# GEOLOGY OF THE WHITE BEAR LAKE
# WEST QUADRANGLE, MINNESOTA

By

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GEOLOGY OF THE WHITE BEAR LAKE

WEST QUADRANGLE, MINNESOTA

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# ABSTRACT

This study presents a three-dimensional picture of the surficial geology and of the bedrock geology of the White Bear Lake West Quadrangle, an area in east-central Minnesota near St. Paul and Minneapolis.

The Minneapolis-St. Paul area is covered by unconsolidated glacial and post-glacial deposits of variable thickness overlying a roughly circular 100-mile diameter bedrock basin warped and faulted in the Paleozoic sedimentary rocks. The glacial deposits are primarly Wisconsinan in age and were deposited by three main lobes: the Wadena Lobe from the north, the Superior Lobe from the northeast, and the Grantsburg Sublobe from the west. Pre-Wisconsinan glacial deposits appear to exist in the buried valleys, but little is known about them.

The present surface morphology of the study area is dominated by glacial features such as lake and outwash plains, and morainic topography dotted with kettle holes, lakes, and swamps. The area lacks a well integrated surface drainage pattern due in part to the nature of the glacial deposits, and to the geologically short exposure to erosion.

The Twin Cities Artesian Basin is a warped and faulted shallow basin with approximately 1000 feet of closure. The Paleozoic strata dip approximately ten feet per mile southwestward in the White Bear Lake West Quadrangle. The area is faulted with major Precambrian faults and small scale Paleozoic and Quaternary faults. One bedrock fault is mapped in the subsurface in the study area. Its movement is consistent

with the basin formation by step faulting theory.

The establishment of a depositional sequence in a glacial terrain is difficult because the units often are juxtaposed instead of superposed. The time-transgressive aspects of the till units, and the formation and disappearance of ice-marginal lakes and of outwash torrents with the advance and retreat of the ice sheets, produce a discontinuous character of glacial deposits that does not allow all units to occur in stratigraphic superposition in any one place. The glacial units recognized in the quadrangle, in their approximate order of formation are:

1) various unnamed tills, clays, and sands in the buried bedrock valleys

2) yellow till deposited by the Wadena Lobe

3) the Willernie Formation, reddish-brown till of northeastern provinance deposited by ice of the Superior Lobe

4) the Hillside Sand, a retreatal and proglacial outwash deposit

5) the Twin Cities Formation, a complex mixture of gray and red till deposited by the ice of the Grantsburg Sublobe

6) the Falcon Heights Sand, a retreatal outwash deposit of the Grantsburg Sublobe

7) the Hugo Sand, an ice-marginal lake deposit

8) outwash deposited by the Grantsburg ice

9) the Turtle Lake Sand, an ice-marginal lake deposit

10) the New Brighton Sand, an ice-marginal lake deposit, and

11) the Fridley Sand, another ice-marginal lake deposit.

The Twin Cities Basin was a site of extrusive mafic lava flows during the Middle Keweenawan, and for deposition of thick red bed sequences during the Late Keweenawan. Major faulting occurred at some time during the Precambrian. During the Paleozoic, the area was part of a shallow warm sea. Faulting is thought to have continued on a much smaller scale during the Paleozoic. An unconformity exists between the Middle Ordovician and the Pleistocene. It is assumed that the area was glaciated during all of the main glacial advances, and subjected to long interglacial erosional periods during which the major bedrock valleys probably were formed. The events of the most recent Wisconsinan glaciation have been reconstructed through the spasmodic advances and retreats of first the Superior Lobe from the northeast, and then of the Grantsburg Sublobe from the west. Later, after the retreat of the Grantsburg ice, ice in the drift melted to produce many hundreds of kettle holes, some of which are now occupied by lake or swamp deposits, and a poorly integrated drainage system was formed. The works of Man have had a major impact on the landscape with extensive development and urbanization.

Environmental geology is broadly interpreted in this report as the use of geological information in the practical activities of Man.

The major bedrock aquifers in the Twin Cities Artesian Basin are the St. Peter Sandstone, the Franconia Formation, and the sandstones of the Dresbach and Hinkley Formations. The saturated glacial drift provides some residential water in less developed areas.

The information inthe report provides some of the physical data necessary for the assessment, planning, and development of land and mineral resouces in the study area.

The information in the engineering geology tables, when related to the surficial map, could be useful for residential development, open space design and zoning, protection of groundwater recharge areas, as well as preliminary site investigations for construction projects in the area.

# INTRODUCTION

This report, the second in a series of $7\frac{1}{2}$-minute quadrangle reports on the geology of the Minneapolis-St. Paul area, summarizes the stratigraphy, the geomorphology, the geologic history, the environmental geology, the engineering geology, and the hydrogeology of the White Bear Lake West Quadrangle, Minnesota (see Figure 1). Formal Quaternary geomorphic units, and formal stratigraphic units are described and discussed.

The White Bear Lake West Quadrangle is four miles north of downtown St. Paul, Minnesota, and covers approximately fifty-two square miles in northern Ramsey, southern Anoka, and western Washington counties (see Figure 1). The quadrangle includes all or parts of the towns of Shoreview, North Oaks, Vadnais Heights, Roseville, Little Canada, White Bear Lake, Lake Shore Park, Gem Lake, North St. Paul, and Maplewood.

## Objectives of Study

The primary objective of this study is to present a three-dimensional picture of the geology of the White Bear Lake West Quadrangle for planning, engineering, and construction purposes. Surficial geology and glacial stratigraphy are used in the assessment of groundwater sources, land uses, mineral resources, and other environmental factors. This report is intended for use by laymen, politicians, engineers, planners, architects, geologists, and others.

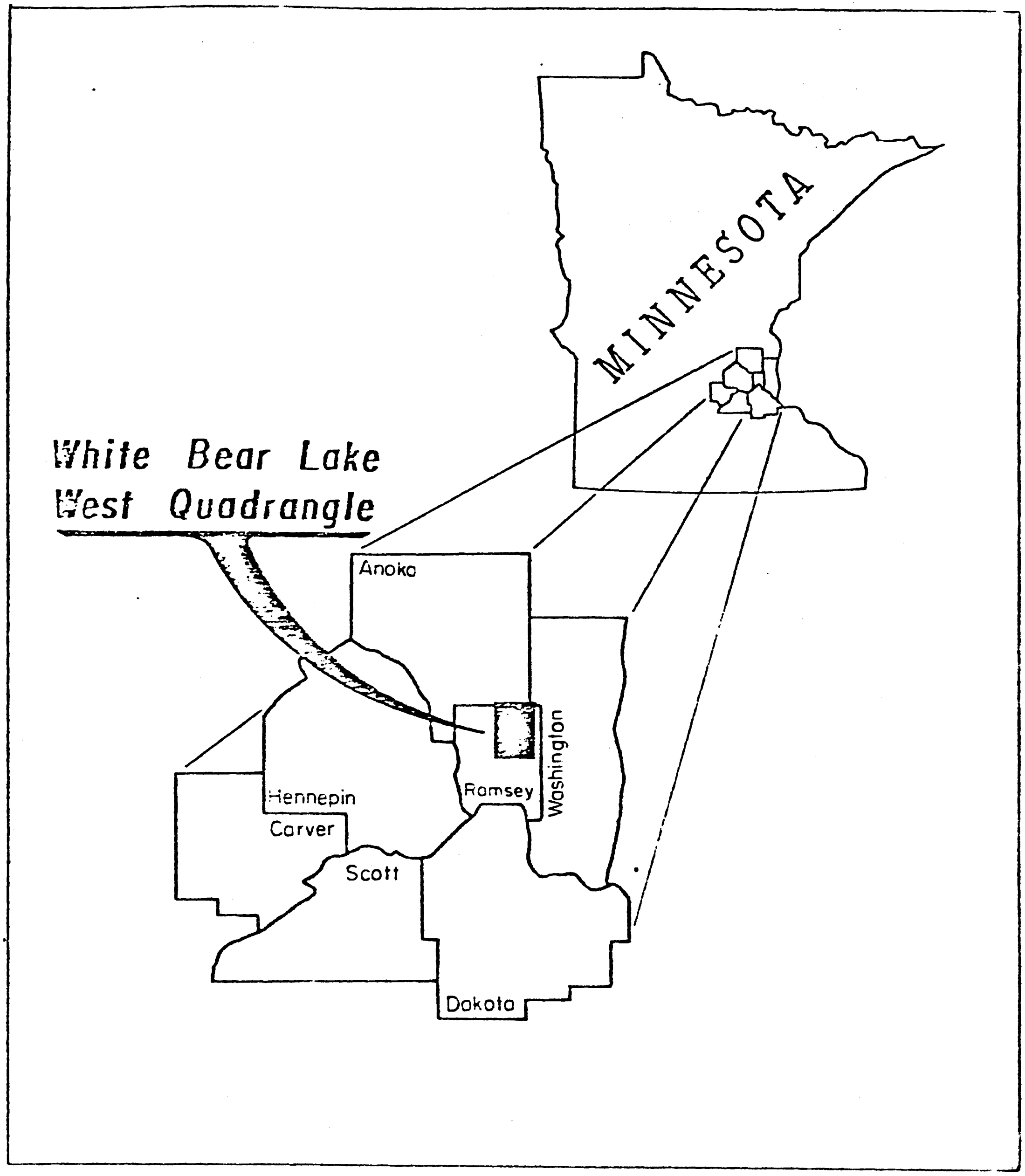



Figure 1. Maps of Minnesota and the Minneapolis-St. Paul area showing location of the White Bear Lake West Quadrangle, Minnesota

The reconstruction of the geologic history in order to expand the scientific knowledge of the glacial deposits in the area is another objective of the study. Furthermore, it is hoped that this report is written in such a manner as to be instructive and informative to non-technical persons and will increase their interest in the area and in this type of report.

## Previous Investigations

A comprehensive report on the surficial geology of the adjacent New Brighton Quadrangle by Stone (1966a), a generalized publication on the status of urban geology in the Minneapolis-St. Paul area by Stone (1965), and a reconnaissance map of the surficial geology of the Minneapolis-St. Paul area by Stone (1966b) have provided the best background information on the White Bear Lake West Quadrangle. The only other relatively comprehensive geologic reports on the area are by Sardeson (1916), who emphasized the glacial geology, and by Schwartz (1936), who emphasized the bedrock geology. Both reports now are substantially out of date. Other publications that describe some aspects of the geology of the White Bear Lake West area are Winchell (1878 and 1888), Upham (1900), Leverett (1932), and Cooper (1935). These reports undoubtedly have been worth many hundreds of thousands (if not millions) of dollars to planners, engineers, and contractors in the Twin Cities area. The present need, however, is for much more detailed geologic information, such as this report.

## Methods of Study

The surficial geology of the area was mapped initially by using geomorphology and available exposures along roadcuts and in borrow pits and construction excavations. Closer determination of contacts was accomplished by making a series of shallow hand-auger borings and by digging holes with a tiling spade.

The geology and the topography of the buried bedrock was interpreted from drillers' logs of several hundred water wells in the quarrangle. All of the water-well information used now is on file at the Minnesota Geological Survey, having been collected from various sources in 1973 and 1974. Since the logs used came from several drillers, each using different, often non-technical terminology, correlating the logs required interpretation. Careful study showed, however, that various units could be recognized and traced in the subsurface despite differences in terminology used by different drillers.

Many problems make surficial geologic mapping difficult in the study area. Vegetation obscures the unit boundaries even on most road cuts. Many of the most interesting areas have been developed into residential neighborhoods which have been landscaped extensively, making finding inplace material difficult, and obtaining permission to excavate for data nearly impossible. Throughout the study area, the lack of relief in many areas precludes roadcuts, and there is no integrated drainage system, so the natural exposures of the surficial deposits are severely limited.

## Acknowledgements

The writer is grateful to many individuals who assisted him during this study. Dr. John E. Stone, author of several publications on the urban geology of the Minneapolis-St. Paul area, suggested and supervised the study. Bruce M. Olson of the Minnesota Geological Survey aided in the interpretation of the bedrock topography and bedrock geology. Dr. Paul K. Sims, former director of the Minnesota Geological Survey, provided financial support for field investigations during the summer of 1972. Dr. Matt Walton, present director of the Minnesota Geological Survey, is encouraging publication of this study. Mr. Robert W. Arko, longtime friend and fellow graduate student at Oklahoma State University, and Dr. Walter E. Parham of the Minnesota Geological Survey, offered many constructive suggestions. Mr. Richard Darling drafted the maps. Finally, the author is grateful to his mother for her encouragement and support.

## REGIONAL GEOLOGY

The Minneapolis-St. Paul area is covered by glacial and post-glacial deposits of variable thickness. These unconsolidated deposits overlie a roughly circular bedrock basin approximately 100 miles in diameter. The basin has been warped in the approximately 900 feet of Cambrian and Ordovician sandstones, dolomites, and shales which overlie Precambrian sandstones, and siltstones and, locally, mafic lava flows (see Table I).

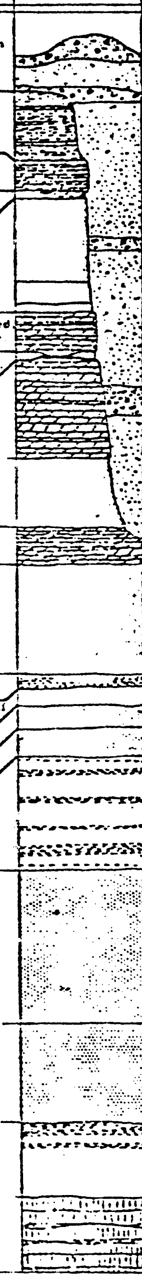
The buried bedrock surface has considerable relief, especially where it is dissected by deep narrow valleys (see Plate 3). These bedrock valleys may have been cut by earlier glacial runoff or during interglacial erosional periods.

Deposits of the Wadena Lobe of the Wisconsinan glaciation are thought to exist in the Twin Cities area and in the White Bear Lake West Quadrangle in the buried bedrock valleys (see Figure 4 and Plate 3). These deposits are deeply buried by Superior Lobe and Grantsburg Sublobe drifts and have not yet been physically traced to the type area of the Wadena drift 70 miles to the north.

