

**MINNESOTA GEOLOGICAL SURVEY**

*Matt Walton, Director*

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**SCIENTIFIC CORE DRILLING IN  
CENTRAL MINNESOTA:  
SUMMARY OF  
LITHOLOGIC AND GEOCHEMICAL RESULTS**



**UNIVERSITY OF MINNESOTA**

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CENTRAL MINNESOTA:  
SUMMARY OF  
LITHOLOGIC AND GEOCHEMICAL RESULTS**

By

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The University of Minnesota is committed to the policy that all persons shall have equal access to its programs, facilities, and employment without regard to race, creed, color, sex, national origin, or handicap.



## INTRODUCTION

In 1980 the Minnesota Geological Survey (MGS) began a program of scientific test drilling for the purpose of acquiring a better understanding of the complex Precambrian bedrock of central Minnesota. The areas investigated in this project (Fig. 1) contain very few bedrock outcrops; the Precambrian rocks are thickly covered by unconsolidated surficial deposits of Quaternary age, and the only way they can be directly sampled and studied is by core drilling. This circular is an essentially uninterpreted summary of basic lithologic and chemical data derived from the scientific core drilling project.

As originally conceived, the drilling project was to focus on the Great Lakes tectonic zone in west-central Minnesota (Morey and Sims, 1976; Sims and others, 1980; Southwick, 1980) in the western part of area A of Figure 1. The Great Lakes tectonic zone is a major Archean structural break that has been interpreted as a belt of suturing and tectonic imbrication (Gibbs and others, 1984) and which, by analogy with exposed continental suture zones elsewhere, has a latent potential for containing mineral deposits. As the drilling progressed, however, it became clear that previously unknown Proterozoic sedimentary and volcanic rocks similar to those in the Cuyuna district lie above the Archean basement in Todd County and adjacent areas well to the west of the mapped western end of the Animikie basin (Morey and others, 1981). Because of this unexpected development, the drilling program was broadened to investigate the structural relationship between the Proterozoic "cover" and the underlying Archean rocks. To accomplish this broadened objective, the area of investigation was expanded to east-central and northeastern Minnesota (Fig. 1).

The drilling program has been closely coordinated with geophysical surveying throughout Minnesota, and the selection of drilling targets has been guided by geophysics to the maximum extent practicable. Drilling targets in 1980 and 1981 were chosen largely on the basis of older aeromagnetic and gravity maps at scale 1:250,000 (Bath and others, 1965; U.S. Geological Survey, 1970; McGinnis and others, 1978; Ervin, 1980), together with the preliminary results of seismic reflection profiling across the Great Lakes tectonic zone which was completed in 1979 by the Consortium for Continental Reflection Profiling (COCORP) (Gibbs and others, 1984). The first 11 holes were drilled on or close to the COCORP line of traverse in order to acquire information on rock type that could aid the seismic interpretation.

From 1982 onward the drilling program has relied heavily on a second-generation aeromagnetic survey that was begun in 1979 with funding provided by the Legislative Commission on Minnesota Resources. These new aeromagnetic maps were constructed from digital data acquired by a proton magnetometer flown 150 meters above the ground along flight lines spaced 400 meters apart. They give a detailed magnetic image of the buried Precambrian rocks that is greatly superior to that provided by the older generation of aeromagnetic surveys. Moreover, the new digital data can be enhanced or suppressed by various computational methods to reveal subtleties not visible in the older surveys. The new aeromagnetic maps specifically used in the drilling project include the 1:250,000-scale regional compilations by Chandler (1983a,b,c; 1985), the shaded relief map by Chandler and others (1984), and various 7.5-minute quadrangle maps at scale 1:24,000.

We emphasize that this drilling program was undertaken to improve our comprehension of the regional Precambrian geology of central Minnesota. In general, therefore, we have chosen to drill geophysical anomalies of relatively large dimensions, the logic being that by identifying the major rock units responsible for the larger anomalies we could construct a regional geologic map of the Precambrian basement on which the first-order features were reasonably well delineated. In addition, we have done considerable petrographic and geochemical work on the recovered cores to aid our geologic interpretation. A revised bedrock geologic map resulting from this combination of drilling with regional geophysics is in preparation, and is tentatively slated for publication in late 1986.

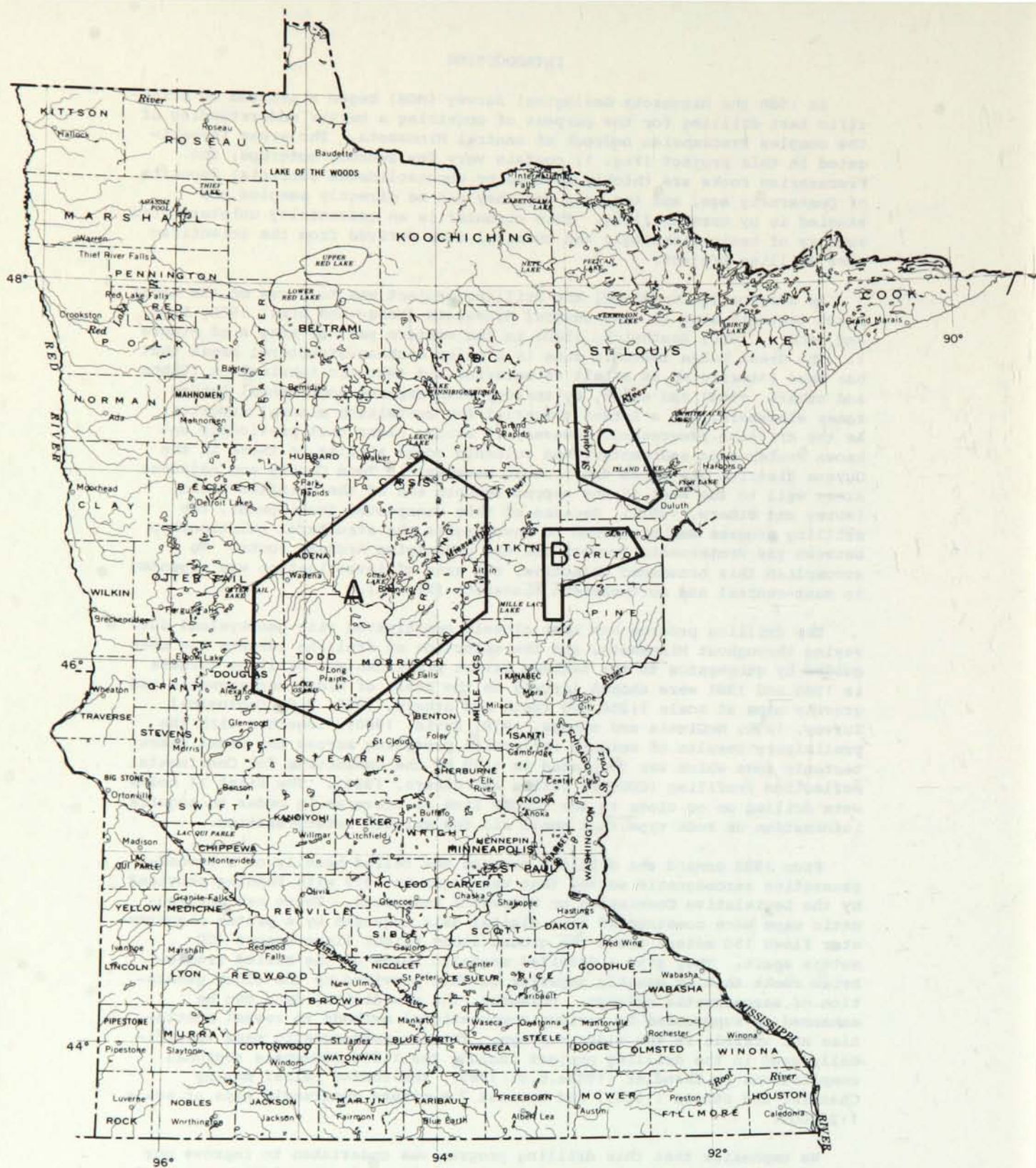


Figure 1--Areas investigated by scientific drilling program.

Area A: targeted on the Great Lakes tectonic zone, Cuyuna district, and Cuyuna-Mesabi gap (65 holes).

Area B: targeted on basement-cover relationships and geologic structures along the south margin of the Animikie basin (11 holes).

Area C: targeted on geologic structures within the main bowl of the Animikie basin (7 holes).

A secondary but very important objective of the drilling program has been the acquisition of subsurface data on the stratigraphy, lithology, and thickness of the Quaternary surficial deposits which overlie the Precambrian bedrock throughout central Minnesota. Some results of the work on surficial materials have been summarized by Meyer (1986), and additional reports will be forthcoming. Although basic data on overburden thickness and lithology are included in the abbreviated logs in this circular, readers interested in the surficial materials are referred to the report by Meyer (1986).

#### LOGISTICS AND DRILLING METHODS

Insofar as possible the drilling for this project was done on state land or within the rights-of-way of public roads to avoid infringing on private property or disturbing the populace with mud and noise. In some cases, however, it was necessary to drill on private land where the geophysical target contained no public land or was not adjacent to a public roadway, or where there were no suitable places for situating the drill rig along public roads. This latter problem was particularly acute in the low-lying, marshy areas of Aitkin, Carlton, and southern St. Louis Counties where the ditches alongside roads are commonly water-filled. Where drilling was done on private land, the landowners granted permission in advance, and retained title to all mineral rights.

Conventional rotary-drilling equipment was used to penetrate the unconsolidated overburden, which consists of the Quaternary surficial deposits, local erosional remnants of Upper Cretaceous marine and terrigenous strata, and a pre-Late Cretaceous saprolitic regolith developed on Precambrian rocks. A hole 6 inches to 10 inches (15.2 to 25.4 cm) in diameter was drilled through these materials and then cased with steel pipe to the top of sound rock. A rotary core barrel (size NX or larger, depending on the tooling of the drill rig) was then employed inside the casing for core drilling into Precambrian rock. Most commonly 10 feet (3 m) of core was drilled per site, but larger or smaller amounts were obtained where drilling conditions or scientific considerations so dictated. A typical hole in this project entailed about 300 feet of rotary drilling in unconsolidated overburden and about 10 feet of core drilling in sound rock. The drilling was done by three different contract-drilling firms and the Minnesota Department of Transportation (MnDOT), as summarized in Table 1.

Table 1--Summary of work by drilling contractors

Agency or firm	Years	Number of sites drilled	Number of cores recovered
MnDOT, St. Paul	1980-81	7	7
Donabauer Well & Pump, St. Joseph	1981-82	4	1
North Star Drilling, Little Falls	1982	15	12
Ben Ervin Well Co., Olivia	1983-85	55	54
TOTALS	-	81	74

Mudline cuttings from the unconsolidated overburden were continuously monitored and described by the drill-site geologist, and samples were collected at 5-foot (1.5-m) intervals. The unconsolidated interval of many holes was logged by down-hole geophysical methods to further refine the stratigraphy penetrated (see Meyer, 1986, for details).

The short drill cores of Precambrian rock were logged visually in the field, and later in greater detail at the offices of the Minnesota Geological Survey. Samples were selected for geochemical analysis after petrographic study. The geochemical work was performed by analysts at the University of Manitoba, the University of Minnesota, Cornell University,



Geochemical Services, Inc. of Torrence, California, and X-ray Assay Laboratories, Ltd. of Don Mills, Ontario. All cores and overburden samples are available for public examination at the MGS offices.

#### ORGANIZATION OF THE DATA

The following section includes basic data for every hole from which a sample of Precambrian rock was recovered. Data are presented for all cored holes, and also for those holes that reached Precambrian rock but were not cored, either because of poor rock conditions or a technical decision that core sampling was not necessary. Most of the uncored holes produced clean cuttings of sound rock which were amenable to petrographic and chemical study.

The data are organized geographically by county, and the counties are arranged alphabetically. The location of each hole is shown approximately on the county maps. Locations are described precisely on each log in the abbreviated township-range-section (T-R-S) system (see below), and plotted on a topographic map of the particular section of land in which the hole was drilled.

#### Explanation of the abbreviated T-R-S system

A great majority of townships in Minnesota are north of a zero standard parallel and west of a zero principal meridian. Therefore every Minnesota township is T.(Y)N., R.(X)W., and, since T. and R. are understood and N. and W. apply to all, a particular township can be specified as Y-X. For example, T.130N., R.33W., the legal description of Hartford Township in Todd County, can be abbreviated as 130-33. Section 29 of Hartford Township would be indicated 130-33-29 in the abbreviated T-R-S system. More precise locations within a legal section can be specified by the ABCD system, which is a simplification of the "NW<sup>1</sup>/<sub>4</sub>SE<sup>1</sup>/<sub>4</sub>..." system that traditionally has been used in legal land descriptions. In the ABCD system (Fig. 2), A is the northeast quadrant, B is the northwest quadrant, C is the southwest quadrant, and D is the southeast quadrant, and the largest quadrant pertaining to a location is given first. For example, the location of a hole in the NE<sup>1</sup>/<sub>4</sub> of the SE<sup>1</sup>/<sub>4</sub> of the SW<sup>1</sup>/<sub>4</sub> of the SW<sup>1</sup>/<sub>4</sub> of the NW<sup>1</sup>/<sub>4</sub> of section 29, Hartford Township, Todd County, would be described as 130-22-29 BCCDA.

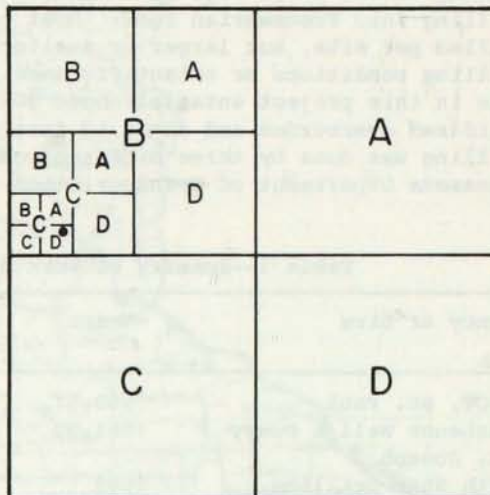


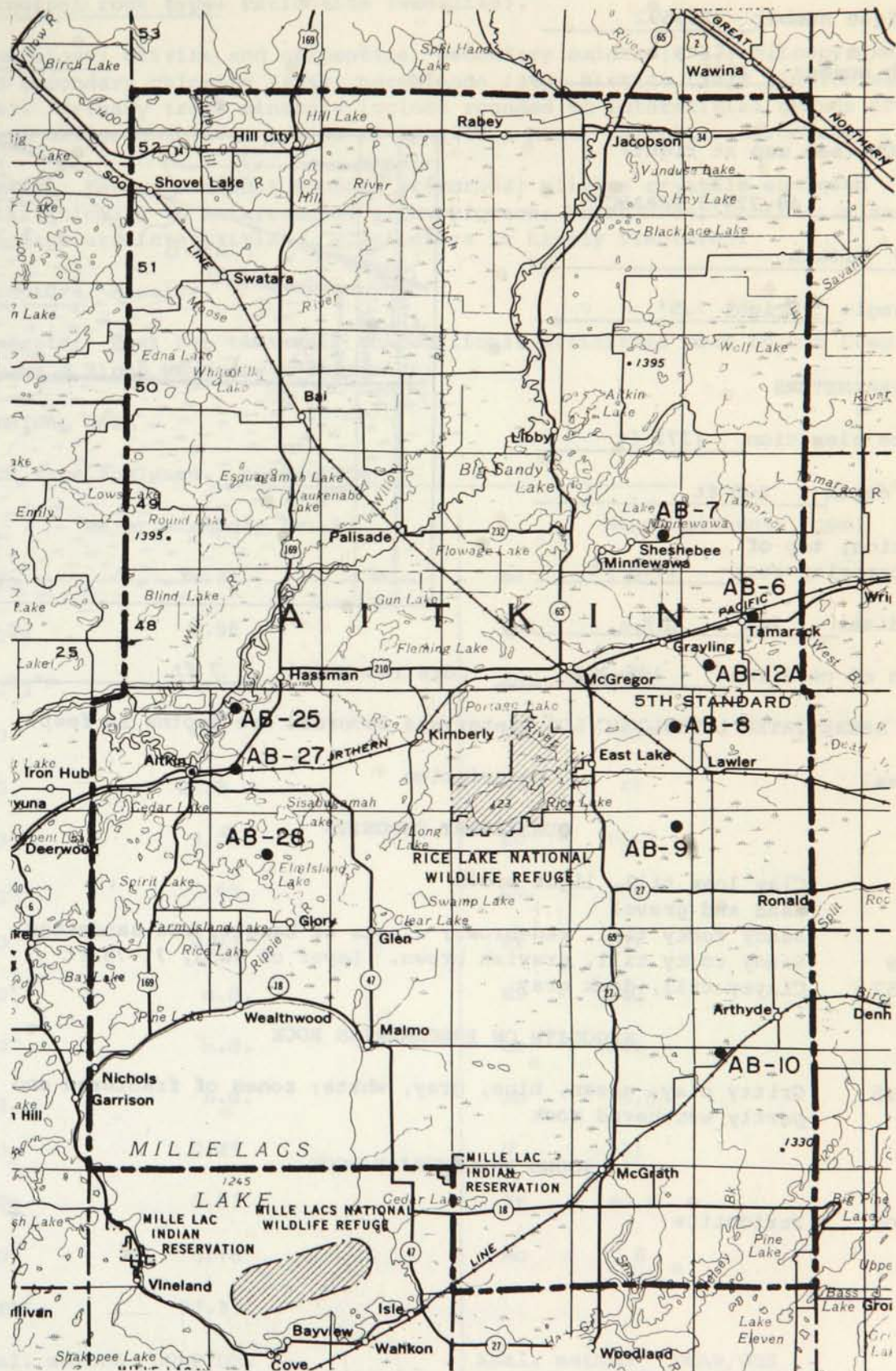
Figure 2--Location of the hole in the example given.

#### Acronyms of analytical methods employed in chemical analyses

Several different analytical techniques were employed in the geochemical investigations summarized on the data sheets. The methods are abbreviated as follows:

- XRF: X-ray fluorescence spectrometry
- DCAP/OES: Direct current argon plasma/optical emission spectrometry
- ICP/AES: Inductively coupled plasma/atomic emission spectrometry
- INNA: Induced nuclear neutron activation







Field number AB-6

Date Completed July 12, 1984

MGS unique number 235692

MGS lab number 2036

LOCATION (see map at right)

T-R-S 48-22-15 BDAABC

County Aitkin

Quadrangle Wright 7.5'

HOLE PARAMETERS

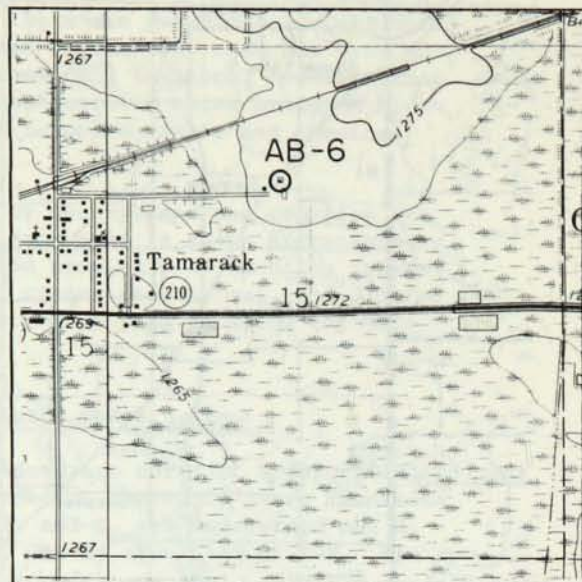
Surface elevation 1272 ft

Total depth 205 ft

Elevation, top of  
Precambrian rock 1115 ft

Core diam. 2.5"

Length of core run 195-202 Core recovered 7 ft



ABBREVIATED LITHOLOGIC LOG (intervals recorded are depths in feet)

Interval	Description
QUATERNARY DEPOSITS	
0-26	Clay loam till, light brown
26-33	Sand and gravel
33-53	Sandy rocky till, red-brown; clasts of basalt, red sandstone
53-119	Sandy rocky till, grayish brown. Layer of sand, 71-73 ft
119-157	Clayey till, dark gray
REGOLITH ON PRECAMBRIAN ROCK	
157-195	Gritty clay, green, blue, gray, white; zones of fractured and partly weathered rock
SOUND PRECAMBRIAN ROCK	
195-205	Peridotite



PETROGRAPHIC DESCRIPTION OF CORE

Principal rock type: Peridotite (wehrlite).

Mineralogy: Olivine and serpentine, secondary oxides (45%); clinopyroxene and secondary chlorite (40%); hornblende (3%); biotite (3%); plagioclase (8%). Primary trace minerals include rounded to interstitial grains of Fe-Ti oxides and large prisms of apatite. Minor sericite, carbonate.

Texture: Early, somewhat rounded (resorbed) olivine crystals enclosed poikilitically in intercumulus clinopyroxene; hornblende, biotite, plagioclase are interstitial. Plagioclase is highly fractured.

Structure: Massive.

Comments: Rock has textural, compositional affinities with Duluth Complex; may be a minor Keweenawan intrusion.

CHEMICAL DATA

Rock type analyzed peridotite

Major elements (wt.%)		Minor elements (ppm)	
SiO <sub>2</sub>	38.9	Ba	133 Y 12.7
Al <sub>2</sub> O <sub>3</sub>	4.88	Be	0.54
Fe <sub>2</sub> O <sub>3</sub> *	13.0	Zn	87.2
FeO	--	Cu	152
MgO	25.9	Au	<1
CaO	3.06	Sc	15.2
Na <sub>2</sub> O	0.60	Co	116
K <sub>2</sub> O	0.33	Sr	131
H <sub>2</sub> O <sup>+</sup>	n.d.	Ni	1240
H <sub>2</sub> O <sup>-</sup>	n.d.	Cr	3900
CO <sub>2</sub>	n.d.	Rb	5.5
TiO <sub>2</sub>	0.45	V	131
P <sub>2</sub> O <sub>5</sub>	0.03	Zr	40.8
MnO	0.16	Mo	8
TOTAL	87.31		
Anal. method	<u>DCAP/OES</u>	Anal. method	<u>DCAP/OES</u>
Analyst	<u>R. Knoche, Univ. of Minn.</u>	Analyst	<u>R. Knoche, Univ. of Minn.</u>

Field number AB-7

Date Completed May 31, 1984

MGS unique number 235677

MGS lab number 2021

LOCATION (see map at right)

T-R-S 49-23-26 ADDCDD

County Aitkin

Quadrangle Tamarack 7.5'

HOLE PARAMETERS

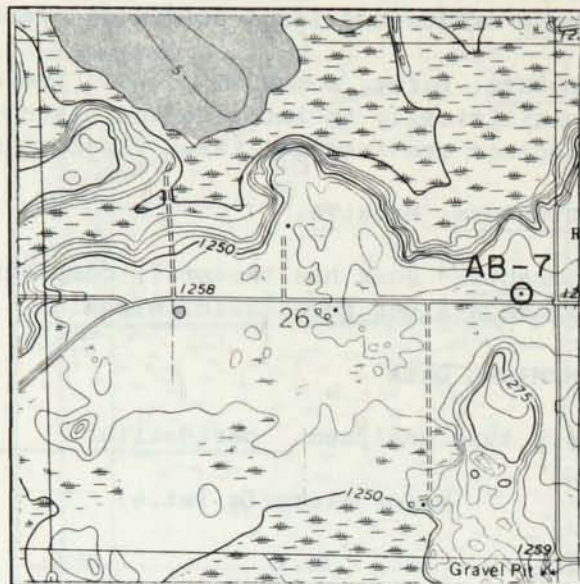
Surface elevation 1260 ft

Total depth 355 ft

Elevation, top of  
Precambrian rock 915 ft

Core diam. 2.5"

Length of core run 345-355 Core recovered 10 ft



ABBREVIATED LITHOLOGIC LOG (intervals recorded are depths in feet)

Interval	Description
QUATERNARY DEPOSITS	
0-8	Sand
8-23	Silty till, brown to gray-brown; clasts of metagraywacke, basalt, coarse feldspar
23-109	Interlayered clay, silt, sand; grayish brown
109-133	Sandy till, mottled color; clasts of amphibolite, various other mafic rocks, granite
133-158	Sandy to silty clay till, gray
158-188	Sand and gravel
188-218	Clay, dark gray to black, Cretaceous?
218-222	Sand and gravel
REGOLITH ON PRECAMBRIAN ROCK	
222-305	Regolith, possibly reworked in part; consist of clay, blue and gray
305-345	Rock, black to gray-black, and clay, blue and gray
SOUND PRECAMBRIAN ROCK	
345-355	Laminated, slaty argillite

PETROGRAPHIC DESCRIPTION OF CORE

Principal rock type: Laminated, slaty argillite.

Mineralogy: Quartz, plagioclase, chlorite, sericitic muscovite; fine-grained graphite varies in amount from layer to layer. Minor pyrite dispersed throughout.

Texture: Original muddy layers are totally neoblastic and strongly foliated parallel to slaty cleavage. Original silty layers retain sedimentary texture, somewhat modified by deformation.

Structure: Strong slaty cleavage crosses sedimentary layering at a high angle.

CHEMICAL DATA

Rock type analyzed no analyses

Field number AB-8

Date Completed June 6, 1984

MGS unique number 235679

MGS lab number 2023

LOCATION (see map at right)

T-R-S 47-23-12 BCCCC

County Aitkin

Quadrangle Lawler 7.5'

HOLE PARAMETERS

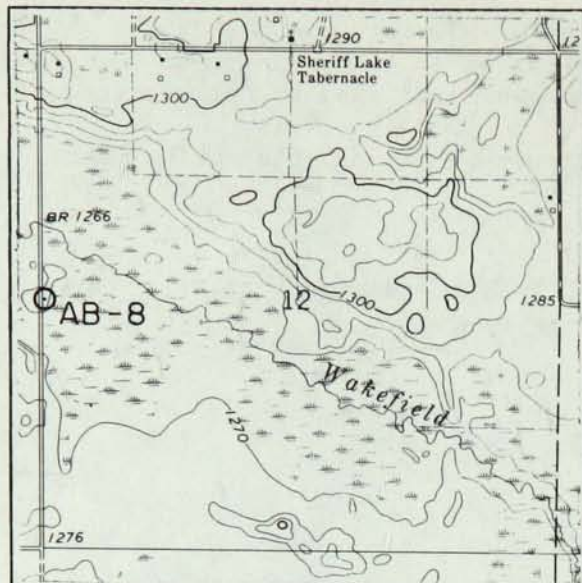
Surface elevation 1272 ft

Total depth 202 ft

Elevation, top of  
Precambrian rock 1171 ft

Core diam. 2.5"

Length of core run 192-202 Core recovered 10 ft



ABBREVIATED LITHOLOGIC LOG (intervals recorded are depths in feet)

Interval	Description
QUATERNARY DEPOSITS	
0-17	Silty clay till, yellowish red to gray
17-62	Gravelly sandy till, reddish gray; abundant clasts of red, coarse sandstone
62-68	Boulders and sand
68-101	Very gravelly sandy till, grayish brown
REGOLITH ON PRECAMBRIAN ROCK	
101-149	Clay, variegated; contains minor veins of unweathered quartz
149-181	Variably weathered rock and clay
SOUND PRECAMBRIAN ROCK	
181-202	Muscovite-quartz phyllite/schist



PETROGRAPHIC DESCRIPTION OF CORE

Principal rock type: Muscovite-quartz phyllite/schist.

Mineralogy: Quartz, muscovite, plagioclase, chlorite; traces of graphite. Secondary clinozoisite within plagioclase grains; minor leucoxene, opaque Fe-Ti oxides.

Texture: Neoblastic, foliated to granoblastic; variable from lens to lens (see below).

Structure: Powerful crenulation foliation has all but obliterated earlier cleavage. Rock consists of lens-shaped microlithons defined by crenulation surfaces; mica fabric within microlithons differs markedly from lens to lens.

Comments: Rootless isoclinal closures are subhorizontal; crenulation foliation is axial-planar to these folds.

CHEMICAL DATA

Rock type analyzed phyllite

Major elements (wt.%)		Minor elements (ppm)	
SiO <sub>2</sub>	57.8	Ba	543
Al <sub>2</sub> O <sub>3</sub>	18.9	Be	2.26
Fe <sub>2</sub> O <sub>3</sub> <sup>*</sup>	7.70	Zn	74
FeO	--	Cu	21.76
MgO	2.18	Au	<1
CaO	0.10	Sc	23.9
Na <sub>2</sub> O	0.36	Co	19.8
K <sub>2</sub> O	4.53	Sr	69.5
H <sub>2</sub> O <sup>+</sup>	n.d.	Ni	55.2
H <sub>2</sub> O <sup>-</sup>	n.d.	Cr	138.5
CO <sub>2</sub>	n.d.	Rb	157
TiO <sub>2</sub>	0.74	V	130
P <sub>2</sub> O <sub>5</sub>	0.13	Zr	123
MnO	0.04	Y	13.3
TOTAL	92.48		
Anal. method	<u>DCAP/OES</u>	Anal. method	<u>DCAP/OES</u>
Analyst	<u>R. Knoche, Univ. of Minn.</u>	Analyst	<u>R. Knoche, Univ. of Minn.</u>

Field number AB-9

Date Completed June 4, 1984

MGS unique number 235678

MGS lab number 2022

LOCATION (see map at right)

T-R-S 46-23-2 DDDCCA

County Aitkin

Quadrangle Split Rock Lake 7.5'

HOLE PARAMETERS

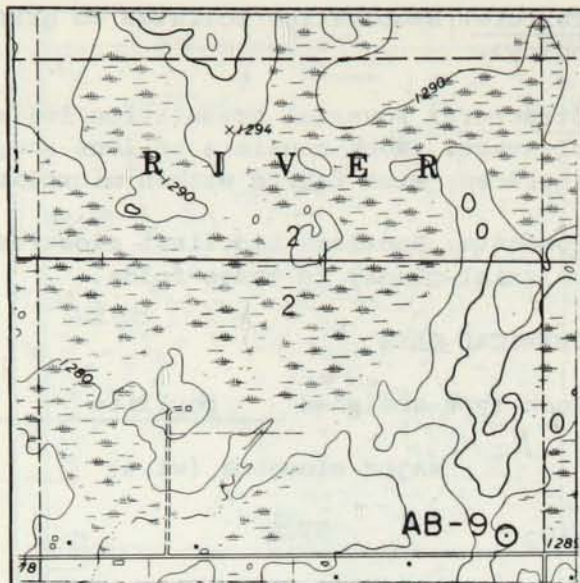
Surface elevation 1292 ft

Total depth 77 ft

Elevation, top of  
Precambrian rock 1231.5 ft

Core diam. 2.5"

Length of core run 67-77 Core recovered approx. 10 ft



ABBREVIATED LITHOLOGIC LOG (intervals recorded are depths in feet)

Interval	Description
QUATERNARY DEPOSITS	
0-2	Sandy till, brown
2-15	Very gravelly sandy till, reddish brown; clasts of mafic rock, felsite, red sandstone
15-27	Sand and gravel
27-43	Very gravelly sandy till, reddish gray
43-61	Very gravelly sandy till, grayish brown; abundant clasts of granite, rare clasts of carbonate

SOUND PRECAMBRIAN ROCK

61-77 Amphibolite

PETROGRAPHIC DESCRIPTION OF CORE

Principal rock type: Quartz-biotite amphibolite.

Mineralogy: Blue-green hornblende (60%), plagioclase (20%), quartz (10%), biotite (10%); trace amounts of Fe-Ti oxides, apatite, zircon, sphene; minor secondary chlorite, epidote.

Texture: Neoblastic, weakly foliated; hornblende, plagioclase form coarse grains (2-3 mm) that are partially and unsystematically recrystallized to a fine mosaic of quartz, biotite, plus secondary plagioclase, hornblende.

Structure: Weak foliation is carried by preferred orientation of hornblende prisms.

Comments: Interpreted as amphibolite-grade metamorphic rock that has partly reequilibrated under greenschist-facies conditions.

CHEMICAL DATA

Rock type analyzed amphibolite

Major elements (wt.%)		Minor elements (ppm)		
SiO <sub>2</sub>	48.6	Ba	531	Y 37.6
Al <sub>2</sub> O <sub>3</sub>	11.58	Be	1.732	
Fe <sub>2</sub> O <sub>3</sub> *	19.0	Zn	142	
FeO	--	Cu	152	
MgO	4.82	Au	<1	
CaO	7.36	Sc	49.2	
Na <sub>2</sub> O	1.87	Co	48	
K <sub>2</sub> O	1.28	Sr	162	
H <sub>2</sub> O <sup>+</sup>	n.d.	Ni	24.6	
H <sub>2</sub> O <sup>-</sup>	n.d.	Cr	5.3	
CO <sub>2</sub>	n.d.	Rb	33.6	
TiO <sub>2</sub>	2.64	V	580	
P <sub>2</sub> O <sub>5</sub>	0.20	Zr	178.3	
MnO	0.24	Mo	30	
TOTAL	97.66			
Anal. method <u>DCAP/OES</u>		Anal. method <u>DCAP/OES</u>		
Analyst <u>R. Knoche, Univ. of Minn.</u>		Analyst <u>R. Knoche, Univ. of Minn.</u>		

Field number AB-10

Date Completed May 21, 1984

MGS unique number 234191

MGS lab number 2019

LOCATION (see map at right)

T-R-S 44-22-5 ACDCAD

County Aitkin

Quadrangle Solana 7.5'

HOLE PARAMETERS

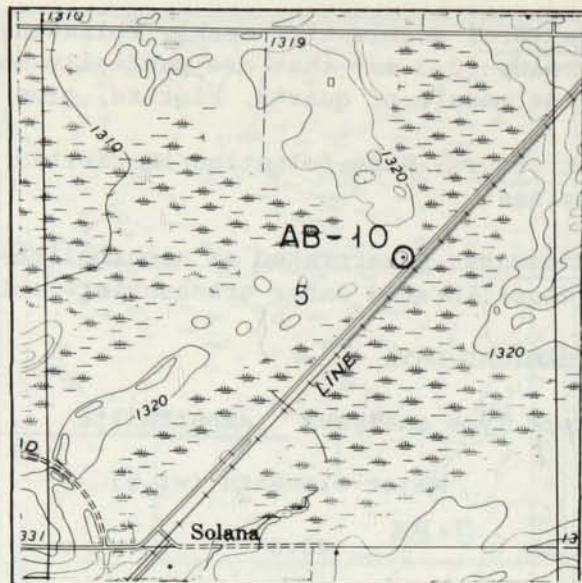
Surface elevation 1322 ft

Total depth 94.5 ft

Elevation, top of  
Precambrian rock 1258 ft

Core diam. 2.5"

Length of core run 80-87 Core recovered approx. 7 ft



ABBREVIATED LITHOLOGIC LOG (intervals recorded are depths in feet)

Interval	Description
QUATERNARY DEPOSITS	
0-10	Sandy gravelly till, yellowish red; clasts of red sandstone
10-15	Sand and gravel
15-46	Rocky, gravelly, sandy till, reddish brown; clasts of felsite, basalt, schist, slate, phyllite, red sandstone, minor agate
46-64	Gravelly sandy till, dark grayish brown; larger fraction of granite and iron-formation clasts than above
REGOLITH ON PRECAMBRIAN ROCK	
64-74	Clay, blue, mixed with rock
SOUND PRECAMBRIAN ROCK	
74-94.5	Biotite quartz-feldspar gneiss with biotite schist inclusions or layers (McGrath Gneiss)



PETROGRAPHIC DESCRIPTION OF CORE

Principal rock type: Biotite-quartz-feldspar gneiss.

