend from north to south and are stacked from east to west, providing cross section coverage for the western edge of Freeborn County. The cross sections R-R' to T-T' show the Galena limestone becoming significantly thinner near the southern border of the county. The most plausible explanation for the thinning is the erosion of the Galena limestone prior to Cedar Valley deposition. As the Cedar Valley limestone deposits advanced into Minnesota, the Galena topography may have been a series of hills and valleys. The Cedar Valley limestone was deposited on top of these areas.

The bedrock units of the Cedar Valley-Maquoketa-Galena aquifer system, which are so dominant throughout Freeborn County, are significantly thinner in the northwest corner of the county. The variation in thickness of these bedrock units is influenced by past erosion of the bedrock surface and by the dip of the bedrock strata from north to south. The cross sections illustrate that the confining conditions of the Decorah, St. Lawrence, and Eau Claire formations are present throughout Freeborn County. Thus, the St. Peter-Prairie du Chien-Jordan, the Franconia-Ironton-Galesville, and the Mt. Simon-Hinckley bedrock aquifer systems are protected by confining bedrock layers throughout the county.

EXPLANATION

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

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Bedrock aquifer, chiefly sandstone, limestone, and dolomite; water yielding unit of an aquifer system.

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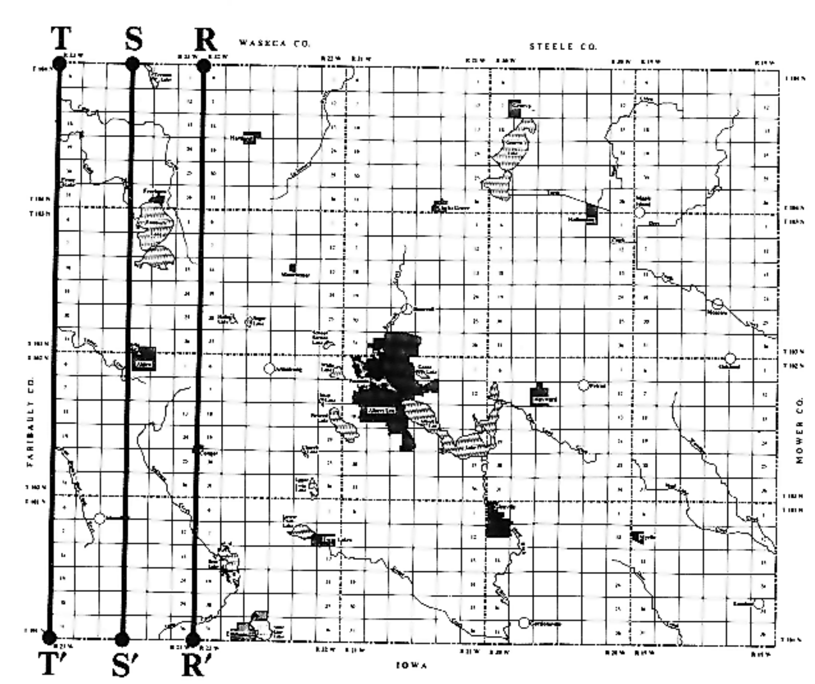
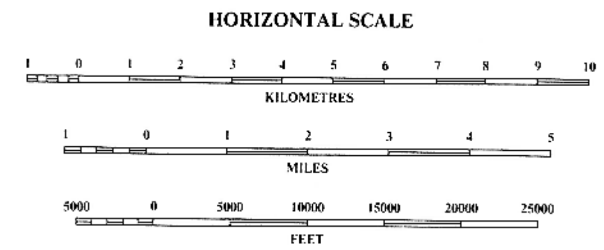
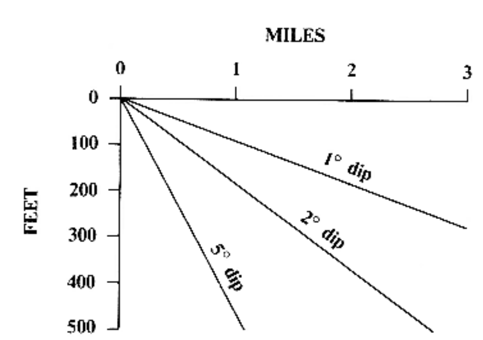
INDEX TO GEOLOGIC CROSS SECTIONS





CONVERSION OF APPARENT DIP TO TRUE DIP
Vertical Exaggeration × 20



BEDROCK HYDROGEOLOGY

BEDROCK AQUIFER SYSTEMS

Four major bedrock aquifer systems, separated on the basis of hydrogeologic properties, are present in Freeborn County. They are the Cedar Valley-Maquoketa-Galena aquifer system, the St.Peter-Prairie du Chien-Jordan aquifer system, the Franconia-Ironton-Galesville aquifer system, and the Mt.Simon-Hinckley aquifer system.