The eastern and southern parts of the Twin Cities area are underlain by glacial deposits of the Superior Lobe, which had flowed into the area from the north and northeast out of the Superior Lowland (see Figure 2) bringing a reddish-brown drift (see Figures 3 and 5) and then retreating about 14,000 years ago (Wright and Ruhe, 1965). The western and northern parts of the Twin Cities area (including the White Bear

Table 1. Stratigraphic column showing geologic units and aquifers in the Minneapolis-St. Paul area, Minnesota (from Stone, 1965)

| SYSTEM | FORMATION AND MEMBER | | APPROX. THICKNESS (in feet) | DESCRIPTION | GRAPHIC COLUMN* | AQUIFERS AND AQUITARDS |
|---|---|---|---|---|---|---|
| QUATERNARY | Undifferentiated glacial drift | | 0-500 | Glacial till, outwash sand and gravel, valley-train sand and gravel, lake deposits, and alluvium of several ages and several provenances. vertical and horizontal distribution of units is complex. | | Distribution of aquifers and aquitards is poorly known. Sand and gravel aquifers containing moderate to large amounts of water appear to be common in buried bedrock valle |
| ORDOVICIAN | Decorah Fm. | | 90 | Shale, bluish-green to bluish-gray, blocky, thin, discontinuous beds of fossiliferous limestone throughout formation | | Aquifer zone (in bedrock). Small quantities of water available from fractures and solution cavities |
| ORDOVICIAN | Platteville Fm. | | Up to 35 | Dolomitic limestone and dolomite dark-gray hard thin-bedded to medium-bedded some shale partings. can be divided into five members | | |
| ORDOVICIAN | Glenwood Fm. | | Up to 5 | Shale bluish-gray to bluish-green generally soft but becomes dolomitic and harder toward east. | | Aquitard zone (in bedrock). |
| ORDOVICIAN | St. Peter Ss. | | 150 | Sandstone, white, fine- to medium-grained well sorted, quartzose; locally iron-stained and well-cemented; rounding and frosting of grains is common; 5-50 feet of siltstone and shale near bottom of formation. | | Aquifer zone (in bedrock). Small to moderate amounts of water available. Aquitard (in bedrock). |
| ORDOVICIAN | Prairie du Chien Fm. | Shakopee Member | 50 | Dolomite, light-brown to buff, thin- to thick-bedded cherty, shale partings commonly sandy and oolitic | | Aquifer zone (in bedrock) Large quantities of water available. The most widely used source of ground water in the area. |
| ORDOVICIAN | Prairie du Chien Fm. | New Richmond Memb. | 0-10 | Sandstone and sandy dolomite buff often missing. | | |
| ORDOVICIAN | Prairie du Chien Fm. | Oneota Memb. | 50-120 | Dolomite, light-brownish-gray to buff, thin- to thick-bedded, vuggy. | | |
| CAMBRIAN | Jordan Ss. | | 90 | Sandstone white to yellowish, fine to coarse-grained massive to bedded cross-bedded in places, quartzose commonly iron-stained. | | |
| CAMBRIAN | St. Lawrence Fm. | | 50 | Dolomitic siltstone and fine-grained dolomitic sandstone, glauconitic, in part. | | Aquitard. |
| CAMBRIAN | Franconia Fm. | Reno Memb. | 120 | Sandstone, very fine-grained, moderately to highly glauconitic; worm-bored in places. | | Aquifer zone. Small amounts of water available |
| CAMBRIAN | Franconia Fm. | Mazomanie Memb. | Missing | | | |
| CAMBRIAN | Franconia Fm. | Tomah Memb. | 20 | Interbedded very fine-grained sandstone and shale. mica flakes common. | | Aquitard zone. |
| CAMBRIAN | Franconia Fm. | Birkmose Memb. | 20 | Glauconitic fine-grained sandstone and orange to buff silty fine-grained sandstone (often worm-bored). | | Aquifer zone. Moderate amounts of water available. |
| CAMBRIAN | Franconia Fm. | Woodhill Memb. | 30 | Sandstone, medium- to coarse-grained cross-bedded | | |
| CAMBRIAN | Dresbach Fm. | Galesville Memb. | 35 | Sandstone, yellow- to white, medium- to coarse-grained poorly cemented | | |
| CAMBRIAN | Dresbach Fm. | Eau Claire Memb. | Up to 150 | Sandstone siltstone and shale, gray to reddish-brown, very fossiliferous. | | Aquitard. |
| CAMBRIAN | Dresbach Fm. | Mt. Simon Memb. | Up to 200 | Sandstone, gray to pink medium- to coarse-grained. | | Aquifer zone. Moderate quantities of water available. |
| | Unconformity | | | | | |
| KEWEENAWAN | Hinckley Ss. | | Up to 200 | Sandstone, buff to reddish coarse-grained. | | |
| | Unconformity | | | | | |
| KEWEENAWAN | "Red clastics" | | Up to 4,000 | Silty feldspathic sandstone and lithic sandstone, fine-grained, probably also includes red shale. | | Aquiclude zone. |
| | Unconformity | | | | | |
| KEWEENAWAN | Volcanic rocks | | Up to 20,000 | Mostly mafic lava flows but includes thin interlayers of tuff and breccia. | | |



* The unit thicknesses are approximately to scale except for the two lowermost units

J. E. Stone, Minn. Geol. Survey.

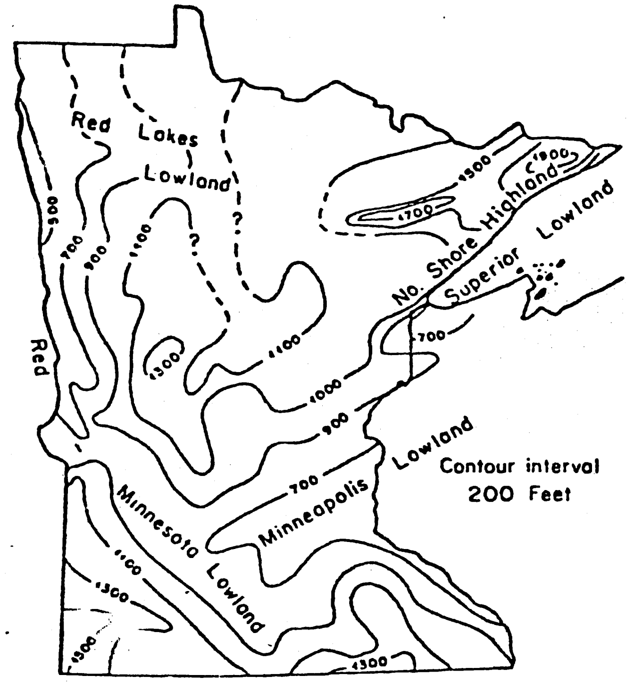



Figure 2. Generalized topographic map of the bedrock surface in Minnesota (after Wright, 1965)

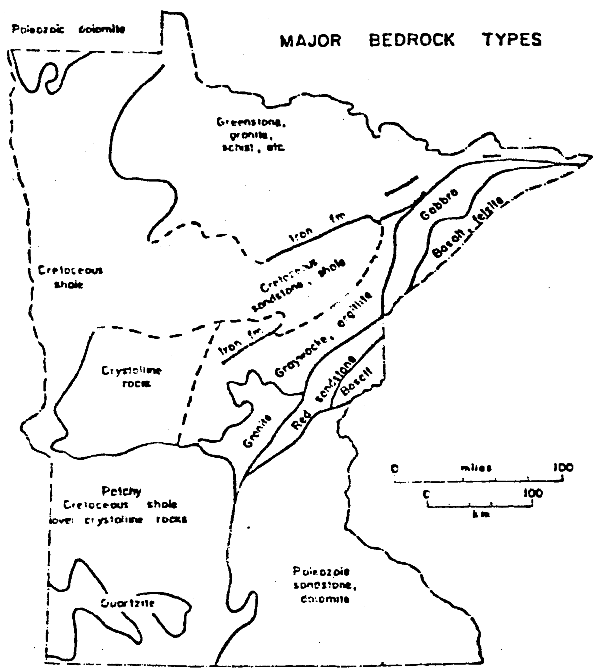



Figure 3. Generalized map of the bedrock of Minnesota (after Wright, 1965)

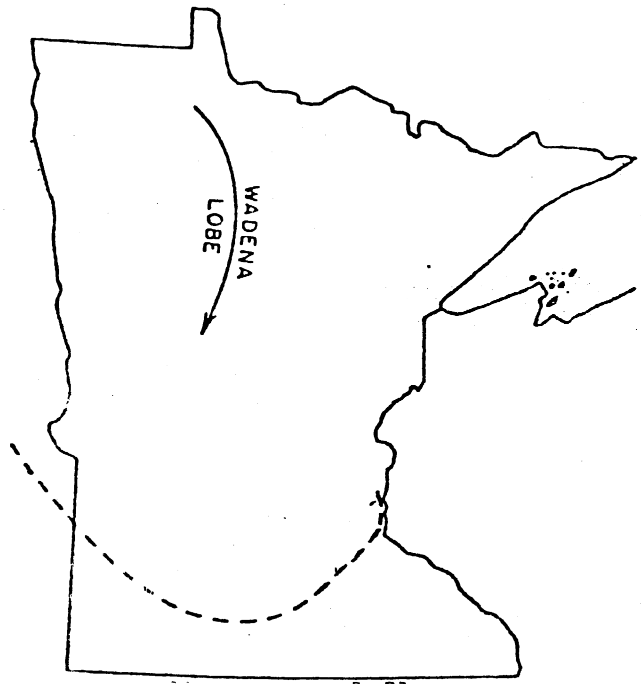



Figure 4. Map showing direction of flow and probable maximal extent of the Wadena Lobe of the Wisconsinan glaciation in Minnesota (after Wright (1972)

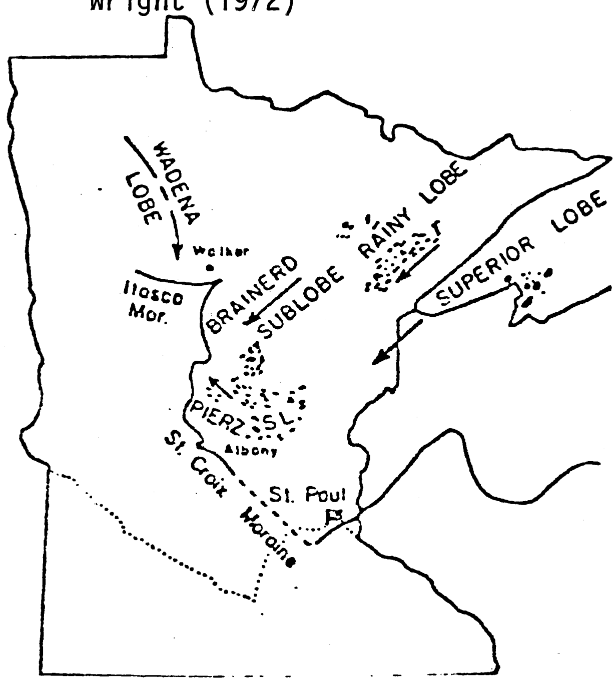



Figure 5. Map showing direction of flow and location of the St. Croix Moraine of the Superior Lobe of the Wisconsinan glaciation in Minnesota (after Wright, 1972)

Lake West Quadrangle) are underlain by deposits of the Grantsburg Sublobe, which flowed into the area down the Minnesota Lowland (see Figure 2) from the southwest to the northwest as an offshoot of the Des Moines Lobe (see Figure 6), and then retreated about 12,500 years ago (Wright and Ruhe, 1965). The Grantsburg Sublobe brought yellowish-brown drift derived in part from Cretaceous in the west (see Figure 3) overriding deposits of the Superior Lobe. These events left behind a moderately rugged morainic topography interrupted by outwash plains, lake plains, and kames, transected by the terraces and flood plains of the Mississippi River. Thus, most of the surface features and deposits in the Twin Cities area are of Wisconsin age or younger (Stone, 1966a).

Pre-Wisconsinan glacial deposits appear to exist in the buried bedrock valleys, but little is known about them. These older glacial deposits are exposed in the southeastern part of the Twin Cities area.

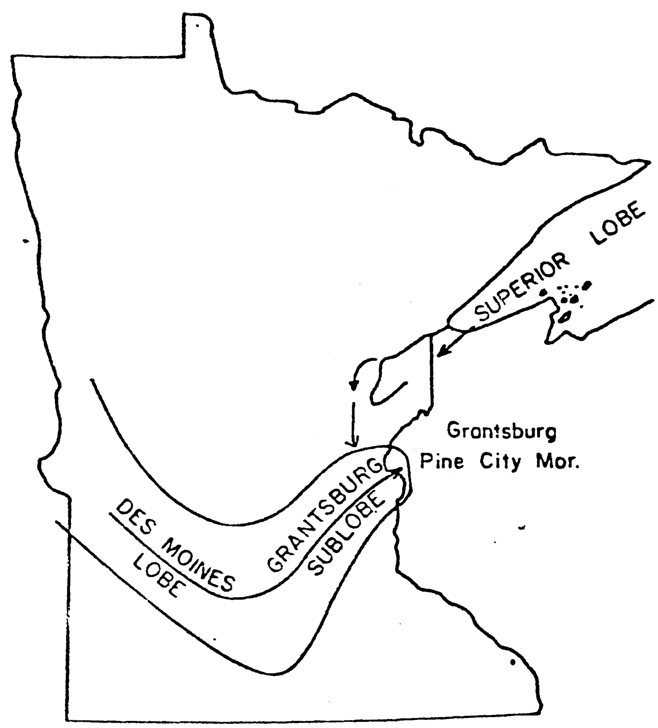



Figure 6. Map showing direction of flow and maximal extent of the Des Moines Lobe and Grantsburg Sublobe of the Wisconsinan glaciation in Minnesota (after Wright, 1972)

## BEDROCK STRATIGRAPHY

Bedrock deposits in the study area record the Keweenawan, Cambrian, and Ordovician periods (see Table I). Any post-Ordovician bedrock that may have been deposited in the area has been destroyed by erosion so that there is a major post-Ordovician, pre-Quaternary unconformity. No bedrock crops out in the White Bear Lake West Quadrangle, so all of the bedrock information is derived from well data or from observations outside the quadrangle. Geophysical studies have shown a gravity anomaly indicating major fault movement in the basement complex which is a very thick sequence of Keweenawan volcanics and red sandstones and shales. A two hundred-foot thick coarse grained buff sandstone is the uppermost unit of Keweenawan sequence (see Table I). The Cambrian System consists of sandstones and siltstones with one dolomite. The sequence of marine deposits continues through the Ordovician with three more relatively thin dolomite deposits between sandstones and shales (Table I). All of the sandstones and some of the carbonates are aquifers in the Twin Cities Artesian Basin (see Table I). The shales and siltstones act as aquitards (Table I).

## GEOMORPHOLOGY

The surface morphology of the White Bear Lake West Quadrangle is dominated by glacial features (see Figure 7 and Plate 1). The St. Croix Moraine, a prominent ridge cutting across the southeastern corner of the study area (see Figure 7) and extending around the Twin Cities area (see Figure 5), and the Arden Hills Moraine, named by Stone (1966a) for the town of Arden Hills which lies just west of the study area, provide most of the relief which ranges from 50 to 150 feet. This morainic topography is dotted with kettle holes ranging from 100 to 4000 feet across.

Lake plains, which are partially collapsed because of kettle holes, are another important feature of the area. The lake plains in the White Bear Lake West Quadrangle are the Hugo Lake Plain, named by Stone (1972), in the central and northeastern parts, the Turtle Lake Lake plain, named for Turtle Lake by Stone (1966a), in the west-central part, and the Fridley Lake Plain, named by Stone (1966a), in the northwestern part (see Figure 7). The Fridley Lake Plain extends northward from the study area to cover the southeastern one-third of Anoka County (see Figures 1 and 7). The Falcon Heights Outwash Plain, named by Stone (1966a), is a pitted surface, because of kettle holes, extending south from White Bear Lake (see Figure 7). This large outwash plain extends southward from the study area across the City of St. Paul and funnels down the Mississippi River. The outwash plain probably correlates with terraces along the Mississippi Valley, but exact correlation is yet to be made.