Mineralogy: Quartz, plagioclase (antiperthitic), microcline, biotite; minor muscovite. Accessory apatite, zircon.

Texture: Granoblastic, foliated; megacrysts (2-3 mm) of plagioclase in gneissose rock about 0.5 mm in average grain size.

Structure: Anastomosing foliation carried mainly by biotite.

Comments: Typical McGrath Gneiss; core contains thin mafic layers interpreted as inclusions.

CHEMICAL DATA

Rock type analyzed no analyses

Field number AB-12A

Date Completed July 18, 1984

MGS unique number 235693

MGS lab number 2037

LOCATION (see map at right)

T-R-S 48-22-29 DBCCBC

County Aitkin

Quadrangle Lawler 7.5'

HOLE PARAMETERS

Surface elevation 1266 ft

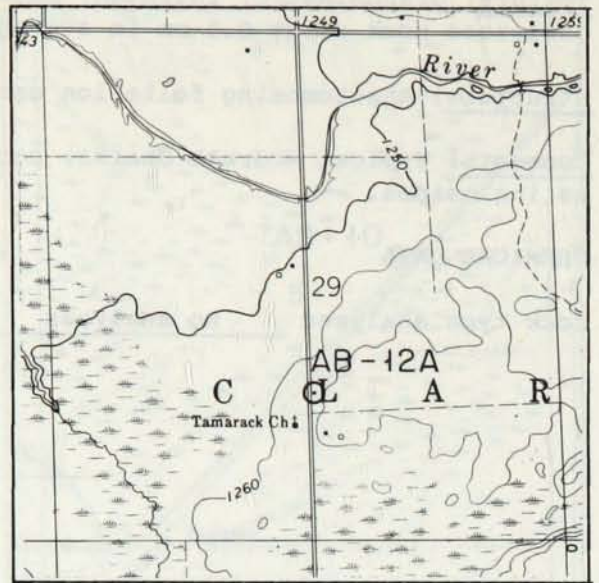
Total depth 298.5 ft

Elevation, top of  
Precambrian rock 1056 ft

Core diam. 2.5"

Length of core run 294-298.5

Core recovered approx. 4.5 ft



ABBREVIATED LITHOLOGIC LOG (intervals recorded are depths in feet)

Interval	Description
QUATERNARY DEPOSITS	
0-9	Clayey till, dark brown
9-18	Sand
18-80	Sandy till, reddish brown
80-84	Gravel
84-162	Sandy till; alternating layers are gray and reddish brown; abundant clasts of basalt
162-182	Sand, gravel, boulders
182-210	Sandy till, reddish brown
REGOLITH ON PRECAMBRIAN ROCK	
210-292	Gritty clay, gray to dark greenish gray, with some rock fragments
SOUND PRECAMBRIAN ROCK	
292-299	Chlorite-muscovite phyllite

PETROGRAPHIC DESCRIPTION OF CORE

Principal rock type: Chlorite-muscovite phyllite.

Mineralogy: Quartz, plagioclase (mainly albite), chlorite, muscovite; scattered graphite. Minor amounts of pyrite, limonite, leucoxene, ilmenite.

Texture: Fine-grained neoblastic; strongly foliated; close to definitional boundary between phyllite and slate.

Structure: Dominant fabric element is very strong crenulation cleavage ( $S_2$ ); earlier slaty fabric ( $S_1$ ) has been largely transposed into  $S_2$ .

Comments: Spheroidal quartz-chlorite clots may be small, retrograded porphyroblasts of garnet.

CHEMICAL DATA

Rock type analyzed no analyses

Field number AB-25

Date Completed May 29, 1985

MGS unique number 236097

MGS lab number 2049

LOCATION (see map at right)

T-R-S 47-26-5 CDBBCA

County Aitkin

Quadrangle Aitkin 7.5'

HOLE PARAMETERS

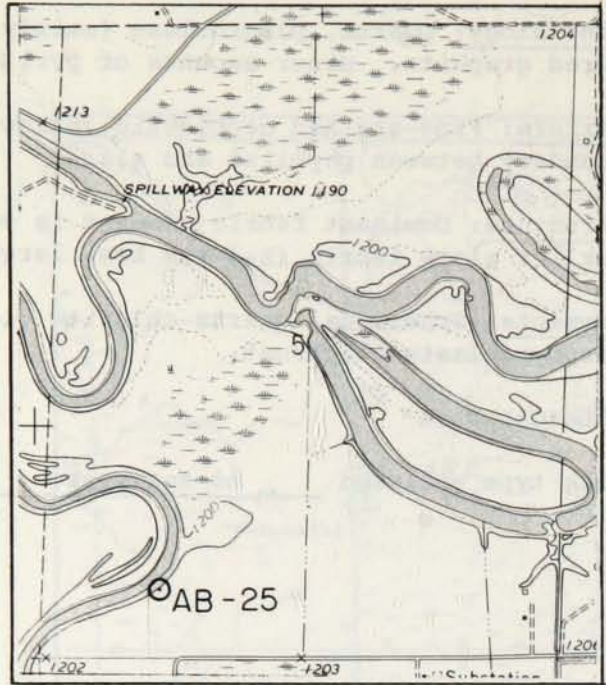
Surface elevation 1198 ft

Total depth 427 ft

Elevation, top of  
Precambrian rock 998 ft

Core diam. 2.5"

Length of core run 418-427 Core recovered approx. 9 ft



ABBREVIATED LITHOLOGIC LOG (intervals recorded are depths in feet)

Interval	Description
<b>QUATERNARY DEPOSITS</b>	
0-125	Silt and clay
125-135	Sandy till, dark gray brown
135-189	Sandy till, dark reddish brown. Layer of sand and gravel, 163-170 ft
189-200	Sand
<b>REGOLITH ON PRECAMBRIAN ROCK</b>	
200-365	Clay, red and green
365-414	Clay, red and gray; zones of soft rock
<b>SOUND PRECAMBRIAN ROCK</b>	
414-427	Slaty argillite

PETROGRAPHIC DESCRIPTION OF CORE

Principal rock type: Slate derived from laminated argillite.

Mineralogy: Quartz, sericitic muscovite, chlorite; disseminated, very fine grained pyrite is partly oxidized to limonite.

Texture: Very fine grained neoblastic, foliated; vestiges of sedimentary texture in some silty layers.

Structure: Muddy laminations (5-12 mm thick) alternate with very fine silt laminations (1-3 mm thick). Very strong slaty cleavage transverse to bedding is carried by quartz fabric, oriented phyllosilicates.

CHEMICAL DATA

Rock type analyzed no analyses



Field number AB-27

Date Completed May 20, 1985

MGS unique number 236095

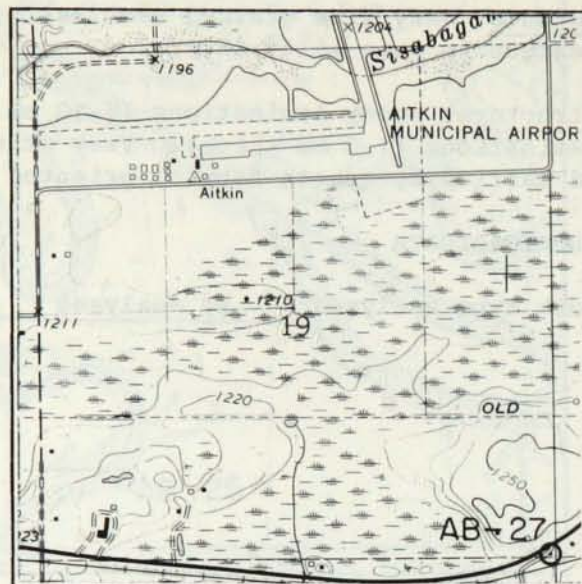
MGS lab number 2045

LOCATION (see map at right)

T-R-S 47-26-19 DDDDDC

County Aitkin

Quadrangle Aitkin 7.5'



HOLE PARAMETERS

Surface elevation 1241 ft

Total depth 218.5 ft

Elevation, top of  
Precambrian rock 1078 ft

Core diam. 2.5"

Length of core run 209-218.5 Core recovered approx. 8.5 ft

ABBREVIATED LITHOLOGIC LOG (intervals recorded are depths in feet)

Interval

Description

QUATERNARY DEPOSITS

- 0-16 Silty till, light yellowish brown, slightly calcareous
- 16-22 Loamy till, brown to dark gray
- 22-25 Sandy till, reddish brown to gray
- 25-107 Sand, sandy gravel, cobbly gravel interbedded; minor clayey silt
- 107-118 Silty clay and silt, gray
- 118-138 Cobbly sand and gravel
- 138-157 Clayey to loamy till, greenish gray, noncalcareous
- 157-163 Sand and pebbly sand

REGOLITH ON PRECAMBRIAN ROCK

- 163-203 Clay, black, with minor reddish brown and green zones; zones of broken rock

SOUND PRECAMBRIAN ROCK

- 203-218.5 Graphitic argillite, brecciated, with quartz veinlets

PETROGRAPHIC DESCRIPTION OF CORE

Principal rock type: Graphitic argillite.

Mineralogy: Graphite is dominant phase; admixed with varying amounts of extremely fine grained Fe-oxides and sulfides, chert.

Texture: Exceedingly fine, granular; chert locally forms very small pellets.

Structure: Massive, unbedded over length of core; cut by numerous fracture-filling quartz veins, generally thinner than 5 mm, which locally aggregate to about 10% of rock volume.

Comments: Rock provisionally interpreted and named as sedimentary; however it has some attributes of seafloor hydrothermal deposits.

CHEMICAL DATA

Rock type analyzed massive graphitic argillite with quartz veinlets (214.3)  
massive graphitic argillite (218)

Major elements (wt.%)	Minor elements (ppm)		
	(214.3)	(218)	
not determined	Ag	2.673	0.6869
	As	525.7	75.47
	Au	0.0324	0.0053
	Cu	5916	429.2
	Hg	14.54	2.596
	Mo	108.9	65.79
	Pb	40.45	12.12
	Sb	97.36	14.09
	Tl	1.273	2.782
	Zn	323.1	227.6

Anal. method ICP/AES

Analyst Geochemical Services, Inc.  
Torrance, California

Field number AB-28

Date Completed May 15, 1985

MGS unique number 236094

MGS lab number 2044

LOCATION (see map at right)

T-R-S 46-26-9 DDCAAB

County Aitkin

Quadrangle Spirit Lake 7.5'

HOLE PARAMETERS

Surface elevation 1273 ft

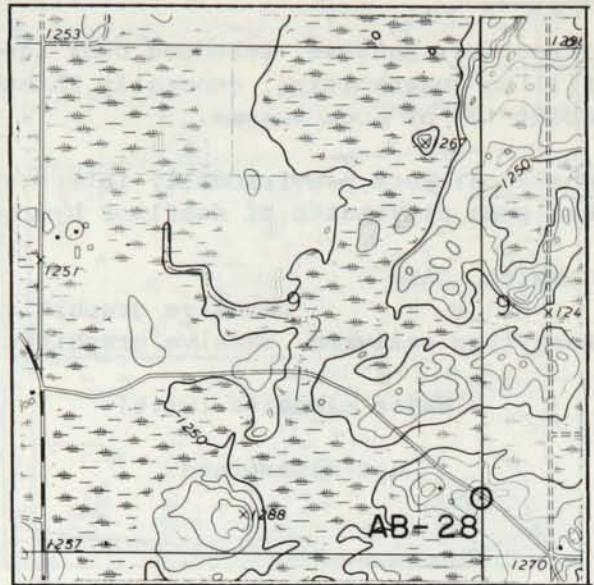
Total depth 154.5 ft

Elevation, top of  
Precambrian rock 1135.5 ft

Core diam. 2.5"

Length of core runs 141-144  
152.5-154.5

Core recovered approx. 5 ft



ABBREVIATED LITHOLOGIC LOG (intervals recorded are depths in feet)

Interval	Description
QUATERNARY DEPOSITS	
0-5	Silty till, brown, noncalcareous
5-16	Sandy clay till, yellowish brown to brown, slightly calcareous
16-43	Silty clay loam, silt to clayey silt, silty clay
43-61	Sand and gravel
61-75	Sandy till, dark gray
75-138	Sand and gravel
REGOLITH ON PRECAMBRIAN ROCK	
138-154.5	Alternating zones of hard and soft amygdaloidal greenstone; minor sandy clay, green



PETROGRAPHIC DESCRIPTION OF CORE

Principal rock type: Amygdaloidal meta-andesite (greenstone).

Mineralogy: Plagioclase, heavily saussuritized; actinolite, epidote, biotite; accessory ilmenite, sphene.

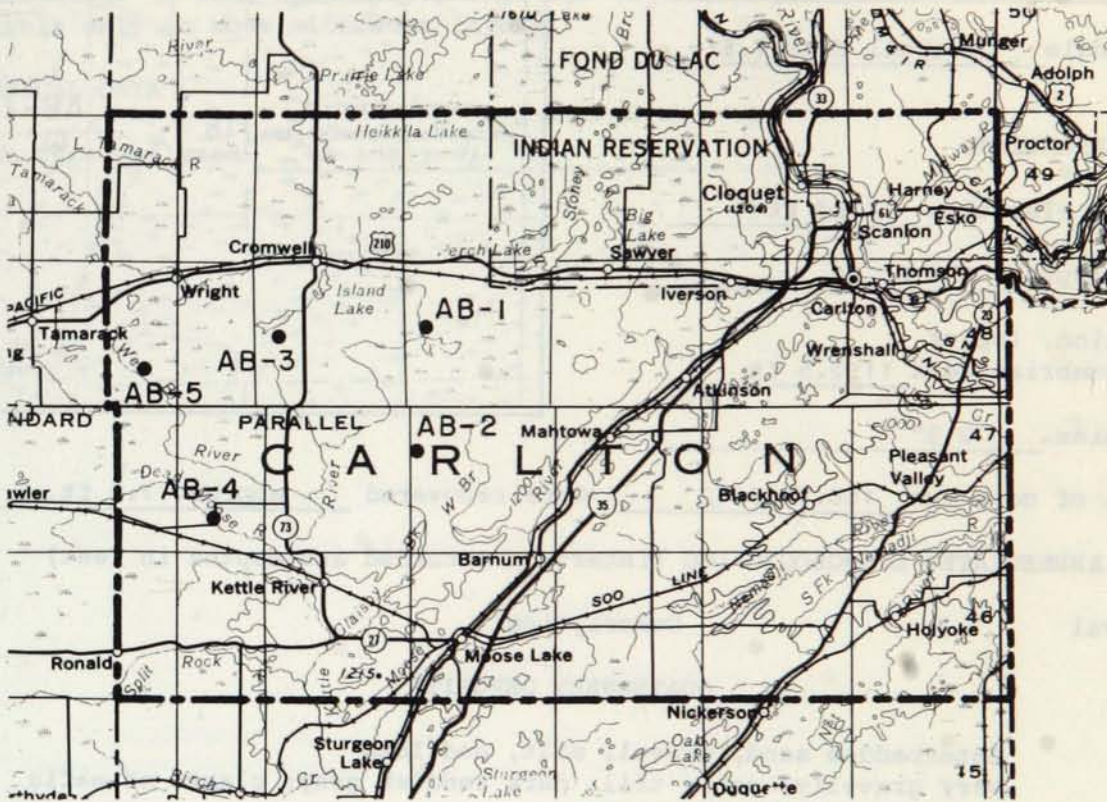
Texture: Volcanic texture extensively modified by metamorphic recrystallization. Bulk of rock exhibits felted texture of plagioclase laths; original mafic phases are totally replaced by metamorphic actinolite, biotite. Amygdules (typical <1 mm in diam.) are mostly epidote-filled and have quenched margins.

Structure: Essentially massive.

CHEMICAL DATA

Rock type analyzed no analyses





Field number AB-1

Date Completed June 13, 1984

MGS unique number 235682

MGS lab number 2026

LOCATION (see map at right)

T-R-S 48-19-18 DAABBB

County Carlton

Quadrangle Cromwell East 7.5'

HOLE PARAMETERS

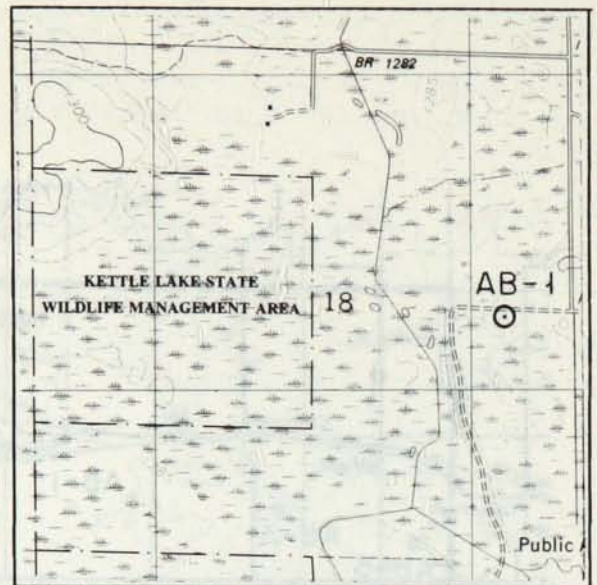
Surface elevation 1284 ft

Total depth 158.2 ft

Elevation, top of  
Precambrian rock 1192.5 ft

Core diam. 2.5"

Length of core run 150.7-158.2 Core recovered approx. 7.5 ft



ABBREVIATED LITHOLOGIC LOG (intervals recorded are depths in feet)

Interval	Description
QUATERNARY DEPOSITS	
0-36	Interbedded sand, gravel, silt, and loam
36-60	Very gravelly, sandy till, dark reddish gray; clasts of mafic rocks, felsite, red sandstone
60-78	Sand and gravel
78-87	Gravelly sandy till, reddish gray
87-92	Cobbly gravel
REGOLITH ON PRECAMBRIAN ROCK	
92-146	Silty clay, gray and greenish gray
SOUND PRECAMBRIAN ROCK	
146-158.2	Laminated slate

PETROGRAPHIC DESCRIPTION OF CORE

Principal rock type: Laminated slate, dark gray to nearly black.

Mineralogy: Quartz, plagioclase, sericitic muscovite; lesser amounts of chlorite, graphite, dolomite.

Texture: Predominantly neoblastic and foliated; some relict sedimentary clasts in silty laminae. Dolomite forms late-stage small porphyroblasts choked with inclusions of quartz and sericite.

Structure: Strong slaty cleavage ( $S_1$ ) is essentially parallel to sedimentary lamination. A weak crenulation cleavage ( $S_2$ ) is inclined about  $35^\circ$  to  $S_1$ ; visible only in most micaceous layers.

CHEMICAL DATA

Rock type analyzed no analyses



Field number AB-2

Date Completed July 9, 1984

MGS unique number 235691

MGS lab number 2035

LOCATION (see map at right)

T-R-S 47-19-7 CBBCAC

County Carlton

Quadrangle Cromwell SE 7.5'

HOLE PARAMETERS

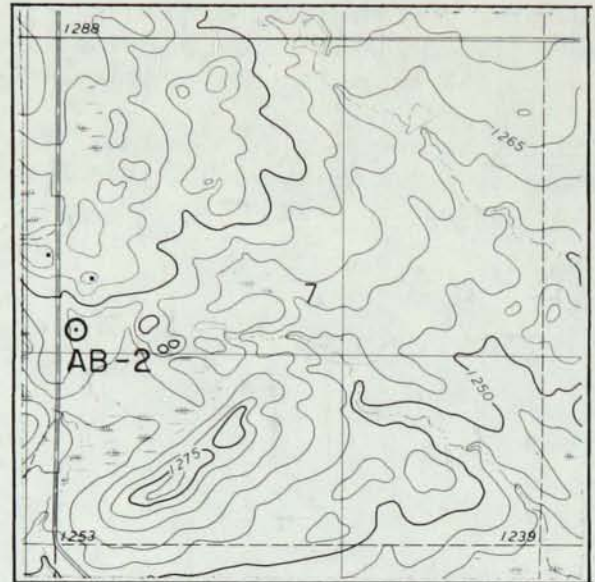
Surface elevation 1269 ft

Total depth 103 ft

Elevation, top of  
Precambrian rock 1227 ft

Core diam. 2.5"

Length of core run 93-103 Core recovered 10 ft



ABBREVIATED LITHOLOGIC LOG (intervals recorded are depths in feet)

Interval	Description
QUATERNARY DEPOSITS	
0-16	Clayey till, red brown; clasts of basalt, red sandstone
16-42	Clayey till, dark brown to gray brown, somewhat sandy; clasts of basalt, red sandstone
REGOLITH ON PRECAMBRIAN ROCK	
42-93	Clay and rock, black
SOUND PRECAMBRIAN ROCK	
93-103	Graphitic phyllite

PETROGRAPHIC DESCRIPTION OF CORE

Principal rock type: Crenulated graphitic phyllite.

Mineralogy: Quartz, sericitic muscovite, graphite; lesser amounts of chlorite, pyrite. Some layers contain 50% or more graphite. Pyrite is dispersed throughout rock as films, small individual crystals; locally it forms pods as thick as 5 cm. Chlorite is restricted to graphite-poor layers.

Texture: Neoblastic and foliated; fine grained.

Structure: Strong slaty cleavage ( $S_1$ ) is essentially parallel to layering; layers are 1-7 mm thick. Strong conjugate crenulation cleavage ( $S_2$ ) has developed symmetrically with respect to normal to  $S_1$ .

Comments: Analyses below are of normal graphitic phyllite (AB-2) and a pyritic lens (AB-2-PY).

CHEMICAL DATA

Rock type analyzed graphitic phyllite (AB-2); pyritic layer (AB-2-PY)

Major elements (wt.%)	Minor elements (ppm)	
	(AB-2)	(AB-2-PY)
not determined	Ag 0.2599	1.682
	As 9.375	134.0
	Au 0.0031	0.5409
	Cu 66.11	314.5
	Hg <0.473	<0.500
	Mo 5.503	1.831
	Pb 3.516	33.43
	Sb 1.592	3.681
	Tl <0.946	<1.00
	Zn 56.25	113.6
	Anal. method ICP/AES	
	Analyst <u>Geochemical Services, Inc.</u> Torrance, California	

Field number AB-3

Date Completed June 15, 1984

MGS unique number 235683

MGS lab number 2027

LOCATION (see map at right)

T-R-S 48-20-20 BBBBCC

County Carlton

Quadrangle Cromwell West 7.5'

HOLE PARAMETERS

Surface elevation 1322 ft

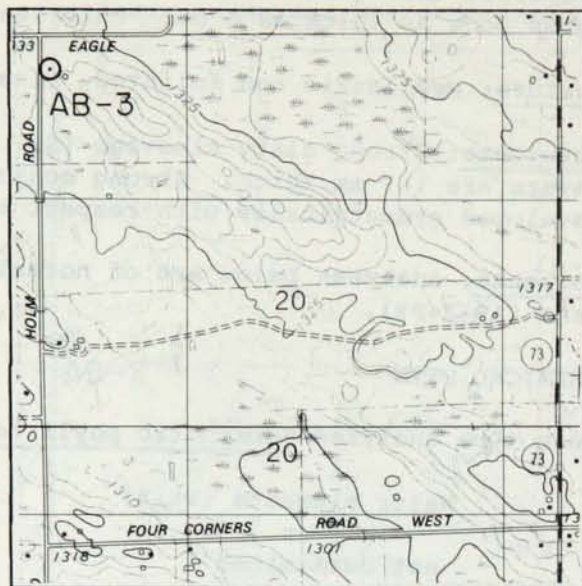
Total depth 226 ft

Elevation, top of  
Precambrian rock 1116 ft

Core diam. 2.5"

Length of core run 216-226

Core recovered 10 ft



ABBREVIATED LITHOLOGIC LOG (intervals recorded are depths in feet)

Interval	Description
QUATERNARY DEPOSITS	
0-61	Gravelly sandy till, reddish brown; mafic rock clasts
61-72	Silty clay to clayey silt, dark gray, noncalcareous; some organic-rich layers
72-120	Gravelly sandy till, reddish brown; clasts of slate, mafic rock, felsite, sandstone
120-128	Sand and gravel
128-134	Sandy till, reddish brown, and clay, reddish brown
134-206	Clayey till, very dark gray; calcareous, some carbonate clasts
REGOLITH ON PRECAMBRIAN ROCK	
206-212	Sandy clay, greenish
SOUND PRECAMBRIAN ROCK	
212-226	Graywacke



PETROGRAPHIC DESCRIPTION OF CORE

Principal rock type: Metagraywacke.

Mineralogy: Framework grains are quartz, plagioclase, K-feldspar, detrital muscovite, chert; matrix minerals are sericitic muscovite, chlorite, fine quartz and feldspar, dusty opaques; heavy detrital grains are zircon, sphene, epidote, rutile. Small pyrite rosettes and carbonate patches are dispersed in matrix.

Texture: Classic sedimentary graywacke texture weakly modified by deformation. Framework grains mainly in size range 0.2-0.5 mm, but grade smoothly downward into silt range in matrix.

Structure: Rock is thick bedded, nearly massive. Single weak cleavage has developed at high angle to bedding.

CHEMICAL DATA

Rock type analyzed no analyses

Field number AB-4

Date Completed June 12, 1984

MGS unique number 235681

MGS lab number 2025

LOCATION (see map at right)

T-R-S 47-21-15 ADDCBA

County Carlton

Quadrangle Heikkila Creek 7.5'

HOLE PARAMETERS

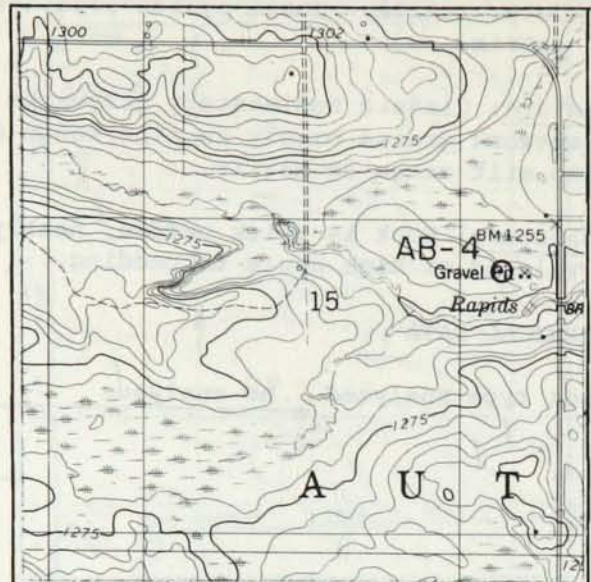
Surface elevation 1253 ft

Total depth 164 ft

Elevation, top of  
Precambrian rock 1111 ft

Core diam. 2.5"

Length of core run 154-164 Core recovered 10 ft



ABBREVIATED LITHOLOGIC LOG (intervals recorded are depths in feet)

Interval	Description
QUATERNARY DEPOSITS	
0-72	Sand and gravel, silty sand, sandy silt
72-76	Gravelly sandy till, reddish gray
76-142	Clayey till, dark gray; moderately calcareous, clasts of carbonate, various Cretaceous rocks (lignite, limestone, gray shale, speckled shale, pyrite, pyritic sandstone)
REGOLITH ON PRECAMBRIAN ROCK	
142-150	Clay, bluish gray, and rock
SOUND PRECAMBRIAN ROCK	
150-164	Phyllite

PETROGRAPHIC DESCRIPTION OF CORE

Principal rock type: Laminated, crenulated phyllite.

Mineralogy: Quartz, plagioclase, chlorite, muscovite; lesser, variable amounts of graphite. Trace to minor amounts of granular opaques (in part pyrite), secondary calcite, leucoxene, apatite.

Texture: Neoblastic, foliated. Former metagraywacke layers tend toward granoblastic texture.

Structure: Strong slaty cleavage ( $S_1$ ) is essentially parallel to layering in parts of core and is transverse to layering in other parts, implying inclined  $F_1$  folds; very strong crenulation cleavage ( $S_2$ ) has locally transposed  $S_1$ .

CHEMICAL DATA

Rock type analyzed gray phyllite

Major elements (wt.%)		Minor elements (ppm)	
SiO <sub>2</sub>	52.9	Ba	813
Al <sub>2</sub> O <sub>3</sub>	18.7	Zn	134
Fe <sub>2</sub> O <sub>3</sub> *	10.62	Cu	32.2
FeO	--	Au	<1
MgO	3.66	Sc	31.26
CaO	0.36	Co	28.9
Na <sub>2</sub> O	2.05	Sr	145.0
K <sub>2</sub> O	3.35	Ni	82.9
H <sub>2</sub> O <sup>+</sup>	n.d.	Cr	162
H <sub>2</sub> O <sup>-</sup>	n.d.	Rb	157
CO <sub>2</sub>	n.d.	V	192
TiO <sub>2</sub>	0.92	Zr	150
P <sub>2</sub> O <sub>5</sub>	0.30	Y	26.3
MnO	0.06		
TOTAL	92.92		
Anal. method <u>DCAP/OES</u>		Anal. method <u>DCAP/OES</u>	
Analyst <u>R. Knoche, Univ. of Minn.</u>		Analyst <u>R. Knoche, Univ. of Minn.</u>	

Field number AB-5

Date Completed June 8, 1984

MGS unique number 235680

MGS lab number 2024

LOCATION (see map at right)

T-R-S 48-21-29 BADCDC

County Carlton

Quadrangle Automba 7.5'

HOLE PARAMETERS

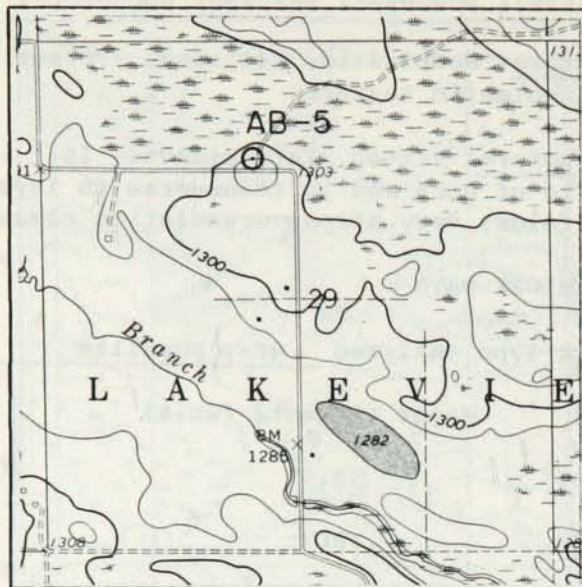
Surface elevation 1312 ft

Total depth 184 ft

Elevation, top of  
Precambrian rock 1142 ft

Core diam. 2.5"

Length of core run 174-184 Core recovered 10 ft



ABBREVIATED LITHOLOGIC LOG (intervals recorded are depths in feet)

Interval	Description
QUATERNARY DEPOSITS	
0-28	Gravelly till, reddish brown
28-34	Sand and gravel
34-38	Gravelly sandy till, reddish brown
38-52	Sand and clay, grayish brown
52-79	Gravelly sandy till, grayish brown
79-105	Fine sand and sandy clay
105-140	Loamy till, dark gray, calcareous; clasts of granite, greenstone, dolomite
140-170	Loamy till, very dark gray, slightly calcareous
SOUND PRECAMBRIAN ROCK	
170-184	Metagraywacke, minor slate (hornfels)



PETROGRAPHIC DESCRIPTION OF CORE

Principal rock type: Spotted biotite hornfels.

Mineralogy: Biotite, quartz, plagioclase, muscovite, cordierite(?).

Texture: Former argillaceous layers of sedimentary rock have developed fine-grained, foliated, neoblastic texture. Oval spots of porphyroblastic cordierite(?), choked with minute inclusions of biotite, muscovite, and quartz, comprise 60% of such layers. Former silty layers retain clastic texture; angular to subangular silt grains of quartz, plagioclase are embedded in a recrystallized matrix of biotite, muscovite.

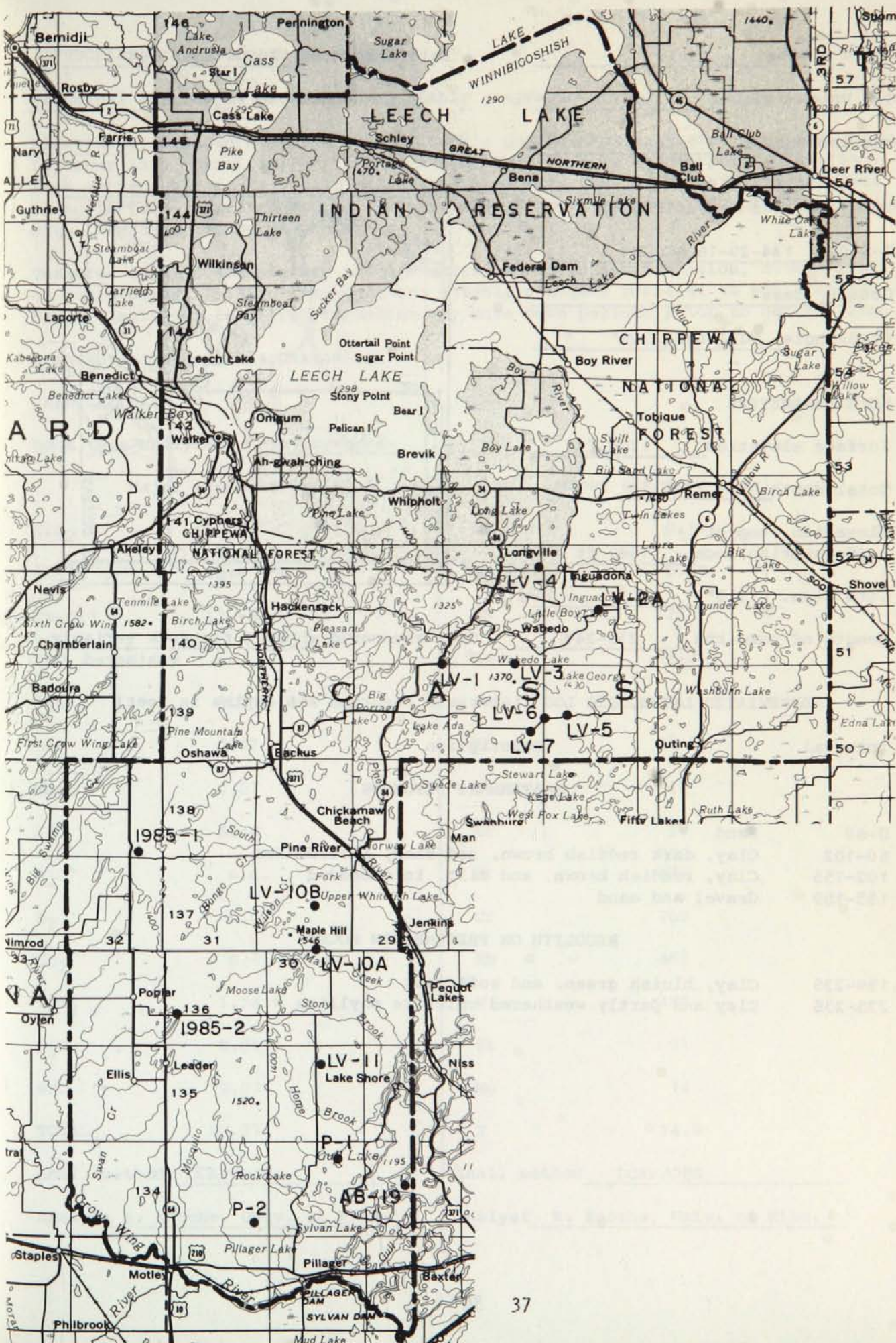
Structure: Cleavage carried by biotite is inclined to bedding, and passes directly into inclusions within cordierite spots.