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 hard fractured sedimentary rocks such as limestone or dolomite. A bedrock aquifer system is a connected set of individual bedrock aquifers that act hydrologically as a single unit. The data suggests that there is good hydraulic connection between the bedrock units within each of the four aquifer systems in Freeborn County.

Of the three bedrock units that form the Cedar Valley-Maquoketa-Galena aquifer system, all three are commonly present in Freeborn County. The Galena limestone is present throughout Freeborn County and occupies the bedrock surface in the northwest corner of the county. The Maquoketa limestone commonly forms the bedrock surface in an area extending from the westcentral part of Freeborn County to the northeastern corner of the county. The Cedar Valley limestone is commonly present throughout the southern three-fourths of Freeborn County where it forms the bedrock surface. Although the Cedar Valley and Maquoketa may have one day covered the entire county, they have since been worn down by erosion. Rock of low permeability of the Decorah Formation underlies the Galena limestone and separates the Cedar Valley-Maquoketa-Galena aquifer system from the underlying St. Peter-Prairie du Chien-Jordan aquifer system.

The St. Peter-Prairie du Chien-Jordan aquifer system is present throughout Freeborn County. The major bedrock aquifers in this system are the St. Peter and Jordan sandstones, which yield water from between individual grains, and the Prairie du Chien dolomites, which yield water through fractures and crevices. These three bedrock units function as a single aquifer system because all three are sources of groundwater with no regional confining bed separating them. The Decorah confining bed overlies the St.Peter-Prairie du Chien-Jordan aquifer system throughout Freeborn County. Rock of low permeability of the St. Lawrence Formation underlies the Jordan sandstone and separates the St. Peter-Prairie du Chien-Jordan aquifer system from the underlying Franconia-Ironton-Galesville aquifer system.

The Franconia-Ironton-Galesville aquifer system is overlain by the St. Lawrence confining bed throughout Freeborn County. The upper aquifer unit in this system is the Franconia glauconitic sandstone which yields moderate supplies of groundwater. The lower aquifer unit in this system is the Ironton-Galesville sandstones which are generally a more productive aquifer than the overlying Franconia. Rock of low permeability of the Eau Claire Formation directly underlie the Ironton-Galesville sandstone. The Eau Claire separates the Franconia-Ironton-Galesville aquifer system from the Mt.Simon-Hinckley aquifer system.

The Mt.Simon-Hinckley aquifer system is deepest of the four bedrock aquifer systems in Freeborn County. These deep sandstone aquifers are overlain by the confining conditions of the Eau Claire formation. Very little information is available on the hydrology of the Mt.Simon-Hinckley aquifer system because it is reached by only a few deep water wells.

SHALLOW BEDROCK AQUIFER SYSTEMS

The shallow bedrock aquifer system consists of those bedrock units that commonly directly underlie the glacial drift and are recharged locally. The major bedrock aquifer units in the shallow bedrock aquifer systems are members of the Cedar Valley-Maquoketa-Galena aquifer system. The Cedar Valley, Maquoketa and Galena aquifers occupy the shallow bedrock aquifer position throughout Freeborn County. The Cedar Valley limestone directly underlies the glacial drift and occupies the shallow bedrock aquifer position in the southern three-fourths of Freeborn County. Elsewhere the Maquoketa and Galena limestones occupy the shallow bedrock aquifer position. The confining conditions of the Decorah Formation underlie the Galena limestone and separate the Cedar Valley-Maquoketa-Galena aquifer system from the St.Peter-Prairie du Chien-Jordan aquifer system throughout Freeborn County.

The shallow bedrock aquifers are the 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.

DEEP BEDROCK AQUIFER SYSTEMS

The deep bedrock aquifer systems consist of those bedrock units that are covered by confining bedrock conditions. The St. Peter-Prairie du Chien-Jordan aquifer system is overlain by the Decorah confining bed throughout Freeborn county. Similarly, the St.Lawrence confining bed covers the Franconia-Ironton-Galesville aquifer system throughout the county and rock of low permeability of the Eau Claire Formation separates the deeper Mt.Simon-Hinckley aquifer system from the overlying Franconia-Ironton-Galesville aquifer system. Four major sandstone aquifers are present in the deep bedrock aquifer systems; the St. Peter, Jordan, Ironton-Galesville and the Mt.Simon sandstones.