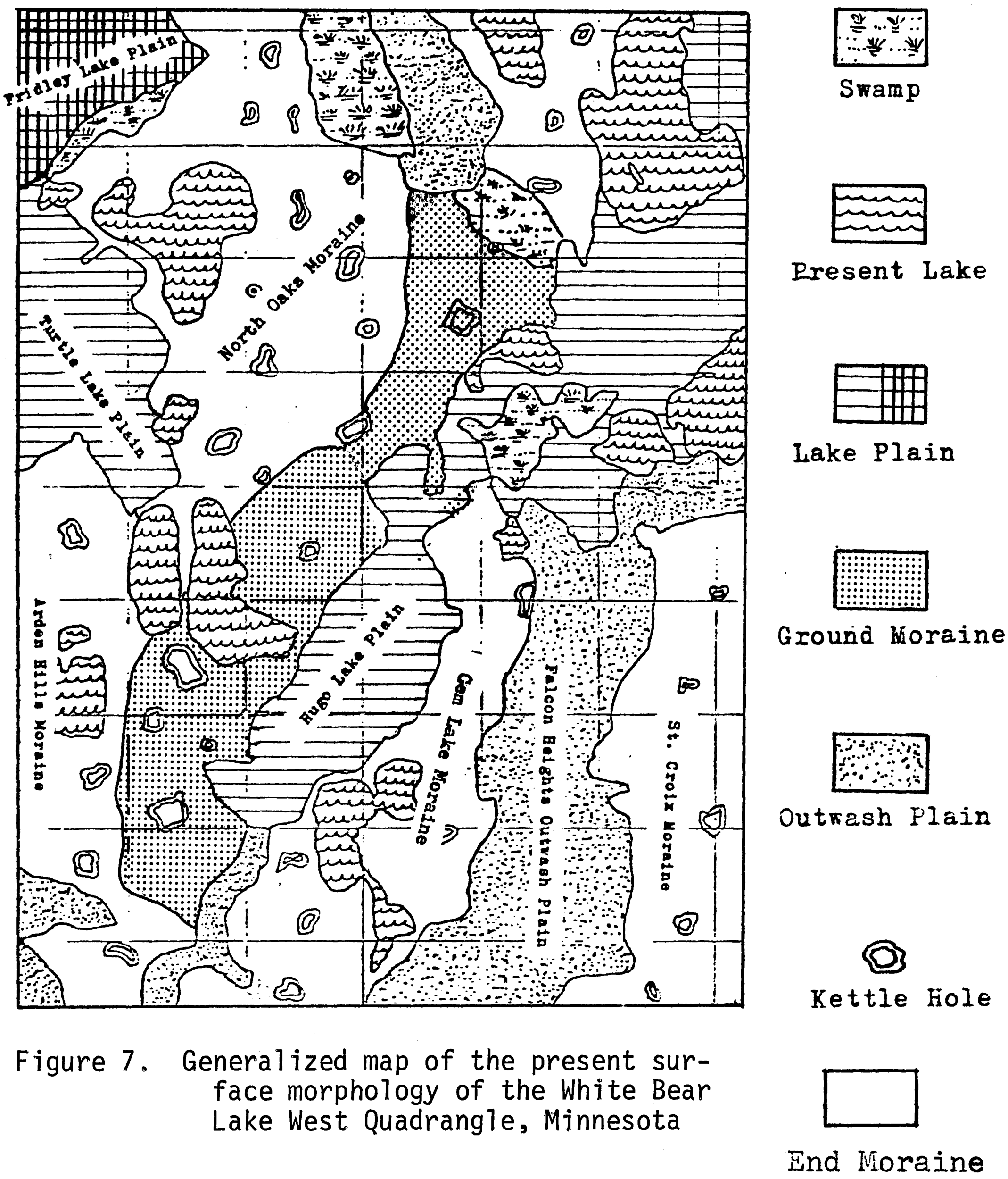



Figure 7. Generalized map of the present surface morphology of the White Bear Lake West Quadrangle, Minnesota

The area lacks a well integrated surface drainage pattern due in part to the nature of the glacial deposits, and to the geologically short exposure to erosion. Trapped ice in the deep buried valleys produced chains of collapse depression lakes upon melting (see Plates 2 and 3). The major lakes in the area were formed in this manner and are from one to two square miles in area and have depths up to 40 feet. The rest of the area is dotted with smaller lakes which formed in much the same way, except on a smaller scale.

## STRUCTURAL GEOLOGY

The Twin Cities Basin is a warped and faulted shallow basin in the Paleozoic bedrock with approximately 1000 feet of closure (see Figure 8). The Paleozoic strata dip approximately ten feet per mile southwestward in the White Bear Lake West Quadrangle (see Figure 9). The basin measures 65 miles in length and 40 miles in width, trending northeast-southwest (see Figure 8).

The Twin Cities Basin overlies the southern end of the St. Croix Horst (see Figure 10). The horst is a faulted structure which lies within the Keweenawan syncline. It is inferred from this that the Paleozoic basin is superimposed on the earlier Keweenawan faulted basin by continued fault movement through the Paleozoic (Morey, 1974).

Three major faults flank the Twin Cities basin, the Pine Fault on the northwest, the Belle Plain Fault on the south, and the Cottage Grove Fault on the east (see Figure 10).

Detailed subsurface work by Stone (1966a) has produced evidence of five previously unsuspected northeast trending faults that cut the Paleozoic bedrock in the subsurface of the New Brighton Quadrangle. One bedrock fault has been located from well log information in the south-central part of the study area (see Plate 2). Approximately 40 feet of throw is shown with the west side downthrown relative to the east side (see Figure 9). A major bedrock valley follows the fault, showing possible drainage orientation control by fault zones. Lack of

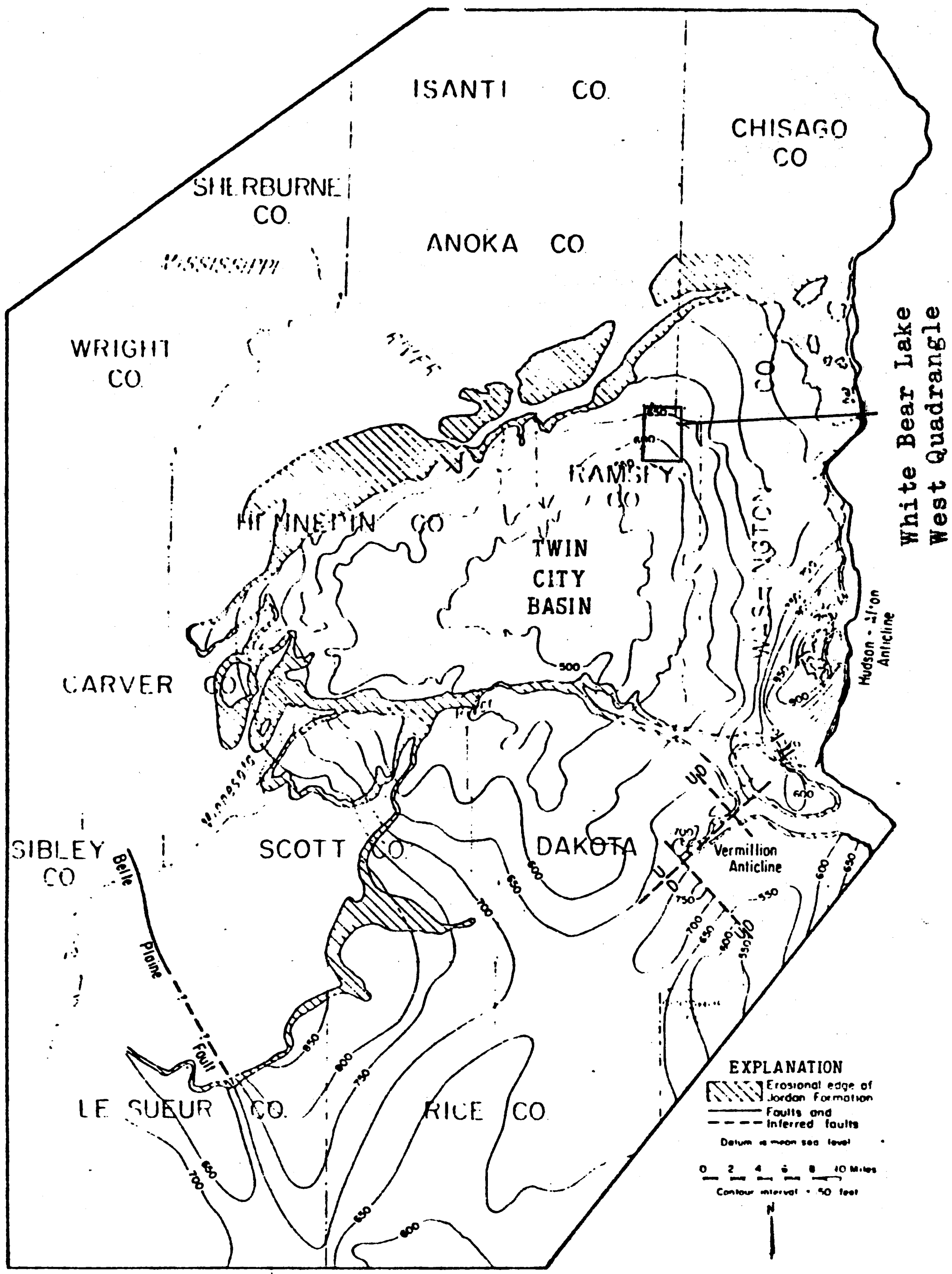



Figure 8. Structure contour map on the top of the Jordan Sandstone showing the configuration of the Twin Cities Artesian Basin (after Mossler, 1972)

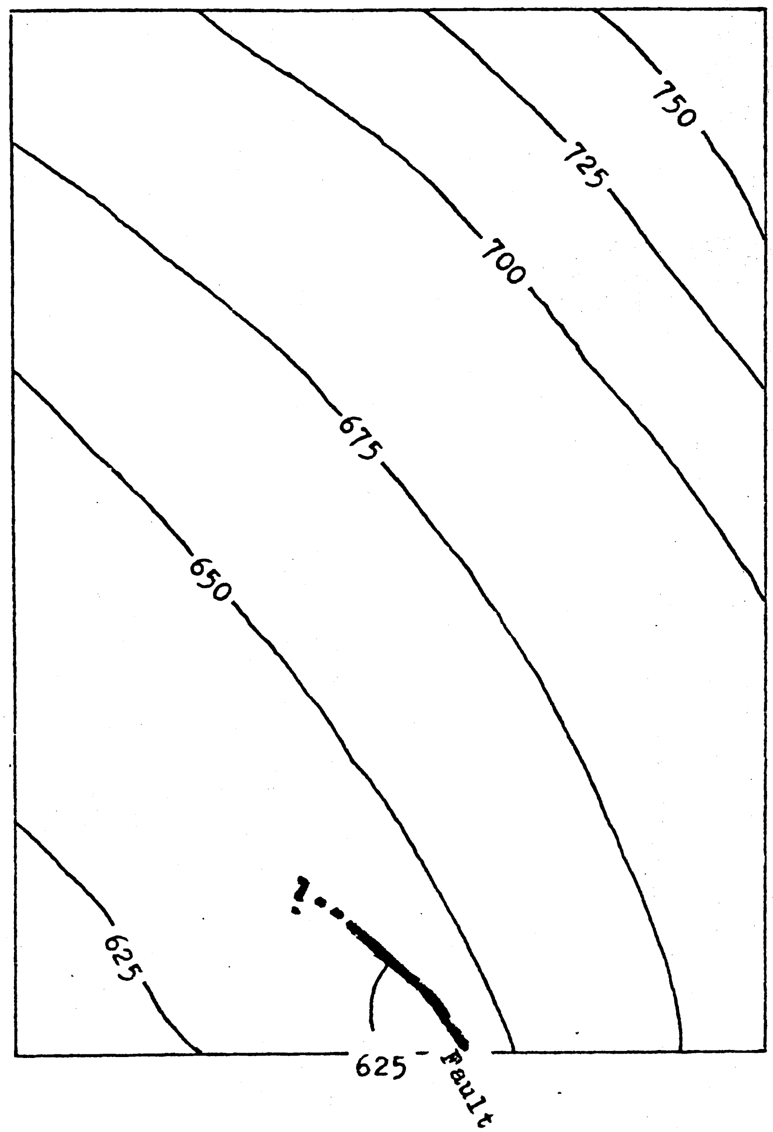



Figure 9. Structure contour map on top of the Prarie du Chien Fromation showing basin structure and faulting in the White Bear Lake West Quadrangle, Minnesota

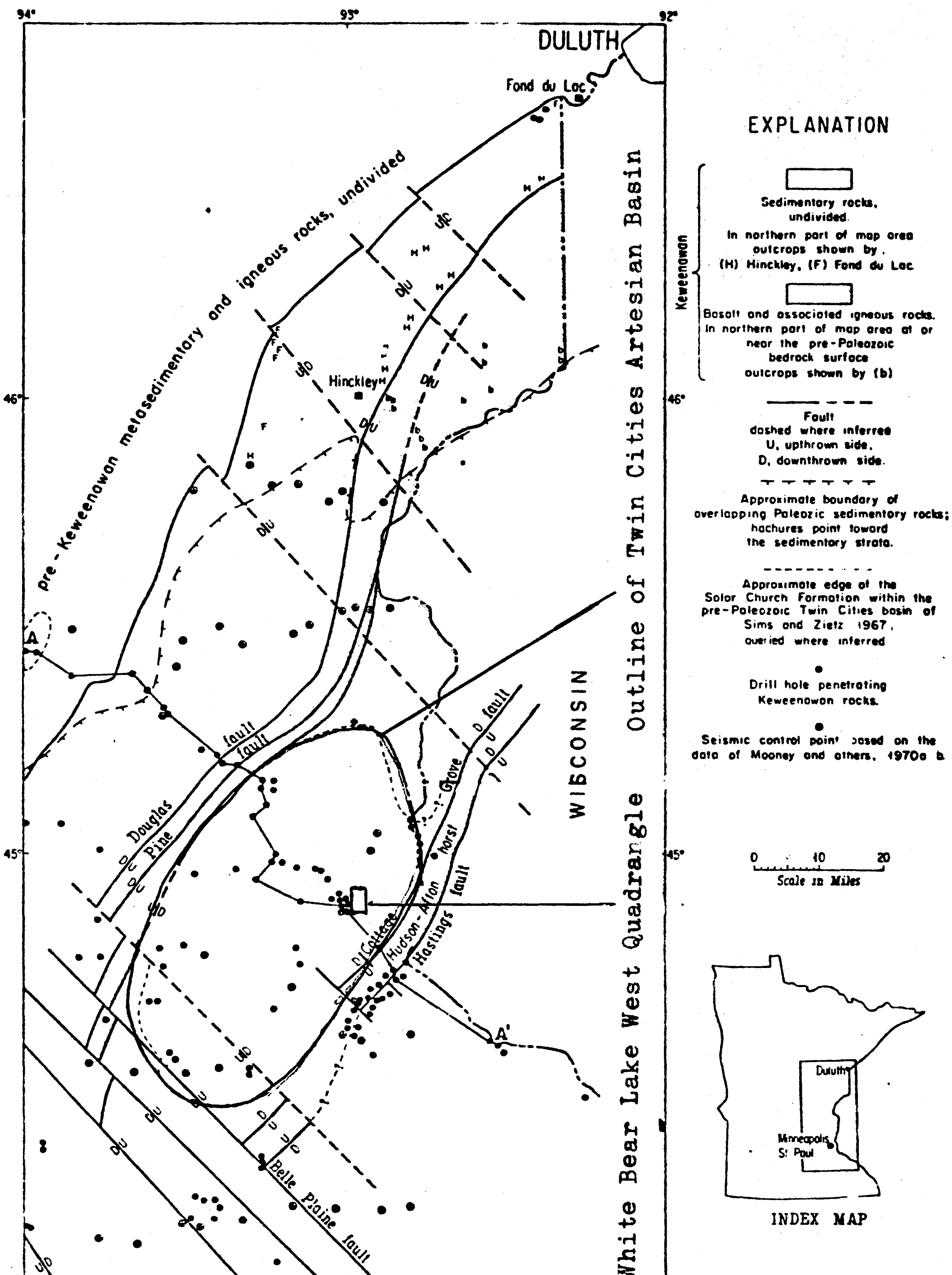



Figure 10. Generalized bedrock geologic map of east-central Minnesota showing major bedrock faults and the inferred distribution of the sub-Paleozoic rocks in southeastern Minnesota (after Morey, 1974)

adequate bedrock well control has prevented delineation of the extent of this fault to the northwest; however, the fault is consistent with well data to the south, although conclusive number of control points is lacking.