Comments: Rock interpreted as cleaved, laminated argillite which was hornfelsed at contact of intrusive peridotite. See AB-6 (Aitkin County).

CHEMICAL DATA

Rock type analyzed no analyses







Field number AB-19

Date Completed August 2, 1984

MGS unique number 235697

MGS lab number 2043

LOCATION (see map at right)

T-R-S 134-29-16 ACDECA

County Cass

Quadrangle Gull Lake 7.5'

HOLE PARAMETERS

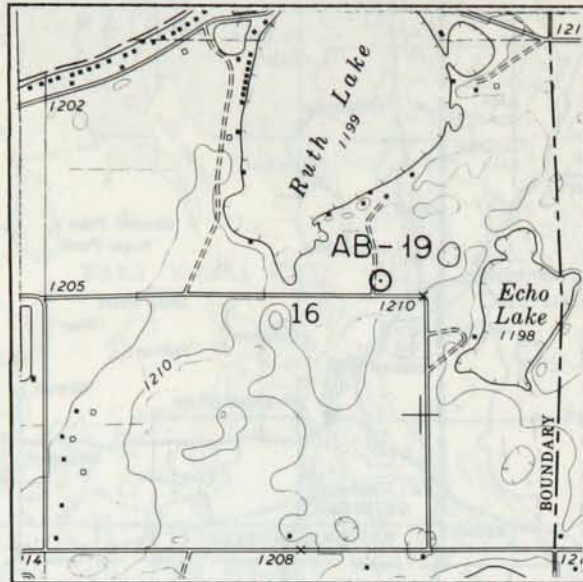
Surface elevation 1208 ft

Total depth 256 ft

Elevation, top of  
Precambrian rock 1049 ft

Core diam. 2.5"

Length of core run 239-247 Core recovered about 2 ft; rock variably weathered



ABBREVIATED LITHOLOGIC LOG (intervals recorded are depths in feet)

Interval	Description
QUATERNARY DEPOSITS	
0-60	Sand
60-102	Clay, dark reddish brown, and sand, interbedded
102-155	Clay, reddish brown, and silt, interbedded
155-159	Gravel and sand
REGOLITH ON PRECAMBRIAN ROCK	
159-235	Clay, bluish green, and soft rock
235-256	Clay and partly weathered chlorite phyllite



PETROGRAPHIC DESCRIPTION OF CORE

Principal rock type: Metamorphosed lithic graywacke.

Mineralogy: Framework grains (80% of rock): Quartz (10%), plagioclase (5%), K-feldspar (5%), biotite (2%); lithic fragments of coarse metamorphic rocks (5%), fine metamorphic rocks (10%), chert (3%), and very fine meta-argillite and lean silicate iron-formation (60%). Matrix (20% of rock) consists of chlorite, sericite, hematite, limonite, chert.

Texture: Clastic sedimentary texture modified by recrystallization, development of schistosity. Lithic fragments are notably elongate parallel to schistosity. Some "clasts" of lean iron-formation may have been pellets prior to deformation.

Structure: Pervasive schistosity.

CHEMICAL DATA

Rock type analyzed metagraywacke

Major elements (wt.%)		Minor elements (ppm)	
SiO <sub>2</sub>	51.9	Ba	0.11
Al <sub>2</sub> O <sub>3</sub>	18.6	Be	5.32
Fe <sub>2</sub> O <sub>3</sub> *	12.18	Zn	125
FeO	--	Cu	34.8
MgO	1.70	Au	<1
CaO	0.07	Sc	65.2
Na <sub>2</sub> O	0.07	Co	45
K <sub>2</sub> O	6.46	Sr	34
H <sub>2</sub> O <sup>+</sup>	n.d.	Ni	177
H <sub>2</sub> O <sup>-</sup>	n.d.	Cr	769
CO <sub>2</sub>	n.d.	Rb	462
TiO <sub>2</sub>	1.26	V	488
P <sub>2</sub> O <sub>5</sub>	0.01	Zr	91
MnO	0.02	Mo	14
TOTAL	92.27	Y	14.9
Anal. method <u>DCAP/OES</u>		Anal. method <u>DCAP/OES</u>	
Analyst <u>R. Knoche, Univ. of Minn.</u>		Analyst <u>R. Knoche, Univ. of Minn.</u>	

Field number LV-1

Date Completed July 29, 1982

MGS unique number 233043

MGS lab number 1877

LOCATION (see map at right)

T-R-S 139-29-1 BABBAA

County Cass

Quadrangle Woman Lake 7.5'

HOLE PARAMETERS

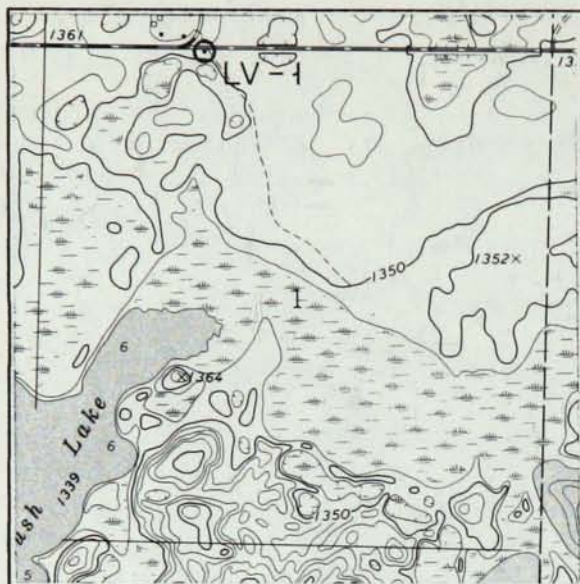
Surface elevation 1356 ft

Total depth 372.3 ft

Elevation, top of  
Precambrian rock 1021 ft

Core diam. 2.5"

Length of core run 362-372.3 Core recovered 10.3 ft



ABBREVIATED LITHOLOGIC LOG (intervals recorded are depths in feet)

Interval	Description
QUATERNARY DEPOSITS	
0-101	Sand, gravel, silt, and clay, interbedded
101-115	Gravelly till, gray, somewhat calcareous
115-138	Gravelly sand
138-172	Loamy till, dark brown to dark gray, noncalcareous
172-220	Mixed tills, dominantly sandy till, light gray to red to reddish gray, somewhat calcareous; prominent dolomite clasts
220-235	Clayey till, dark gray; dolomite clasts, calcareous
235-272	Sand and gravel. Contains abundant dolomite and some wood bits
272-325	Sandy silt and clay
325-335	Clayey till, dark gray; dolomite clasts
REGOLITH ON PRECAMBRIAN ROCK	
335-359	Sandy clay, grayish green. Soft rock fragments and sandy clay; residual quartz and feldspar grains increase downward
SOUND PRECAMBRIAN ROCK	
359-372	Granite gneiss

PETROGRAPHIC DESCRIPTION OF CORE

Principal rock type: Gneissose biotite-hornblende tonalite.

Mineralogy: Quartz (15%), plagioclase, moderately sericitized (65%), blue-green hornblende (17%), biotite and alteration products (3%). Secondary chlorite, adularia, sphene, prehnite are mainly replacing biotite. Accessory epidote, apatite, magnetite.

Texture: Original hypidiomorphic granular texture extensively modified by deformation. Quartz entirely subcrystals, some with strain lamellae. Plagioclase, hornblende grains strained, fractured, microfaulted; local granulation at grain boundaries.

Structure: Steeply dipping megascopic foliation carried by quartz shape fabric, aligned mafic aggregates.

CHEMICAL DATA

Rock type analyzed no analyses



Field number LV-2A

Date Completed August 2, 1982

MGS unique number 233041

MGS lab number 1875

LOCATION (see map at right)

T-R-S 140-27-14 AABBBB

County Cass

Quadrangle Laura Lake 7.5'

HOLE PARAMETERS

Surface elevation 1362 ft

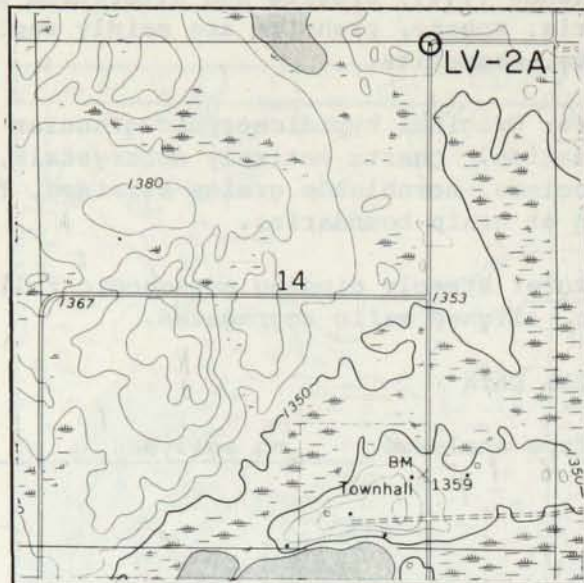
Total depth 685.7 ft

Elevation, top of  
Precambrian rock 974 ft

Core diam. 2.5"

Length of core run 675.3-685.7

Core recovered 10.4 ft



ABBREVIATED LITHOLOGIC LOG (intervals recorded are depths in feet)

Interval	Description
QUATERNARY DEPOSITS	
0-28	Gravelly till, strong brown, noncalcareous
28-78	Sandy gravel
78-108	Gravelly till, red brown. Gravel, sand interbeds throughout
108-130	Silty till, yellowish brown, calcareous
130-215	Clayey till, gray, calcareous; clasts of dolomite, chert, metagraywacke, slate. Layer of very dark gray clay, 165-178 ft
215-243	Clayey till, dark grayish brown with red streaks, moderately calcareous, small red clasts
243-316	Sandy till, dark grayish brown; clasts of slate, red rock, some dolomite
CRETACEOUS SEDIMENTARY ROCKS	
316-319	Lignite
319-337	Claystone, minor lignite, very dark gray
337-372	Friable kaolinitic quartz sandstone and siltstone, interbedded with claystone, light gray
372-388	Friable quartz sandstone, white
REGOLITH ON PRECAMBRIAN ROCK	
388-604	Clay, variegated; soft rock fragments increase with depth
SOUND PRECAMBRIAN ROCK	
604-674	Medium to hard argillite, black
674-685.7	Chert and silicate-carbonate iron-formation



PETROGRAPHIC DESCRIPTION OF CORE

Principal rock type: Iron-formation (cored).

Mineralogy: Laminated carbonate-silicate iron-formation contains detrital quartz, chert, stilpnomelane, minnesotaite, siderite, ankerite, and graphite. Associated chert layers contain chert, stilpnomelane, quartz, and ankerite.

Texture: The major carbonate-silicate facies is laminated on the scale of 0.3-1.0 cm and is clearly clastic. Clastic silt-sand grains of quartz are mixed with pellets of Fe-silicates, chert, and carbonate in varying proportions. Pellets are 0.2 mm and smaller in diameter. The matrix is very fine stilpnomelane, minnesotaite, and carbonate. Ankerite forms rhombic porphyroblasts.

Structure: Primary sedimentary structures include micro-scouring and low-angle cross-lamination. A few layers exhibit wavy internal lamination. The rock is not deformed tectonically.

Comments: The iron-formation is interpreted as a lens or layer within argillite; it is of the "Emily" type.

CHEMICAL DATA

Rock type analyzed carbonate-bearing chert (676)  
carbonate-chert-silicate iron-formation (682)

Major elements (wt.%)	Minor elements (ppm)		
	(676)	(682)	
not determined	Ag	0.0762	<0.050
	As	9.175	14.25
	Au	0.0047	0.0027
	Cu	19.27	23.98
	Hg	<0.498	0.6701
	Mo	3.669	1.613
	Pb	7.813	3.438
	Sb	3.615	<1.0
	Tl	<0.996	<1.0
	Zn	18.29	17.68
	Anal. method <u>ICP/AES</u>		
	Analyst <u>Geochemical Services, Inc.</u> <u>Torrance, California</u>		

Field number LV-3

Date Completed July 29, 1982

MGS unique number 233042

MGS lab number 1876

LOCATION (see map at right)

T-R-S 139-28-2 ABABAA

County Cass

Quadrangle Longville 7.5'

HOLE PARAMETERS

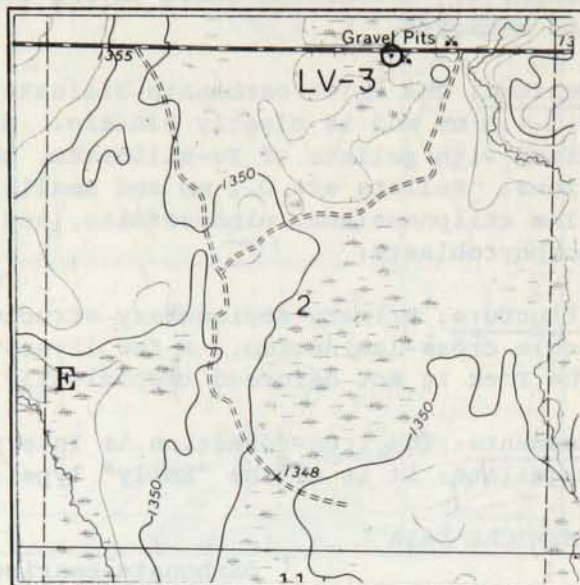
Surface elevation 1342 ft

Total depth 389.4 ft

Elevation, top of  
Precambrian rock 1026 ft

Core diam. 2.5"

Length of core run 373-389.4 Core recovered approx. 15 ft



ABBREVIATED LITHOLOGIC LOG (intervals recorded are depths in feet)

Interval	Description
QUATERNARY DEPOSITS	
0-5	Sandy till, yellowish brown, noncalcareous
5-18	Sandy till, light olive brown to grayish brown; dolomite clasts
18-40	Sand and minor gravel
40-107	Gravelly till, dark reddish brown, noncalcareous; clasts of felsite and black rocks, some granite
107-121	Sandy till, brown to gray to olive brown, noncalcareous
121-191	Sand to gravel, fining upward
191-196	Sandy till, dark reddish gray, calcareous
196-224	Clayey till, gray, calcareous
224-235	Sand
235-260	Sand, sandy silt, and silt
260-270	Loamy till, dark gray; dolomite clasts
270-309	Sandy till, gray, slightly calcareous; clasts of red felsite
309-316	Sand and silt
REGOLITH ON PRECAMBRIAN ROCK	
316-319	Rocky clay, black
SOUND PRECAMBRIAN ROCK	
319-389	Argillite, black

PETROGRAPHIC DESCRIPTION OF CORE

Principal rock type: Argillite, very dark gray and laminated.

Mineralogy: Quartz, K-feldspar, sericitic muscovite, chlorite, graphite; a few small lithic fragments of sericite slate. Traces of epidote(?).

Texture: Laminae 0.5-1.0 mm thick; vary in proportion of graphite, silt-size grains. Coarsest grains about 0.1 mm in diameter; more are smaller than 0.02 mm.

Structure: Undeformed.

CHEMICAL DATA

Rock type analyzed graphitic argillite (378.5)

Major elements (wt.%)		Minor elements (ppm)			
SiO <sub>2</sub>	61.3	Ag	0.9752	Sr	71
Al <sub>2</sub> O <sub>3</sub>	17.1	As	12.28	Tl	<0.992
Fe <sub>2</sub> O <sub>3</sub> *	6.82	Au	0.0123	Y	31
FeO	--	Ba	620	Zn	399
MgO	2.79	Be	2.4	Zr	162
CaO	0.36	Co	12	V	187
Na <sub>2</sub> O	1.54	Cr	139		
K <sub>2</sub> O	3.83	Cu	84.6		
H <sub>2</sub> O <sup>+</sup>	n.d.	Hg	1.214		
H <sub>2</sub> O <sup>-</sup>	n.d.	Mo	6.854		
CO <sub>2</sub>	n.d.	Ni	69		
TiO <sub>2</sub>	0.72	Pb	20.09		
P <sub>2</sub> O <sub>5</sub>	0.15	Rb	128		
MnO	0.04	Sb	4.738		
TOTAL	94.6	Sc	25		
Anal. method <u>DCAP/OES</u>		Anal. method <u>DCAP/OES and ICP/AES</u>			
Analyst <u>R. Knoche, Univ. of Minn.</u>		Analyst <u>R. Knoche, Univ. of Minn., and Geochemical Services, Inc., Torrance, California</u>			



Field number LV-4

Date Completed July 30, 1982

MGS unique number 233040

MGS lab number 1874

LOCATION (see map at right)

T-R-S 141-28-36 DDDACC

County Cass

Quadrangle Longville 7.5'

HOLE PARAMETERS

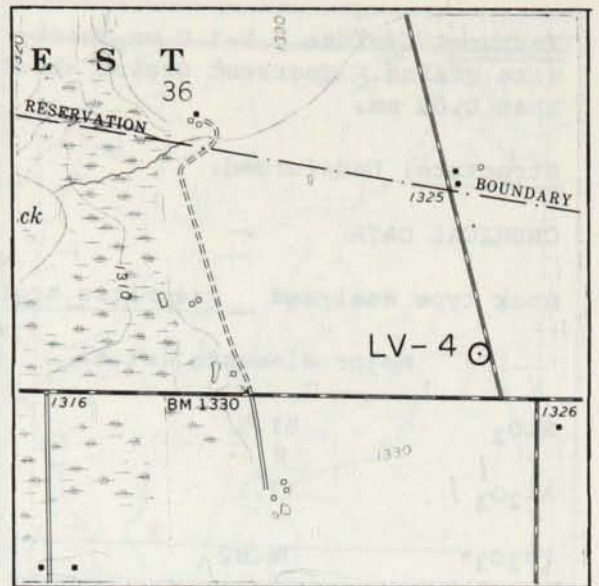
Surface elevation 1326 ft

Total depth 256.1 ft

Elevation, top of  
Precambrian rock 1099 ft

Core diam. 2.5"

Length of core run 245.8-256.1 Core recovered 10.3 ft



ABBREVIATED LITHOLOGIC LOG (intervals recorded are depths in feet)

Interval	Description
QUATERNARY DEPOSITS	
0-15	Silt
15-26	Sandy till, grayish brown, calcareous. Layers of sand and gravel
26-89	Pebbly to cobbly sand; clasts include dolomite and lignitic shale. Minor interbeds of fine sand, clayey silt
89-101	Sandy till, reddish gray to gray. Layers of sand and gravel
101-165	Sand and gravel, pebbly, gray and brown
165-196	Clayey till, gray to dark gray; dolomite clasts. Layer of sand, 189-192 ft
196-227	Sandy till, gray
REGOLITH ON PRECAMBRIAN ROCK	
227-242	Clay, green and pink and white grains; zones of soft rock
SOUND PRECAMBRIAN ROCK	
242-256	Granite



PETROGRAPHIC DESCRIPTION OF CORE

Principal rock type: Biotite leucogranite.

Mineralogy: Quartz (30%), plagioclase, moderately sericitized (35%), perthitic microcline (30%), biotite and alteration products (5%). Secondary muscovite, chlorite, granular opaques are mainly replacing biotite. Accessory rutile, zircon, apatite.

Texture: Allotriomorphic granular, coarse.

Structure: Essentially massive.

CHEMICAL DATA

Rock type analyzed no analyses

Field number LV-5

Date Completed July 28, 1982

MGS unique number 233550

MGS lab number 1883

LOCATION (see map at right)

T-R-S 139-27-20 BBDCCA

County Cass

Quadrangle Stewart Lake 7.5'

HOLE PARAMETERS

Surface elevation 1462 ft

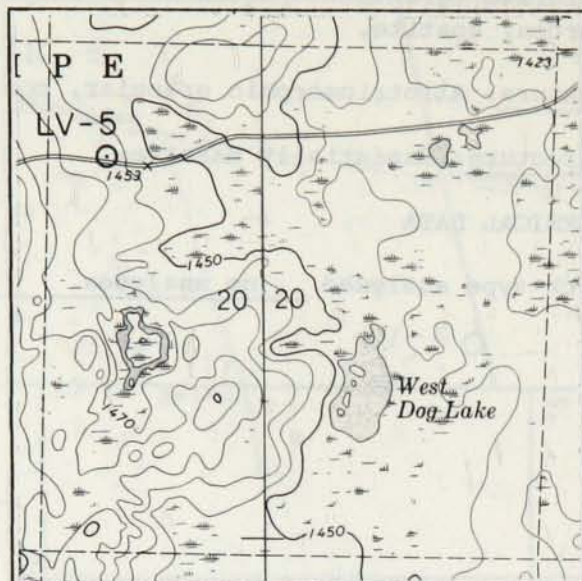
Total depth 512 ft

Elevation, top of  
Precambrian rock 1037 ft

Core diam. 2.5"

Length of core run 492-512

Core recovered approx. 20 ft



ABBREVIATED LITHOLOGIC LOG (intervals recorded are depths in feet)

Interval	Description
QUATERNARY DEPOSITS	
0-63	Gravelly sandy till, brown, moderately calcareous in places. Layers of silt, gravel
63-75	'Mixed' gravelly sandy till, brown and reddish brown, non-calcareous
75-120	Gravelly sandy till, reddish brown to gray, slightly calcareous; minor dolomite clasts
120-140	Sandy till, gray, moderately calcareous
140-200	Silty sand, sandy silt; some beds of better sorted gravel and sand
200-235	Gravelly sandy till, brownish gray, moderately calcareous. Layers of sand and gravel
235-273	Sandy to loamy till, olive yellow to gray, calcareous
273-321	Silty till, dark brown to gray, calcareous; clasts of dolomite, red felsite, coarse feldspar
321-322	Sand and gravel
322-342	Clayey till, olive gray; dolomite clasts
342-348	Sand and gravel; dominantly dolomite clasts
348-425	Silty till, olive gray; clasts of dolomite, quartz, dark mafic rocks
REGOLITH ON PRECAMBRIAN ROCK	
425-479	Gritty clay, aqua green, white, brown. Soft rock toward bottom
SOUND PRECAMBRIAN ROCK	
479-512	Argillite, black

PETROGRAPHIC DESCRIPTION OF CORE

Principal rock type: Laminated argillite; rare thin beds of micritic limestone.

Mineralogy: Quartz, plagioclase, K-feldspar, chlorite, sericitic muscovite, graphite, carbonate. The carbonate is of two types: (1) fine-grained granoblastic, choked with minute inclusions, dusky gray; (2) coarse-grained, neoblastic, clear, forming veins and replacement masses.

Texture: Clastic texture well preserved in silty layers; argillaceous and carbonate layers are variably recrystallized. Silt grains are angular and smaller than 0.1 mm.

Structure: Silty laminae exhibit micrograding and commonly rest on scoured surfaces.

CHEMICAL DATA

Rock type analyzed argillite

Major elements (wt.%)		Minor elements (ppm)			
SiO <sub>2</sub>	60.94	Cr	182.70	Yb	2.55
Al <sub>2</sub> O <sub>3</sub>	17.07	Co	24.30	Lu	0.4090
Fe <sub>2</sub> O <sub>3</sub>	--	Ni	90.30	Sc	28.90
FeO*	6.81	Cs	4.80		
MgO	3.54	Ba	603		
CaO	1.97	Hf	4		
Na <sub>2</sub> O	2.29	Ta	0.695		
K <sub>2</sub> O	3.25	Th	7.06		
H <sub>2</sub> O <sup>+</sup>	} 3.37 (LOI)	U	3.20		
H <sub>2</sub> O <sup>-</sup>		La	15.54		
CO <sub>2</sub>		Ce	37.79		
TiO <sub>2</sub>	0.66	Nd	21.70		
P <sub>2</sub> O <sub>5</sub>	n.d.	Sm	4.16		
MnO	0.10	Eu	0.828		
TOTAL	100 (normalized)	Tb	0.635		

Anal. method INNA

Anal. method INNA

Analyst P. O'Day, Cornell Univ.

Analyst P. O'Day, Cornell Univ.



Field number LV-6

Date Completed August 5, 1982

MGS unique number 233549

MGS lab number 1884

LOCATION (see map at right)

T-R-S 139-28-24 DABDCB

County Cass

Quadrangle Stewart Lake 7.5'

HOLE PARAMETERS

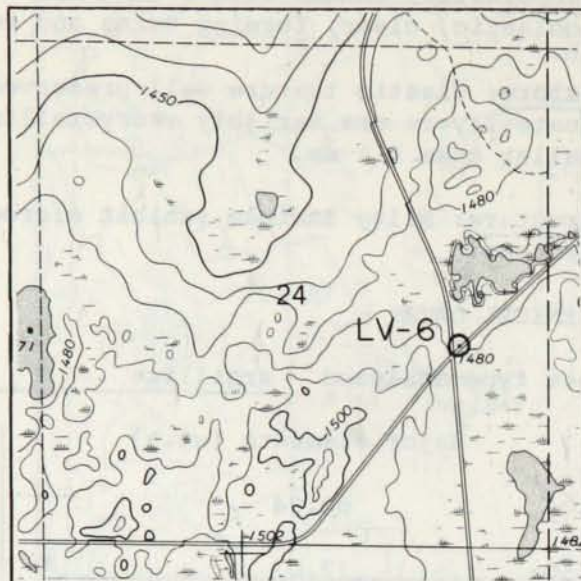
Surface elevation 1479 ft

Total depth 560 ft

Elevation, top of  
Precambrian rock 1067 ft

Core diam. \_\_\_\_\_

Length of core run \_\_\_\_\_ Core recovered no core; cuttings only



ABBREVIATED LITHOLOGIC LOG (intervals recorded are depths in feet)

Interval	Description
QUATERNARY DEPOSITS	
0-75	Gravelly sandy till, brown, noncalcareous; clasts of granite, mafic rocks, iron-formation, felsite, agate
75-106	Mixed gravelly till, red and brown, noncalcareous
106-213	Gravelly sandy till, reddish gray; more calcareous toward base. Clasts of basalt, felsite, iron-formation, slate, granite. Layer of sand and gravel, 192-195 ft
213-304	Sandy till, brown to olive brown; some dolomite clasts
304-318	Loamy till, reddish gray
318-330	Mixed loamy till, reddish gray and gray, moderately calcareous
330-345	Loamy till, gray, calcareous; dolomite clasts
345-353	Sand and clay; abundant dolomite clasts
353-375	Loamy to clayey till, gray; abundant dolomite clasts
375-405	Sandy till, gray
405-412	Mixed till, reddish brown and greenish colors; dolomite clasts
REGOLITH ON PRECAMBRIAN ROCK	
412-470	Clay, variegated; zones of soft argillite
SOUND PRECAMBRIAN ROCK	
470-560	Argillite, dark gray to black



PETROGRAPHIC DESCRIPTION OF CORE

No thin section made. Rock is gray laminated argillite similar to sample LV-5.

CHEMICAL DATA

Rock type analyzed no analyses

Field number LV-7

Date Completed August 13, 1982

MGS unique number 233548

MGS lab number 1902

LOCATION (see map at right)

T-R-S 139-28-26 AABABA

County Cass

Quadrangle Stewart Lake 7.5'

HOLE PARAMETERS

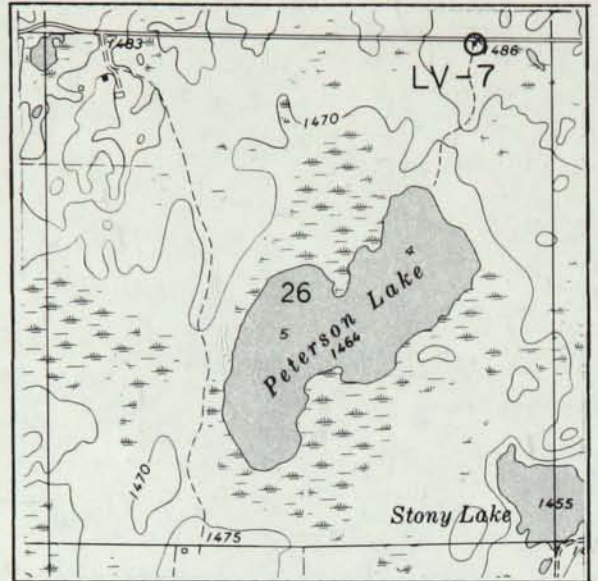
Surface elevation 1488 ft

Total depth 690 ft

Elevation, top of  
Precambrian rock 1053 ft

Core diam. \_\_\_\_\_

Length of core run \_\_\_\_\_ Core recovered no core; cuttings only



ABBREVIATED LITHOLOGIC LOG (intervals recorded are depths in feet)

Interval	Description
QUATERNARY DEPOSITS	
0-115	Gravelly sandy loam till, yellowish brown to reddish brown, noncalcareous to slightly calcareous; clasts of granite, gabbro, felsite, basalt
115-182	Sandy loam till, mixed colors; clasts of fine-grained mafic rocks, cherty iron-formation
182-234	Loamy till, brown, slightly calcareous
234-255	Silty sand and gravel
255-280	Loamy till, mixed colors
280-327	Fine sand and silt; interbeds of reddish-gray clayey silt
327-371	Clayey till, dark gray to olive gray, calcareous; clasts of dolomite, basalt, granite, shale
371-390	Fine sand with many interbeds of silt
390-435	Clayey till, gray
REGOLITH ON PRECAMBRIAN ROCK	
435-460	Gritty clay; many intervals of soft hematitic rock
460-690	Gritty clay and hard to soft hematitic rock; irregular layers of cherty iron-formation

PETROGRAPHIC DESCRIPTION OF CORE

No thin section made owing to extreme softness of recovered sample. Rock is badly fractured hematitic iron-formation.

CHEMICAL DATA

Rock type analyzed no analyses

Field number LV-10A

Date Completed September 10, 1982

MGS unique number 233144

MGS lab number 1915

LOCATION (see map at right)

T-R-S 137-30-34 DDCCDC

County Cass

Quadrangle Pine River 7.5'

HOLE PARAMETERS

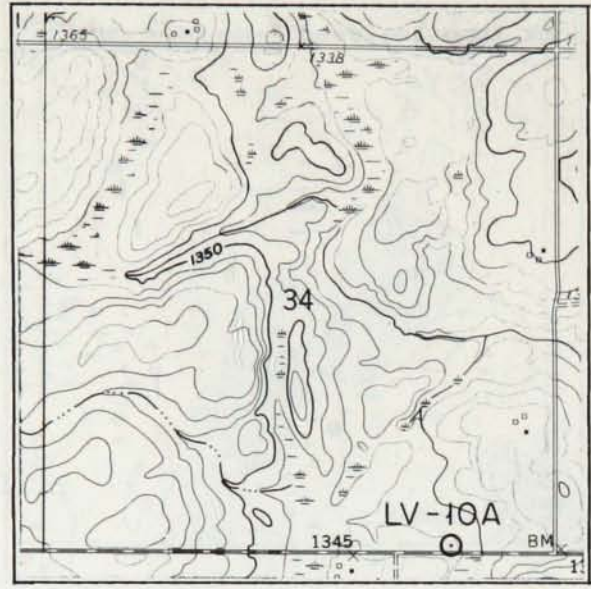
Surface elevation 1333 ft

Total depth 288.2 ft

Elevation, top of  
Precambrian rock 1121.5 ft

Core diam. 2.5"

Length of core run 278-288.2 Core recovered 10.2 ft



ABBREVIATED LITHOLOGIC LOG (intervals recorded are depths in feet)

Interval	Description
QUATERNARY DEPOSITS	
0-11	Sand and gravel
11-51	Sandy till, dark gray to brown; clasts of iron-formation, granite, mafic rocks, felsite
51-61	Sand and gravel
61-86	Sandy till, reddish brown to gray, calcareous; clasts of dolomite, red sandstone
86-140	Silty till, gray, calcareous; some dolomite clasts
140-146	Sand and gravel
146-190	Loamy to silty till, gray to dark gray, calcareous. Layer of silt at base
190-212	Loamy to sandy till, reddish brown to dark gray, calcareous
REGOLITH ON PRECAMBRIAN ROCK	
212-230	Sandy clay, green to black; zones of partly decomposed rock
230-258	Partly decomposed rock, some clay
SOUND PRECAMBRIAN ROCK	
258-288	Biotite schist



PETROGRAPHIC DESCRIPTION OF CORE

Principal rock type: Chlorite-biotite schist.

Mineralogy: Quartz, plagioclase, chlorite, biotite, clinozoisite; accessory sphene, magnetite, zircon(?).

Texture: Neocrystalline, foliated, microporphyroblastic. Main mass of rock is foliated, fine-grained quartz, plagioclase, chlorite, biotite (grain size about 0.07 mm). Porphyroblasts of biotite are as long as 1 mm.

Structure: Strong schistosity at low angle to modal layering.