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 Freeborn County, the water pressure in bedrock aquifers is usually 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. On the bedrock aquifer map, static water level is shown by means of contours. The static water level contours are drawn on the basis of data from water wells for which static water levels have been recorded. The direction of groundwater movement is approximately perpendicular to the static water level contours. In Freeborn County, current water well driller data are only sufficient to demonstrate the general direction of groundwater movement.

BEDROCK AQUIFER MAPS

A bedrock aquifer map was constructed for the Cedar Valley-Maquoketa-Galena aquifer system because of the abundance of available hydrologic data. More water wells are drilled into the upper bedrock units than into the lower ones. Consequently, the hydrologic conditions are not as well known for the deeper aquifer systems.

Water wells have been drilled into the St. Peter sandstone for nearly 100 years, yet little detailed hydrologic information is available specifically for this aquifer. This is because wells drilled into the St. Peter are often left uncased into the overlying aquifer and draw water simultaneously from several sources. Similarly, the static water level data for wells finished in the Franconia-Ironton-Galesville aquifer system reflect the water levels in the overlying aquifer systems. Thus, a bedrock aquifer map for the Franconia-Ironton-Galesville aquifer system would not provide anymore insight into the confined conditions present within the aquifer system. A bedrock aquifer map for the Mt. Simon-Hinckley aquifer system was not constructed because so little hydrologic data is available for this aquifer system. Few wells need to penetrate so deep to find adequate water supplies in Freeborn County.

WATER WELL CONSTRUCTION

In 1974, implementation of the Minnesota water well code standardized water well construction practices. Before the Minnesota water well code was implemented, well construction practices were used that are no longer allowed.

Prior to 1974, a water well requiring high pumping capacity would often be cased into the uppermost bedrock aquifer and left as an open borehole through the underlying bedrock layers until adequate water supplies were available to support the required yields. When soft sediments were encountered during drilling, pieces of well casing would often be inserted to prevent portions of the well wall from collapsing into the open borehole and plugging the hole. These open boreholes serve as conduits that interconnect individual bedrock aquifers or pierce a confining bed and interconnect separate aquifer systems. These wells serve as conduits for spreading pollution into otherwise unspoiled supplies of groundwater.