The extent of faulting in the Paleozoic bedrock of the Twin Cities area is unknown. The evidence for small-scale faulting in the area is:

1) subsurface work in the adjoining New Brighton area,

2) faults visible in the bluffs of the Mississippi and St. Croix River valleys,

3) reports by drillers of offsets of market units on the southwest side of the Twin Cities Basin,

4) reports of fault zones by tunnelers, and

5) offsets of Quaternary terraces along the Mississippi Valley.

All of these suggest that there was some continued movement during the Paleozoic along some of the major Precambrian faults in the Minneapolis-St. Paul area (see Figure 10). This evidence, along with the lack of thickening in the sedimentary rocks in the basin center lead to the conclusion that the Twin City Artesian Basin has been formed by a combination of step-faulting and warping.

The thinning of the St. Peter Sandstone east of the fault could indicate that the fault movement occurred during its deposition. Some geologists, however, believe that the contact between the Prarie du Chien Formation and the St. Peter Sandstone is an erosional surface.

The exposed bedrock in the Twin Cities area is jointed, and it is presumed that the buried bedrock in the mapping area is similarly fractured.

## QUATERNARY STRATIGRAPHY

The establishment of a depositional sequence in a glacial terrain is difficult because the units often are juxtaposed instead of superposed. The time-transgressive aspects of the till units, and the formation and disappearance of ice-marginal lakes and of outwash torrents with the advance and retreat of the ice sheets produce a discontinuous character of glacial deposits that does not allow all the units to occur in stratigraphic superposition in any one place.

Problems with the stratigraphic relationships in the glacial deposits have necessitated some changes in the terminology of the rock-stratigraphic unit as defined in the 1961 Stratigraphic Code (Anonymous, 1961). The rock-stratigraphic unit is used here in accordance with the Policy of the Minnesota Geological Survey on Nomenclature and Classification for the Quaternary of Minnesota (Stone and others, 1966). The Minnesota Geological Survey defines a rock-stratigraphic unit as a subdivision of the rocks of the earth's crust generally distinguished and delimited on the basis of lithic characteristics, but occasionally also on the basis of surface morphology. Inferred origin may be an important factor in deciding what should be established as a rock-stratigraphic unit (Stone and others, 1966, p. 4). This position is in agreement with the International Subcommission of Stratigraphic Nomenclature which recognizes that lithogenesis and physiographic expression properly influence the definition of lithostratigraphic units (Stone and others, 1966). The stratigraphic division of the various lake plains based on differences in elevation and age, and the differentiation of the redeposited Superior till from insitu Superior till are examples of this policy.

It should be emphasized that considering morphology and/or genesis is not always necessary in establishing rock-stratigraphic units in glacial deposits. Indeed, in many cases, units are completely buried so that constructional morphology, if it still exists, is obscured. As a general rule, rock-stratigraphic units at the surface in a recently glaciated terrain will have more than one morphologic unit developed on them (Stone and others, 1966). For example, several end moraines, an esker, and extensive areas of ground moraine may have been developed on top of the same stratigraphic till unit (see Plate 3, C-C'). The time-transgressive units further complicate stratigraphy because several outwash aprons and ice-marginal lakes may be related to one till (see section on geologic history).

The glacial units recognized in the quadrangle, in their approximate order of formation are:

1) various unnamed tills, clays, and sands in the buried bedrock valleys

2) yellow till deposited by the Wadena Lobe

3) the Willernie Formation, reddish-brown till of northeastern provenance deposited by ice of the Superior Lobe

4) the Hillside Sand, a retreatal and proglacial deposit

5) the Twin Cities Formation, a complex mixture of gray and red till deposited by the ice of the Grantsburg Sublobe

6) the Falcon Heights Sand, a retreatal outwash deposit of the

Grantsburg Sublobe

7) the Hugo Sand, an ice-marginal lake deposit

8) outwash deposited by the Grantsburg ice

9) the Turtle Lake Sand, an ice-marginal lake deposit

10) the New Brighton Sand, an ice-marginal lake deposit, and

11) the Fridley Sand, another ice-marginal lake deposit (Plate 10).

The Twin Cities Formation was formed over a relatively long period of time and some parts of it are contemporaneous with each of the other surficial units (Stone, 1966a, p. 8). Most of the other surficial units lie directly upon the Twin Cities Formation. It should be emphasized that at no one place do all of the glacial units occur in stratigraphic superposition.

## Unnamed Subsurface Units

Unnamed, probably discontinuous sands, tills, gravels, and clays are recognized in the subsurface, especially in the buried bedrock valleys on the basis of drillers' logs (see Plate 3), but little is known about them. These unnamed units, which are thought to be remnants of once more extensive deposits that were protected in the bedrock valleys from subsequent glacial erosion obviously are pre-Superior Lobe in age, probably are pre-Wadena Lobe in age, and may even be pre-Wisconsinan.

## Wadena Lobe (?) Till

A yellowish-brown clayey calcareous till apparently without Cretaceous shale pebbles has been found at depth in some of the buried bedrock valleys (see Plates 2 and 3). This till has the right lithology and is in the right stratigraphic position to be till of the Wadena

Lobe (see Figure 4). Since this unit has not been physically correlated with the type area of the Wadena Lobe, it will be called Wadena Lobe (?) Till in this report.

## Willernie Formation

The Willernie Formation, named by Arko (1975), is a reddish-brown sandy till deposited by ice of the Superior Lobe of the Wisconsin glaciation. The deposit forms the St. Croix Moraine (see Figure 5), which cuts across the southeastern part of the study area. The formation consists primarily of silty clayey sand with some pebbles, cobbles, and boulders. It is a generally very poorly sorted predominantly sandy till with occasional pockets of water-worked sand and gravel. The pebbles show northeastern provenance with characteristic red sandstone, basalt, gabbro, and foliated mafics (see Figure 3). The Willernie Formation is in the subsurface in most of the study area and is exposed on the east side of the quadrangle (see Plates 1 and 3).

## Hillside Sand

The Hillside Sand, formally established by Stone (1966a), is a very pale brown to brown, poorly sorted medium to coarse pebbly sand, locally cobbly. This sand has been traced extensively in the subsurface, but it is exposed only in the sidewalls of gravel pit excavations in the central part of the White Bear Lake West Quadrangle. It is concluded that the Hillside Sand, at least the upper part, is proglacial outwash derived from mixed red and gray drift in the Grantsburg Ice. The lower part of the Hillside Sand is thought to be a retreatal outwash deposit of the Superior Lobe. The unit is almost everywhere directly overlain by the Twin Cities Formation. The Hillside Sand ranges in thickness from about five to 75 feet and has an irregular upper surface. This can be explained as a result of variations in the rate of advance and the rate of melting of the overriding ice from the Grantsburg Sublobe with kames having been formed on the upper surface of the unit (Stone, 1966a, p. 9), and/or as the result of variation in the rate of retreat and of melting of the Superior Lobe.

## Twin Cities Formation

The Twin Cities Formation, formally established by Stone (1966a), is a complex mixture of the previously deposited reddish-brown Willernie Formation till and the light-gray clayey till brought from the west by the Grantsburg Sublobe of the Des Moines Lobe (see Figure 6). The reddish-brown sandy till was picked up locally and incorporated into the ice of the Grantsburg Sublobe. The two basic tills that have been mixed to varying degrees within the formation are:

1) a light-gray clayey till with characteristic white limestone and gray shale pebbles among others in a montmorillonitic sandy silty clay matrix, and

2) a reddish-brown sandy till containing pebbles of red sandstone, basalt, and gabbro among others (see Figure 3).

Both tills contain some pebbles, cobbles, and boulders and have lenses and layers of water-worked material.

Three facies have been mapped within the Twin Cities Formation. Facies a is a complex mixture of light-gray clayey till and reddish-brown sandy till. The mixtures vary from juxtaposition and superposition of large and small masses of the two tills to blebs of one till in the other to complete mixing detectable only by pebble counts or clay mineralogy. Facies b is light-gray clayey till underlain by redeposited reddish-brown sandy till with a relatively thin zone of obvious intermixing between them. Facies c is a complex variable mixture of light-gray clayey till and redeposited reddish-brown sandy till with quite substantial amounts of water-laid material at the surface. Facies c is interpreted as a stagnant ice deposit of the Grantsburg Sublobe.

The Twin Cities Formation occurs in the subsurface (see Plate 3) and is exposed in the western two-thirds of the Quadrangle (see Plate 1). The Twin Cities Formation, like all tills, is time transgressive.

## Falcon Heights Sand

The Falcon Heights Sand, formally established by Stone (1966a), is a brown, poorly sorted, cross-bedded gravelly sand with some cobbles. The sand contains some pebbles of white limestone and gray shale of western provenance as well as a large proportion of pebbles of red sandstone, basalt, gabbro, and felsite of northeastern provenance (see Figure 3), indicating that the outwash was derived from mixed tills. The deposit was formed after the Grantsburg Ice pulled back from its maximal eastward advance (see Figure 12). Gravel pockets, channel fills, and layers of sandy gravel are all common near the northern and western margins of the unit, near where the ice contact was during deposition of the outwash. The Falcon Heights Sand is interpreted as an outwash body deposited by meltwater running off the Grantsburg Ice. The unit occurs in the extreme southwestern corner and through the east-central portion of the quadrangle (see Plate 1) and extends southward from the study area across the City of St. Paul and down the Mississippi River Valley.

## Hugo Sand

The Hugo Sand, named by Stone (1972), is a pale brown, mostly fine-grained to medium-grained sand with some layers and lenses of silt. It was deposited in ice-marginal Lake Hugo as the Grantsburg Sublobe halted briefly in its retreat shortly after reaching its maximal advance (see Figure 12). This largely sand deposit was laid down in a high energy lake which removed much of the fine material. The sand is laminated and cross-laminated. The sands within most individual lamina are well sorted. The deposit includes laminae, lenses, and large bodies of clayey silt. The unit overlies the Twin Cities Formation and extends from the south-central part to the northeastern corner of the quadrangle (see Plate 1).

## Unnamed Outwash

These outwash deposits are of such limited extent that it was not logical to identify them with formal names. Pebbles show that both outwash deposits were derived from mixed Grantsburg till.

### Unit A

The outwash deposited near Otter Lake in the northeastern part of the quadrangle is a medium-grained to coarse-grained gravelly sand with pockets and channels of gravel throughout the unit formed from runoff of the active ice to the west and stagnant ice to the east (see Figure 14). The deposit is characterized by pebbles of gray shale and white limestone, showing its relation to the Grantsburg Sublobe.

Unit B

The outwash deposit south of Little Canada, not formally named (see Plate 1), is a poorly sorted medium-grained to coarse-grained gravelly sand formed from runoff of the stagnant ice to the west. The unit contains pebbles of gray shale and white limestone, among others, relating it to the Grantsburg Sublobe. This deposit is interpreted as occupying the outlet channel of ice-marginal Glacial Lake Hugo (see Figure 14).

## Turtle Lake Sand

The Turtle Lake Sand, formally established by Stone (1966a), is a very pale brown, fine-grained to medium-grained sand with occasional lenses and layers of silt. The sands and silts were deposited in ice-marginal Glacial Turtle Lake after the high ice had retreated to the northwestern corner of the quadrangle (see Figure 16). The deposit is laminated to thin bedded. Sands within each laimina generally are very well sorted. The Turtle Lake Sand lies directly on the Twin Cities Formation. The fine to medium sands are interpreted as having been deposited in a high energy lake marginal to the Grantsburg Ice (Figure 16). The Turtle Lake Sand is exposed in the west-central part of the quadrangle (see Plate 1).

## New Brighton Sand

The New Brighton Sand, formally established by Stone (1966a), is a mostly brown, fine-grained to medium-grained sand with some silt. The deposit is laminated and cross-laiminated and includes some crossbedding. The fine to medium sands are interpreted as having been deposited in the outflow area of Glacial Lake New Brighton, a high energy ice-marginal lake, which developed two miles west of the study area after Glacial Turtle Lake had disappeared (see Figure 16). In the White Bear Lake West Quadrangle, the New Brighton Sand occurs only in the extreme southwestern corner (see Plate 1).

## Fridley Sand

The Fridley Sand, formally established by Stone (1966a), is a mostly brown, fine-grained to medium-grained sand with some silt. The deposit is generally laminated and cross-laminated, and the sand within most lamina is well sorted. Occasional lenses and layers of silt occur. The Fridley Sand was deposited in a high energy, ice-marginal glacial lake in the retreat of the Grantsburg Ice (see Figure 18). The Fridley Sand occurs only in the northwestern corner of the study area (see Plate 1) but extends northward through much of adjacent Anoka County (see Figure 1).

## Eolian Sand

Eolian sand deposits occur in localized patches in the lake bed deposits. The wind has reworked the upper few inches to the upper two feet by winnowing out the silt-sized and clay-sized particles, leaving well sorted loose sand to be blown around. Because of the localized nature of these deposits, they were not mapped. The wind action which caused these deposits to form occurred soon after the retreat of the ice. Vegetation has slowed the process considerably; however, in periods of drought, increased wind erosion should be expected.

## Loess

Deposits of silt and clay which have been winnowed out by wind action occur in the study area. These deposits are mostly thin and patchy and have not been found continuously enough to map as units. The sources of the silt and clay are the abandoned lake beds.

## Colluvium

Material that has moved down slopes by means of creep and sheetwash occurs on almost all of the steeper slopes in the clay materials in the study area. On account of the lack of bedding surfaces, colluvium is very difficult to recognize and therefore was not mapped. The dense vegetation also obscures the colluvium deposits.

## Swamp Deposits

Swamp deposits in the White Bear Lake West Quadrangle are mostly peat and muck, but include some organic sand, silt, marl, and clay. Most of the swamps in the area occupy former lake basins which have been filled with detritus and especially with organic material. In some swamps, marl was deposited before the lakes became swamps, but its occurrence is not predictable. Swamp deposits of variable thickness occur throughout the quadrangle, but are most common in the clayey till deposits because of its irregular topography.

## Lake Deposits

Most of the lakes in the area are filling. Some of the sediment in the lake bottoms is organic material mixed in with soil and glacial material eroded from the areas directly surrounding the lakes.

## Anthropic Deposits

The term "anthropic deposit" is used here as a substitute for the more common term "artificial fill." Anthropic deposits are defined as any deposits emplaced by Man. The anthropic deposits in the quadrangle are primarily sand, gravel, and rubble transported from afar and fills of locally derived material emplaced during site leveling or for increased bearing capacity. The anthropic deposits were emplaced to varying extents along the roads and on building sites in the quadrangle because of the irregular terrain and the locally poor competence of the surficial deposits (see section on engineering geology). These deposits are so common in the area that because of the expense of drafting, it was not economically feasible to include them on the surficial geologic map. For a better representation of the frequency of occurrence, see Stone (1966a).

## GEOLOGIC HISTORY

The Twin Cities Basin was a site of extrusive mafic lava flows during the middle Keweenawan and for deposition of thick red bed sequences during the later Keweenawan (see Table I). During the Cambrian and Ordovician periods, the basin continued to be a site for deposition of sediments. These rocks are composed of four recurrent lithologies that record at least five transgressions of marine waters across the area during the Late Cambrian and Early and Middle Ordovician (Mossler, 1972). During the Cambrian, silts and quartzitic sands were deposited. The Lower and Middle Ordovician rocks of the basin are primarily quartzose sandstones, carbonates, and shales. The bedrock geologic history of the area after the Middle Ordovician and prior to the Pleistocene can only be inferred from surrounding areas because erosion has removed any sedimentary rocks that once may have overlain the Middle Ordovician shales and carbonates.