CHEMICAL DATA

Rock type analyzed no analyses

Field number LV-10B

Date Completed September 20, 1982

MGS unique number 233129

MGS lab number 1917

LOCATION (see map at right)

T-R-S 137-30-22 AABBBB

County Cass

Quadrangle Pine River 7.5'

HOLE PARAMETERS

Surface elevation 1310 ft

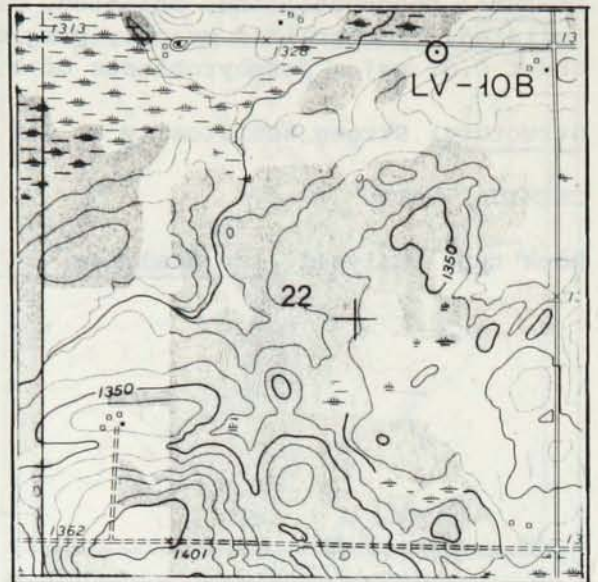
Total depth 422 ft

Elevation, top of  
Precambrian rock 1126 ft

Core diam. 2.5"

Length of core run 412-422

Core recovered approx. 9 ft



ABBREVIATED LITHOLOGIC LOG (intervals recorded are depths in feet)

Interval

Description

QUATERNARY DEPOSITS

- |         |  |
|---------|--|
| 0-26    | Loamy till, yellow brown to dark gray, noncalcareous; clasts of felsite, gabbro, basalt, granite, iron-formation |
| 26-34   | Sandy loam till, weak red, calcareous; clasts of felsite, gabbro, basalt, iron-formation, granite                |
| 34-65   | Sandy loam till, dark gray, slightly or noncalcareous; clasts of basalt, gabbro, granite                         |
| 65-76   | Cobbly loam till, dark reddish gray to gray; clasts of iron-formation with some felsite, gabbro, basalt, granite |
| 76-128  | Sandy clayey silt  |
| 128-150 | Loam till, dark gray, slightly calcareous; clasts as in above tills  |
| 150-155 | Sand   |
| 155-184 | Sand, silty clay, clayey silt  |

REGOLITH ON PRECAMBRIAN ROCK

- |         |  |
|---------|--|
| 184-402 | Gritty clay, variegated, and soft rock |
|---------|--|

SOUND PRECAMBRIAN ROCK

- |         |                |
|---------|----------------|
| 402-422 | Biotite schist |
|---------|----------------|

PETROGRAPHIC DESCRIPTION OF CORE

Principal rock type: Garnet muscovite-biotite schist.

Mineralogy: Quartz, plagioclase, biotite, muscovite; lesser garnet. Minor retrograde chlorite. Prominent porphyroblast-like clots have cores of sphene, rutile, leucoxene and overgrowths of biotite.

Texture: Neoblastic, foliated. Small porphyroblasts of garnet; also porphyroblast-like clots of Ti-phases and biotite, mentioned above.

Structure: Relict graded bedding reflected in phyllosilicate abundance and type. Strong schistosity at low angle to bedding.

CHEMICAL DATA

Rock type analyzed garnet-biotite schist

Major elements (wt.%)		Minor elements (ppm)	
SiO <sub>2</sub>	58.2	Ba	820
Al <sub>2</sub> O <sub>3</sub>	18.6	Be	1.7
Fe <sub>2</sub> O <sub>3</sub>	<0.1	Sc	24
FeO	7.1	V	138
MgO	3.67	Cr	174
CaO	1.44	Co	29
Na <sub>2</sub> O	3.29	Ni	100
K <sub>2</sub> O	4.02	Cu	81
H <sub>2</sub> O <sup>+</sup>	n.d.	Zn	103
H <sub>2</sub> O <sup>-</sup>	n.d.	Rb	85
CO <sub>2</sub>	n.d.	Sr	395
TiO <sub>2</sub>	0.63	Y	18
P <sub>2</sub> O <sub>5</sub>	0.17	Zr	155
MnO	0.08		
TOTAL	97.2		
Anal. method <u>DCAP/OES</u>		Anal. method <u>DCAP/OES</u>	
Analyst <u>R. Knoche, Univ. of Minn.</u>		Analyst <u>R. Knoche, Univ. of Minn.</u>	



Field number LV-11

Date Completed September 8, 1982

MGS unique number 233143

MGS lab number 1914

LOCATION (see map at right)

T-R-S 135-30-10 BBBBAB

County Cass

Quadrangle Pine River SW 7.5'

HOLE PARAMETERS

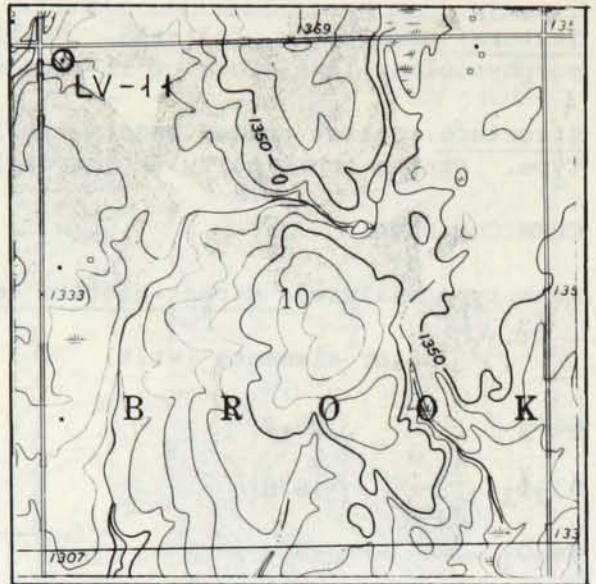
Surface elevation 1305 ft

Total depth 265.2 ft

Elevation, top of  
Precambrian rock 1109.5 ft

Core diam. 2.5"

Length of core run 255-265.2 Core recovered 10.2 ft



ABBREVIATED LITHOLOGIC LOG (intervals recorded are depths in feet)

Interval	Description
QUATERNARY DEPOSITS	
0-34	Gravelly sandy till, brown, gray, and yellowish red; clasts of iron-formation, mafic rocks, minor dolomite
34-93	Silty gravel, sandy loam, sand, and gravel
93-100	Sandy till, reddish brown to yellowish red, noncalcareous, iron-stained
100-151	Sand and gravel
151-155	Sandy till, reddish brown
155-165	Sandy silt, silty sand, pebbly sand
165-172	Silty till, gray
172-190	Clayey till, dark reddish brown to dark gray, calcareous; dolomite clasts
190-196	Clayey till, dark gray to dark greenish gray
REGOLITH ON PRECAMBRIAN ROCK	
196-245	Sandy clay, grayish green; zones of soft rock
SOUND PRECAMBRIAN ROCK	
245-265	Greenstone derived from diabase sill or coarse flow



PETROGRAPHIC DESCRIPTION OF CORE

Principal rock type: Metadiabase (greenstone).

Mineralogy: Relict primary plagioclase, dark olive-green hornblende; secondary blue-green actinolitic hornblende, sodic plagioclase, chlorite, epidote, clinozoisite, leucoxene; traces of quartz. Prominent skeletal crystals of ilmenite.

Texture: Diabasic, modified by metamorphic recrystallization. Grain size increases from 0.5 mm at top of core to about 2 mm at bottom.

Structure: Essentially massive.

CHEMICAL DATA

Rock type analyzed metadiabase

Major elements (wt.%)		Minor elements (ppm)	
SiO <sub>2</sub>	47.3	Ba	281
Al <sub>2</sub> O <sub>3</sub>	13.4	Be	1.9
Fe <sub>2</sub> O <sub>3</sub>	1.8	Sc	29
FeO	13.8	V	290
MgO	7.68	Cr	34
CaO	6.37	Co	55
Na <sub>2</sub> O	2.46	Ni	78
K <sub>2</sub> O	0.88	Cu	52
H <sub>2</sub> O <sup>+</sup>	n.d.	Zn	167
H <sub>2</sub> O <sup>-</sup>	n.d.	Rb	22
CO <sub>2</sub>	n.d.	Sr	340
TiO <sub>2</sub>	2.35	Y	29
P <sub>2</sub> O <sub>5</sub>	0.32	Zr	201
MnO	0.21		
TOTAL	96.6		
Anal. method <u>DCAP/OES</u>		Anal. method <u>DCAP/OES</u>	
Analyst <u>R. Knoche, Univ. of Minn.</u>		Analyst <u>R. Knoche, Univ. of Minn.</u>	

Field number P-1

Date Completed August 4, 1983

MGS unique number 234177

MGS lab number 1995

LOCATION (see map at right)

T-R-S 134-30-11 ACBABB

County Cass

Quadrangle Wilson Bay 7.5'

HOLE PARAMETERS

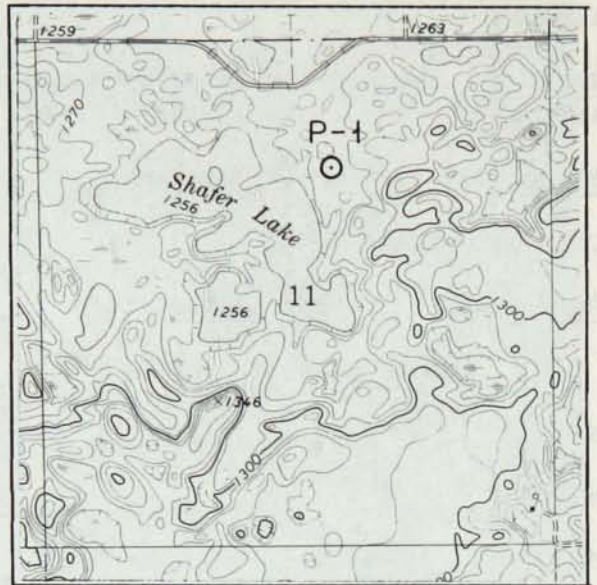
Surface elevation 1265 ft

Total depth 231.2 ft

Elevation, top of  
Precambrian rock 1063 ft

Core diam. 2.5"

Length of core run 223-231.2 Core recovered approx. 8.2 ft



ABBREVIATED LITHOLOGIC LOG (intervals recorded are depths in feet)

Interval	Description
QUATERNARY DEPOSITS	
0-10	Gravelly sand
10-82	Very sandy gravelly till, various shades of yellowish brown, greenish gray, and dark gray; abundant clasts of red aphanitic rock, agate, basalt, quartz; minor dolomite clasts
82-129	Sand and gravel
129-156	Sandy clay till, brown to gray, calcareous; clasts of basalt, felsite, agate, minor dolomite
156-180	Sandy clay till, gray, calcareous; some shale clasts
180-195	Sandy till, gray, calcareous
195-202	Sand and clay, gray; wood fragments
REGOLITH ON PRECAMBRIAN ROCK	
202-220	Clay, gray green; intervals of soft rock
SOUND PRECAMBRIAN ROCK	
220-231	Greenstone

PETROGRAPHIC DESCRIPTION OF CORE

Principal rock type: Metabasalt (greenstone).

Mineralogy: Tremolite, sodic plagioclase, epidote, biotite, leucoxene, Fe-Ti oxides.

Texture: Relict basaltic texture strongly modified by growth of metamorphic minerals. Biotite forms very fine grained radial clumps.

Structure: Essentially massive.

CHEMICAL DATA

Rock type analyzed metabasalt

Major elements (wt.%)		Minor elements (ppm)	
SiO <sub>2</sub>	48.5	Ba	375
Al <sub>2</sub> O <sub>3</sub>	15.4	Be	1.1
Fe <sub>2</sub> O <sub>3</sub>	5.0	Sc	42
FeO	7.2	V	310
MgO	7.63	Cr	164
CaO	9.2	Co	46
Na <sub>2</sub> O	1.38	Ni	71
K <sub>2</sub> O	0.82	Cu	148
H <sub>2</sub> O <sup>+</sup>	n.d.	Zn	93
H <sub>2</sub> O <sup>-</sup>	n.d.	Rb	17
CO <sub>2</sub>	n.d.	Sr	610
TiO <sub>2</sub>	1.36	Y	21
P <sub>2</sub> O <sub>5</sub>	0.11	Zr	84
MnO	0.17		
TOTAL	96.8		
Anal. method <u>DCAP/OES</u>		Anal. method <u>DCAP/OES</u>	
Analyst <u>R. Knoche, Univ. of Minn.</u>		Analyst <u>R. Knoche, Univ. of Minn.</u>	



Field number P-2

Date Completed August 10, 1983

MGS unique number 234178

MGS lab number 1996

LOCATION (see map at right)

T-R-S 134-31-36 BBABBB

County Cass

Quadrangle Casino 7.5'

HOLE PARAMETERS

Surface elevation 1302 ft

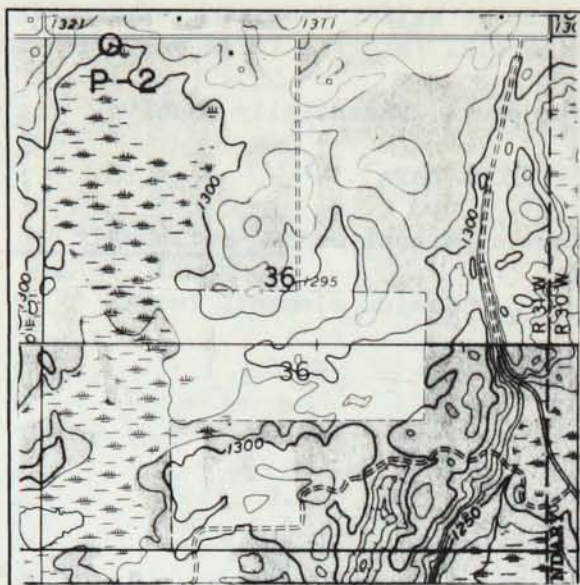
Total depth 282.7 ft

Elevation, top of  
Precambrian rock 1091 ft

Core diam. 2.5"

Length of core run 274.5-282.7

Core recovered 8.2 ft



ABBREVIATED LITHOLOGIC LOG (intervals recorded are depths in feet)

Interval	Description
QUATERNARY DEPOSITS	
0-24	Very sandy gravelly till, yellow brown; clasts of red felsite, basalt, quartz
24-32	Sand, brown
32-40	Sandy silty till, brown
40-124	Silty clay, grayish brown, and sand, clay, gravel
124-136	Clayey till, dark grayish brown to dark gray, calcareous
136-157	Very sandy till
157-163	Sand and gravel
163-177	Till, gray, calcareous; clasts of dolomite, basalt
177-209	Gravelly sand
209-211	Gravelly sand containing fragments of regolith
REGOLITH ON PRECAMBRIAN ROCK	
211-258	Clay, blue green to gray green; intervals of soft rock
SOUND PRECAMBRIAN ROCK	
258-283	Metagraywacke and slate, in part slightly decomposed, with minor clay seams



PETROGRAPHIC DESCRIPTION OF CORE

Principal rock type: Lithic metagraywacke; thin slaty interbeds.

Mineralogy: Framework grains: quartz, plagioclase, lithic fragments; minor microcline. Lithic clasts include metabasalt, chert, fine-grained schistose rocks. Matrix: comminuted quartz, plagioclase, sericitic muscovite, chlorite, biotite. Accessory apatite, granular opaque minerals.

Texture: Clastic texture substantially modified by recrystallization, cleavage development. Chlorite, biotite have grown metamorphically.

Structure: Strong cleavage; films anastomose around clastic grains, which are flattened.

CHEMICAL DATA

Rock type analyzed phyllitic slate (P-2-SL); metagraywacke (P-2-GWKE)

	Major elements (wt.%)		Minor elements (ppm)	
	(P-2-SL)	(P-2-GWKE)	(P-2-SL)	(P-2-GWKE)
SiO <sub>2</sub>	42.0	65.9	Ba	1530
Al <sub>2</sub> O <sub>3</sub>	23.5	13.9	Be	2.4
Fe <sub>2</sub> O <sub>3</sub>	1.5	0.1	Sc	36
FeO	9.7	6.0	V	240
MgO	7.65	4.18	Cr	280
CaO	0.65	0.45	Co	38
Na <sub>2</sub> O	0.54	2.13	Ni	159
K <sub>2</sub> O	5.04	2.09	Cu	96
H <sub>2</sub> O <sup>+</sup>	n.d.	n.d.	Zn	121
H <sub>2</sub> O <sup>-</sup>	n.d.	n.d.	Rb	170
CO <sub>2</sub>	n.d.	n.d.	Sr	70
TiO <sub>2</sub>	0.95	0.48	Y	27
P <sub>2</sub> O <sub>5</sub>	0.27	0.16	Zr	202
MnO	0.11	0.06		
TOTAL	92.9	95.5		

Anal. method DCAP/OES

Anal. method DCAP/OES

Analyst R. Knoche, Univ. of Minn.

Analyst R. Knoche, Univ. of Minn.

Field number 1985-1

Date Completed September 6, 1985

MGS unique number 236125

MGS lab number 2173

LOCATION (see map at right)

T-R-S 138-32-35 DDBBAD

County Cass

Quadrangle Spider Lake 7.5'

HOLE PARAMETERS

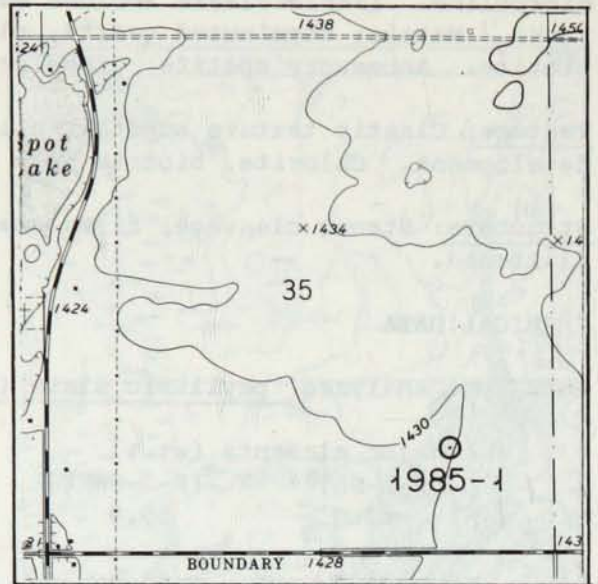
Surface elevation 1430 ft

Total depth 496 ft

Elevation, top of  
Precambrian rock 967 ft

Core diam. 2.5"

Length of core run 486-496 Core recovered 10 ft



ABBREVIATED LITHOLOGIC LOG (intervals recorded are depths in feet)

Interval	Description
QUATERNARY DEPOSITS	
0-30	Sand and gravel
30-101	Sandy till, pale brown to gray; clasts of granite, gabbro, iron-formation. Layer of sand and gravel, 72-81 ft
101-135	Sand and gravel and sandy loam
135-167	Sandy till, yellowish brown to greenish gray; clasts of granite, felsite, mafic rocks, minor carbonate
167-180	Silty sandy till, gray; carbonate clasts
180-239	Sand and gravel; abundant carbonate
239-288	Silty sandy and silty clay till, gray to greenish gray
288-322	Silt and sand and some gravel
322-357	Silty till, gray; clasts of carbonate, mafic rocks
357-365	Silty sand to silt, brown
365-425	Sandy till, reddish brown to dark gray
425-446	Silty clay, dark gray
446-463	Clayey till, dark gray; contains brown wood and coal bits
REGOLITH ON PRECAMBRIAN ROCK	
463-479	Clay, blue green to light gray
SOUND PRECAMBRIAN ROCK	
479-496	Argillite with thin interbeds of graded graywacke-siltstone

PETROGRAPHIC DESCRIPTION OF CORE

Principal rock type: Argillite; minor thin beds of siltstone.

Mineralogy: Siltstone layers contain detrital quartz, plagioclase, muscovite, biotite, chlorite, graphite; also irregular clumps of kaolinite interpreted to be pseudomorphs of K-feldspar grains. Argillite layers have similar mineralogy but contain a higher fraction of phyllosilicates. Accessory minerals are sphene, apatite, leucoxene, pyrite.

Texture: Sedimentary textures modified somewhat by recrystallization of fine-grained constituents. Most siltstone layers are sharply graded.

Structure: Marked bedding-parallel fissility carried by oriented phyllosilicates.

CHEMICAL DATA

Rock type analyzed no analyses



Field number 1985-2

Date Completed August 22, 1985

MGS unique number 236124

MGS lab number 2172

LOCATION (see map at right)

T-R-S 136-31-19 DCDCD

County Cass

Quadrangle Leader 7.5'

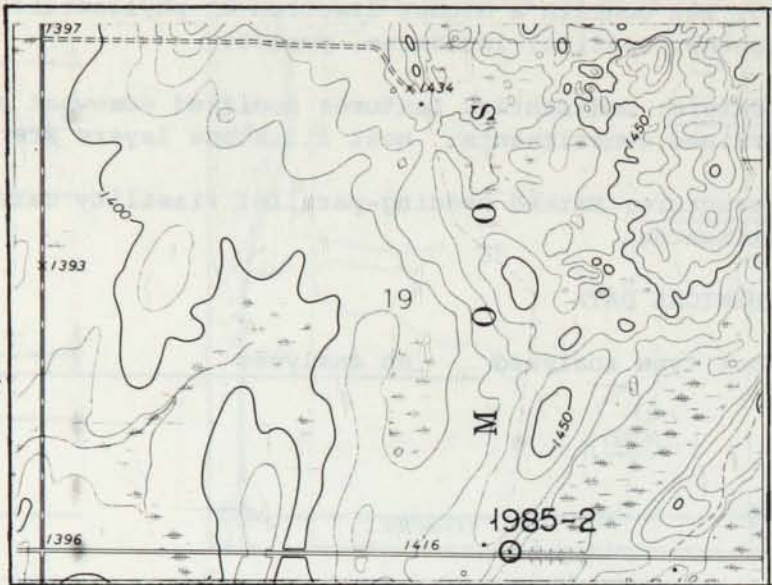
HOLE PARAMETERS

Surface elevation 1415 ft

Total depth 292.1 ft

Elevation, top of  
Precambrian rock 1140 ft

Core diam. 2.5"



Length of core run 282-292.1 Core recovered 10 ft

ABBREVIATED LITHOLOGIC LOG (intervals recorded are depths in feet)

Interval	Description	Till unit of Meyer (1986)
QUATERNARY DEPOSITS		
0-15	Sand and gravel	
15-88	Sandy gravelly till, light yellowish brown to gray; felsite, some dolomite and red sandstone clasts	Wadena
88-117	Sandy till, gray; clasts of mafic rocks	
117-128	Sandy clay till, gray	
128-138	Sand and gravel	
138-162	Sandy to sandy clay till, greenish gray; carbonate clasts	
162-176	Silty till, dark gray; wood fragments and carbonate clasts	
176-201	Sand, silt, gravel	
201-207	Clayey till, dark gray	
207-223	Fine sandy silty till, greenish gray to light gray; wood, carbonate clasts	Meyer Lake
223-239	Sandy clay till, brown	
239-260	Clayey till, olive gray to dark gray	Eagle Bend ?
260-275	Sandy clay till, gray	Elmdale ?

REGOLITH ON PRECAMBRIAN ROCK

275-279 Sandy clay, greenish gray; intervals of broken rock

SOUND PRECAMBRIAN ROCK

279-292 Diorite



PETROGRAPHIC DESCRIPTION OF CORE

Principal rock type: Appinitic diorite.

Mineralogy: Clinopyroxene and secondary chlorite (50%), plagioclase (40%), biotite and secondary chlorite (5%), hornblende (2%), magnetite (3%); also secondary muscovite, quartz, calcite, clinozoisite, actinolite. Abundant accessory apatite.

Texture: Hypidiomorphic granular; grain size 0.5-1 mm. Clinopyroxene tends toward euhedral form.

Structure: Essentially massive.

CHEMICAL DATA

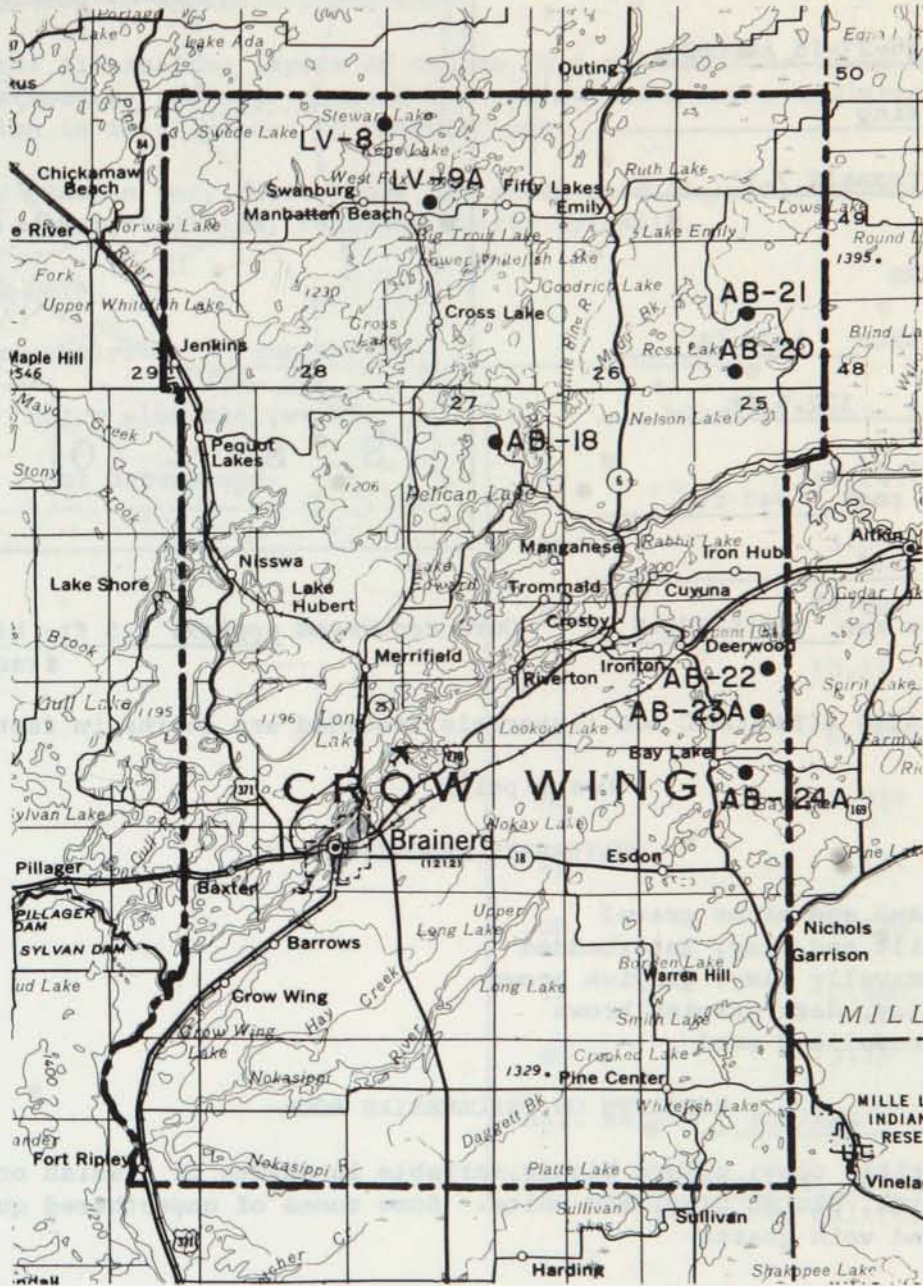
Rock type analyzed appinitic diorite

Major elements (wt.%)	Minor elements (ppm)			
not determined	Ag	0.059	Te	<0.5
	As	<1.0	Tl	<0.5
	Au	0.003	Zn	42.5
	Bi	<0.5		
	Cd	<1.0		
	Cu	38.9		
	Ga	1.37		
	Hg	<0.5		
	Mo	0.75		
	Pb	2.87		
	Pd	<0.25		
	Pt	<0.5		
	Sb	0.50		
	Se	<1.0		
	Sn	<0.5		

Anal. method ICP/AES

Analyst Geochemical Services Inc.  
Torrance, California





Field number AB-18

Date Completed July 30, 1984

MGS unique number 235696

MGS lab number 2042

LOCATION (see map at right)

T-R-S 136-27-15 ADDDBD

County Crow Wing

Quadrangle Trommald 7.5'

HOLE PARAMETERS

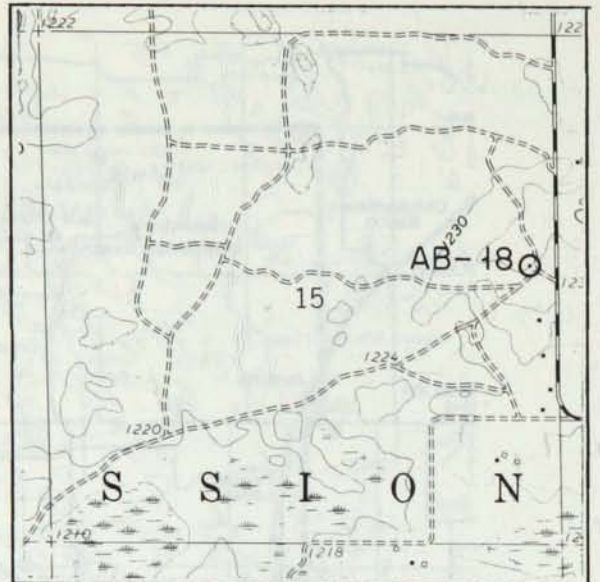
Surface elevation 1238 ft

Total depth 372.5 ft

Elevation, top of  
Precambrian rock 940 ft

Core diam. 2.5"

Length of core run 366.5-372.5 Core recovered approx. 1.5 ft; highly fractured



ABBREVIATED LITHOLOGIC LOG (intervals recorded are depths in feet)

Interval	Description
QUATERNARY DEPOSITS	
0-122	Sand and minor gravel
122-258	Silt and clay, interbedded
258-261	Gravelly clay, grayish brown
261-278	Clay, dark grayish brown
278-298	Gravel and sand
REGOLITH ON PRECAMBRIAN ROCK	
298-362	Gritty clay; colors highly variable in shades of reddish orange, pink, bluish gray, and white. Some zones of unweathered quartzite and vein quartz
SOUND PRECAMBRIAN ROCK	
362-373	Quartzite



PETROGRAPHIC DESCRIPTION OF CORE

Principal rock type: Quartzite; strongly recrystallized.

Mineralogy: Quartz (85-90%), albite (8-10%), chlorite (1%); traces of sericitic muscovite, carbonate, dusty clinozoisite.

Texture: Granoblastic mosaic; good shape and crystallographic fabric of quartz is transverse to apparent layering.

Structure: Alternating layers of coarse (0.5 mm) and fine (0.05 mm) texture are construed as bedding. Layers are 1-3 mm thick and crenulated. Quartz elongation is axial-planar to crenulations.

Comments: Sample very poor. Rock is interpreted as metasedimentary, but could also be a recrystallized, refolded quartz mylonite.

CHEMICAL DATA

Rock type analyzed quartzite

Major elements (wt.%)

not determined

Minor elements (ppm)

Ag	<0.049
As	3.051
Au	<0.001
Cu	10.51
Hg	0.5094
Mo	3.939
Pb	5.351
Sb	3.020
Tl	<0.988
Zn	13.75

Anal. method ICP/AES

Analyst Geochemical Services, Inc.  
Torrance, California

Field number AB-20

Date Completed July 25, 1984

MGS unique number 235695

MGS lab number 2039

LOCATION (see map at right)

T-R-S 137-25-33 BDBBBD

County Crow Wing

Quadrangle Ross Lake 7.5'

HOLE PARAMETERS

Surface elevation 1256 ft

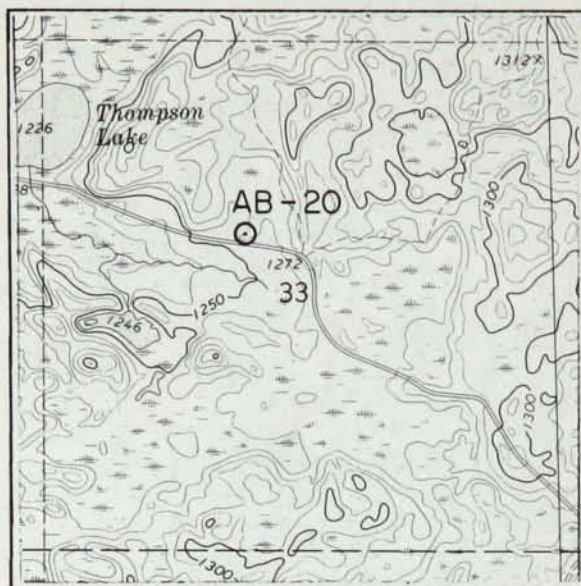
Total depth 260 ft

Elevation, top of  
Precambrian rock 1045 ft

Core diam. 2.5"

Length of core run 250-260

Core recovered 10 ft



ABBREVIATED LITHOLOGIC LOG (intervals recorded are depths in feet)

Interval	Description
QUATERNARY DEPOSITS	
0-51	Sandy till, dark brown to gray; clasts of basalt, some granite
51-61	Sand and seams of peat
61-117	Sandy till, dark reddish brown to dark gray. Layer of sand, 64-76 ft
117-152	Sand
152-186	Sandy till, gray to dark greenish gray
186-194	Sandy clay till, dark gray
194-211	Sandy till, dark gray, with wood fragments
REGOLITH ON PRECAMBRIAN ROCK	
211-242	Clay, green, gray, blue
242-249	Soft rock and clay
SOUND PRECAMBRIAN ROCK	
249-260	Thin-bedded metagraywacke and argillite

PETROGRAPHIC DESCRIPTION OF CORE

Principal rock type: Thin-bedded argillite-graywacke.

Mineralogy: Graywacke beds: framework grains are dominantly quartz (80-90%); remainder are plagioclase. Matrix composed of comminuted quartz, plagioclase together with sericitic muscovite, chlorite, stilpnomelane, minor graphite. Accessory minerals are tourmaline, zircon. Argillite beds: mineralogy comparable to graywacke matrix, but higher fraction of phyllosilicates.

Texture: Graywacke is matrix-rich; framework grains (0.15-0.2 mm) are rarely in contact. Metamorphic fabric manifested by clast elongation in cleavage planes, and neoblastic, foliated texture of matrix. The argillite is completely recrystallized.

Structure: Beds range in thickness from 1 to 20 cm; primary slump and compaction structures are common. Strong spaced cleavage is transverse to bedding; it is bundled and refracted on passing from bed to bed.

CHEMICAL DATA

Rock type analyzed quartz wacke

Major elements (wt.%)	Minor elements (ppm)	
not determined	Ag	<0.048
	As	<0.961
	Au	0.003
	Cu	16.77
	Hg	<0.480
	Mo	0.999
	Pb	3.864
	Sb	1.017
	Tl	<0.961
	Zn	23.71
	Anal. method <u>ICP/AES</u>	
	Analyst <u>Geochemical Services, Inc.</u> <u>Torrance, California</u>	

Field number AB-21

Date Completed July 21, 1984

9GS unique number 235694

MGS lab number 2038

LOCATION (see map at right)

T-R-S 137-25-16 DDAAB

County Crow Wing

Quadrangle Ross Lake 7.5'

HOLE PARAMETERS

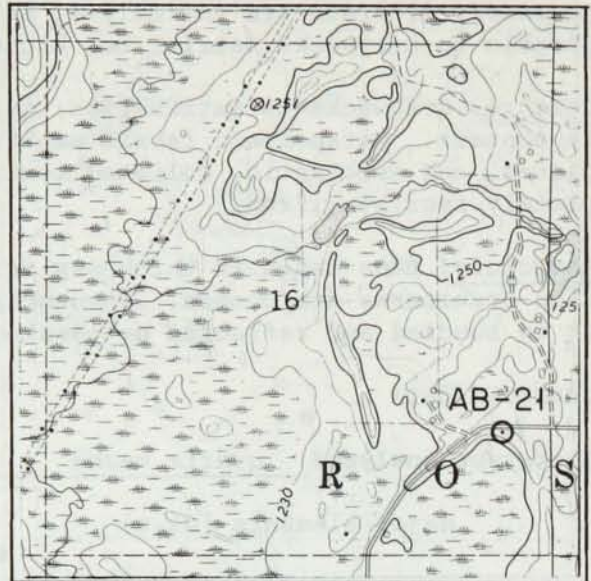
Surface elevation 1272 ft

Total depth 284.5 ft

Elevation, top of  
Precambrian rock 1052 ft

Core diam. 2.5"

Length of core run 274.5-284.5 Core recovered 10 ft



ABBREVIATED LITHOLOGIC LOG (intervals recorded are depths in feet)

Interval	Description
QUATERNARY DEPOSITS	
0-1	Sand
1-18	Sandy till, dark brown; abundant clasts of basalt, metasedimentary rocks
18-58	Sandy clay till, dark gray
58-68	Sand
68-82	Clay, very dark gray to black
82-124	Sandy clay till, dark gray; clasts of basalt, granite
124-155	Sand and gravel
155-220	Sandy clay till, dark gray to black
REGOLITH ON PRECAMBRIAN ROCK	
220-239	Gritty clay, yellowish red to white
239-266	Soft rock, iron-rich rock, dark red
SOUND PRECAMBRIAN ROCK	
266-284.5	Cherty ironstone



PETROGRAPHIC DESCRIPTION OF CORE

Principal rock type: Thin-bedded, cherty ironstone.