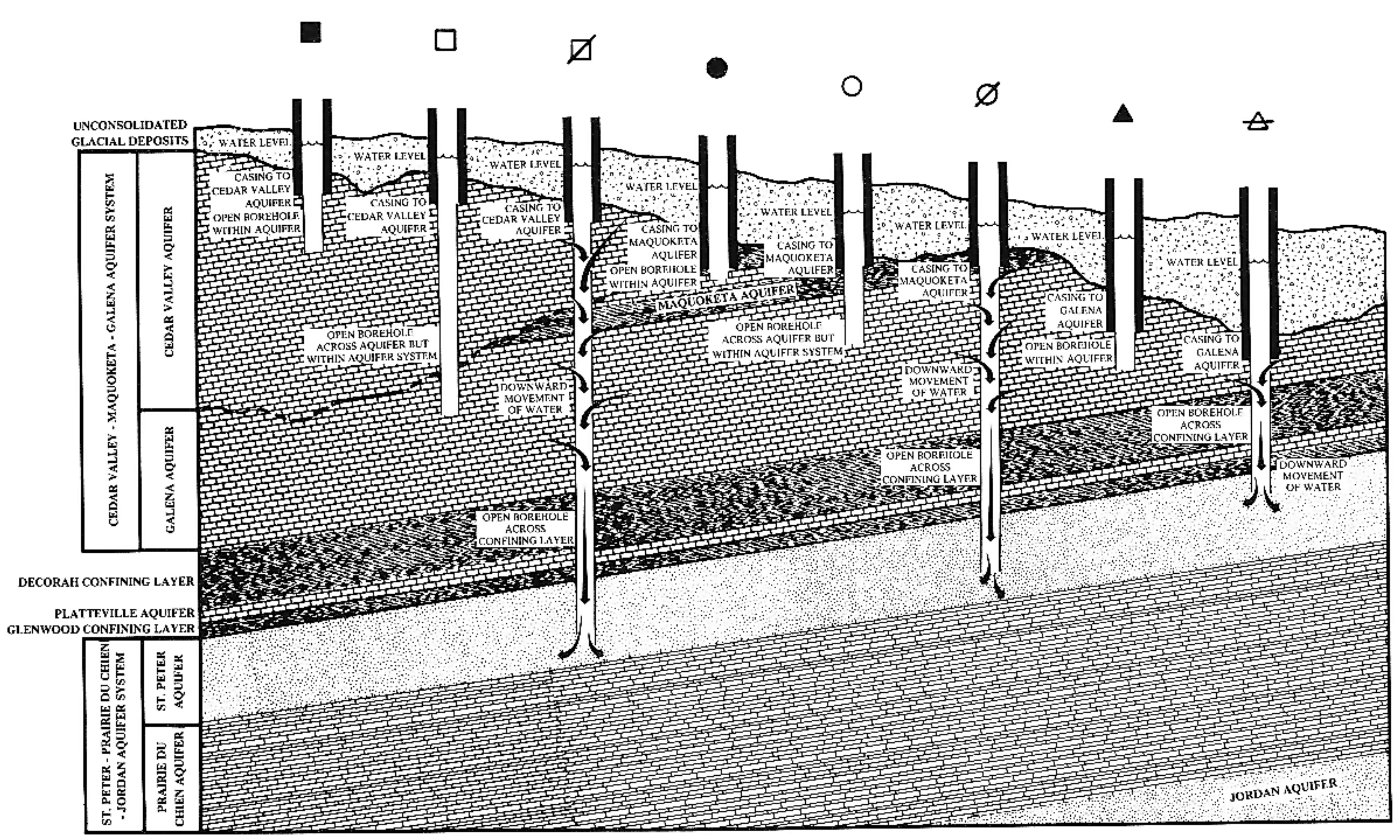


FIGURE 6. The illustration shows various combinations of casing length versus total depth of open borehole for wells finished in the Cedar Valley-Maquoketa-Galena aquifer system. Square shaped symbols are used to represent wells that are cased into the Cedar Valley limestone, circle shaped symbols represent wells that are cased into the Maquoketa limestone, and triangle shaped symbols represent wells cased into the Galena limestone. Solid symbols represent wells for which both well casing and open borehole are finished in the same bedrock aquifer. Open symbols represent wells for which the well casing is finished in one bedrock aquifer but the open borehole penetrates into a lower bedrock aquifer; these wells are still limited to the Cedar Valley-Maquoketa-Galena aquifer system. Open symbols with a slash through them represent wells for which the well casing is finished in the Cedar Valley-Maquoketa-Galena bedrock aquifer system but the open borehole extends through the Decorah confining layer and into the underlying St.Peter-Prairie du Chien-Jordan aquifer system or may even penetrate the St. Lawrence confining layer to the Franconia-Ironton-Galesville aquifer system.

CEDAR VALLEY - MAQUOKETA - GALENA AQUIFER SYSTEM

By

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1991

EXPLANATION

Possible variations in Cedar Valley aquifer use.

- Well casing and open hole finished in the Cedar Valley aquifer.
- Well casing finished in the Cedar Valley aquifer; open hole to Maquoketa or Galena aquifer.
- Well casing finished in the Cedar Valley aquifer; open hole to underlying aquifer system.

Possible variations in Maquoketa aquifer use.

- Well casing and open hole finished in the Maquoketa aquifer.
- Well casing finished in the Maquoketa aquifer; open hole to Galena aquifer.
- Well casing finished in the Maquoketa aquifer; open hole to underlying aquifer system.

Possible variations in Galena aquifer use.

- Well casing and open hole finished in the Galena aquifer.
- Well casing finished in the Galena aquifer; open hole to underlying aquifer system.