The area was glaciated during the Nebraskan, Kansan, and Illinoian glacial ages and subjected to long interglacial erosional periods during which these glacial features were removed or modified and well integrated drainage systems probably were established (Stone, 1966a, p. 28). The major bedrock valleys of the area, which were caused by several episodes of erosion (Stone, 1975, personal communication), probably were eroded during the Pleistocene Epoch prior to the Wisconsinan glaciation. The earliest known Wisconsinan Age glacial drift in the White Bear Lake West Quadrangle probably is the Wadena (?) Lobe till, deposited by the Wadena Lobe (see Figure 4 and Plate 3). Thick Wisconsinan glacial ice again covered most of the Twin Cities area when the Superior Lobe entered the area from the north, depositing the reddish-brown Willernie Formation till and creating the St. Croix Moraine (see Figure 5). As this ice retreated northward about 14,000 years ago (Wright and Ruhe, 1965), the lower part of the Hillside Sand was deposited as a retreatal outwash. About 13,000 years ago (Wright and Ruhe, 1965), the Grantsburg Sublobe advanced into the area from the southwest bringing gray drift and picking up some of the previously deposited red drift, especially that which still was frozen in stagnant ice. During this advance, the remainder of the Hillside Sand was deposited as proglacial outwash derived from mixed red and gray drift in the Grantsburg ice. The ice of the Grantsburg Sublobe deposited the Twin Cities Formation (see Plate 1 and Figure 11) throughout the time during which it flowed in the area. As the Grantsburg Sublobe began to withdraw from its short-lived position of maximum advance (which crosses the southeastern portion of the White Bear Lake West Quadrangle) the Falcon Heights Outwash Plain was formed between high ice on the west and the high St. Croix Moraine on the east (see Figure 12).

Small ice-marginal lake plains were formed at progressively lower elevations as the ice front halted temporarily in its retreat to the northeast. Lake Hugo, one of the larger of these high energy ice-marginal sand bottomed lakes, was formed early in the westward retreat of the Grantsburg Ice (see Figure 13) with high terrain on the east and high active ice on the west. Glacial Lake Hugo drained across the Falcon Heights Outwash Plain just to the south of the quadrangle (see

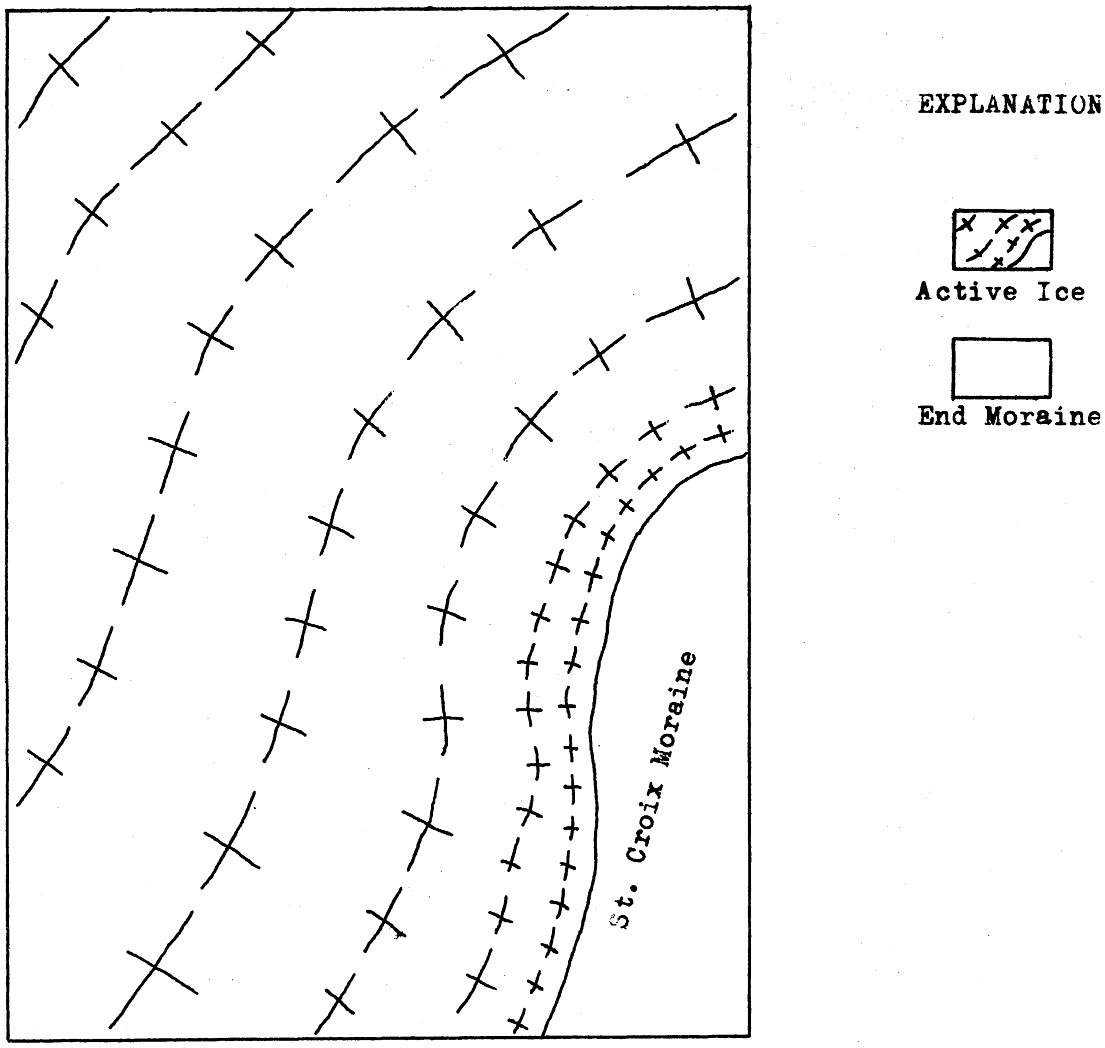



Figure 11. Map showing maximal advance of the Grantsburg Sublobe in the White Bear Lake West Quadrangle

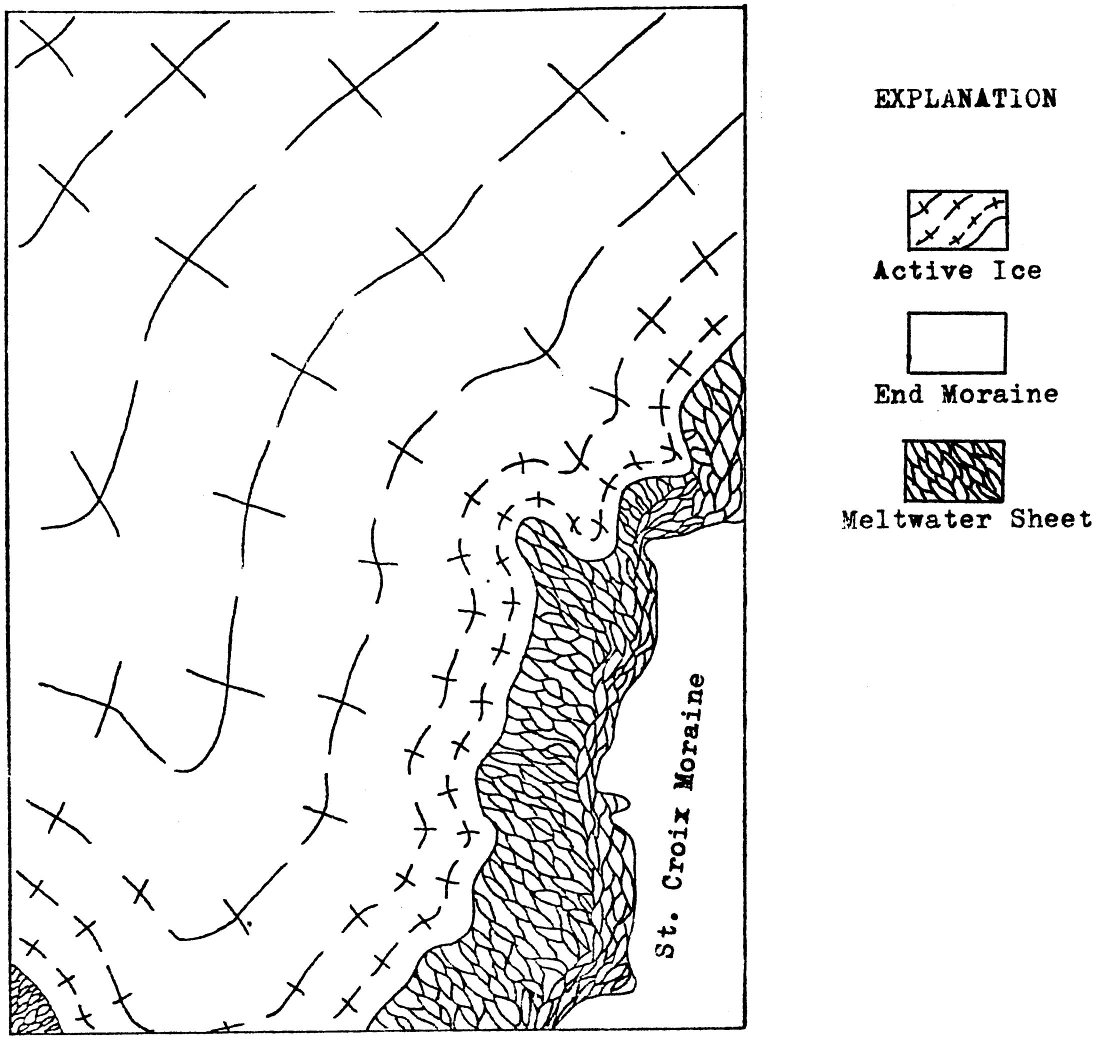



Figure 12. Formation of the Falcon Heights Outwash Plain by meltwater from Grantsburg ice and formation of the Elm Lake Moraine

Figure 13).

The small outwash plain in the north-central quadrangle (see Plate 1) near Otter Lake was deposited during the time the ice was still active but wasting very slowly westward (see Figure 14). The small outwash plain south of Little Canada was deposited in part by water running off the stagnant ice to the west, and part by the sediment-laden water flowing out of Glacial Lake Hugo and later, Glacial Turtle Lake. This combination of sediment sources explains the mixture of well sorted fine sand of the outlet channel of Glacial Lake Hugo and the coarse gravel pockets from the ice.

Later, the ice in the North Oaks area was a high area of stagnant ice, and the active ice in the west was forming the Arden Hills Moraine (see Figures 14, 15, and 16). Next, ice-marginal Glacial Turtle Lake, ponded between the topographic high terrain in the east and high ice on the west and north, was formed (see Figure 16) and drained southward utilizing the drainage channel of Glacial Lake Hugo.

The active ice retreated toward the west and north into the New Brighton Quadrangle producing a long, narrow ice-marginal lake which drained across the extreme southwestern corner of the White Bear Lake West Quadrangle (see Figure 16).

Finally, the active ice retreated completely from the quadrangle to positions in the north and west, producing the quite large ice-marginal Glacial Lake Fridley at a lower level than any of the earlier lakes (see Figure 18). Glacial Lake Fridley existed long enough to establish off-shore, near-shore, and beach facies which have been identified in the adjacent Centerville Quadrangle by Stone (1972). As the Grantsburg Sublobe gradually retreated from the area, exposing large