Mineralogy: Gray layers (dominant): chiefly quartz (chert and recrystallized chert) with chlorite, white mica; may also contain greenalite, minnesotaite. Trace amounts of carbonate, stilpnomelane, sphene, tourmaline. Red layers: as above plus abundant hematite, minor magnetite.

Texture: Fine-grained granoblastic with scattered, deformed chert ooids as long as 3 mm.

Structure: Good planar fabric (cleavage) transverse to bedding is carried by elongated quartz grains, elongated ooids, and preferred orientation of phyllosilicates.

CHEMICAL DATA

Rock type analyzed cherty ironstone

Major elements (wt.%)	Minor elements (ppm)	
not determined	Ag	<0.049
	As	7.413
	Au	0.0075
	Cu	20.84
	Hg	0.8380
	Mo	3.527
	Pb	18.25
	Sb	4.132
	Tl	<0.996
	Zn	14.90
	Anal. method <u>ICP/AES</u>	
	Analyst <u>Geochemical Services, Inc.</u> Torrance, California	

Field number AB-22

Date Completed June 24, 1985

MGS unique number 236102

MGS lab number 2054

LOCATION (see map at right)

T-R-S 46-28-13 CCABDA

County Crow Wing

Quadrangle Bay Lake 7.5'

HOLE PARAMETERS

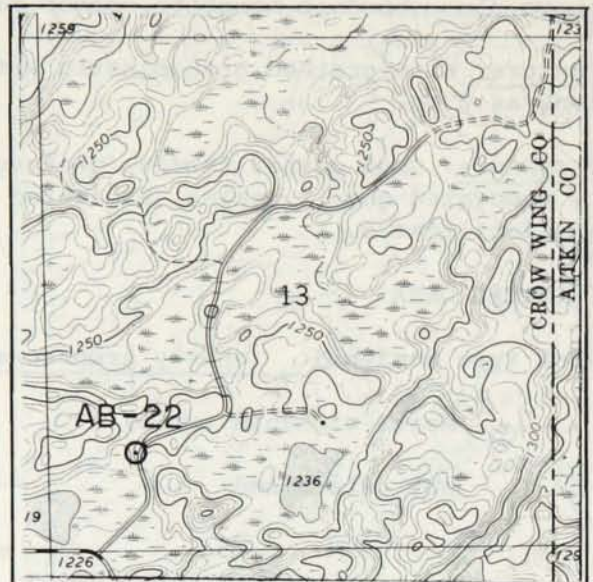
Surface elevation 1242 ft

Total depth 217.7 ft

Elevation, top of  
Precambrian rock 1046 ft

Core diam. 2.5"

Length of core run 208-217.7 Core recovered 9.7 ft



ABBREVIATED LITHOLOGIC LOG (intervals recorded are depths in feet)

Interval	Description
QUATERNARY DEPOSITS	
0-29	Clayey till, brown to yellow brown
29-36	Sand and gravel
36-71	Sandy till, gray; clasts of granite, felsite
71-140	Sand, gravel, and lenses of silty clay
140-153	Sandy till, gray, calcareous
153-160	Clay, brown
160-181	Sandy till, brown and gray, calcareous
181-194	Very sandy till, brown; clasts of felsite, mafic rocks, granite; minor carbonate, slate
194-196	Sand
SOUND PRECAMBRIAN ROCK	
196-217.8	Metavolcanic rock (greenstone), plagioclase-phyric

PETROGRAPHIC DESCRIPTION OF CORE

Principal rock type: Metabasalt.

Mineralogy: Groundmass consists of albitic plagioclase laths, abundant small prisms of actinolite, and lesser amounts of epidote, chlorite, and leucoxene. Plagioclase phenocrysts are partly recrystallized to albite, calcite, and epidote. Minor biotite is unevenly distributed in groundmass and as replacement mineral in phenocrysts.

Texture: Well preserved volcanic textures despite greenschist facies metamorphism. Rock is glomeroporphyritic (individual phenocrysts as long as 1 mm) and weakly amygdaloidal.

Structure: Actinolite prisms, albite laths show weak alignment.

Comments:

CHEMICAL DATA

Rock type analyzed metabasalt

Major elements (wt.%)

not determined

Minor elements (ppm)

Ag	<0.025	Se	<0.1
As	1.22	Sn	<0.5
Au	0.12	Te	<0.5
Bi	<0.5	Tl	<0.5
Cd	<1.0	Zn	157
Cu	340		
Ga	7.51		
Hg	<0.5		
Mo	<0.5		
Pb	3.46		
Pd	<0.25		
Pt	<0.5		
Sb	0.372		

Anal. method ICP/AES

Analyst Geochemical Services Inc.  
Torrance, California



Field number AB-23A

Date Completed June 19, 1985

MGS unique number 236101

MGS lab number 2053

LOCATION (see map at right)

T-R-S 46-28-26 ADDCCA

County Crow Wing

Quadrangle Bay Lake 7.5'

HOLE PARAMETERS

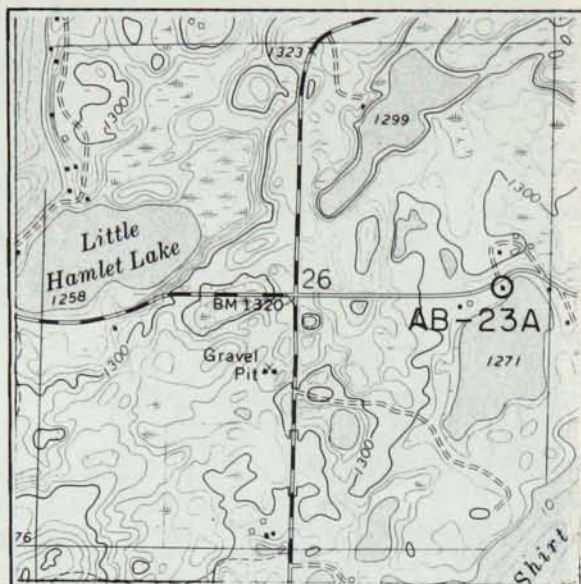
Surface elevation 1283 ft

Total depth 500 ft

Elevation, top of  
Precambrian rock 1052 ft

Core diam. 2.5"

Length of core run 488-500 Core recovered approx. 10 ft



ABBREVIATED LITHOLOGIC LOG (intervals recorded are depths in feet)

Interval	Description
QUATERNARY DEPOSITS	
0-5	Gravelly till, brown
5-7	Clayey till, brown
7-22	Sandy till, reddish brown; clasts of felsite
22-140	Gravelly sand
140-179	Clayey silt, minor sand, gray
179-189	Rocky sandy clay till, reddish gray
189-217	Sandy clay till, gray to reddish gray; some clasts of carbonate
217-224	Clayey till, gray; clasts of carbonate
224-231	Gravelly till, reddish gray
REGOLITH ON PRECAMBRIAN ROCK	
231-279	Clay, red; minor zones of soft rock
279-343	Clay, dark red and some gray, yellow, and brown
343-440	Clay, greenish gray, with quartz fragments
440-480	Clay, gray and red; zones of soft rock, chert, quartz veins
480-500	Soft slate, grayish green, and sulfide iron-formation; red, granular hematite iron-formation at base (cored)



PETROGRAPHIC DESCRIPTION OF CORE

Principal rock type: Granular, hematitic iron-formation.

Mineralogy: Quartz (recrystallized chert), white mica (in part minnesotaite), grunerite, hematite, limonite.

Texture: Originally pelletoidal (pellets ca. 0.5 mm long), but recrystallized such that pellet outlines are very indistinct. Iron silicate minerals are very fine grained and of bladed to acicular habit.

Structure: Pellets, hematite blebs are flattened and aligned in rough cleavage.

Comments:

CHEMICAL DATA

Rock type analyzed granular, lean iron-formation

Major elements (wt.%)	Minor elements (ppm)			
not determined	Ag	<0.025	Sn	<0.5
	As	29.6	Te	<0.5
	Au	0.004	Tl	<0.5
	Bi	<0.5	Zn	29.7
	Cd	<1.0		
	Cu	9.93		
	Ga	1.66		
	Hg	<0.5		
	Mo	1.22		
	Pb	3.23		
	Pd	<0.25		
	Pt	<0.5		
	Sb	0.27		
	Se	<1.0		

Anal. method ICP/AES

Analyst Geochemical Services Inc.  
Torrance, California

Field number AB-24A

Date Completed June 7, 1985

MGS unique number 236099

MGS lab number 2051

LOCATION (see map at right)

T-R-S 45-28-2 CDBCCC

County Crow Wing

Quadrangle Bay Lake 7.5'

HOLE PARAMETERS

Surface elevation 1273 ft

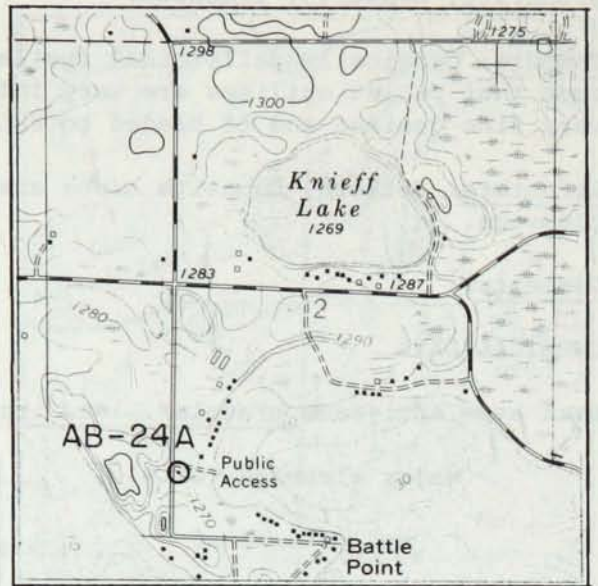
Total depth 423 ft

Elevation, top of  
Precambrian rock 1029 ft

Core diam. 2.5"

Length of core run 413-423

Core recovered 10 ft



ABBREVIATED LITHOLOGIC LOG (intervals recorded are depths in feet)

Interval	Description
QUATERNARY DEPOSITS	
0-5	Sand
5-12	Gravelly till
12-30	Silt and silty clay, dark red-brown
30-44	Gravelly till, grayish red
44-54	Silty sand
54-132	Silty clay, minor gravel, grayish brown to brown
132-197	Bouldery gravel, minor clay layers
197-236	Sandy loam, probably till, dark greenish gray; interbeds of sand and clay
236-244	Sand and gravel
REGOLITH ON PRECAMBRIAN ROCK	
244-399	Clay, brown, red, black, olive gray; zones of soft rock
SOUND PRECAMBRIAN ROCK	
399-423	Sulfide-bearing graphitic phyllite

PETROGRAPHIC DESCRIPTION OF CORE

Principal rock type: Graphitic, laminated slate/phyllite (near definitional boundary).

Mineralogy: Quartz, sericitic muscovite, chlorite, graphite, disseminated pyrite.

Texture: Rock consists of two kinds of layers: exceedingly fine-grained, quartz-poor pelitic slate, and somewhat coarser, quartz-rich, micaceous phyllite. Grains in latter are as large as 0.2 mm. Both layer types are totally neoblastic and well foliated.

Structure: Layers range in thickness from 1 to 20 mm. Penetrative slaty cleavage transects layering at 20° angle, and is deformed by superb crenulation cleavage.

Comments:

CHEMICAL DATA

Graphitic, pyritic, laminated slate (413)

Rock type analyzed Graphitic laminated slate (416)

Major elements (wt.%)	Minor elements (ppm)					
	(413)	(416)	(413)	(416)		
not determined	Ag	0.16	0.115	Se	1.42	1.39
	As	<1.0	1.06	Sn	<0.5	<0.5
	Au	0.004	0.003	Te	<0.5	<0.5
	Bi	0.726	0.5	Tl	<0.5	<0.5
	Cd	<0.1	<0.1	Zn	13.4	34.8
	Cu	20.7	56.8			
	Ga	<0.5	1.14			
	Hg	<0.5	<0.5			
	Mo	2.24	1.41			
	Pb	6.67	4.59			
	Pd	<0.25	<0.25			
	Pt	<0.5	<0.5			
	Sb	1.22	0.5			

Anal. method ICP/AES

Analyst Geochemical Services Inc.  
Torrance, California



Field number LV-8

Date Completed August 23, 1982

MGS unique number 233146

MGS lab number 1904

LOCATION (see map at right)

T-R-S 138-28-12 ADBBCA

County Crow Wing

Quadrangle Stewart Lake 7.5'

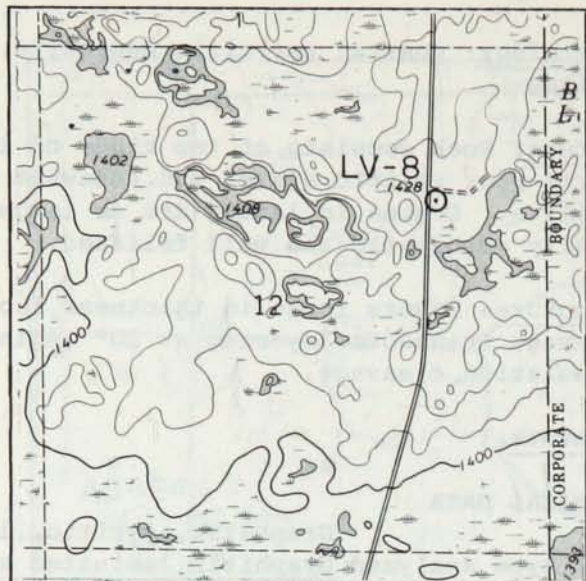
HOLE PARAMETERS

Surface elevation 1428 ft

Total depth 724 ft

Elevation, top of  
Precambrian rock 783 ft

Core diam. \_\_\_\_\_



Length of core run \_\_\_\_\_ Core recovered no core; cuttings only

ABBREVIATED LITHOLOGIC LOG (intervals recorded are depths in feet)

Interval	Description
QUATERNARY DEPOSITS	
0-17	Sand, clay, and silty clay
17-37	Gravelly sandy till, yellowish brown; clasts of quartz, basalt, granite
37-62	Sand and gravel
62-75	Silty clay to loam, very dark brown
75-107	Gravelly sandy clay till, olive gray; clasts of basalt, quartz, granite
107-170	Gravelly till, reddish gray; clasts of basalt, felsite, quartz, chert, granite, minor dolomite
170-205	Gravelly till, dark grayish brown; clasts of basalt, quartz, granite, some dolomite and red felsite
205-225	Gravelly till, olive gray; clasts of basalt; some dolomite, red felsite, and slate
225-290	Silty gravelly sand, greenish gray to dark gray. Dolomite-rich sand and white clay predominant toward base
290-305	Silty clay till, olive gray to dark gray; clasts of dolomite, quartz, basalt
305-343	Loamy till, dark grayish brown; calcareous and noncalcareous intervals. Clasts of dolomite, basalt
343-389	Loamy till, dark gray; clasts of basalt, dolomite; wood chips. Boulders at base
CRETACEOUS SEDIMENTARY ROCKS	
389-645	Clay, minor sand, red, pink, white, and greenish gray
REGOLITH ON PRECAMBRIAN ROCK	
645-696	Clay, sandy silt, brown, light yellowish green; soft rock intervals
696-724	Soft rock; partly decomposed quartzite, graywacke



PETROGRAPHIC DESCRIPTION OF CORE

No thin section made owing to small size and contamination of cuttings. Binocular examination of cuttings indicates that rock consists of interlayered quartzite, quartz-rich wacke, and argillite; it is interpreted to resemble sample AB-20.

CHEMICAL DATA

Rock type analyzed no analyses

Field number LV-9A

Date Completed August 27, 1982

MGS unique number 233145

MGS lab number 1905

LOCATION (see map at right)

T-R-S 138-27-29 ACACCC

County Crow Wing

Quadrangle Cross Lake 7.5'

HOLE PARAMETERS

Surface elevation 1318 ft

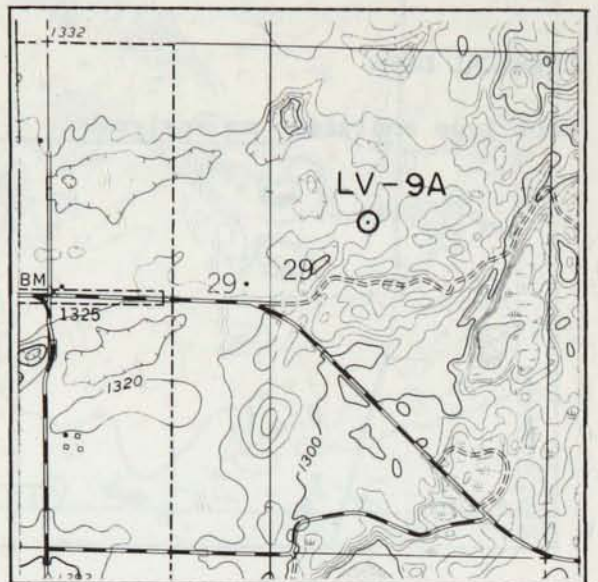
Total depth 346.3 ft

Elevation, top of  
Precambrian rock 1065.5 ft

Core diam. 2.5"

Length of core run 336-346.3

Core recovered 10.3 ft



ABBREVIATED LITHOLOGIC LOG (intervals recorded are depths in feet)

Interval	Description
QUATERNARY DEPOSITS	
0-51	Sand and gravel
51-99	Gravelly sandy till, brown to greenish gray, noncalcareous; clasts of felsite, iron-formation, quartzite, argillite
99-151	Silty sand, gravelly sand, black sandy clay, silt
151-183	Very sandy gravelly till, gray
183-200	Very sandy till, greenish gray, slightly calcareous; some dolomite clasts
200-218	Silty sand
218-235	Sandy till, greenish gray, calcareous; dolomite clasts
235-240	Sand
240-253	Very sandy till, gray, calcareous; clasts of black and red aphanitic rocks, some granite and dolomite
REGOLITH ON PRECAMBRIAN ROCK	
253-277	Sandy clay, green, yellowish green, aqua green, with intervals of schistose rock
277-283	Clay as above, with intervals of partly decomposed gneissic rock
283-319	Clay as above, with intervals of schistose rock
SOUND PRECAMBRIAN ROCK	
319-346.3	Chlorite schist

PETROGRAPHIC DESCRIPTION OF CORE

Principal rock type: Chlorite phyllite/schist, very dark green to almost black.

Mineralogy: Quartz, plagioclase, chlorite, biotite; lesser sericitic muscovite, clinozoisite. Accessory apatite, tourmaline (rel. abundant). Numerous thin veinlets of pyrite.

Texture: Neocrystalline, strongly foliated.

Structure: Strongest foliation ( $S_1$ ) is essentially layer-parallel; modal layers contain remnants of rootless isoclinal folds and therefore are not simple bedding. Prominent crenulation cleavage ( $S_2$ ) crosses  $S_1$  at a high angle.

CHEMICAL DATA

Rock type analyzed chlorite phyllite

Major elements (wt.%)		Minor elements (ppm)			
SiO <sub>2</sub>	58.1	Ag	<0.050	Sr	290
Al <sub>2</sub> O <sub>3</sub>	16.7	As	<1.00	Tl	<1.00
Fe <sub>2</sub> O <sub>3</sub>	0.5	Au	0.116	Y	16
FeO	6.7	Ba	400	Zn	69.7
MgO	6.40	Be	1.4	Zr	145
CaO	1.35	Co	29	V	144
Na <sub>2</sub> O	4.35	Cr	165		
K <sub>2</sub> O	1.34	Cu	11.8		
H <sub>2</sub> O <sup>+</sup>	n.d.	Hg	0.8072		
H <sub>2</sub> O <sup>-</sup>	n.d.	Mo	0.5777		
CO <sub>2</sub>	n.d.	Ni	126		
TiO <sub>2</sub>	0.62	Pb	3.728		
P <sub>2</sub> O <sub>5</sub>	0.19	Rb	23		
MnO	0.07	Sb	<1.00		
TOTAL	96.3	Sc	23		

Anal. method DCAP/OES

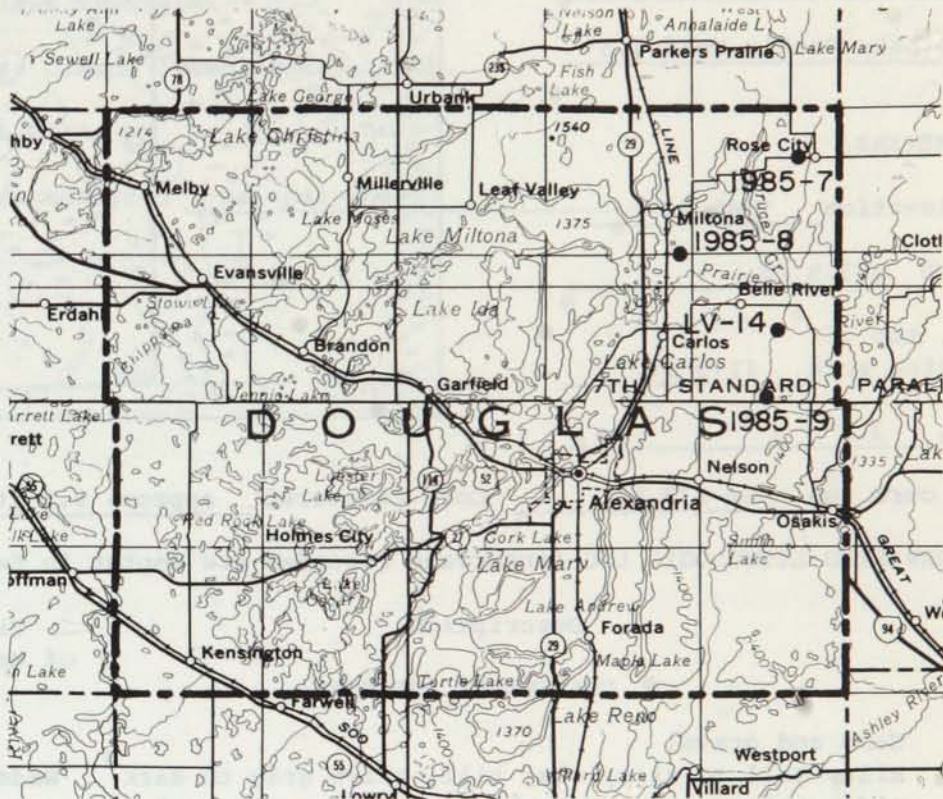
Analyst R. Knoche, Univ. of Minn.

Anal. method DCAP/OES and ICP/AES

Analyst R. Knoche, Univ. of Minn. & Geochemical Services, Inc., Torrance, California







Field number LV-14

Date Completed September 3, 1982

MGS unique number 233132

MGS lab number 1913

LOCATION (see map at right)

T-R-S 129-36-22 ABCBBB

County Douglas

Quadrangle Lake Osakis West 7.5'

HOLE PARAMETERS

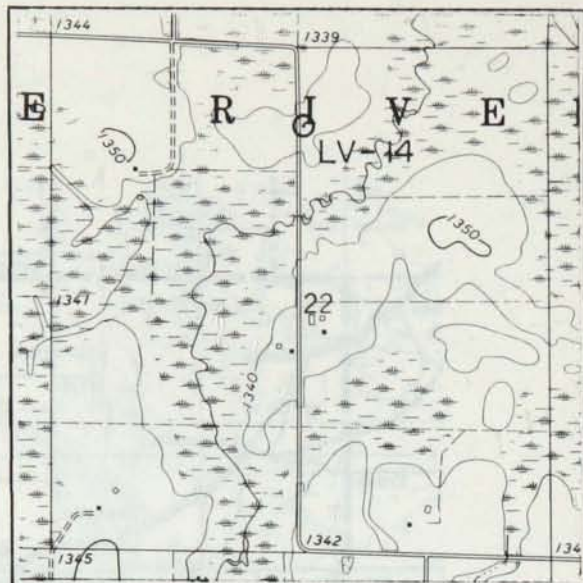
Surface elevation 1345 ft

Total depth 273.5 ft

Elevation, top of  
Precambrian rock 1110 ft

Core diam. 2.5"

Length of core run 264-273.5 Core recovered approx. 9.2 ft



ABBREVIATED LITHOLOGIC LOG (intervals recorded are depths in feet)

Interval	Description	Till unit of Meyer (1986)
QUATERNARY DEPOSITS		
0-21	Sand and gravel	
21-40	Silty till to silty clay till, olive gray to dark gray, calcareous. Interbeds of sand and gravel	Wadena
40-55	Sand and gravel; dolomite clasts	
55-72	Silty till, gray to olive gray, calcareous	Green
72-102	Sand and gravel	
102-162	Sandy till, various shades of gray, olive gray, dark gray; calcareous; clasts of dolomite, granite, mafic rocks. Layer of sand and gravel, 130-148 ft	Meyer Lake
162-214	Clayey till, various shades of dark gray, olive, gray calcareous; clasts of dolomite, mafic rocks, granite, shale	Eagle Bend
214-235	Loamy sandy till, gray to olive; contains fragments of regolith	Elmdale
REGOLITH ON PRECAMBRIAN ROCK		
235-260	Sandy clay, grayish green, with intervals of partly decomposed rock	
SOUND PRECAMBRIAN ROCK		
260-274	Biotite-hornblende tonalite	

PETROGRAPHIC DESCRIPTION OF CORE

Principal rock type: Biotite-hornblende granodiorite.

Mineralogy: Quartz (12%), plagioclase (50%), hornblende (15%), biotite (12%), microcline (10%); minor myrmekite. Small amounts of secondary chlorite, epidote. Accessory sphene, apatite, opaque phases.

Texture: Hypidiomorphic granular; grain size 1-3 mm.

Structure: Igneous flowage implied by planar alignment of subhedral plagioclase crystals.

Comments: Clean, fresh igneous rock.

CHEMICAL DATA

Rock type analyzed no analyses



Field number 1985-7

Date Completed October 1, 1985

MGS unique number 236130

MGS lab number 2178

LOCATION (see map at right)

T-R-S 130-36-11 DCCDDC

County Douglas

Quadrangle Rose City 7.5'

HOLE PARAMETERS

Surface elevation 1432 ft

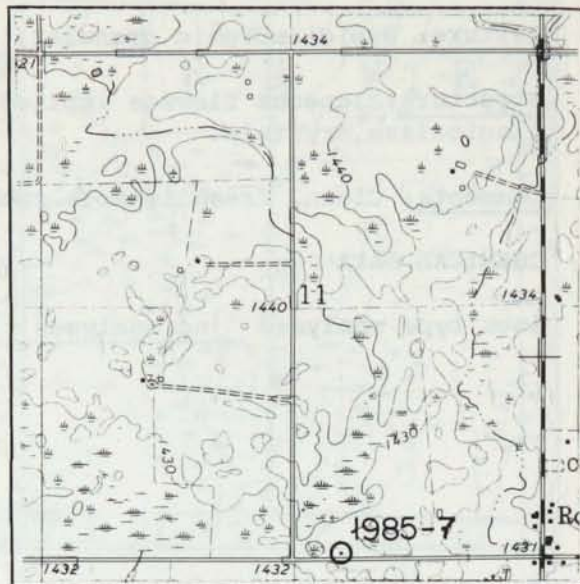
Total depth 363 ft

Elevation, top of  
Precambrian rock 1121 ft

Core diam. 2.5"

Length of core run 358-363

Core recovered 5 ft



ABBREVIATED LITHOLOGIC LOG (intervals recorded are depths in feet)

Interval	Description	Till unit of Meyer (1986)
QUATERNARY DEPOSITS		
0-9	Sand and gravel	
9-118	Sandy clay till, light yellowish brown to gray. Infrequent thin layers of sand and gravel	Wadena ?
118-145	Sand and gravel	
145-168	Loamy till, gray; carbonate clasts	
168-197	Loamy till, greenish gray. Thin layers of gravel	
197-233	Sandy clay till, gray	
233-236	Clayey to silty clay till, brownish	
236-246	Sandy clay till, gray	
246-255	Cobbly gravel	
255-304	Clayey till, olive to dark gray	Eagle Bend
304-311	Clayey till, olive gray to dark gray; Cretaceous limestone clasts	Elmdale
REGOLITH ON PRECAMBRIAN ROCK		
311-353	Silty clay, bluish gray to greenish gray. Zones of fractured rock	
SOUND PRECAMBRIAN ROCK		
353-363	Biotite-quartz-plagioclase schist with scattered sulfide grains	



PETROGRAPHIC DESCRIPTION OF CORE

Principal rock type: Andalusite-cordierite-biotite schist.

Mineralogy: Quartz, plagioclase (slightly sericitized), biotite, cordierite; lesser amounts of andalusite, garnet. Accessory apatite, magnetite, graphite.

Texture: Neoblastic, foliated; grain size of quartz, plagioclase is variable, ranging from 0.1-1 mm.

Structure: Strong schistosity carried by oriented biotite, shape fabric of quartz and plagioclase grains.

Comments: Staurolite may have been present at peak metamorphic conditions; possible pseudomorphs remain.

CHEMICAL DATA

Rock type analyzed no analyses

Field number 1985-8

Date Completed October 3, 1985

MGS unique number 236131

MGS lab number 2179

LOCATION (see map at right)

T-R-S 129-37-1 BAABBB

County Douglas

Quadrangle Lake Miliona East 7.5'

HOLE PARAMETERS

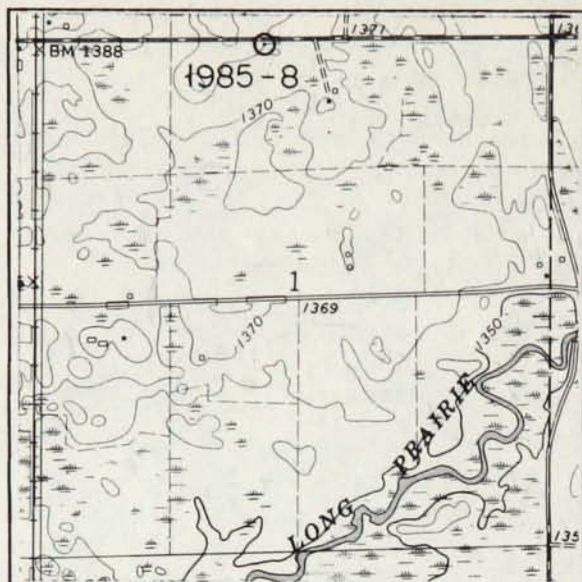
Surface elevation 1385 ft

Total depth 185.5 ft

Elevation, top of  
Precambrian rock 1230 ft

Core diam. 2.5"

Length of core run 165-185.5 Core recovered approx. 19.8 ft



ABBREVIATED LITHOLOGIC LOG (intervals recorded are depths in feet)

Interval	Description	Till unit of Meyer (1986)
QUATERNARY DEPOSITS		
0-3	Sand and gravel	
3-14	Silty clay till, light yellowish brown	Des Moines
14-24	Sandy till, light brown	Wadena ?
24-30	Sand	
30-40	Sandy till, gray; clasts of carbonate, felsite predominant; minor mafic rocks	
40-44	Sand	
44-54	Sandy till, pale brown; abundant carbonate	Wadena
54-133	Sand and gravel	
133-155	Sandy till, gray to greenish gray	Meyer Lake ?
REGOLITH ON PRECAMBRIAN ROCK		
155-157	Loam, greenish gray	
SOUND PRECAMBRIAN ROCK		
157-186	Biotite-hornblende granodiorite with inclusions of biotite-sillimanite schist	

PETROGRAPHIC DESCRIPTION OF CORE

Principal rock type: Biotite-hornblende granodiorite (intruded by minor diabase dike).

Mineralogy: Quartz, plagioclase, microcline, biotite, hornblende; accessory epidote, apatite, sphene, zircon, opaques, monazite(?).

Texture: Hypidiomorphic granular; grain size about 3.5 mm. Quartz is moderately strained; subgrains have not developed.

Structure: Weak megascopic foliation.

Comments: Granodiorite contains xenoliths of sillimanite-biotite schist. Crosscutting diabase dike is petrographically identical to dikes of Kenora-Kabetogama swarm.

CHEMICAL DATA

Rock type analyzed no analyses

Field number 1985-9

Date Completed October 8, 1985

MGS unique number 236132

MGS lab number 2180

LOCATION (see map at right)

T-R-S 129-36-33 DDAAAA

County Douglas

Quadrangle Lake Osakis West 7.5'

HOLE PARAMETERS

Surface elevation 1338 ft

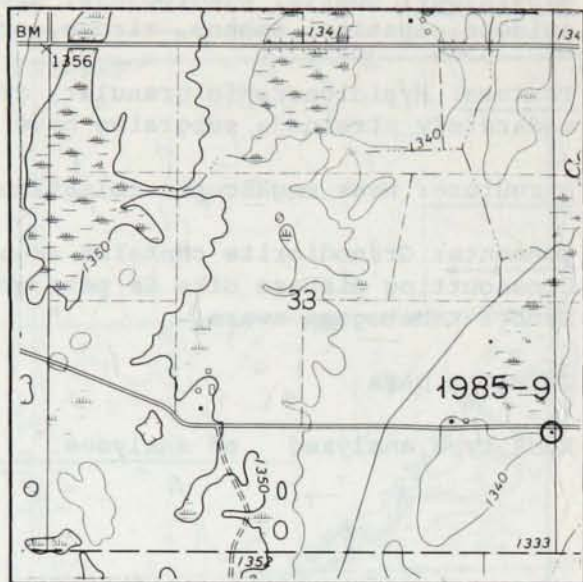
Total depth 305 ft

Elevation, top of  
Precambrian rock 1092 ft

Core diam. 2.5"

Length of core run 295-305

Core recovered 10 ft



ABBREVIATED LITHOLOGIC LOG (intervals recorded are depths in feet)

Interval

Description

QUATERNARY DEPOSITS

0-4	Loam, organic, black
4-11	Sandy clay till, light yellowish brown; carbonate clasts
11-22	Silty clay (till?), gray; some carbonate clasts
22-35	Sand
35-41	Sandy clay till and sand
41-46	Clay, organic, overlying silty clay, gray
46-56	Sandy clay till, light greenish gray; carbonate clasts
56-79	Sand and gravel
79-97	Fine sandy silty till, greenish gray; carbonate clasts
97-112	Sand and gravel
112-120	Sandy till, reddish brown to gray
120-180	Sandy clay till, gray to dark gray. Layer of sand, 162-166 ft
180-224	Clay, silty clay, gray; interbeds of silt, sand, and gravel
224-246	Silty till, dark gray

REGOLITH ON PRECAMBRIAN ROCK

246-291 Clay to silty clay, green and white

SOUND PRECAMBRIAN ROCK

291-305 Gneissic biotite-hornblende tonalite



PETROGRAPHIC DESCRIPTION OF CORE

Principal rock type: Gneissose biotite-hornblende tonalite.