1200

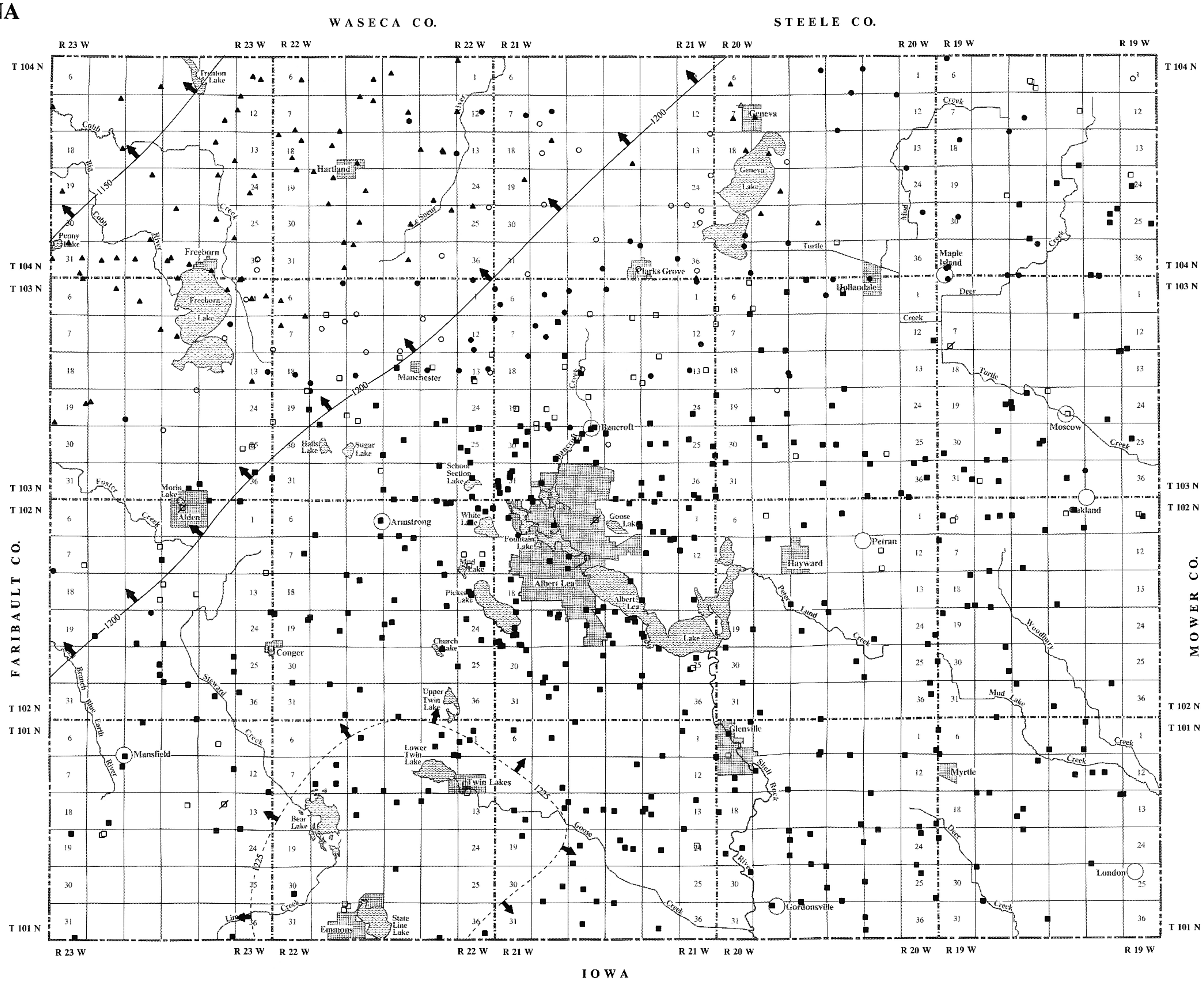
Contour interval 50 feet

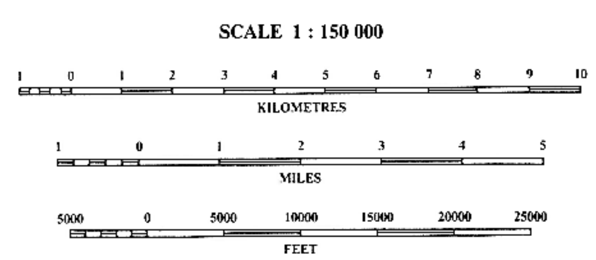
1225

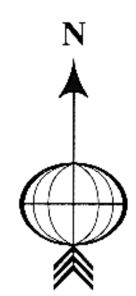
Contour interval 25 feet

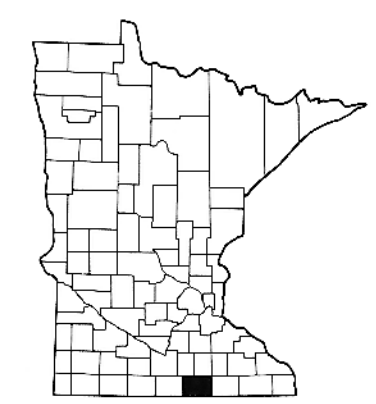
Shows average elevation in feet above mean sea level of the static water level in water wells that are finished in the Cedar Valley-Maquoketa-Galena aquifer system.

Arrow points in general direction of groundwater movement.









LOCATION DIAGRAM