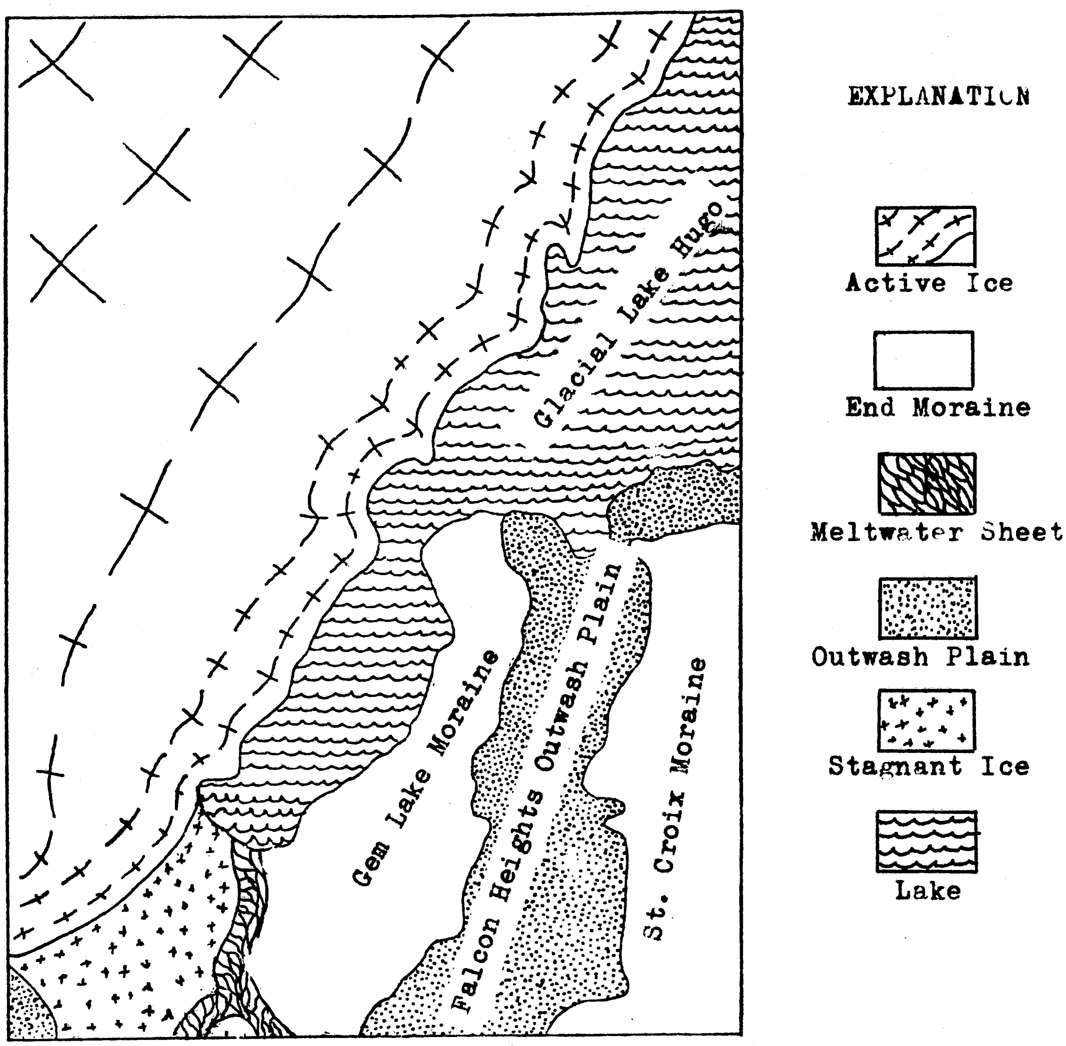



Figure 13 Development of small outwash apron west of present Bald Eagle Lake

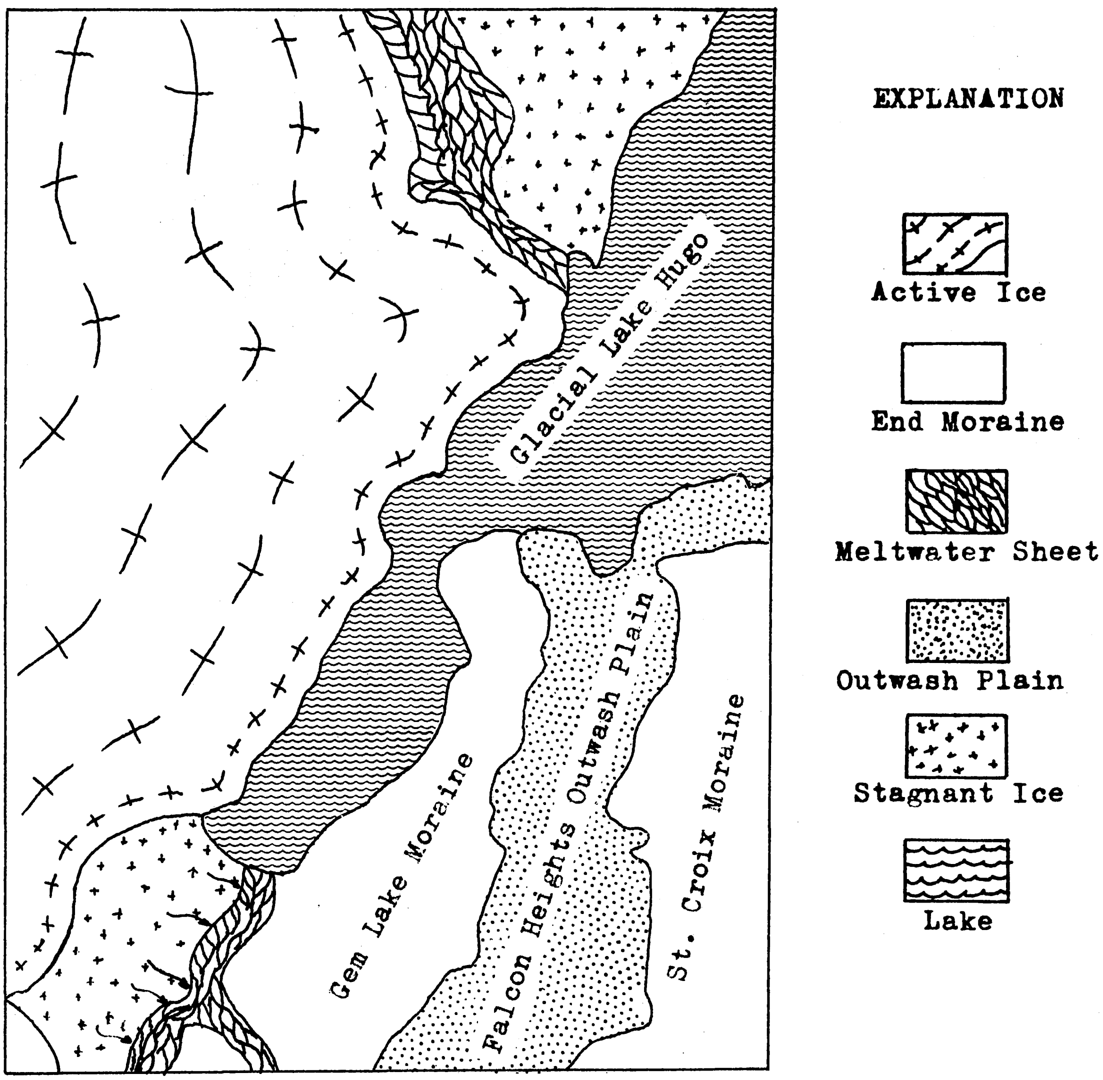



Figure 14. Development of ice-marginal Lake Hugo between active ice on the northwest and high terrain on the east

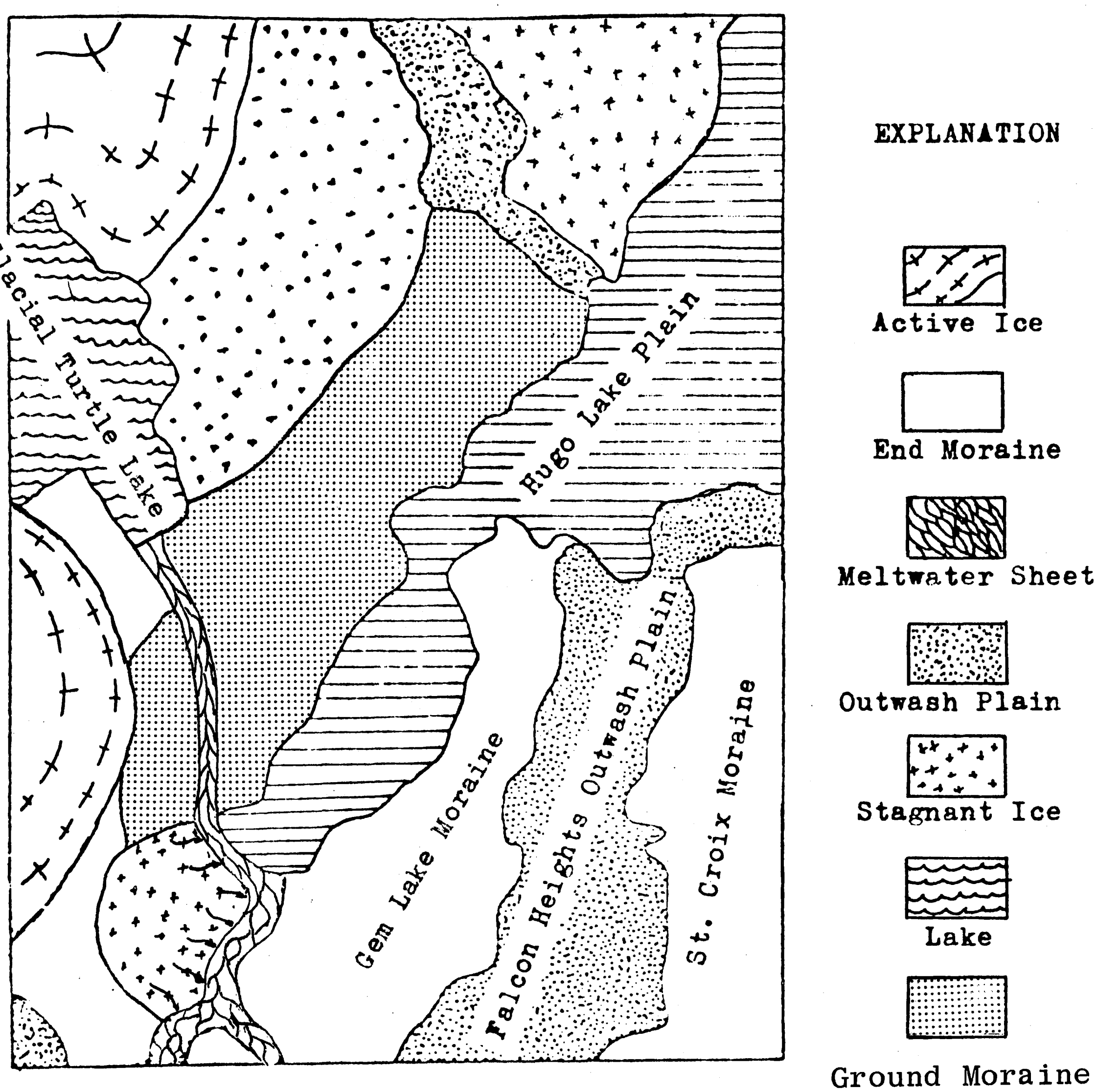



Figure 15. Formation of the Arden Hills Moraine and of Glacial Lake Turtle Lake in the White Bear Lake West Quadrangle, Minnesota

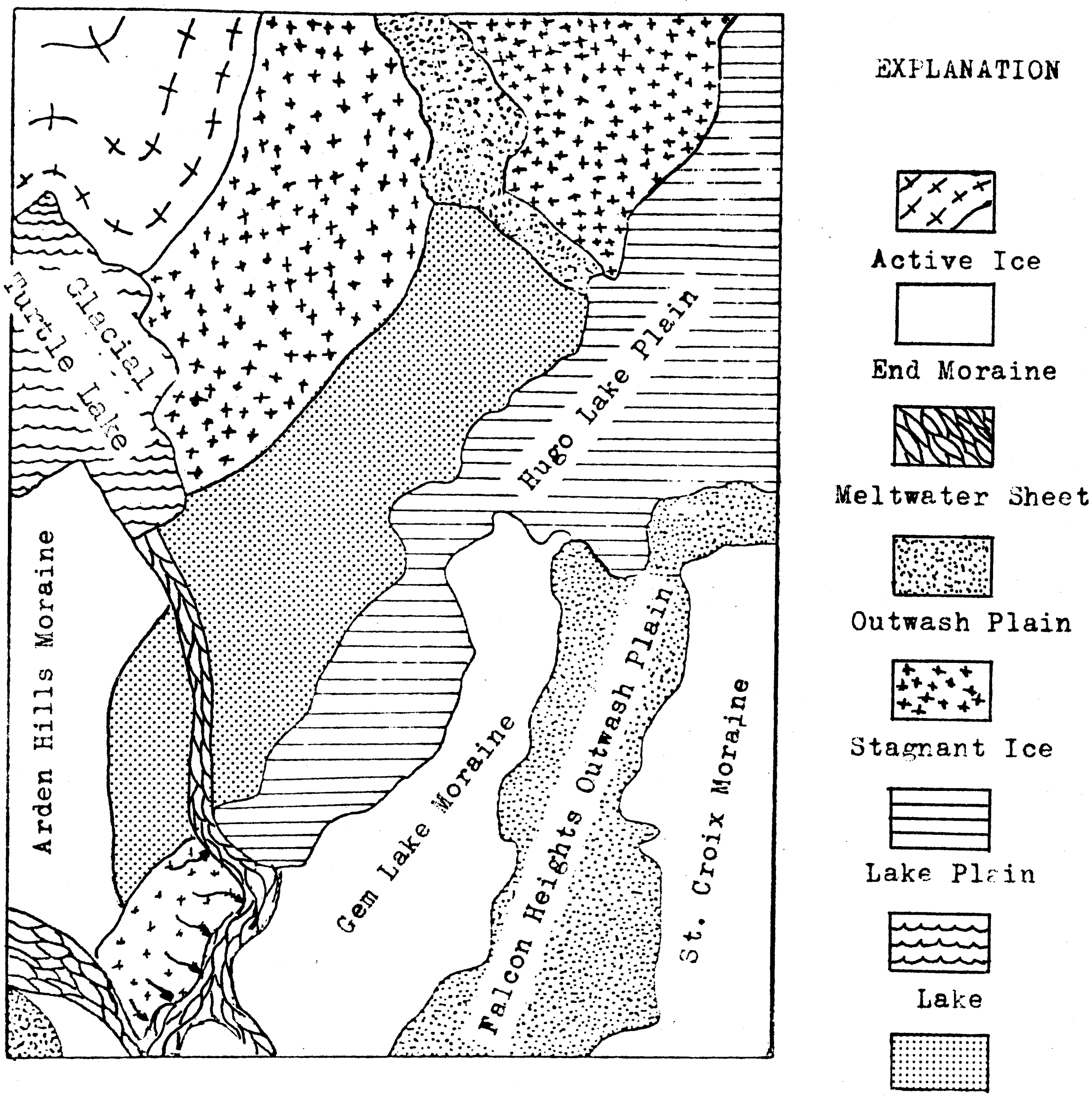



Figure 16. Deposition of New Brighton Sand in the southwestern corner of the White Bear Lake West Quadrangle by the outflow from Glacial Lake New Brighton

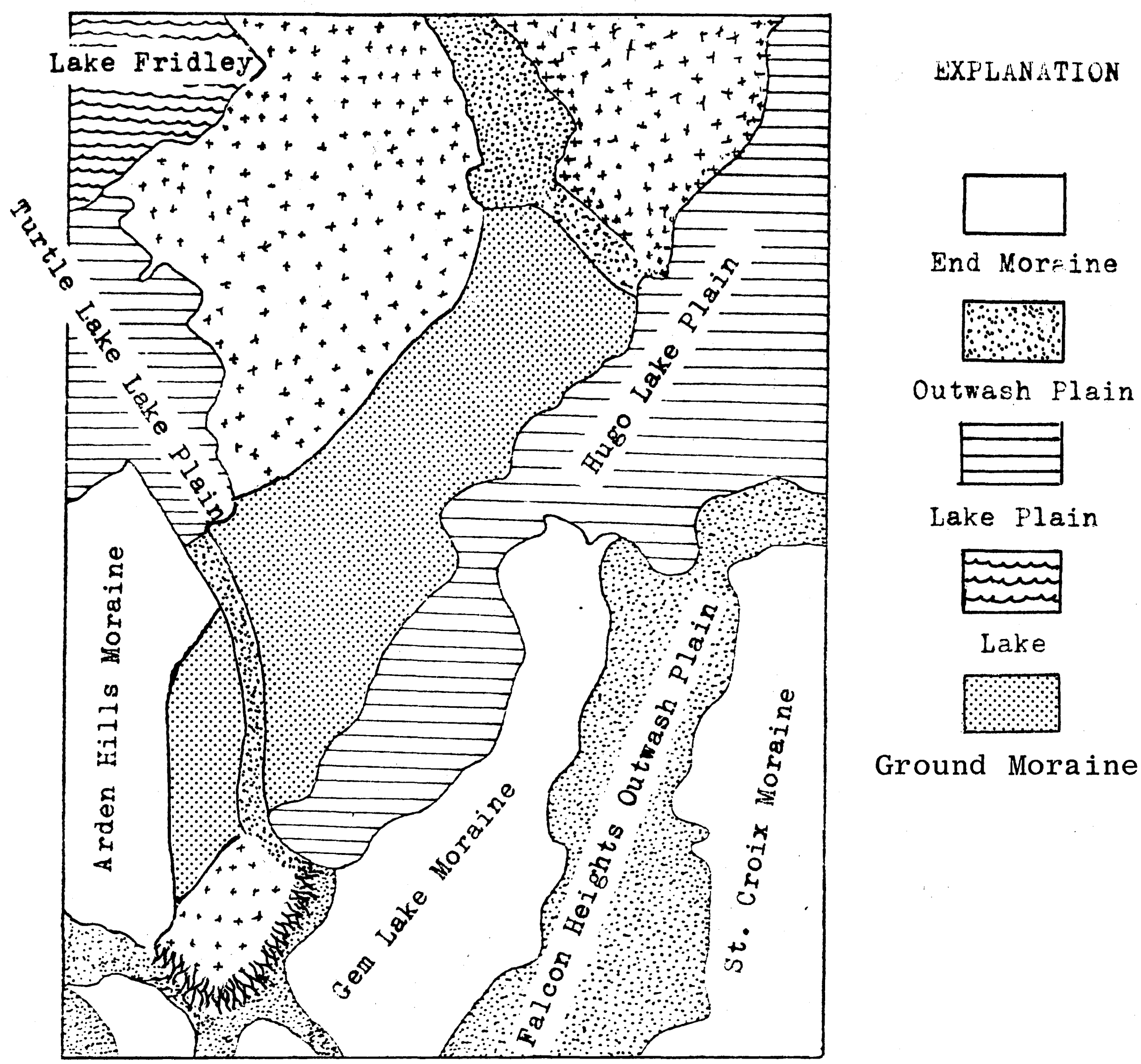



Figure 17. Formation of Glacial Lake Fridley between high terrain on the south and east and high ice on the north and west and deposition of outwash unit B by stagnant ice