Mineralogy: Quartz (15%); plagioclase, slightly sericitized, saussuritized (65%); microcline (3%); hornblende (10%); biotite (5%); epidote (2%). Epidote occurs as primary zoned euhedra and secondary granular aggregates. Accessory apatite, zircon, sphene, monazite(?); secondary chlorite, leucoxene.

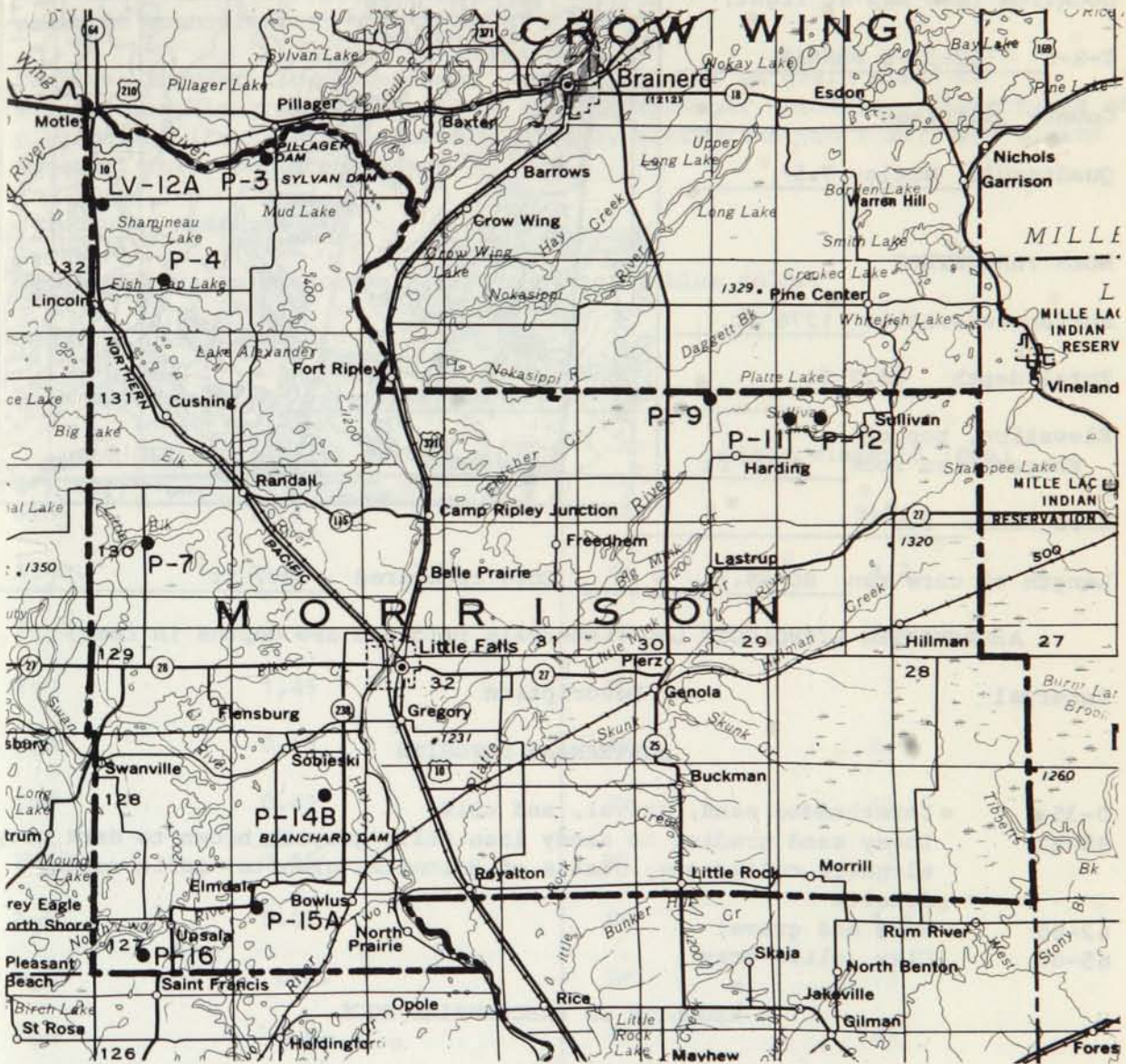
Texture: Modified hypidiomorphic granular; gneissose structure due mainly to flattening, recrystallization of quartz, planar orientation of hornblende clots.

Structure: Inclined foliation carried megascopically by planar orientation of hornblende clots and centimeter-scale amphibolite inclusions.

CHEMICAL DATA

Rock type analyzed no analyses







Field number LV-12A

Date Completed August 30, 1982

MGS unique number 233130

MGS lab number 1911

LOCATION (see map at right)

T-R-S 132-31-6 BBAAA

County Morrison

Quadrangle Motley 7.5'

HOLE PARAMETERS

Surface elevation 1276 ft

Total depth 88.7 ft

Elevation, top of  
Precambrian rock 1209 ft

Core diam. 2.5"

Length of core run 80-88.7

Core recovered 8.7 ft



ABBREVIATED LITHOLOGIC LOG (intervals recorded are depths in feet)

Interval	Description
QUATERNARY DEPOSITS	
0-35	Interbedded sand, gravel, and silt
35-62	Loamy sand grading to sandy loam till, grayish brown to dark gray, slightly calcareous; clasts of dolomite, granite, mafic rocks, felsite
62-65	Sand and gravel
65-67	Clay, olive gray
REGOLITH ON PRECAMBRIAN ROCK	
67-75	Fractured rock; seams of clay
SOUND PRECAMBRIAN ROCK	
75-89	Granite



PETROGRAPHIC DESCRIPTION OF CORE

Principal rock type: Granite porphyry.

Mineralogy: Quartz, orthoclase, perthitic microcline, plagioclase, biotite; latter is very dark brown to almost black. Secondary sericitic muscovite, chlorite, hematite. Accessory allanite, epidote, zircon, xenotime(?); minor magmatic muscovite.

Texture: Porphyritic; groundmass (approx. 0.1-0.4 mm grain size) is allotriomorphic granular mosaic of quartz, feldspar, biotite. Phenocrysts of plagioclase (to 2.5 mm), quartz (to 5 mm), microcline (to 7 mm) tend toward euhedral forms but are embayed.

Structure: Massive.

Comments: Quartz phenocrysts have distinctly blue color.

CHEMICAL DATA

Rock type analyzed granite porphyry

Major elements (wt.%)		Minor elements (ppm)	
SiO <sub>2</sub>	73.4	Ba	910
Al <sub>2</sub> O <sub>3</sub>	13.5	Be	4.2
Fe <sub>2</sub> O <sub>3</sub>	1.14	Sc	3.3
FeO	1.45	V	3
MgO	0.15	Cr	2.8
CaO	0.42	Co	<5
Na <sub>2</sub> O	3.65	Ni	2
K <sub>2</sub> O	5.00	Cu	4.6
H <sub>2</sub> O <sup>+</sup>	n.d.	Zn	73
H <sub>2</sub> O <sup>-</sup>	n.d.	Rb	183
CO <sub>2</sub>	n.d.	Sr	74
TiO <sub>2</sub>	0.26	Y	151
P <sub>2</sub> O <sub>5</sub>	0.03	Zr	440
MnO	0.02		
TOTAL	99		
Anal. method	<u>DCAP/OES</u>	Anal. method	<u>DCAP/OES</u>
Analyst	<u>R. Knoche, Univ. of Minn.</u>	Analyst	<u>R. Knoche, Univ. of Minn.</u>

Field number P-3

Date Completed August 12, 1983

MGS unique number 234179

MGS lab number 1997

LOCATION (see map at right)

T-R-S 133-30-29 ABBBBB

County Morrison

Quadrangle Pillager 7.5'

HOLE PARAMETERS

Surface elevation 1202 ft

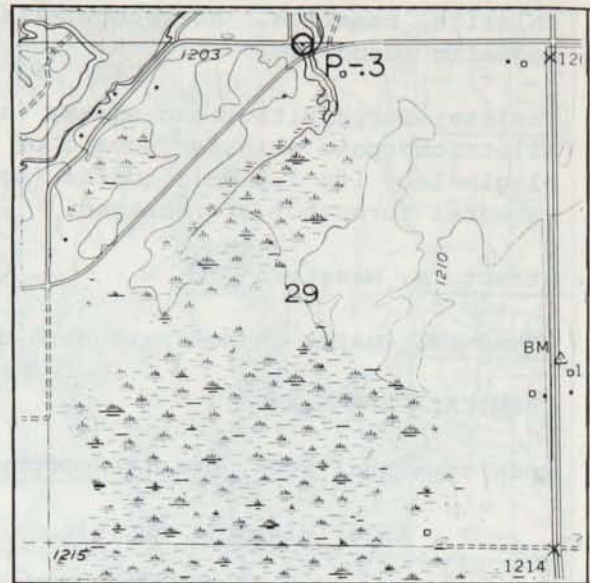
Total depth 185 ft

Elevation, top of  
Precambrian rock 1050 ft

Core diam. 2.5"

Length of core run 174.5-185

Core recovered 10.5 ft



ABBREVIATED LITHOLOGIC LOG (intervals recorded are depths in feet)

Interval	Description
QUATERNARY DEPOSITS	
0-50	Sand and gravel
50-62	Clayey silt, probably fine sand also (poor sample recovery)
62-83	Gravelly sandy till, gray; clasts of granitic and mafic rocks; also some felsite, dolomite
83-85	Sand
85-104	Clayey till, gray, calcareous; dolomite clasts. Layer of coarse bouldery gravel, 94-99 ft
104-130	Sand and gravel
130-152	Very gravelly sandy till, gray and greenish gray; clasts of dolomite, felsite, various aphanitic green rocks. Layer of cobbly gravel, 139-145 ft
REGOLITH ON PRECAMBRIAN ROCK	
152-174	Clay, yellow green; intervals of soft rock
SOUND PRECAMBRIAN ROCK	
174-185	Ferruginous quartzite; friable along weathered seams

PETROGRAPHIC DESCRIPTION OF CORE

Principal rock type: Arkosic sandstone, fine-grained.

Mineralogy: Microcline, orthoclase, quartz, plagioclase framework grains; stilpnomelane, hematite in matrix. Accessory epidote, tourmaline.

Texture: Framework grains in size range 0.1-0.2 mm; subangular. Quartz cement, phyllosilicate matrix both present originally; both have recrystallized.

Structure: Megascopic weak cleavage at high angle to bedding.

CHEMICAL DATA

Rock type analyzed arkosic sandstone

Major elements (wt.%)		Minor elements (ppm)	
SiO <sub>2</sub>	80.7	Ba	690
Al <sub>2</sub> O <sub>3</sub>	7.64	Be	0.6
Fe <sub>2</sub> O <sub>3</sub>	4.3	Sc	3
FeO	0.1	V	9
MgO	0.30	Cr	19
CaO	0.04	Co	4
Na <sub>2</sub> O	1.01	Ni	4.2
K <sub>2</sub> O	3.49	Cu	10.1
H <sub>2</sub> O <sup>+</sup>	n.d.	Zn	10
H <sub>2</sub> O <sup>-</sup>	n.d.	Rb	85
CO <sub>2</sub>	n.d.	Sr	65
TiO <sub>2</sub>	0.11	Y	5.5
P <sub>2</sub> O <sub>5</sub>	0.01	Zr	127
MnO	0.01		
TOTAL	97.7		
Anal. method <u>DCAP/OES</u>		Anal. method <u>DCAP/OES</u>	
Analyst <u>R. Knoche, Univ. of Minn.</u>		Analyst <u>R. Knoche, Univ. of Minn.</u>	

Field number P-4

Date Completed August 22, 1983

MGS unique number 234180

MGS lab number 1998

LOCATION (see map at right)

T-R-S 132-31-21 DDAAAA

County Morrison

Quadrangle Cushing 7.5'

HOLE PARAMETERS

Surface elevation 1288 ft

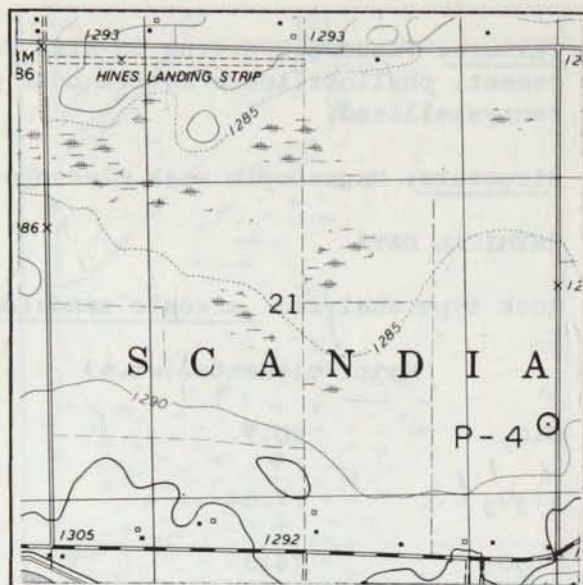
Total depth 294 ft

Elevation, top of  
Precambrian rock 1015.5 ft

Core diam. 2.5"

Length of core run 273.5-294

Core recovered 20.5 ft



ABBREVIATED LITHOLOGIC LOG (intervals recorded are depths in feet)

Interval	Description
QUATERNARY DEPOSITS	
0-85	Layers of silty sandy clay, silty clayey sand, sandy silt, sand and cobbles
85-161	Gravelly sandy till, greenish gray to gray
161-172	Silty sandy clay, black to dark gray; abundant organic matter
172-192	Gravelly sandy till, dark gray
CRETACEOUS SEDIMENTARY ROCKS	
192-273	Interbedded claystone, siltstone, and quartzose sandstone of variegated colors
SOUND PRECAMBRIAN ROCK	
273-294	Deformed lithic conglomerate composed chiefly of metagraywacke pebbles



PETROGRAPHIC DESCRIPTION OF CORE

Principal rock type: Metaconglomerate.

Mineralogy: Pebble lithologies include sericitic argillite, quartzose meta-siltstone, carbonate-cemented quartz siltstone, sericitic quartz wacke, spheriolic metarhyolite, meta-andesite, chlorite schist, biotite-chlorite schist, and magnetite-silicate iron-formation. Metasedimentary clasts exceed volcanic about 3:1. Matrix consists of quartz, sericite, biotite, abundant carbonate.

Texture: Pebbles, matrix strongly deformed into tectonite fabric; plane of schistosity is subvertical. Pebbles range to 12 cm in length; average length about 2-3 cm. Matrix is totally recrystallized with significant growth of metamorphic biotite.

Structure: Pronounced schistosity anastomoses among deformed pebbles.

Comments: Pebbles derived mainly from Mille Lacs Group rock units.

CHEMICAL DATA

Rock type analyzed no analyses

Field number P-7

Date Completed September 14, 1983

MGS unique number 234183

MGS lab number 2001

LOCATION (see map at right)

T-R-S 130-31-21 CBBBAA

County Morrison

Quadrangle Randall West 7.5'

HOLE PARAMETERS

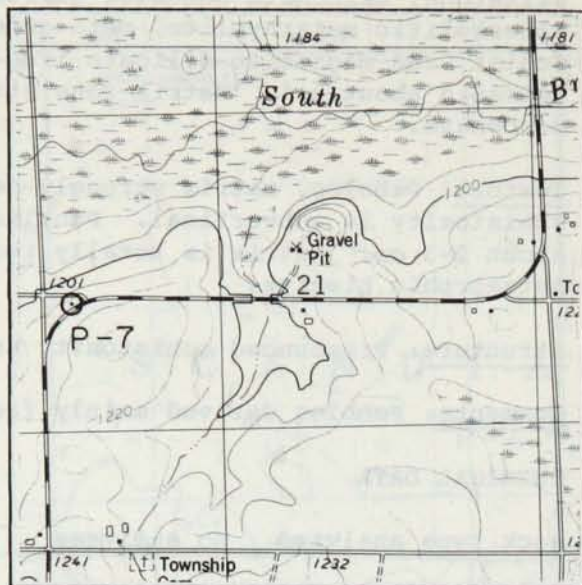
Surface elevation 1212 ft

Total depth 278.8 ft

Elevation, top of  
Precambrian rock 1131 ft

Core diam. 2.5"

Length of core run 275-278.8 Core recovered approx. 3.8 ft



ABBREVIATED LITHOLOGIC LOG (intervals recorded are depths in feet)

Interval	Description	Till unit of Meyer (1986)
QUATERNARY DEPOSITS		
0-42	Very sandy till, brown to gray; clasts of various red rocks	Pierz
42-54	Sandy clay till, gray, calcareous; some dolomite clasts	Wadena
54-81	Clayey till, light olive gray to olive, calcareous; dolomite clasts	Eagle Bend
REGOLITH ON PRECAMBRIAN ROCK		
81-269	Clay, variegated, and soft rock	
SOUND PRECAMBRIAN ROCK		
269-279	Metagraywacke and slate	

PETROGRAPHIC DESCRIPTION OF CORE

Principal rock type: Strongly deformed phyllitic argillite.

Mineralogy: Quartz, sericitic muscovite, chlorite, graphite; unevenly distributed carbonate. Minor granular opaques, sphene.

Texture: Fine-grained neoblastic, foliated; vestiges of sedimentary clastic texture in coarsest silt laminations.

Structure: Strong cleavage (approaching schistosity) is axial-planar to very tight, disharmonic small folds in millimeter-scale laminations. Cleavage dips steeply.

CHEMICAL DATA

Rock type analyzed phyllite

Major elements (wt.%)		Minor elements (ppm)	
SiO <sub>2</sub>	58.8	Ba	400
Al <sub>2</sub> O <sub>3</sub>	17.9	Be	1.3
Fe <sub>2</sub> O <sub>3</sub>	1.5	Sc	27
FeO	7.7	V	134
MgO	3.80	Cr	179
CaO	0.81	Co	29
Na <sub>2</sub> O	3.51	Ni	93
K <sub>2</sub> O	1.77	Cu	36
H <sub>2</sub> O <sup>+</sup>	n.d.	Zn	119
H <sub>2</sub> O <sup>-</sup>	n.d.	Rb	59
CO <sub>2</sub>	n.d.	Sr	198
TiO <sub>2</sub>	0.83	Y	28
P <sub>2</sub> O <sub>5</sub>	0.17	Zr	151
MnO	0.06		
TOTAL	96.9		
Anal. method <u>DCAP/OES</u>		Anal. method <u>DCAP/OES</u>	
Analyst <u>R. Knoche, Univ. of Minn.</u>		Analyst <u>R. Knoche, Univ. of Minn.</u>	

Field number P-9

Date Completed October 14, 1983

MGS unique number 234184

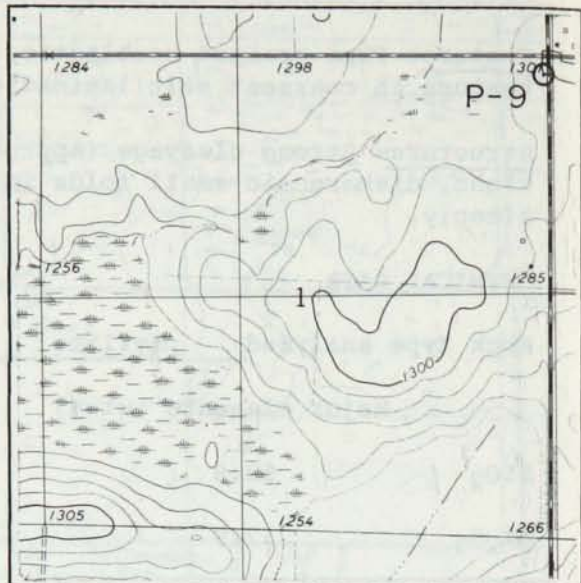
MGS lab number 2002

LOCATION (see map at right)

T-R-S 42-30-1 AAAAAD

County Morrison

Quadrangle Shephard 7.5'



HOLE PARAMETERS

Surface elevation 1300 ft

Total depth 239.2 ft

Elevation, top of  
Precambrian rock 1163.5 ft

Core diam. 2.5"

Length of core run 229-239.2 Core recovered approx. 9.7 ft

ABBREVIATED LITHOLOGIC LOG (intervals recorded are depths in feet)

Interval	Description
QUATERNARY DEPOSITS	
0-95	Gravelly sandy till, brown to dark brown to dark gray, non-calcareous; clasts of granite and felsite
95-115	Sand and gravel
115-123	Gravelly sandy till, dark gray, noncalcareous
123-124	Sand
124-126	Clayey till, very dark gray, moderately calcareous
126-127	Sand
127-137	Sandy till, light olive brown, gray and greenish gray; moderately calcareous
REGOLITH ON PRECAMBRIAN ROCK	
137-209	Clay, olive and turquoise, and soft rock
SOUND PRECAMBRIAN ROCK	
209-239	Garnet-biotite schist with quartz veins; very minor clay seams



PETROGRAPHIC DESCRIPTION OF CORE

Principal rock type: Sillimanite-staurolite-garnet-biotite gneiss

Mineralogy: Quartz, plagioclase, biotite, garnet, staurolite, sillimanite; minor chlorite and muscovite. Accessory Fe-oxides, sphene, rutile, tourmaline, apatite, zircon.

Texture: Mica-rich schistose layers alternate with layers, veins, and stringers of quartz, quartz-rich leucotonalite gneiss. Schistose layers have mean grain size of about 0.7 mm; garnet, staurolite porphyroblasts are as large as 2 mm.

Structure: Strong gneissic layering and schistosity; schistosity defined mainly by biotite.

CHEMICAL DATA

Rock type analyzed no analyses

Field number P-11

Date Completed October 5, 1983

MGS unique number 234185

MGS lab number 2003

LOCATION (see map at right)

T-R-S 42-29-3 DCDDDD

County Morrison

Quadrangle Platte Lake 7.5'

HOLE PARAMETERS

Surface elevation 1277 ft

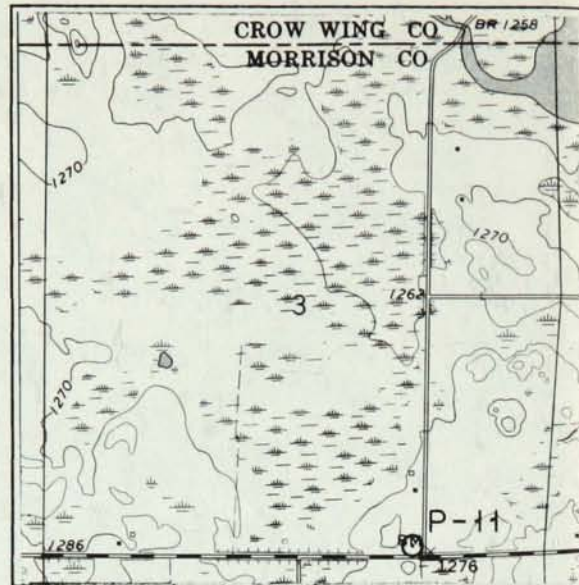
Total depth 148.5 ft

Elevation, top of  
Precambrian rock 1180 ft

Core diam. 2.5"

Length of core run 138.5-148.5

Core recovered 10 ft



ABBREVIATED LITHOLOGIC LOG (intervals recorded are depths in feet)

Interval	Description
QUATERNARY DEPOSITS	
0-62	Sandy gravelly till, brown. Layer of sand and gravel, 42-55 ft
62-82	Sand and gravel
82-90	Sandy till, dark gray
90-97	Sand and gravel
REGOLITH ON PRECAMBRIAN ROCK	
97-101	Gritty clay, greenish gray, whitish, and reddish brown
101-138	Fractured rock with minor clay seams
SOUND PRECAMBRIAN ROCK	
138-149	Layered gneiss

PETROGRAPHIC DESCRIPTION OF CORE

Principal rock type: Hornblende-biotite gneiss.

Mineralogy: Plagioclase, quartz, biotite, hornblende; accessory apatite, zircon, sphene. Very minor Fe-Ti oxides.

Texture: Excellent equilibrium texture in coarse metamorphic rock; grain boundaries tend to be straight and to meet at 120° angles. Grains range between 0.5 and 2 mm in size except in leucotonalite stringers, which are somewhat coarser. Schistosity defined by oriented biotite.

Structure: Gneissic layering defined by variations in hornblende/biotite/tectosilicate ratio. Layer thickness varies widely, from 1 to several tens of centimeters.

CHEMICAL DATA

Rock type analyzed no analyses

Field number P-12

Date Completed October 11, 1983

MGS unique number 234186

MGS lab number 2004

LOCATION (see map at right)

T-R-S 42-29-2 DDCDDC

County Morrison

Quadrangle Platte Lake 7.5'

HOLE PARAMETERS

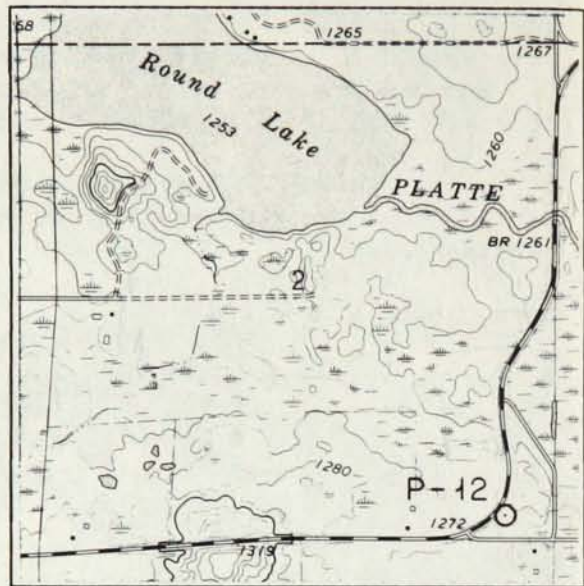
Surface elevation 1268 ft

Total depth 235.5 ft

Elevation, top of  
Precambrian rock 1186 ft

Core diam. 2.5"

Length of core run 225.5-235.5 Core recovered approx. 9.9 ft



ABBREVIATED LITHOLOGIC LOG (intervals recorded are depths in feet)

Interval	Description
QUATERNARY DEPOSITS	
0-30	Very sandy gravelly till, brown to dark brown
30-36	Sand and fine gravel
36-52	Sandy, slightly gravelly till, grayish brown to gray
52-62	Sandy till, grayish brown to gray
62-72	Sand
72-82	Sandy gravelly till with incorporated fragments of regolith
REGOLITH ON PRECAMBRIAN ROCK	
82-115	Gritty clay, blue-green
115-222	Gritty clay, blue-green; intervals of soft rock
SOUND PRECAMBRIAN ROCK	
222-236	Biotite gneiss



PETROGRAPHIC DESCRIPTION OF CORE

Principal rock type: Sillimanite-cordierite-biotite gneiss.

Mineralogy: Quartz, plagioclase, biotite, cordierite, sillimanite; minor staurolite, muscovite. Accessory magnetite, sphene, zircon. About half of cordierite is altered to pale Mg-chlorite.

Texture: Coarse, xenoblastic metamorphic rock. Mean grain size about 0.7 mm except for cordierite, which forms oikocrysts as large as 5 mm. Sillimanite is fibrolitic.

Structure: Well-developed gneissic layering, schistosity.

CHEMICAL DATA

Rock type analyzed no analyses

Field number P-14B

Date Completed September 29, 1983

MGS unique number 234187

MGS lab number 2005

LOCATION (see map at right)

T-R-S 128-30-15 DDADDA

County Morrison

Quadrangle Little Falls West 7.5'

HOLE PARAMETERS

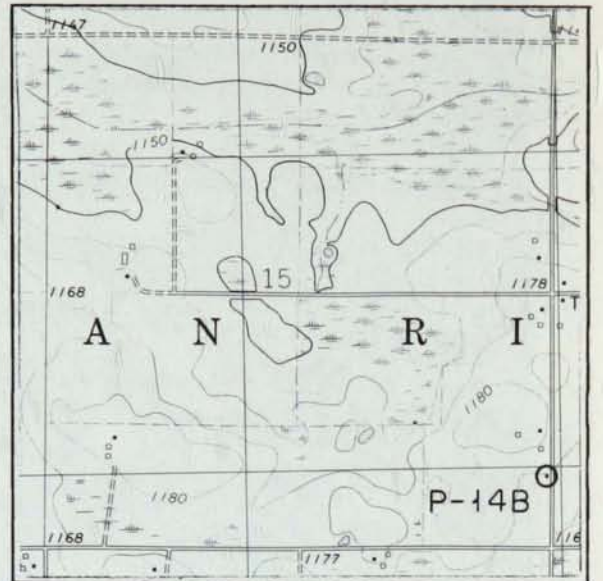
Surface elevation 1169 ft

Total depth 170.8 ft

Elevation, top of  
Precambrian rock 1094 ft

Core diam. 2.5"

Length of core run 161.5-170.8 Core recovered approx. 8 ft



ABBREVIATED LITHOLOGIC LOG (intervals recorded are depths in feet)

Interval	Description	Till unit of Meyer (1986)
QUATERNARY DEPOSITS		
0-8	Gravelly sandy till, brown to yellow brown	Pierz
8-34	Clayey silt and sand	
34-37	Sandy till, gray, calcareous	Wadena
37-44	Very clayey till, very dark gray, calcareous	Wadena
44-61	Clayey till, greenish gray; dolomite clasts. Layer of sand at base, 59-61 ft	Eagle Bend
61-75	Very clayey till, dark gray to very dark gray	Elmdale
REGOLITH ON PRECAMBRIAN ROCK		
75-154	Gritty clay, turquoise, green, yellowish brown; intervals of soft rock	
SOUND PRECAMBRIAN ROCK		
154-171	Mica-bearing olivine clinopyroxenite	

PETROGRAPHIC DESCRIPTION OF CORE

Principal rock type: Olivine clinopyroxenite.

Mineralogy: Olivine (1.3%), serpentine (26.9%), augite (12.8%), Mg-pargasite (29.9%), phlogopite (7.6%); secondary actinolite, chlorite, talc (15.3%), secondary magnetite (6.2%); accessory apatite, Fe-Ti oxides.

Texture: Coarse-grained poikilitic.

Structure: Essentially massive.

CHEMICAL DATA

Rock type analyzed mica-bearing olivine clinopyroxenite

Major elements (wt.%)		Minor elements (ppm)	
SiO <sub>2</sub>	43.4	Ba	103
Al <sub>2</sub> O <sub>3</sub>	4.46	Be	0.5
Fe <sub>2</sub> O <sub>3</sub>	4.8	Sc	36
FeO	5.2	V	91
MgO	25.5	Cr	2800
CaO	7.22	Co	92
Na <sub>2</sub> O	0.66	Ni	770
K <sub>2</sub> O	0.56	Cu	15.5
H <sub>2</sub> O <sup>+</sup>	n.d.	Zn	66
H <sub>2</sub> O <sup>-</sup>	n.d.	Rb	14
CO <sub>2</sub>	n.d.	Sr	120
TiO <sub>2</sub>	0.19	Y	10
P <sub>2</sub> O <sub>5</sub>	0.04	Zr	36
MnO	0.16		
TOTAL	92.2		
Anal. method <u>DCAP/OES</u>		Anal. method <u>DCAP/OES</u>	
Analyst <u>R. Knoche, Univ. of Minn.</u>		Analyst <u>R. Knoche, Univ. of Minn.</u>	

Field number P-15A

Date Completed September 23, 1983

MGS unique number 234189

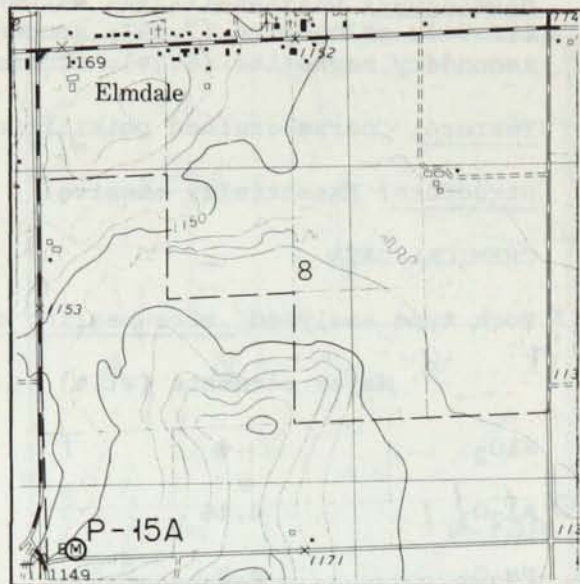
MGS lab number 2007

LOCATION (see map at right)

T-R-S 127-30-8 CCCDD

County Morrison

Quadrangle Bowlus 7.5'



HOLE PARAMETERS

Surface elevation 1153 ft

Total depth 298.7 ft

Elevation, top of Precambrian rock 956.5 ft

Core diam. 2.5"

Length of core run 298-298.7 Core recovered approx. 0.5 ft

ABBREVIATED LITHOLOGIC LOG (intervals recorded are depths in feet)

Interval	Description	Till unit of Meyer (1986)
QUATERNARY DEPOSITS		
0-11	Sandy gravelly till, yellowish brown to dark reddish brown	Pierz
11-47	Sandy clay till, gray; interbeds of cobbly gravel	Browerville
47-54	Sand and gravel	
54-90	Sandy clayey to clayey till, light brownish gray, greenish gray, olive gray; dolomite clasts	Meyer Lake
90-110	Clayey till, very dark gray; seams of sand	Eagle Bend
110-189	Clayey to sandy clay till, very dark gray; clasts of Cretaceous sedimentary rocks	Elmdale
CRETACEOUS SEDIMENTARY ROCKS		
189-197	Claystone and siltstone, lignitic, black; interbeds of friable very fine sandstone and siltstone, light gray to white	
REGOLITH ON PRECAMBRIAN ROCK		
197-240	Clay, greenish gray; silty clay, dark gray	
240-293	Clay as above; intervals of partly decomposed rocks	
SOUND PRECAMBRIAN ROCK		
293-299	Staurolite-garnet-biotite schist	



PETROGRAPHIC DESCRIPTION OF CORE

Principal rock type: Staurolite-garnet-biotite schist.

Mineralogy: Quartz, biotite, garnet, staurolite; minor muscovite, chlorite.  
Accessory opaque phases, tourmaline, zircon.