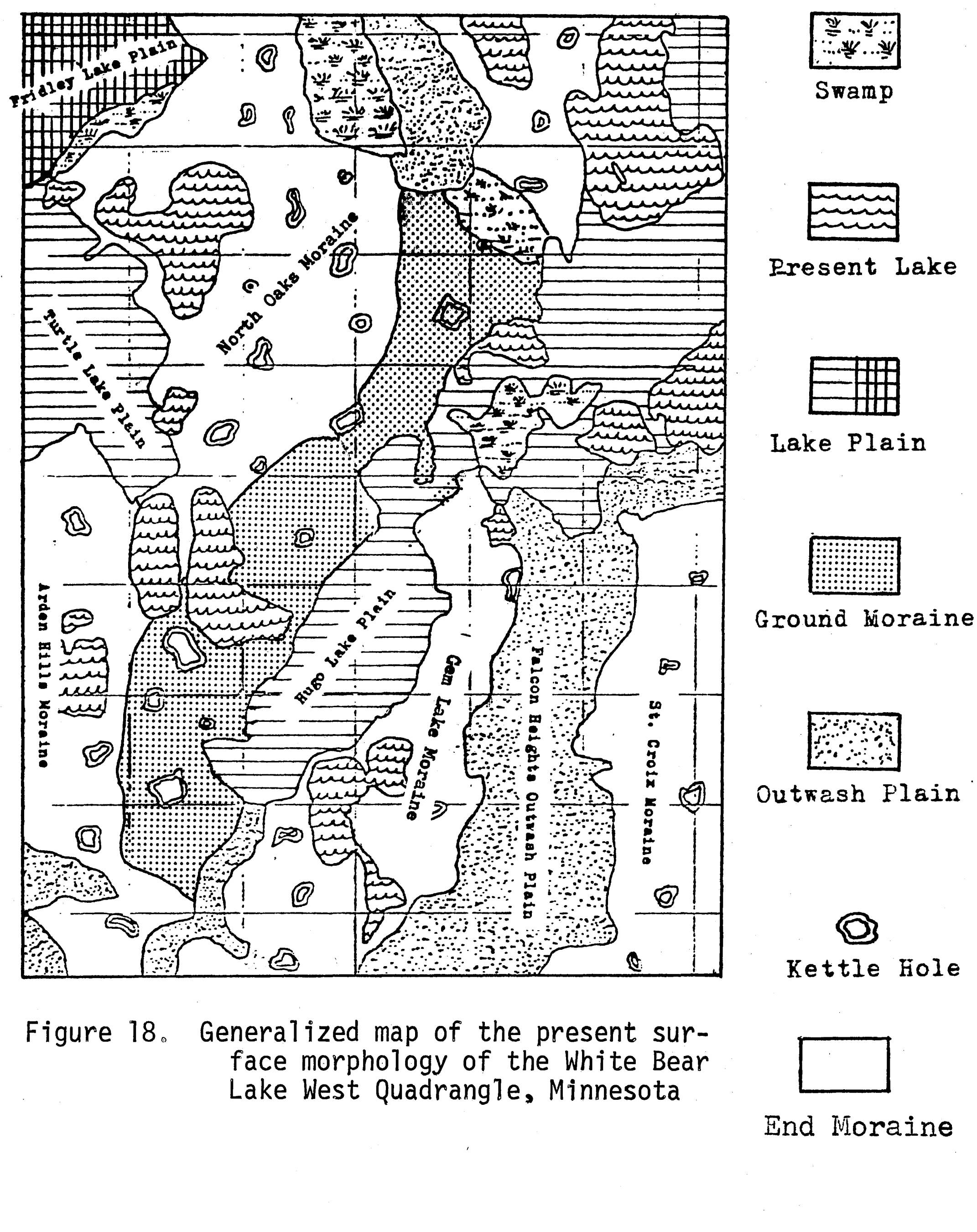



Figure 18. Generalized map of the present surface morphology of the White Bear Lake West Quadrangle, Minnesota

expanses of sandy sediment on the old lake bottoms and before vegetation became established, wind reworked the sand in the upper 1-18 inches of the lake sands and deposited thin (<1 ft.) loess downwind (i.e., to the southeast).

The gradual modification of lakes by geologic processes in post-glacial time is evident in the White Bear Lake West Quadrangle. Almost all of the lake basins result from the irregular down-melting of stagnant glacial ice long after the waning phases of glaciation. Moraines and outwash plains in particular are areas in which stagnant ice remained buried for long periods after active ice left the region. Eventually, when the climate changed at the end of the Pleistocene, the buried ice melted to form kettle holes (Florin and Wright, 1969). Some of the largest ice depressions in the quadrangle are aligned above bedrock valleys, indicating that ice blocks filled substantial portions of these valleys before the most recent glaciation (see Plates 1 and 2).

Post glacial weathering and erosion have modified the glacial topography only slightly (see Figure 7). For example, the area lacks an integrated drainage system, so colluviation and sheet-wash have been the major methods of erosion. Much organic material has been contributed to the lakes from the dense vegetational cover in the area. Many of the lakes are now in the process of becoming swamps due to this sedimentation.

The works of Man have had a major impact on the landscape with extensive development and urbanization. In addition to Man's structures themselves, the landscape has been greatly modified by cutting and filling.

The future potential of geologic processes must not be discounted. Man must learn to deal with these geologic processes in a manner that harmonizes with nature.

# ENVIRONMENTAL GEOLOGY

Environmental geology is interpreted broadly in this report as the use of geological information in the practical activities of Man. Environmental geology could be defined as having the scope of urban geology, but being applied to any and all areas, whether they are urbanized or not.

## Ground-Water Geology

The water table in the White Bear Lake West Quadrangle generally follows the topography and intersects the surface in the many lakes and swamps. The saturated glacial drift provides residential water in the sparsely developed areas. The sand and gravel units, primarily outwash deposits in the tills, produce plentiful supplies of water for home use, but the quality of this water is variable. Pollution from nearby septic fields is the most common problem (see section on septic waste disposal). For this reason, and to protect the many lakes in the area which provide the water supply for St. Paul, a metropolitan sewer has been built to serve the area.

The City of St. Paul operates deep wells which pump water into the lake chain for transportation to the city which lies downhill to the south.

The major bedrock aquifers in the area's artesian basin are the St. Peter Sandstone, the Franconia Formation, and the sandstones of the

Dresbach and Hinkley Formations (see Table I). These bedrock aquifers all are parts of the Twin Cities Artesian Basin (see section on structural geology).

Direct infiltration through the exposed eroded edges of the bedrock aquifers provides most of the ground-water recharge. In the center of the basin, the upper bedrock units receive a substantial part of their recharge by direct infiltration from the saturated glacial drift which fills the eroded bedrock valleys (see Plates 2 and 3).

Because the upper bedrock aquifers have been eroded and subsequently refilled with high-permeability sands and gravels, the potential for bedrock aquifer recharge during times of surplus exists in the area. Diverting floodwater into these bedrock valleys for storage and recharge is a technically interesting possibility. Fault zones, when intersected by water wells, have shown anomalously high well yields and could prove to be important for large-demand water users such as municipalities and certain industries.

## Septic-Waste Disposal

In evaluating the suitability of surficial deposits for proper operation of a septic tank and its accompanying filter field, the permeability of the material is of major importance. If the permeability is too low, adequate filtration does not occur. If the permeability is too high, infiltration of effluent will be so rapid that various pollutants cannot be destroyed or filtered before they reach an aquifer. Areas underlain by the Twin Cities Formation have low permeability, while the outwash areas have too high a permeability.

## Planning and Development Geology

The information in this report provides some of the physical data necessary for the assessment planning and/or development of land and mineral resources in the White Bear Lake West Quadrangle. In the study area, residential use is widely established and land values have been raised beyond the acceptable range for most other uses. The only changes likely to occur are intensified residential uses. The information in the engineering geology tables, when related to the surficial map, could be useful for residential development, open space design and zoning, protection of ground-water recharge areas, as well as preliminary site investigations for future construction projects in the area.

## Engineering Geology

Because all of Man's structures are built on, with, or through earth materials, there is a need for basic physical data on the near surface bedrock and unconsolidated deposits for any engineering endeavors, but especially for those that are large and heavy and/or expensive.

The surficial geologic units mapped in the White Bear Lake West Quadrangle are evaluated in terms of engineering properties and construction practices. The surficial geologic map (Plate 1) and the cross-sections (Plate 3) can be used to show the distribution of these units that are described in Tables II and III. These data are not intended to supplant site investigations, but rather to provide generalized data useful for land and resource planning and development. The point is emphasized that site investigations generally are necessary for all major construction projects.

Table 2. Generalized description of engineering properties of the surficial deposits of the White Bear Lake West Quadrangle, Minnesota

| Geologic Unit | Permeability | Workability | Susceptibility to Frost Heaving | Slope Stability | Foundation Conditions | Possible or Reported Uses |
|---|---|---|---|---|---|---|
| Anthropic deposits | Extremely variable | Variable but generally easy to excavate and compact | Extremely variable | Generally stable | Generally subject to compaction under load unless compacted when emplaced; compressible low-strength lake or swamp deposits may be beneath old fills | |
| Swamp deposits | Generally very low | Generally makes very poorly compressible fill; peat may be easier to dredge than excavate | Fine-grained organic materials highly susceptible | Generally unstable | Generally very poor; low bearing strength and high consolidation common; generally should be excavated and back-filled if fill or structure to be emplaced | Peat useable as fertilizer and soil conditioner |
| Fridley and New Brighton Formations | | | | Generally stands temporarily in steep or vertical cuts but eventually becomes unstable on 30° slopes; susceptible to wind and rain erosion | Moderate to fairly high bearing strength; subject to moderate compaction by vibration | Fill |
| Fine to medium sand facies | Moderate; higher laterally than vertically | Easy to excavate; generally must be compacted by vibration or with rollers | High in fine sand; moderate in medium sand | | | |
| Clayey silt facies | Very low | Easy to excavate except below water table | Very high | Very poor | Very low bearing strength and subject to excessive consolidation | Fill for non-bearing areas such as playgrounds constructed on swampy areas |

Table 2. (continued)

| | | | | | | |
|---|---|---|---|---|---|---|
| Turtle Lake Sand and Hugo Sand | | | | | | |
| Fine to medium sand facies | Moderate; higher laterally than vertically | Easy to excavate; generally must be compacted by vibration and/or smooth rollers | High in fine sand; moderate in medium sand | Will generally stand temporarily in steep or vertical slopes but eventually becomes unstable on 30° cuts; susceptible to wind and rain erosion | Moderate to fairly high bearing strength; subject to moderate compaction by vibration | Fill |
| Gravelly fine to coarse sand facies | Moderate to high | Easy to excavate and compact | Moderate to low | Unstable and free-running on 30° slopes; susceptible to wind and rain erosion | Moderate to high bearing strength where confined | Fill |
| Falcon Heights Sand and Outwash | Moderate to high | Easily excavated and compacted to a rather dense fill | Generally low | Unstable and free-running on 30° slopes; susceptible to wind and rain erosion | Generally high bearing strength where confined | Fill; poor for concrete aggregate because of high shale content |
| Twin Cities Formation | | | | | | |
| Light-gray till | Low except along joints | Moderately easy to excavate and moderately difficult to compact | High to moderate susceptibility | Will stand in moderately dry steep cuts but likely to slump and flow on wet steep cuts, especially in spring thaw | Moderate bearing strength when wet, high when dry; desirable to keep dry beneath footings because of relatively high montmorillonite content | Makes adequate fill |
| Reddish-brown till (Villernie Formation) | Low to moderate | Easy to excavate and compact into a rather dense fill | Moderate | Will stand in moderately steep cuts | Generally high bearing strength | Fill |
| Hillside Sand | High | Easy to excavate and compact | Moderate | Unstable and free-running on 30° slopes; susceptible to wind and rain erosion | High bearing strength where confined | Concrete aggregate and fill |

Table 3. Matrix relating surficial units to engineering activities

| Surficial Units / Matrix Activities | Willernie Formation | Outwash Deposits | Hugo Sand | Turtle Lake Sand | Twin Cities Formation | Falcon Heights Sand | New Brighton Sand | Fridley Formation | Swamp Deposits |
|---|---|---|---|---|---|---|---|---|---|
| Liquid Waste Disposal | - | o | o | o | - | o | o | - | - |
| Solid Waste Disposal | o | - | o | - | o | - | - | - | - |
| Light Construction | o | + | o | o | - | + | o | o | - |
| Heavy Construction | o | o | - | - | - | o | - | - | - |
| Highway Location | o | + | o | o | - | + | o | o | - |
| Aggregate | - | + | - | - | - | + | - | - | - |
| Fill Material | o | + | + | + | o | + | + | o | - |
| Excavation | o | + | o | o | o | + | + | o | - |
| Underground Installations | o | o | o | o | - | o | o | o | - |
| Buried Cables and Pipes | o | + | o | o | - | + | o | o | - |

Anticipated Capability

- Most favorable capability; minimal problems

o Moderately favorable capability; moderate problems

- Least favorable capability; maximal problems

One of the bedrock units, the St. Peter Sandstone, which is widespread in the study area (see Table I), is especially uncommon from an engineering geology standpoint. This sandstone, which is near the surface throughout the Twin Cities area, generally is extremely friable so that it can be tunnelled using rapid, relatively inexpensive hydraulic techniques. The bedrock geologic map shows where this unit is dissected by buried valleys in the study area (see Plate 2).

The bedrock geology and topography have been studied in area-wide gravity studies. These have shown general configurations in the subsurface, but detailed log mapping is the only accurate technique for close determination of bedrock topography and geology.

## Mineral Resources

The sands and gravels which occur in the various glacial deposits are of economic importance to the area. The Hillside Sand is of particular importance in much of the Twin Cities area because of its suitability for concrete aggregate (see Table III), and its proximity to the surface. The other units are of variable value as fill (see Table III for relative ratings).

The swamp deposits containing peat are usable as fertilizer and soil conditioner when properly treated. A detailed exploration of each swamp deposit would be necessary to determine the thickness and type of peat in the various deposits.

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# VITA

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Candidate for the Degree of

Master of Science

Thesis: GEOLOGY OF THE WHITE BEAR LAKE WEST QUADRANGLE, MINNESOTA

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Biographical:

Personal Data: Born in St. Paul, Minnesota, December 18, 1948, the son of Dr. and Mrs. Charles T. Eginton.

Education: Graduated from Highland Park High School, St. Paul, Minnesota, in June, 1967; received the Bachelor of Science degree from the University of Minnesota, Institute of Technology, Minneapolis, Minnesota, in June, 1971; completed requirements for the Master of Science degree at Oklahoma State University, Stillwater, Oklahoma, in July, 1975, with a major in Geology.

Professional Experience: Geological consultant, Minnesota Geological Survey, 1972-73.

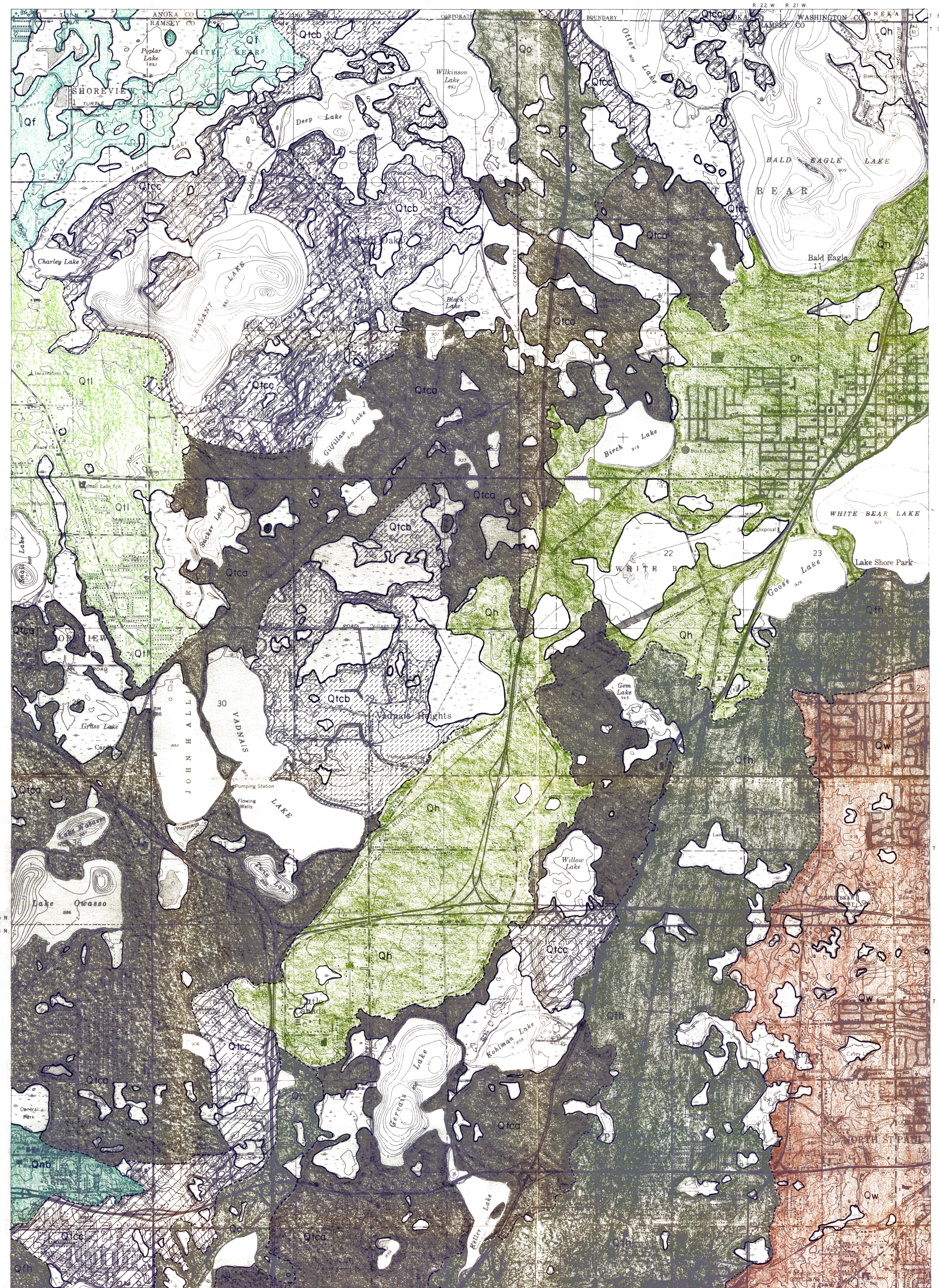
# GEOLOGIC MAP OF THE WHITE BEAR LAKE WEST QUADRANGLE, MINNESOTA



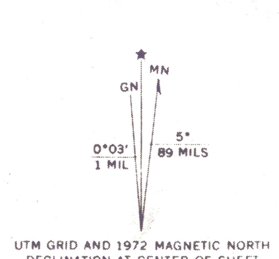
**Plate 1**

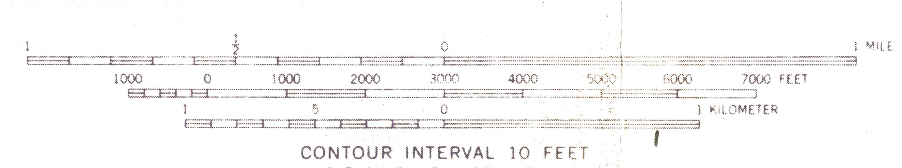
C. W. Eginton






Surficial Geology by C.W. Eginton, 1975




CONTOUR INTERVAL 10 FEET
DATUM IS MEAN SEA LEVEL

## EXPLANATION

**SWAMP DEPOSIT**

Mostly peat and muck, but includes organic sand, silt, marl, and clay.

**Qf**

**FRIDLEY SAND**

Mostly brown fine to medium sand with some silt. Generally laminated and cross-laminated. Sand within most individual laminae is well sorted. ~~Occasional lenses and layers of silt.~~ Deposited in ice-marginal Lake Fridley of the Grantsburg Sublobe.

**Qnb**

**NEW BRIGHTON SAND**

Brown mostly fine to medium sand with occasional layers of coarse sand and pebbles. Laminated and cross-laminated. Includes channels and cross-bedded deposits. Pebbles include white limestone and red sandstone. Many medium-sized sand grains are well rounded and may be related to the local bedrock. Deposited in ice-marginal Lake New Brighton of the Grantsburg Sublobe.

**Qtl**

**TURTLE LAKE SAND**

Very pale brown fine to medium sand with occasional lenses and layers of silt. Laminated to thin-bedded. Sand within each lamina generally very well sorted. Deposited in ice-marginal Lake Turtle Lake of the Grantsburg Sublobe.

**Qo**

**OUTWASH**

Medium to coarse gravelly sand with gravel pockets and channels. The deposit is characterized by pebbles of gray shale and white limestone. It is an outwash deposit of the Grantsburg Sublobe.

**Qh**

**HUGO SAND**

Pale brown mostly fine to medium sand with some silt. Laminated and cross-laminated. Sand within most individual laminae is well sorted. The deposit includes laminae, lenses, and large bodies of clayey silt. Deposited in ice-marginal Lake Hugo of the Grantsburg Sublobe.

**Qfh**

**FALCON HEIGHTS SAND**

Brown gravelly sand with occasional cobbles. Poorly sorted and cross-bedded. Gravel pockets, channel fills and layers of sandy gravel all common near the northern and western margins that were at the ice contact. Contains pebbles of red sandstone, basalt, gabbro, white limestone, and gray shale. Outwash deposit of the Grantsburg Sublobe.

**Qtca | Qtcb | Qtcc**

**TWIN CITIES FORMATION**

Till deposited by the ice of the Grantsburg Sublobe. Two basic lithologies occur: a light-gray clayey till with white limestone and gray shale pebbles in a montmorillonitic sandy silty clay matrix; and a reddish-brown sandy till derived from the older Willernie Formation. Both till lithologies contain some pebbles, cobbles, and boulders, and contain lenses and layers of water-worked material.

Qtca, complex mixtures of light-gray clayey till and reddish-brown sandy till. Mixtures vary from juxtaposition and superposition of large and small masses to blebs of one till in the other.

Qtcb, light-gray clayey till commonly underlain by redeposited reddish-brown sandy till.

Qtcc, complex variable mixtures of light-gray clayey till and redeposited reddish-brown sandy till with quite substantial amounts of water-laid material at the surface. Interpreted as a stagnant ice deposit of the Grantsburg Sublobe.

**Qw**

**WILLERNIE FORMATION**

Reddish-brown sandy till deposited by ice of the Superior Lobe of the Wisconsin glaciation. Silty clayey sand with some pebbles, cobbles, and boulders. Generally very poorly sorted predominantly sandy till with occasional pockets of water-worked sand and gravel. Pebbles show northeastern provinance: red sandstone, basalt, gabbro, and foliated mafics.

**CONTACT**

Dashed where approximate, dotted where inferred.

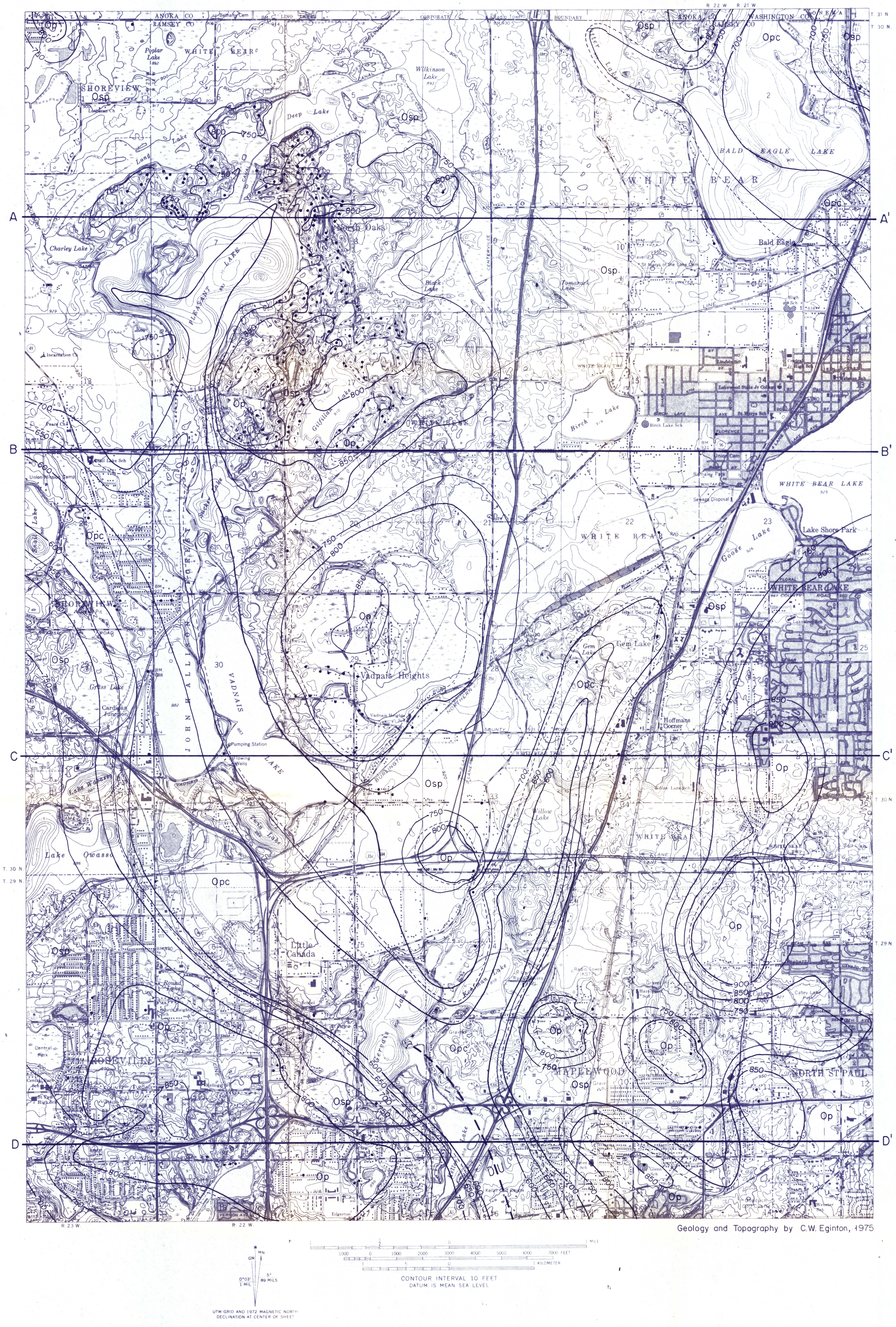
# MAP SHOWING BEDROCK GEOLOGY AND BEDROCK TOPOGRAPHY
# WHITE BEAR LAKE WEST QUADRANGLE, MINNESOTA



## PLATE 2

C.W. Eginton, 1975






## EXPLANATION

ORDOVICIAN

Op
Platteville Formation
(Limestone)

Osp
St. Peter Sandstone
*(Uppermost 5 feet is the Glenwood Formation)*

Opc
Prairie du Chien Formation
(Limestone)

700
750
Topographic contours
*(Drawn on top of bedrock surface. Contour interval is 50 feet. Datum is mean sea level)*

Geologic contact
*all contacts approximate*

Data point

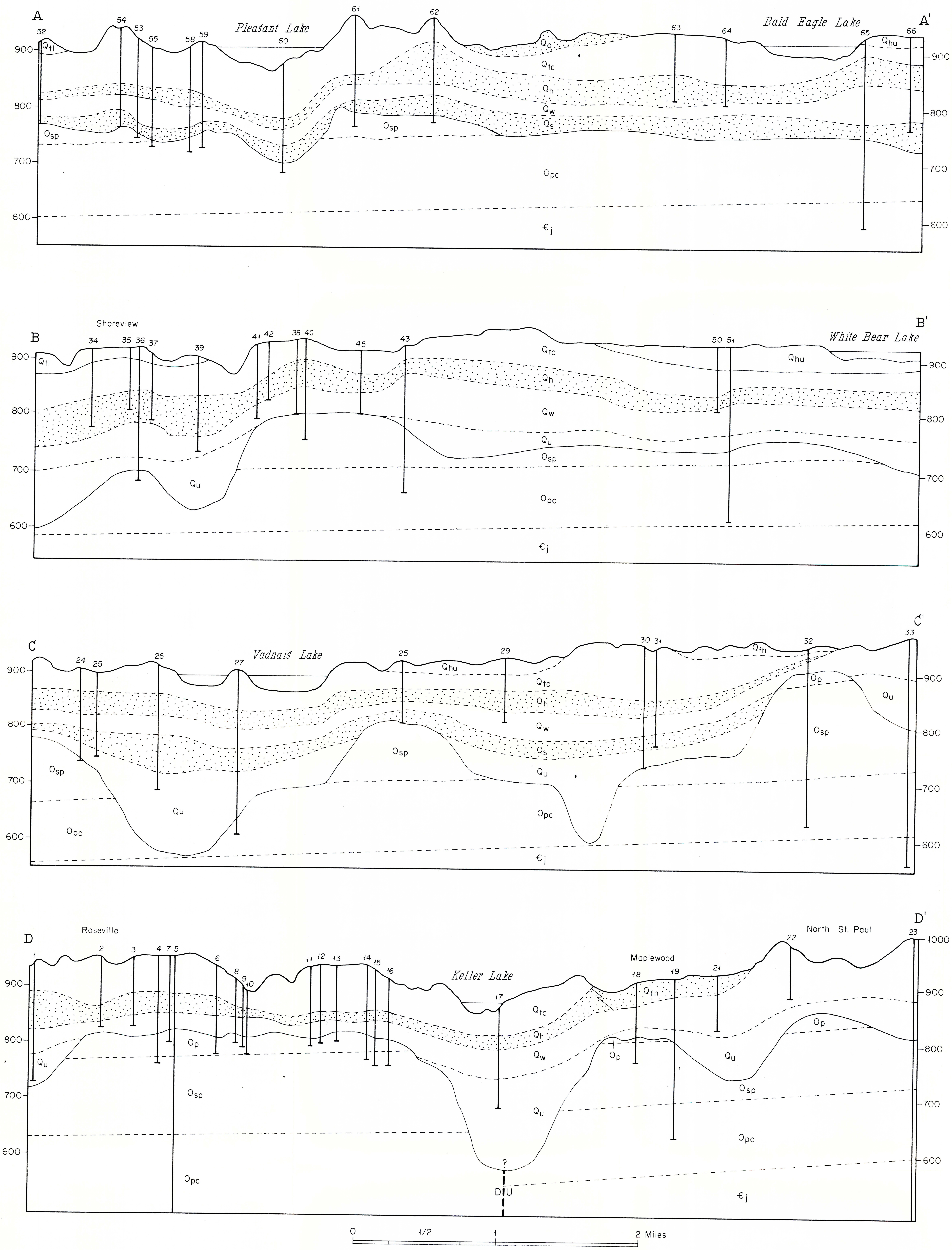
Surface contours

U
D
?
Fault
*(Dashed where inferred; question mark where data are lacking*
D, downthrown side
U, upthrown side*)*

# GEOLOGIC SECTIONS, WHITE BEAR WEST QUADRANGLE, MINNESOTA

PLATE 3

C.W. Eginton, 1975




## EXPLANATION

- $Q_{hu}$ — Hugo Sand
- $Q_{tl}$ — Turtle Lake Sand
- $Q_{o}$ — Unnamed Outwash
- $Q_{tc}$ — Twin Cities Formation
- $Q_{fh}$ — Falcon Heights Sand
- $Q_{h}$ — Hillside Sand
- $Q_{w}$ — Willernie Formation
- $Q_{s}$ — Unnamed Sand
- $Q_{s}$ — Undifferentiated Drift
- $O_{p}$ — Plattville Limestone
- $O_{sp}$ — St. Peter Sandstone
- $O_{pc}$ — Prarie du Chien Formation
- $Є_{j}$ — Jordan Sandstone

For more complete unit discriptions see explanations on Plates 1 and 2

Well numbers used are Minnesota Geological Survey Surficial Map numbers on file from 1974

D U ?

Fault

*Dashed where inferred; question mark where data are lacking.*
*D, downthrown side; U, upthrown side*

Geologic Contact
*all contact approximate*