Texture: Coarsely xenoblastic rock with striking porphyroblasts of garnet, staurolite. Main body of rock consists of mosaic quartz grains (ca. 0.05-0.1 mm) and oriented, larger biotite leaves 1.0-1.5 mm long. Zoned garnets are 1-2 mm in diameter; sieved staurolite porphyroblasts are as long as 2 cm.

Structure: Rock displays a single, strong schistosity.

Comments: Assigned to the Little Falls Formation.

CHEMICAL DATA

Rock type analyzed staurolite-garnet-biotite schist (P-15A)

Major elements (wt.%)		Minor elements (ppm)	
SiO <sub>2</sub>	54.2	Ba	510
Al <sub>2</sub> O <sub>3</sub>	19.2	Be	2.2
Fe <sub>2</sub> O <sub>3</sub>	2.1	Sc	34
FeO	8.3	V	191
MgO	4.15	Cr	197
CaO	2.52	Co	32
Na <sub>2</sub> O	3.58	Ni	99
K <sub>2</sub> O	3.33	Cu	17.2
H <sub>2</sub> O <sup>+</sup>	n.d.	Zn	102
H <sub>2</sub> O <sup>-</sup>	n.d.	Rb	121
CO <sub>2</sub>	n.d.	Sr	308
TiO <sub>2</sub>	0.95	Y	29
P <sub>2</sub> O <sub>5</sub>	0.22	Zr	176
MnO	0.07		
TOTAL	98.6		
Anal. method	<u>DCAP/OES</u>	Anal. method	<u>DCAP/OES</u>
Analyst	<u>R. Knoche, Univ. of Minn.</u>	Analyst	<u>R. Knoche, Univ. of Minn.</u>

Field number P-16

Date Completed September 27, 1983

MGS unique number 234190

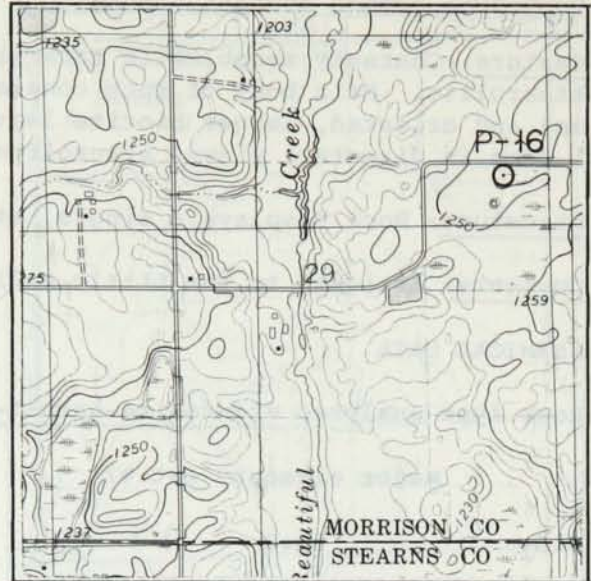
MGS lab number 2008

LOCATION (see map at right)

T-R-S 127-31-29 ADABBD

County Morrison

Quadrangle Upsala 7.5'



HOLE PARAMETERS

Surface elevation 1249 ft

Total depth 195.8 ft

Elevation, top of  
Precambrian rock 1126 ft

Core diam. 2.5"

Length of core run 185.5-195.8 Core recovered 10.3 ft

ABBREVIATED LITHOLOGIC LOG (intervals recorded are depths in feet)

Interval	Description	Till unit of Meyer (1986)
QUATERNARY DEPOSITS		
0-2	Pebbly loam, black	
2-22	Gravelly sandy till, yellowish brown; dolomite clasts	Pierz
22-43	Sandy clay till to very clayey till, gray to very dark gray; dolomite clasts	Wadena
43-51	Gravelly sand	
51-71	Sandy till, reddish brown to gray; dolomite clasts	Red Sandy
71-106	Sandy silty, clayey, and sandy clayey till, gray to dark gray; dolomite clasts. Thin layer of black organic-rich soil on top	Meyer Lake
106-118	Sandy till, dark brown to gray	First Red
118-123	Clayey till, olive to olive gray; dolomite clasts	Eagle Bend
REGOLITH ON PRECAMBRIAN ROCK		
123-180	Clay, bluish gray; zones of partly decomposed rock	
SOUND PRECAMBRIAN ROCK		
180-196	Garnet-staurolite-biotite schist	

PETROGRAPHIC DESCRIPTION OF CORE

Principal rock type: Garnet-staurolite-biotite schist.

Mineralogy: Quartz, biotite, staurolite, garnet, muscovite; minor chlorite.  
Accessory opaque phases, apatite, zircon.

Texture: Coarsely xenoblastic rock with striking porphyroblasts of garnet, staurolite. Quartz, biotite, muscovite grains are about 0.5 to 1.5 mm long; zoned garnets are as large as 2 mm and sieved staurolite porphyroblasts are as long as 3 cm.

Structure: Main schistosity is transverse to bedding, which is defined by modal variations in mica and quartz. A spaced crenulation cleavage is oblique to both bedding and schistosity.

Comments: Assigned to the Little Falls Formation.

CHEMICAL DATA

Rock type analyzed no analyses









Field number CC-32

Date Completed September 24, 1980

MGS unique number 226763

MGS lab number 1642

LOCATION (see map at right)

T-R-S 133-36-1 BBBBCB

County Otter Tail

Quadrangle Wrightstown 7.5'

HOLE PARAMETERS

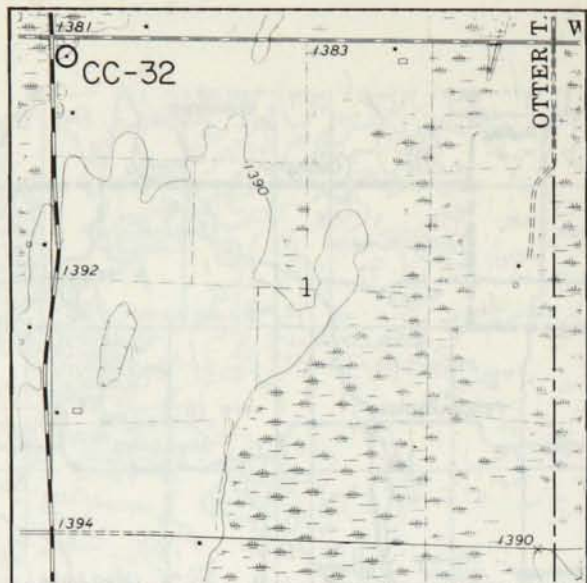
Surface elevation 1377 ft

Total depth 122.2 ft

Elevation, top of  
Precambrian rock 1264 ft

Core diam. 2.1"

Length of core run 114.2-122.2 Core recovered approx. 8 ft



ABBREVIATED LITHOLOGIC LOG (intervals recorded are depths in feet)

Interval	Description	Till unit of Meyer (1986)
QUATERNARY DEPOSITS		
0-3	Loam, black to light brown	
3-41	Sand and gravel	
41-57	Clayey till, gray; clasts of dolomite and mafic rocks	Browerville
57-92	Clayey till, gray; thin interbeds of sand, gravel, and clay	Browerville
92-111	Clayey till, dark gray; clasts of dolomite and mafic rocks	Browerville
111-113	Sand and gravel	
SOUND PRECAMBRIAN ROCK		
113-122	Hornblende diorite	

PETROGRAPHIC DESCRIPTION OF CORE

Principal rock type: Hornblende quartz diorite.

Mineralogy: Plagioclase, severely sericitized, saussuritized (50%); hornblende (30%), quartz (20%). Considerable secondary fibrous amphibole and chlorite; accessory magnetite, apatite. The rock contains no biotite now, but originally it contained 1-2% which has been converted to chlorite and muscovite.

Texture: Medium-grained hypidiomorphic granular; grain size about 4 mm. Clear textural evidence of complex amphibole paragenesis replacing original clinopyroxene.

Structure: Essentially massive.

CHEMICAL DATA

Rock type analyzed hornblende quartz diorite (118)

Major elements (wt.%)		Minor elements (ppm)
SiO <sub>2</sub>	54.31	not determined
Al <sub>2</sub> O <sub>3</sub>	16.75	
Fe <sub>2</sub> O <sub>3</sub>	1.67	
FeO	7.88	
MgO	3.66	
CaO	8.15	
Na <sub>2</sub> O	3.99	
K <sub>2</sub> O	0.44	
H <sub>2</sub> O <sup>+</sup>	1.18	
H <sub>2</sub> O <sup>-</sup>	n.d.	
CO <sub>2</sub>	0.38	
TiO <sub>2</sub>	1.19	
P <sub>2</sub> O <sub>5</sub>	0.11	
MnO	0.12	
TOTAL	99.83	
Anal. method <u>XRF</u>		
Analyst <u>K. Ramlal, Univ. of Manitoba</u>		

Field number CC-33A

Date Completed July 13, 1981

MGS unique number 226768

MGS lab number 1646

LOCATION (see map at right)

T-R-S 132-37-34 DCCCCD

County Otter Tail

Quadrangle Parkers Prairie 7.5'

HOLE PARAMETERS

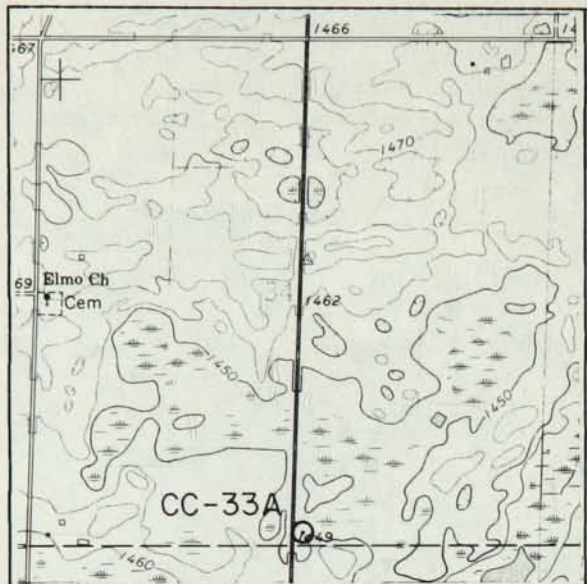
Surface elevation 1443 ft

Total depth 468.1 ft

Elevation, top of  
Precambrian rock 1048 ft

Core diam. 2.1"

Length of core run 453.1-468.1 Core recovered approx. 15 ft



ABBREVIATED LITHOLOGIC LOG (intervals recorded are depths in feet)

Interval	Description
QUATERNARY DEPOSITS	
0-62	Sand and gravel
62-80	Clayey till, olive gray to dark gray; carbonate clasts
80-148	Sand and gravel
148-192	Clayey till, gray to dark gray; clasts of granite, basalt, carbonate
192-217	Silty till, olive; clasts of granite, carbonate, basalt
217-265	Clayey till, olive brown; clasts of basalt, granite, carbonate
265-343	Clayey till, dark gray; abundant carbonate clasts
CRETACEOUS SEDIMENTARY ROCKS	
343-346	Claystone and friable loamy sandstone; black, organic-rich
346-395	Friable quartz sandstone, white to light gray
REGOLITH ON PRECAMBRIAN ROCK	
395-453	Clay, variegated in shades of bluish gray, brown, reddish brown, white, blue
SOUND PRECAMBRIAN ROCK	
453-468	Thin-bedded crystal tuff and fine-grained tuffaceous graywacke



PETROGRAPHIC DESCRIPTION OF CORE

Principal rock type: Variably textured plagioclase-actinolite-chlorite schist; layers of strongly contrasting composition.

Mineralogy: Complex and layer-dependent; principal minerals are plagioclase (heavily saussuritized), quartz, epidote, actinolite, chlorite, zoisite (locally abundant), muscovite, and carbonate. Less common minerals are cummingtonite(?), talc, sphene.

Texture: Extremely variable from bed to bed; dominantly of metamorphic origin. Grain size ranges from <0.1 mm to >1 cm and reflects original clastic grain size to some degree. Shear fabrics are locally present in thin zones parallel to layering. Concordant veins, subsequently sheared, are also present locally.

Structure: Modal layers (beds?) range in thickness from 5 to 50 cm. A strong penetrative schistosity is parallel to layering in finer grained rock types; it is apparent only near the margins of coarse-grained feldspathic layers.

Comments: Sequence is interpreted to be succession of interbedded crystal tuff, lithic tuff, and volcanogenic graywacke, now metamorphosed and variably tectonized. May include some thin porphyry sills.

CHEMICAL DATA

Rock type analyzed (457) thin-bedded crystal tuff  
(467) fine-grained tuffaceous graywacke

	Major elements (wt.%)		Minor elements (ppm)	
	(457)	(467)		
SiO <sub>2</sub>	58.73	64.39	not determined	
Al <sub>2</sub> O <sub>3</sub>	17.28	16.15		
Fe <sub>2</sub> O <sub>3</sub>	0.91	4.07		
FeO	5.56	2.38		
MgO	3.78	2.11		
CaO	4.44	4.50		
Na <sub>2</sub> O	3.80	4.36		
K <sub>2</sub> O	1.13	0.34		
H <sub>2</sub> O <sup>+</sup>	2.12	0.82		
H <sub>2</sub> O <sup>-</sup>	n.d.	n.d.		
CO <sub>2</sub>	0.65	0.20		
TiO <sub>2</sub>	0.70	0.38	TOTAL	99.65                      99.92
P <sub>2</sub> O <sub>5</sub>	0.24	0.12	Anal. method <u>XRF</u>	
MnO	0.31	0.10	Analyst <u>K. Ramlal, Univ. of Manitoba</u>	

Field number 1985-6

Date Completed September 25, 1985

MGS unique number 236129

MGS lab number 2177

LOCATION (see map at right)

T-R-S 131-36-28 DABABA

County Otter Tail

Quadrangle Eagle Bend NW 7.5'

HOLE PARAMETERS

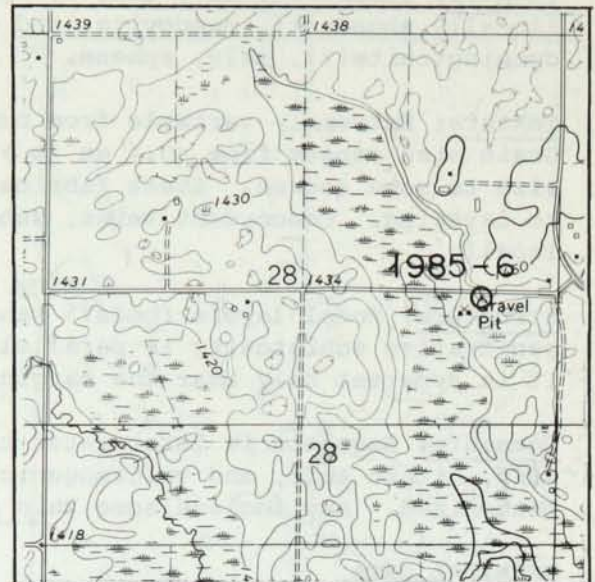
Surface elevation 1435 ft

Total depth 361.5 ft

Elevation, top of  
Precambrian rock 1089 ft

Core diam. 2.5"

Length of core run 351.5-361.5 Core recovered 10 ft



ABBREVIATED LITHOLOGIC LOG (intervals recorded are depths in feet)

Interval	Description	Till unit of Meyer (1986)
QUATERNARY DEPOSITS		
0-49	Sand and gravel	
49-97	Sandy clay till, gray; clasts of carbonate	Wadena ?
97-174	Sand and gravel	
174-182	Sandy silty till, gray	
182-196	Sand and gravel	
196-240	Loamy till, gray; pebbles of Cretaceous limestone. Layer of sand and gravel, black, with some wood, 226-232 ft	Meyer Lake
240-242	Sandy clay till, reddish brown	First Red
242-318	Clayey till, light yellowish brown to dark gray	Eagle Bend
318-346	Clayey till, dark gray; pebbles of Cretaceous limestone. Becomes "mixed" till toward base	Elmdale
REGOLITH ON PRECAMBRIAN ROCK		
346-349	Soft rock and clay, greenish color	
SOUND PRECAMBRIAN ROCK		
349-362	Garnet-biotite schist	

PETROGRAPHIC DESCRIPTION OF CORE

Principal rock type: Garnet-biotite schist.

Mineralogy: Quartz, plagioclase (sericitized in part), biotite, garnet; patchy replacement of biotite, garnet by chlorite. Accessory apatite, magnetite; minor secondary muscovite, epidote.

Texture: Neoblastic, foliated; grain size of quartz, plagioclase 0.2-0.3 mm; garnet porphyroblasts about 1 mm in diameter.

Structure: Pervasive schistosity is carried by oriented biotite, shape fabric of quartz and plagioclase grains.

CHEMICAL DATA

Rock type analyzed no analyses









Field number AB-11

Date Completed July 3, 1984

MGS unique number 235689

MGS lab number 2033

LOCATION (see map at right)

T-R-S 57-19-36 BCCDB

County St. Louis

Quadrangle Kirk 7.5'

HOLE PARAMETERS

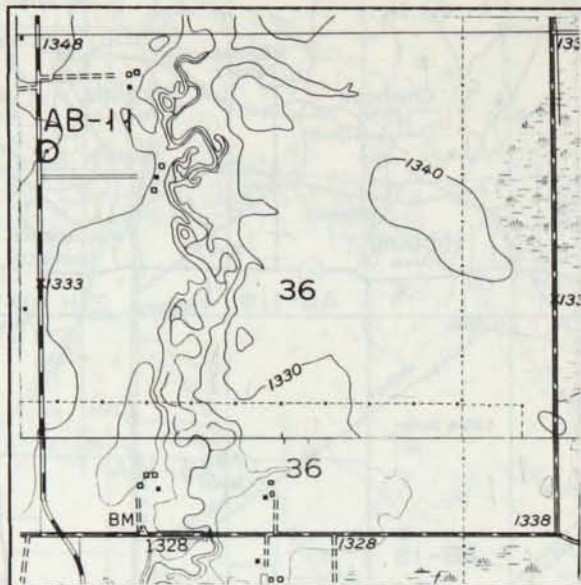
Surface elevation 1340 ft

Total depth 104.5 ft

Elevation, top of  
Precambrian rock 1250 ft

Core diam. 2.5"

Length of core run 94.5-104.5 Core recovered 10 ft



ABBREVIATED LITHOLOGIC LOG (intervals recorded are depths in feet)

Interval

Description

QUATERNARY DEPOSITS

0-6	Gravelly to silty till, dark brown to light brown
6-41	Clay, chiefly very light brown; some layers are dark brown, red-brown, and gray
41-75	Sand
75-90	Gravel and cobbles

SOUND PRECAMBRIAN ROCK

90-104.5	Argillite
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PETROGRAPHIC DESCRIPTION OF CORE

Principal rock type: Laminated argillite.

Mineralogy: Quartz, feldspar, sericitic muscovite, chlorite; graphite (1-2%) in some muddy layers. Very minor disseminated pyrite.

Texture: Original muddy layers somewhat recrystallized; original silty layers retain sedimentary texture that is only slightly modified by recrystallization of matrix.

Structure: Rock is essentially undeformed but displays a marked bedding-parallel orientation of phyllosilicates in muddy layers. Weak microkinks developed at high angles to bedding.

CHEMICAL DATA

Rock type analyzed no analyses

Field number AB-13A

Date Completed July 4, 1984

MGS unique number 235690

MGS lab number 2034

LOCATION (see map at right)

T-R-S 53-19-32 DBCCAC

County St. Louis

Quadrangle Elmer 7.5'

HOLE PARAMETERS

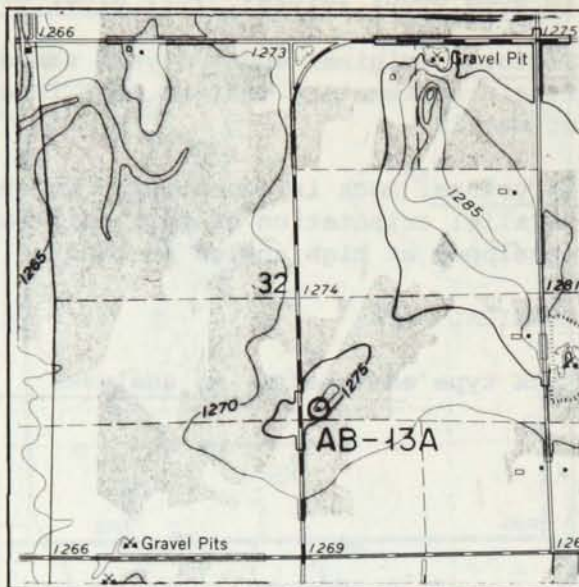
Surface elevation 1278 ft

Total depth 148.5 ft

Elevation, top of  
Precambrian rock 1142 ft

Core diam. 2.5"

Length of core run 141-148.5 Core recovered 7.5 ft



ABBREVIATED LITHOLOGIC LOG (intervals recorded are depths in feet)

Interval	Description
QUATERNARY DEPOSITS	
0-5	Sand
5-25	Clay loam till, light brown to gray to reddish gray
25-37	Silt and clayey silt, dark gray to gray
37-82	Sand, gravel, cobbles
82-86	Clayey silt, dark brown to reddish brown, probably till
86-136	Sand and gravel
SOUND PRECAMBRIAN ROCK	
136-149	Slate (derived from laminated argillite)



PETROGRAPHIC DESCRIPTION OF CORE

Principal rock type: Slate (derived from laminated argillite).

Mineralogy: Quartz, plagioclase, sericitic muscovite, chlorite; graphite makes up as much as 20% of some beds. Granular opaques, pyrite are minor constituents.

Texture: Primarily neoblastic, foliated in finer grained layers; silty layers retain sedimentary texture, somewhat modified by deformation.

Structure: Beds range in thickness from 0.5 to 2 cm; thicker ones are internally laminated. Silty beds locally slump-folded; also display compaction lobes, sedimentary boudinage. Strong slaty cleavage crosses bedding at high angle.

CHEMICAL DATA

Rock type analyzed no analyses

Field number AB-14A

Date Completed June 29, 1984

MGS unique number 235688

MGS lab number 2032

LOCATION (see map at right)

T-R-S 55-18-6 BBBABD

County St. Louis

Quadrangle Casco 7.5'

HOLE PARAMETERS

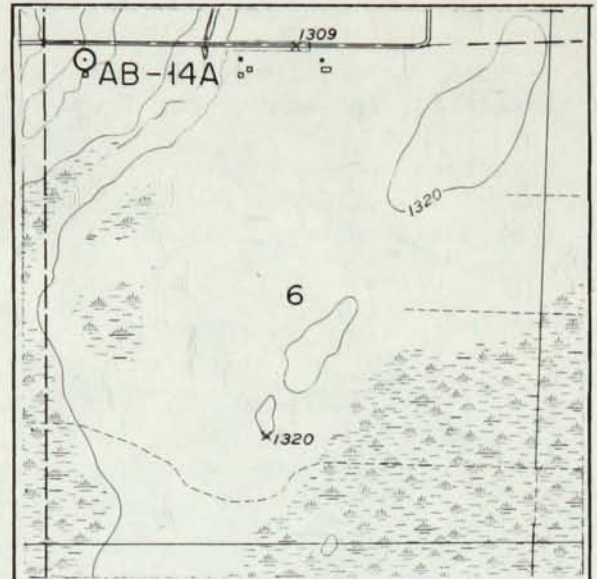
Surface elevation 1322 ft

Total depth 92 ft

Elevation, top of  
Precambrian rock 1259 ft

Core diam. 2.5"

Length of core run 82-92 Core recovered approx. 10 ft



ABBREVIATED LITHOLOGIC LOG (intervals recorded are depths in feet)

Interval	Description
QUATERNARY DEPOSITS	
0-16	Sand
16-20	Clay, gray; probably till
20-25	Laminated clay, red and gray, noncalcareous
25-44	Clay to silty clay, gray, noncalcareous
44-47	Silty clay to clayey silt, gray
47-48	Clay, dark gray; probably till
48-52	Clayey till, reddish gray, some pebbles
52-61	Clay, dark gray
61-63	Sand and gravel
REGOLITH ON PRECAMBRIAN ROCK	
63-78	Fractured rock and minor clay, greenish gray
SOUND PRECAMBRIAN ROCK	
78-92	Laminated argillite

## PETROGRAPHIC DESCRIPTION OF CORE

Principal rock type: Laminated argillite showing incipient slaty cleavage.

Mineralogy: Quartz, feldspar, sericite, chlorite; graphite makes up as much as 15-20% of some laminae. Minor pyrite disseminated throughout rock.

Texture: Silty layers have sedimentary texture that is slightly modified by matrix recrystallization. Muddy layers are entirely recrystallized (see below).

Structure: Silty layers commonly micrograded, showing both normal and inverse grading. Strong bedding-parallel preferred orientation of phyllosilicates in muddy layers. Incipient transverse cleavage marked by stylolite-like seams normal to bedding.

## CHEMICAL DATA

Rock type analyzed no analyses



Field number AB-15

Date Completed June 27, 1984

MGS unique number 235686

MGS lab number 2030

LOCATION (see map at right)

T-R-S 55-20-14 CCDACA

County St. Louis

Quadrangle Toivola 7.5'

HOLE PARAMETERS

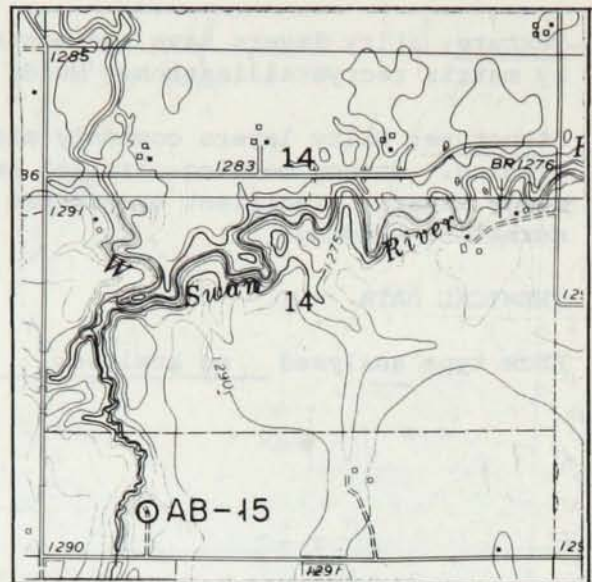
Surface elevation 1293 ft

Total depth 121 ft

Elevation, top of  
Precambrian rock 1191 ft

Core diam. 2.5"

Length of core run 111-121 Core recovered approx. 10 ft



ABBREVIATED LITHOLOGIC LOG (intervals recorded are depths in feet)

Interval	Description
QUATERNARY DEPOSITS	
0-2	Artificial fill
2-10	Laminated silty clay and silt, light gray, iron-stained, calcareous
10-53	Silty clay and clay, more clay-rich toward base, gray and reddish brown, calcareous to slightly calcareous
53-64	Silty clay, gray, slightly calcareous
64-70	Sand, gravel, and silty clay, gray
70-78	Sandy till, gray, calcareous; clasts of carbonate
78-82	Clay, reddish brown
82-102	Very gravelly sandy till, gray; clasts of metasedimentary rocks, granite
REGOLITH ON PRECAMBRIAN ROCK	
102-107	Clay, greenish gray, turquoise, green
SOUND PRECAMBRIAN ROCK	
107-121	Laminated argillite and siltstone with weak slaty cleavage

## PETROGRAPHIC DESCRIPTION OF CORE

Principal rock type: Argillite and siltstone, thin-bedded to laminated; incipient slaty cleavage.

Mineralogy: Coarser silt beds (micrograywacke) contain detrital quartz, plagioclase, chlorite, biotite, and muscovite; finer grained layers and siltstone matrix are composed of recrystallized sericitic muscovite, chlorite, fine quartz, graphite. Graphite content varies greatly from layer to layer.

Texture: Silty layers have sedimentary texture that is slightly modified by matrix recrystallization. Muddy layers are extensively recrystallized.

Structure: Layers range from 1 to 5 mm in thickness. Incipient spaced cleavage normal to bedding is best developed in microlaminated, graphite-rich layers. Cleavage films are graphite rich.

## CHEMICAL DATA

Rock type analyzed no analyses

Field number AB-16

Date Completed June 26, 1984

MGS unique number 235685

MGS lab number 2029

LOCATION (see map at right)

T-R-S 54-18-18 BABABD

County St. Louis

Quadrangle Meadowlands NW 7.5'

HOLE PARAMETERS

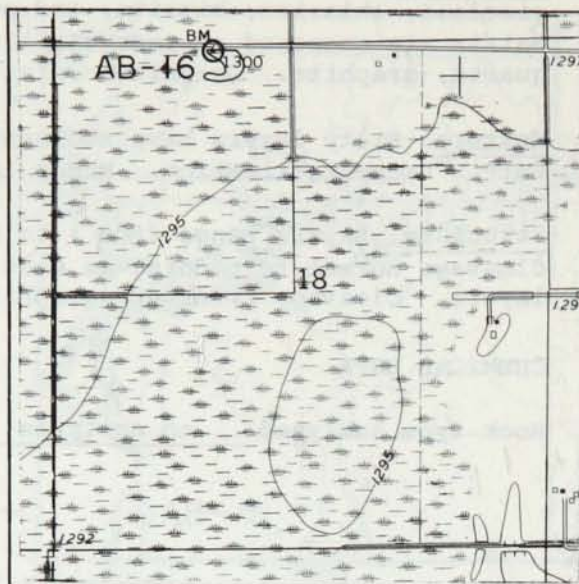
Surface elevation 1301 ft

Total depth 138 ft

Elevation, top of  
Precambrian rock 1187.5 ft

Core diam. 2.5"

Length of core run 128-138 Core recovered approx. 10 ft



ABBREVIATED LITHOLOGIC LOG (intervals recorded are depths in feet)

Interval	Description
QUATERNARY DEPOSITS	
0-9	Sand
9-27	Clay, light gray to gray
27-32	Clay, reddish gray; interbeds of silt and sand
32-39	Clayey till, gray; incorporated blocks of bluish-gray regolith
39-53	Dislodged block of gritty clay regolith, blue
53-82	Gravelly till, reddish gray, gray, and brown
82-114	Cobbly sandy gravel
REGOLITH ON PRECAMBRIAN ROCK	
114-124	Clay, green, greenish gray, brown, and soft rock
SOUND PRECAMBRIAN ROCK	
124-138	Laminated argillite with incipient transverse cleavage

PETROGRAPHIC DESCRIPTION OF CORE

Principal rock type: Laminated argillite; incipient slaty cleavage.

Mineralogy: Quartz, plagioclase, sericitic muscovite, chlorite; variable amounts of graphite from layer to layer. Small amounts of very fine opaque material, including pyrite, leucoxene, possible ilmenite.

Texture: Sedimentary textures, modified somewhat by recrystallization of finer size grades. Phyllosilicates in muddy layers are preferentially aligned parallel to bedding.

Structure: Incipient slaty cleavage is at high angle to bedding. Spaced cleavage films are mainly straight, but some have wavy, stylolite-like morphology. Phyllosilicates, graphite are aligned parallel to cleavage only in immediate vicinity of a particular cleavage film; between films they are parallel to bedding.

CHEMICAL DATA

Rock type analyzed no analyses



Field number AB-17

Date Completed June 20, 1984

MGS unique number 235684

MGS lab number 2028

LOCATION (see map at right)

T-R-S 51-17-16 DDBBAC

County St. Louis

Quadrangle Independence 7.5'

HOLE PARAMETERS

Surface elevation 1265 ft

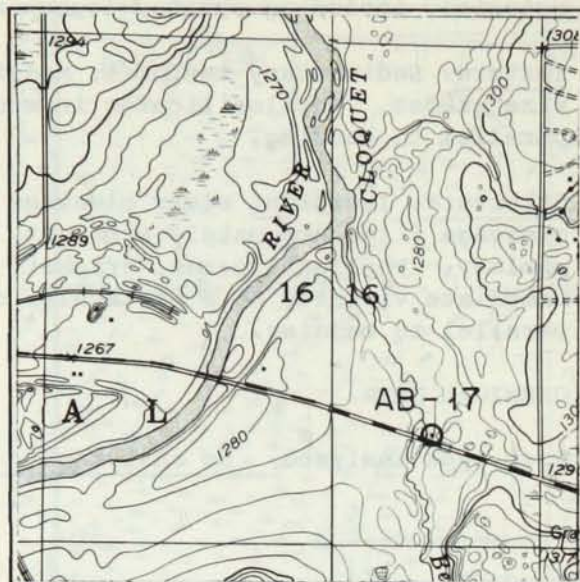
Total depth 194.5 ft

Elevation, top of  
Precambrian rock 1090 ft

Core diam. 2.5"

Length of core run 186-194.5

Core recovered 8.5 ft



ABBREVIATED LITHOLOGIC LOG (intervals recorded are depths in feet)

Interval	Description
QUATERNARY DEPOSITS	
0-10	Gravelly sand
10-17	Clay, brown to gray
17-78	Sand, gravel, and cobbles
78-132	Cobbly gravelly sandy till, brown. Layer of sand, gravel, and silt, 101-109 ft
132-175	Gravelly till, reddish brown
REGOLITH ON PRECAMBRIAN ROCK	
175-183	Gritty clay, olive green to light gray to light blue
SOUND PRECAMBRIAN ROCK	
183-195	Metagraywacke

PETROGRAPHIC DESCRIPTION OF CORE

Principal rock type: Metagraywacke.

Mineralogy: Framework grains are quartz, plagioclase, K-feldspar, and muscovite plus lithic fragments of argillite and chert; matrix minerals are sericitic muscovite, chlorite, and comminuted quartz and feldspar; accessory minerals are epidote, tourmaline, zircon, and rutile.

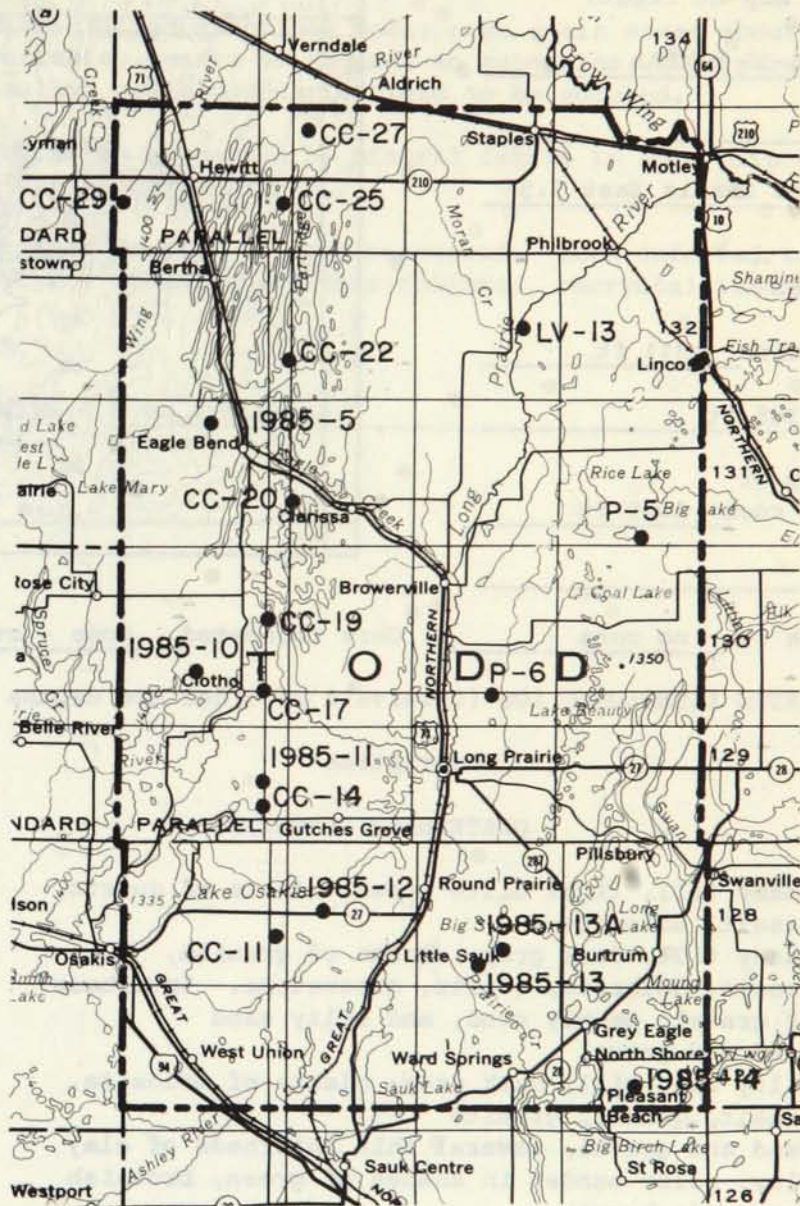
Texture: Classic sedimentary graywacke texture weakly modified by deformation. Framework grains are mainly in size range 0.2-0.5 mm, but grade smoothly downward into silt range in matrix.

Structure: Slump resedimentation suggested by swirled, disorganized, centimeter-scale mixing of lenses of diverse grain size throughout core. Bedding attitude is strongly variable; steep cleavage is weak and variable owing to heterogeneous bedding.

CHEMICAL DATA

Rock type analyzed no analyses







Field number CC-11

Date Completed November 6, 1981

MGS unique number 226769

MGS lab number 1648

LOCATION (see map at right)

T-R-S 128-34-30 BBABAB

County Todd

Quadrangle Lake Osakis East 7.5'

HOLE PARAMETERS

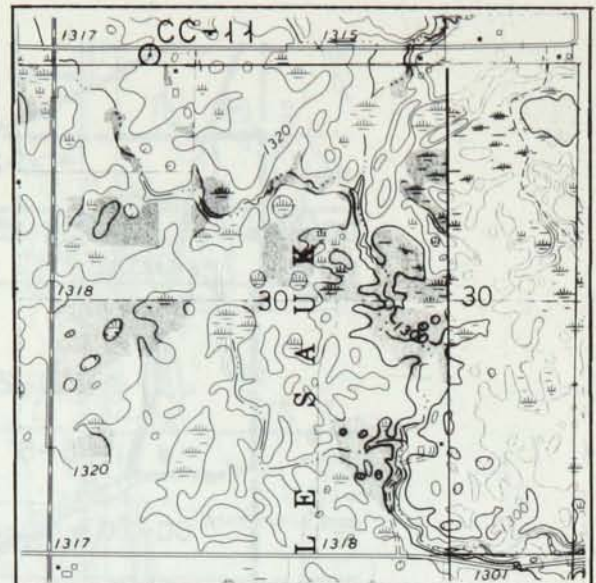
Surface elevation 1311 ft

Total depth 385 ft

Elevation, top of  
Precambrian rock 1069 ft

Core diam. \_\_\_\_\_

Length of core run no core Core recovered none - cuttings only



ABBREVIATED LITHOLOGIC LOG (intervals recorded are depths in feet)

Interval	Description	Till unit of Meyer (1986)
QUATERNARY DEPOSITS		
0-8	Loamy till, light olive brown; clasts of quartz, basalt, dolomite	Des Moines
8-111	Sandy till, dark gray; clasts of granite, basalt, dolomite, quartz, greenstone. Interbeds of gravel, pebbly sand, and silty sand	Wadena
111-116	Sand and gravel	
116-156	Silty clay till, dark gray; clasts of dolomite, basalt, quartz, granite	Meyer Lake
156-197	Sand and gravel; several thin interbeds of clay	
197-218	Clay, color banded in shades of green, brownish green, dark gray	
218-242	Sand and clay layers	
REGOLITH ON PRECAMBRIAN ROCK		
242-375	Clay and soft rock	
SOUND PRECAMBRIAN ROCK		
375-385	Granite gneiss; badly fractured	

PETROGRAPHIC DESCRIPTION OF CORE

Principal rock type: Granodiorite gneiss.

Mineralogy: Quartz (20%), microcline (20%), plagioclase, extensively sericitized (58%), biotite and secondary chlorite (2%). Accessory Fe-Ti oxides; secondary limonite and hematite.

Texture: Medium-grained granitoid rock; mean grain sizes about 3 mm; texture, fabric are variable; quartz is reduced to subgrains, feldspars exhibit mortar structure locally; grain boundaries tend to be sutured.

Structure: Foliation suggested by mineral fabric in some chip samples and the variable texture among chips.

Comments: Cuttings sample; no core recovered. Rock inferred to consist of alternating layers of more- and less-foliated, recrystallized granodiorite.

CHEMICAL DATA

Rock type analyzed no analyses

Field number CC-14

Date Completed December 2, 1981

MGS unique number 231743

MGS lab number 1649

LOCATION (see map at right)

T-R-S 129-35-25 DADAAD

County Todd

Quadrangle Lake Osakis East 7.5'

HOLE PARAMETERS

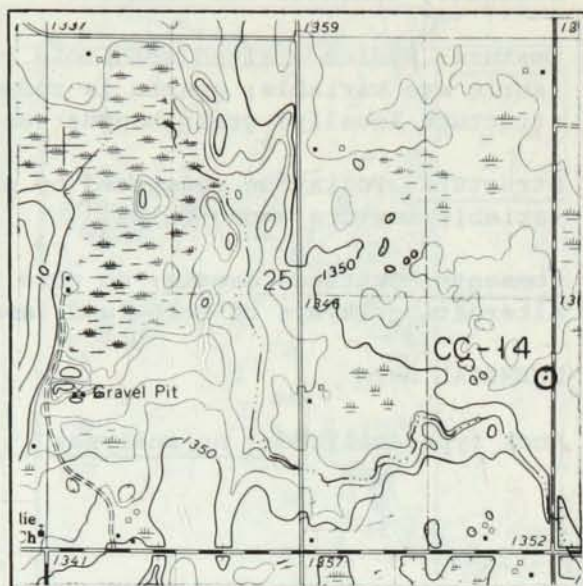
Surface elevation 1358 ft

Total depth 522.5 ft

Elevation, top of  
Precambrian rock 1086 ft

Core diam. 3.4"

Length of core run 515-522.5 Core recovered 7.5 ft



ABBREVIATED LITHOLOGIC LOG (intervals recorded are depths in feet)

Interval	Description	Till unit of Meyer (1986)
QUATERNARY DEPOSITS		
0-5	Artificial fill	
5-80	Sandy till, gray; clasts of granite, carbonate, basalt, quartz	Wadena
80-130	Loamy to clayey till, olive	Green
130-135	Gravel	
135-150	Sandy till, dark gray	Green
150-165	Loam, dark gray	
165-185	Loamy to clayey till, dark gray	Meyer Lake
185-225	Clay, gravelly sandy loam, and clay loam, greenish gray and dark gray	
225-272	Loamy to sandy till, dark gray	Eagle Bend
REGOLITH ON PRECAMBRIAN ROCK		
272-343	Clay, white and greenish gray	
343-483	Gritty clay, minor intervals of soft rock, greenish gray and brown	
SOUND PRECAMBRIAN ROCK		
483-522.5	Biotite paragneiss with granitic stringers	



PETROGRAPHIC DESCRIPTION OF CORE

Principal rock type: Biotite paragneiss with veins, sheets of coarse biotite tonalite.

Mineralogy: Biotite paragneiss - quartz, plagioclase, biotite; latter is strongly altered in discrete layers of the rock to secondary chlorite and adularia. Accessory opaque phases, sphene, apatite, pyrite. Biotite tonalite - quartz (25%), plagioclase (65%), biotite (10%); accessory opaques, apatite.

Texture: Biotite paragneiss - neoblastic, strongly schistose; average grain size about 0.5 mm. Biotite tonalite - granitoid igneous texture strongly modified by deformation; quartz forms recrystallized augen; biotite is bent, extensively recrystallized.

Structure: Strong schistosity/gneissosity

CHEMICAL DATA

Rock type analyzed biotite schist (major component of biotite paragneiss)

Major elements (wt.%)		Minor elements (ppm)
SiO <sub>2</sub>	60.08	not determined
Al <sub>2</sub> O <sub>3</sub>	14.20	
Fe <sub>2</sub> O <sub>3</sub>	1.48	
FeO	8.90	
MgO	4.64	
CaO	1.66	
Na <sub>2</sub> O	2.79	
K <sub>2</sub> O	3.06	
H <sub>2</sub> O <sup>+</sup>	2.03	
H <sub>2</sub> O <sup>-</sup>	n.d.	
CO <sub>2</sub>	0.36	
TiO <sub>2</sub>	0.53	
P <sub>2</sub> O <sub>5</sub>	0.23	
MnO	0.09	
TOTAL	100.05	

Anal. method XRF

Analyst K. Ramlal, Univ. of Manitoba



Field number CC-17

Date Completed February 18, 1982

MGS unique number 233015

MGS lab number 1651

LOCATION (see map at right)

T-R-S 130-35-36 DADDDD

County Todd

Quadrangle Clotho 7.5'

HOLE PARAMETERS

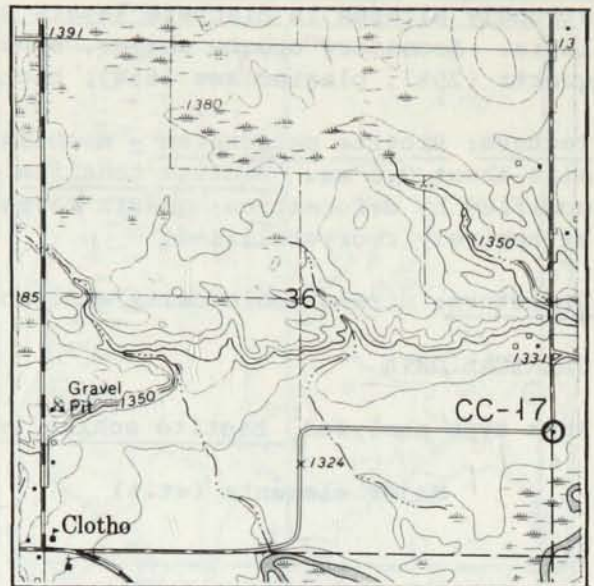
Surface elevation 1324 ft

Total depth 395 ft

Elevation, top of  
Precambrian rock 1091 ft

Core diam. \_\_\_\_\_

Length of core run no core Core recovered none - cuttings only



ABBREVIATED LITHOLOGIC LOG (intervals recorded are depths in feet)

Interval	Description	Till unit of Meyer (1986)
QUATERNARY DEPOSITS		
0-3	Sandy loam, dark brown	
3-44	Gravel	
44-70	Sandy till, gray. Gravel layer, 50-56 ft	Sandy
70-89	Clayey till, dark gray; carbonate clasts	Sandy
89-101	Sand and silt, olive gray; some layers rich in organic material	
101-165	Loamy to clayey till, dark gray	Meyer Lake
165-170	Sand and gravel	
170-183	Loamy to sandy till, reddish brown	First Red
183-205	Loamy to clayey till, olive brown; clasts of dolomite, basalt, quartz	Eagle Bend
205-220	Clayey till, light brown and dark gray	Eagle Bend
220-233	Clayey till, dark gray	Eagle Bend
REGOLITH ON PRECAMBRIAN ROCK		
233-365	Clay, bluish gray; intervals of partly decomposed rock toward base	
SOUND PRECAMBRIAN ROCK		
365-395	Slate, gray	

PETROGRAPHIC DESCRIPTION OF CORE

Principal rock type: Laminated argillite and siltstone, weakly cleaved.

Mineralogy: Quartz, sericitic muscovite, graphite; variable amounts of authigenic carbonate.

Texture: Very fine metasedimentary texture; largest clasts in silt layers about 0.1 mm in diameter. Some modification of grain size, shape by metamorphic recrystallization.

Structure: Bedding-parallel fissility carried by oriented phyllosilicates, graphite; transverse cleavage is best developed in microlaminated graphitic layers.

Comments: Cuttings sample; no core recovered.

CHEMICAL DATA

Rock type analyzed gray argillite and siltstone - composite from cuttings

Major elements (wt.%)		Minor elements (ppm)			
SiO <sub>2</sub>	60.10	Cr	187.90	Yb	2.41
Al <sub>2</sub> O <sub>3</sub>	16.48	Co	22.00	Lu	0.389
Fe <sub>2</sub> O <sub>3</sub>	--	Ni	92.40	Sc	26.73
FeO*	7.06	Cs	4.63		
MgO	3.52	Ba	677.00		
CaO	1.90	Hf	4.24		
Na <sub>2</sub> O	1.95	Ta	0.693		
K <sub>2</sub> O	3.24	Th	7.52		
H <sub>2</sub> O <sup>+</sup>	} 5.07 (LOI)	U	2.81		
H <sub>2</sub> O <sup>-</sup>		La	28.00		
CO <sub>2</sub>		Ce	61.84		
TiO <sub>2</sub>	0.59	Nd	27.13		
P <sub>2</sub> O <sub>5</sub>	n.d.	Sm	5.17		
MnO	0.07	Eu	1.17		
TOTAL	100.0 (normalized)	Tb	0.758		
Anal. method	<u>INNA</u>	Anal. method	<u>INNA</u>		
Analyst	<u>P. O'Day, Cornell Univ.</u>	Analyst	<u>P. O'Day, Cornell Univ.</u>		

Field number CC-19

Date Completed March 3, 1982

MGS unique number 233016

MGS lab number 1650

LOCATION (see map at right)

T-R-S 130-35-13 DAAAAB

County Todd

Quadrangle Clotho 7.5'

HOLE PARAMETERS

Surface elevation 1405 ft

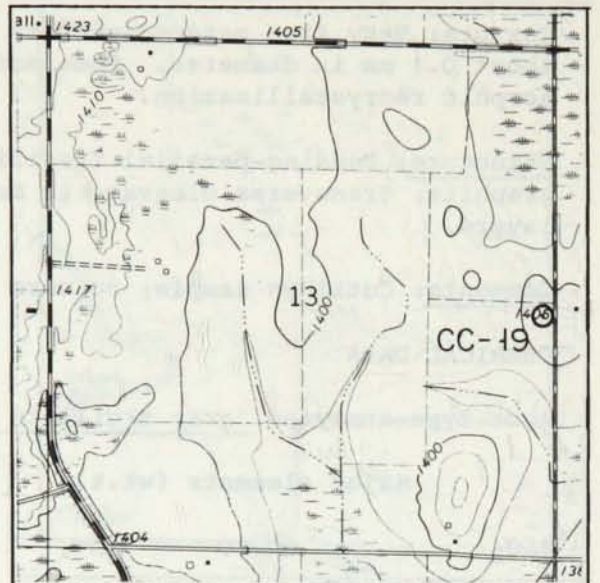
Total depth 428.5 ft

Elevation, top of  
Precambrian rock 984 ft

Core diam. \_\_\_\_\_

Length of core run no core

Core recovered none - cuttings only



ABBREVIATED LITHOLOGIC LOG (intervals recorded are depths in feet)

Interval	Description	Till unit of Meyer (1986)
QUATERNARY DEPOSITS		
0-50	Sandy till, olive yellow brown to gray; clasts of granite, greenstone, dolomite. Scattered thin interbeds of gravel	Wadena
50-84	Clay and sand, light yellow brown; wood in places	
84-129	Clayey till, gray; thin interbeds of sand and gravel	Browerville
129-136	Sand and gravel	
136-152	Sandy till, olive gray	Sandy
152-270	Gravel, sand, and very fine sand; minor clay layers. Contains wood fragments	
270-370	Clay, dark gray	
370-421	Sandy till, olive gray to olive brown; clasts of dolomite, basalt, greenish gray slate and phyllite	Elmdale

REGOLITH ON PRECAMBRIAN ROCK

421-429 Clay, greenish color, and soft slate

PETROGRAPHIC DESCRIPTION OF CORE

Principal rock type: Slaty argillite.

Comments: Cuttings recovered from hole are not adequate for petrographic study.

CHEMICAL DATA

Rock type analyzed no analyses



Field number CC-20

Date Completed November 17, 1980

MGS unique number 226766

MGS lab number 1645

LOCATION (see map at right)

T-R-S 131-34-19 DDDADC

County Todd

Quadrangle Eagle Bend 7.5'

HOLE PARAMETERS

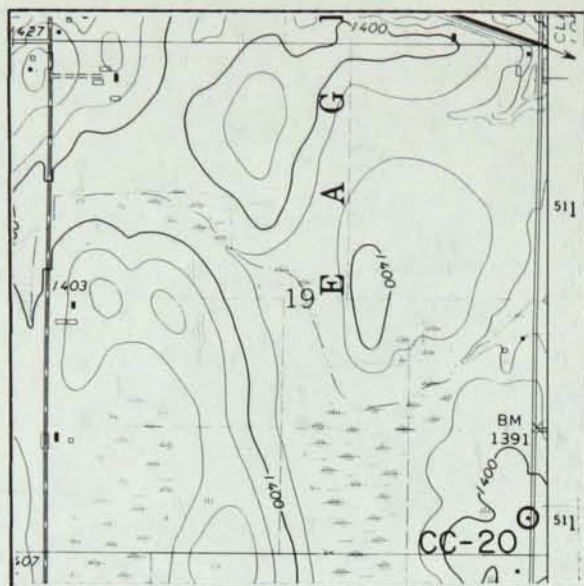
Surface elevation 1403 ft

Total depth 503 ft

Elevation, top of  
Precambrian rock 1095 ft

Core diam. 2.1"

Length of core run 490-490.6 Core recovered approx. 0.1 ft



ABBREVIATED LITHOLOGIC LOG (intervals recorded are depths in feet)

Interval	Description	Till unit of Meyer (1986)
QUATERNARY DEPOSITS		
0-59	Sandy clay till, various shades of yellow brown, gray, olive brown; clasts of dolomite, granite, quartz, basalt	Wadena
59-195	Clayey to silty clay till, gray and olive gray; predominant clasts are dolomite; lesser amounts of granite, basalt. Gravel layer, 175-183 ft	Browerville
195-245	Silty clay till, bluish gray to olive gray; clasts of dolomite, basalt, granite, shale. Very clayey at base	Meyer Lake
245-308	Clayey till, olive brown, clasts of dolomite, basalt, granite, shale	Eagle Bend
REGOLITH ON PRECAMBRIAN ROCK		
308-488	Kaolinitic clay, light greenish gray	
488-503	Clay, dark gray; intervals of soft slate, dark gray	

PETROGRAPHIC DESCRIPTION OF CORE

Principal rock type: Slaty argillite.

Mineralogy: Quartz, plagioclase, sericitic muscovite, chlorite, graphite.

Texture: Sedimentary clastic texture modified by recrystallization, development of cleavage. Small chlorite porphyroblasts occur in muddy layers.

Structure: Millimeter-scale silty beds interlayered with cm-scale muddy beds; silty layers show grading, scouring. Slaty cleavage is transverse to bedding.

CHEMICAL DATA

Rock type analyzed gray slate and siltstone; composite sample (490)

Major elements (wt.%)		Minor elements (ppm)			
SiO <sub>2</sub>	65.60	Cr	178.80	Yb	2.14
Al <sub>2</sub> O <sub>3</sub>	15.25	Co	26.29	Lu	0.346
Fe <sub>2</sub> O <sub>3</sub>	--	Ni	85.10	Sc	20.50
FeO*	6.93	Cs	3.92		
MgO	2.88	Ba	493.00		
CaO	0.32	Hf	3.75		
Na <sub>2</sub> O	2.42	Ta	0.766		
K <sub>2</sub> O	2.52	Th	8.25		
H <sub>2</sub> O <sup>+</sup>	} 3.36 (LOI)	U	2.16		
H <sub>2</sub> O <sup>-</sup>		La	27.11		
CO <sub>2</sub>		Ce	62.14		
TiO <sub>2</sub>	0.61	Nd	26.56		
P <sub>2</sub> O <sub>5</sub>	n.d.	Sm	5.34		
MnO	0.10	Eu	1.02		
TOTAL	100.0 (normalized)	Tb	0.607		

Anal. method INNA

Analyst P. O'Day, Cornell Univ.

Anal. method INNA

Analyst P. O'Day, Cornell Univ.

Field number CC-22

Date Completed October 27, 1980

MGS unique number 226765

MGS lab number 1644

LOCATION (see map at right)

T-R-S 132-34-30 AADDDD

County Todd

Quadrangle Clarissa 7.5'

HOLE PARAMETERS

Surface elevation 1387 ft

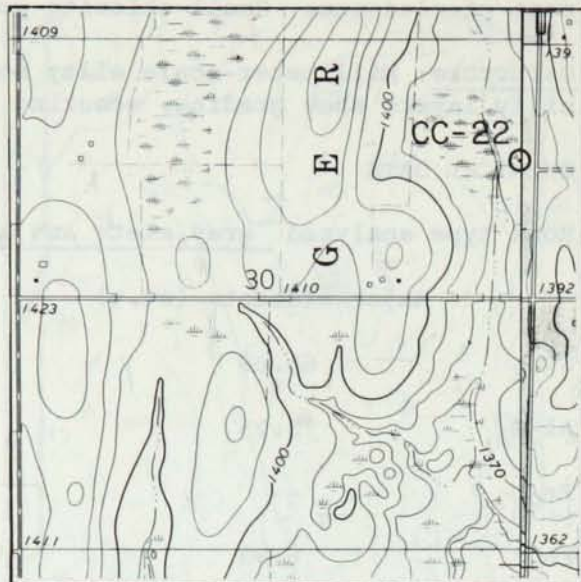
Total depth 224.4 ft

Elevation, top of  
Precambrian rock 1242 ft

Core diam. 2.1"

Length of core run 220-224.4

Core recovered approx. 4.4 ft



ABBREVIATED LITHOLOGIC LOG (intervals recorded are depths in feet)

Interval	Description	Till unit of Meyer (1986)
QUATERNARY DEPOSITS		
0-24	Sandy till, yellow brown to olive to gray; clasts of dolomite, granite, mafic rocks	Wadena
24-58	Sand and gravel	
58-129	Clayey till, dark gray. Several layers of sand and gravel between 90 and 103 ft	Browerville
129-145	Clayey till, olive gray	Eagle Bend
REGOLITH ON PRECAMBRIAN ROCK		
145-217	Gritty clay, light green; intervals of soft and hard rock	
SOUND PRECAMBRIAN ROCK		
217-224	Hornblende diorite	

PETROGRAPHIC DESCRIPTION OF CORE

Principal rock type: Appinitic diorite.

Mineralogy: Plagioclase (50%), hornblende (45%), biotite (3%); sphene, epidote, K-feldspar (2% total). Accessory apatite, Fe-Ti oxides. Secondary chlorite, uralitic amphibole, sericitic muscovite unevenly developed throughout rock; epidote, adularia lenses occur in biotite.

Texture: Medium-grained hypidiomorphic; hornblende, biotite tend toward euhedral form; plagioclase tends to mold around mafic phases.

Structure: Essentially massive.

Comments: Rock compares well with late syenitic and dioritic plugs of the Vermilion district.

CHEMICAL DATA

Rock type analyzed appinitic diorite (221)

Major elements (wt.%)		Minor elements (ppm)
SiO <sub>2</sub>	51.97	not determined
Al <sub>2</sub> O <sub>3</sub>	12.43	
Fe <sub>2</sub> O <sub>3</sub>	2.02	
FeO	4.56	
MgO	12.57	
CaO	8.67	
Na <sub>2</sub> O	2.72	
K <sub>2</sub> O	1.53	
H <sub>2</sub> O <sup>+</sup>	2.33	
H <sub>2</sub> O <sup>-</sup>	n.d.	
CO <sub>2</sub>	0.12	
TiO <sub>2</sub>	0.61	
P <sub>2</sub> O <sub>5</sub>	0.38	
MnO	0.09	
TOTAL	100.00	

Anal. method XRF

Analyst K. Ramlal, Univ. of Manitoba



Field number CC-25

Date Completed September 9, 1980

MGS unique number 226762

MGS lab number 1641

LOCATION (see map at right)

T-R-S 133-34-29 BBBBBA

County Todd

Quadrangle Bertha 7.5'

HOLE PARAMETERS

Surface elevation 1370 ft

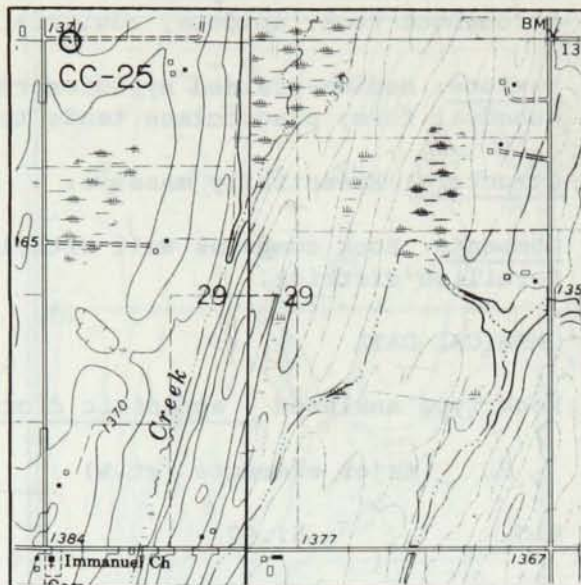
Total depth 276.6 ft

Elevation, top of  
Precambrian rock 1164 ft

Core diam. 2.1"

Length of core run 261.3-276.2

Core recovered approx. 14 ft



ABBREVIATED LITHOLOGIC LOG (intervals recorded are depths in feet)

Interval	Description	Till unit of Meyer (1986)
QUATERNARY DEPOSITS		
0-6	Sandy clay till, light brown and gray	Wadena
6-155	Clayey till, light brown to dark gray; clasts of carbonate, mafic rocks, granite. Several thin interbeds of sand, gravel, silt, clay between 68 and 82 ft	Browerville
155-158	Sand and gravel	
158-190	Loamy till, light to dark gray, calcareous	Meyer Lake
190-197	Silty clay, black to dark gray; some thin sand beds	
197-203	Loamy till, light gray	Eagle Bend
203-206	Silty clay, dark gray to black	
REGOLITH ON PRECAMBRIAN ROCK		
206-249	Clay, very light to dark green. Intervals of partly decomposed rock toward base	
SOUND PRECAMBRIAN ROCK		
249-276	Schistose metafelsite	

PETROGRAPHIC DESCRIPTION OF CORE

Principal rock type: Andesite tuff-breccia (strongly deformed).

Mineralogy: Plagioclase, quartz; abundant secondary sericitic muscovite, Fe-poor epidote, chlorite; minor opaque phases.

Texture: Very fine grained, recrystallized rock; tectonically elongated fragments as large as several cm which are visible in core lose their identity under the microscope. Volcanic origin indicated by rare relict plagioclase phenocrysts as large as 0.5 mm.

Structure: Strong subvertical rodding of fragments; extensive late fracturing and veining.

CHEMICAL DATA

Rock type analyzed andesite tuff-breccia (265)

Major elements (wt.%)		Minor elements (ppm)
SiO <sub>2</sub>	56.83	not determined
Al <sub>2</sub> O <sub>3</sub>	17.30	
Fe <sub>2</sub> O <sub>3</sub>	1.78	
FeO	5.00	
MgO	3.85	
CaO	4.46	
Na <sub>2</sub> O	3.79	
K <sub>2</sub> O	1.22	
H <sub>2</sub> O <sup>+</sup>	2.90	
H <sub>2</sub> O <sup>-</sup>	n.d.	
CO <sub>2</sub>	1.43	
TiO <sub>2</sub>	0.71	
P <sub>2</sub> O <sub>5</sub>	0.24	
MnO	0.32	
TOTAL	99.83	
Anal. method <u>XRF</u>		
Analyst <u>K. Ramlal, Univ. of Manitoba</u>		

Field number CC-27

Date Completed August 21, 1980

MGS unique number 226761

MGS lab number 1640

LOCATION (see map at right)

T-R-S 133-34-4 CCCBCC

County Todd

Quadrangle Aldrich South 7.5'

HOLE PARAMETERS

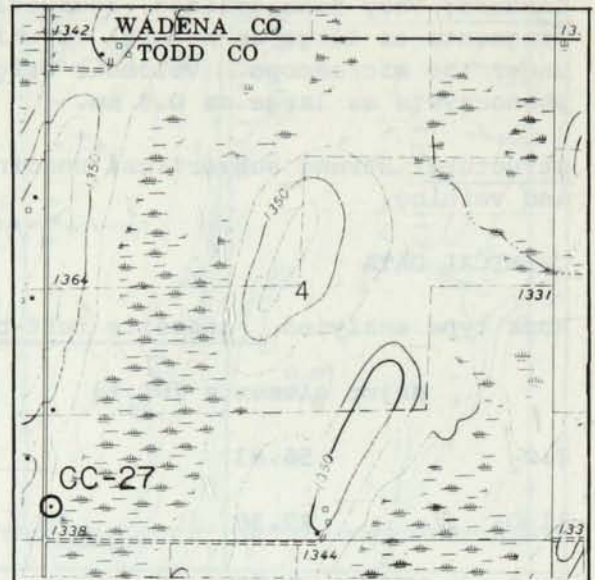
Surface elevation 1335 ft

Total depth 161.4 ft

Elevation, top of  
Precambrian rock 1210 ft

Core diam. 2.1"

Length of core run 154-161.4 Core recovered approx. 6 ft



ABBREVIATED LITHOLOGIC LOG (intervals recorded are depths in feet)

Interval	Description	Till unit of Meyer (1986)
QUATERNARY DEPOSITS		
0-26	Sandy till, gray brown; clasts of carbonate, granite, felsite	Wadena
26-29	Sand and gravel	
29-96	Clayey till, dark gray; clasts of dolomite, granite, mafic rocks, various metamorphic rocks	Browerville
96-108	Sandy till, gray; clasts of dolomite, mafic rocks	Meyer Lake
108-125	Sandy clay till, olive grayish brown	Elmdale
REGOLITH ON PRECAMBRIAN ROCK		
125-153	Gritty clay, gray to greenish gray; intervals of partly decomposed rock, green and black	
SOUND PRECAMBRIAN ROCK		
153-161	Hornblende metagabbro	

PETROGRAPHIC DESCRIPTION OF CORE

Principal rock type: Hornblende metagabbro.

Mineralogy: Hornblende (92%), plagioclase (2%), epidote (2%), magnetite (2%); fine-grained micaceous alteration products (2%). Traces of relict clinopyroxene, secondary anthophyllite, sphene.

Texture: Chiefly medium-grained neoblastic (grains 3-4 mm); however, there are vestiges of relict igneous texture in pseudomorphs of clinopyroxene by amphibole.

Structure: Essentially massive.

CHEMICAL DATA

Rock type analyzed hornblende metagabbro (156)

Major elements (wt.%)		Major elements (wt.%) in hornblende	
SiO <sub>2</sub>	43.38	SiO <sub>2</sub> 45.7	Si <sup>4</sup> 6.652
Al <sub>2</sub> O <sub>3</sub>	11.10	Al <sub>2</sub> O <sub>3</sub> 12.1	Al <sup>4</sup> 1.348
Fe <sub>2</sub> O <sub>3</sub>	4.53	FeO* 13.9	Al <sup>6</sup> 0.728
FeO	9.88	MgO 12.7	Fe 1.692
MgO	13.26	CaO 10.1	Mg 2.755
CaO	10.29	Na <sub>2</sub> O 0.5	Ca 1.575
Na <sub>2</sub> O	1.62	K <sub>2</sub> O 0.53	Na 0.141
K <sub>2</sub> O	0.99	TiO <sub>2</sub> 1.76	K 0.098
H <sub>2</sub> O <sup>+</sup>	3.17	P <sub>2</sub> O <sub>5</sub> 0.0	Ti 0.193
H <sub>2</sub> O <sup>-</sup>	n.d.	MnO 0.43	Mn 0.053
CO <sub>2</sub>	0.00	TOTAL 97.72	Cations per 23 oxygens
TiO <sub>2</sub>	1.80		
P <sub>2</sub> O <sub>5</sub>	0.01		
MnO	0.19		
TOTAL	100.22		
Anal. method	<u>XRF</u>	Anal. method	<u>Electron microprobe</u>
Analyst	<u>K. Ramlal, Univ. of Manitoba</u>	Analyst	<u>P. Weiblen, Univ. of Minn.</u>



Field number CC-29

Date Completed October 8, 1980

MGS unique number 226764

MGS lab number 1643

LOCATION (see map at right)

T-R-S 133-35-30 BBBABC

County Todd

Quadrangle Wrightstown 7.5'

HOLE PARAMETERS

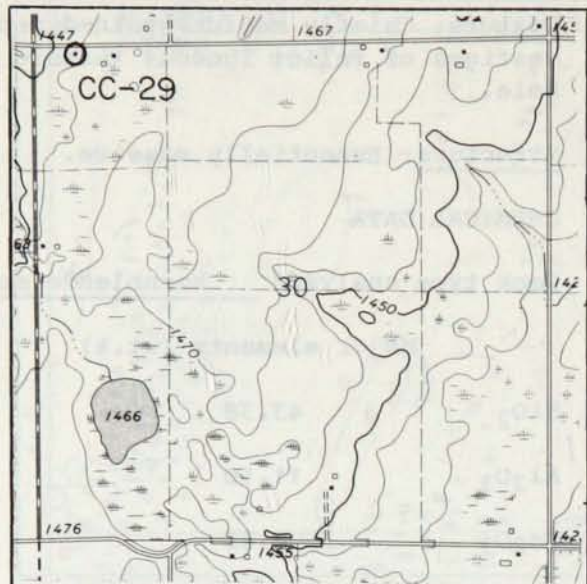
Surface elevation 1458 ft

Total depth 410 ft

Elevation, top of  
Precambrian rock 1164 ft

Core diam. 2.1"

Length of core run 400-400.4 Core recovered approx. 0.2 ft



ABBREVIATED LITHOLOGIC LOG (intervals recorded are depths in feet)

Interval	Description	Till unit of Meyer (1986)
QUATERNARY DEPOSITS		
0-62	Sandy till, brownish yellow to gray; clasts of dolomite, granite, mafic rocks	Wadena
62-65	Sand and gravel	
65-215	Clayey till, olive brown to dark gray; clasts of granite, mafic rocks, dolomite. Prominent layer of sand and gravel, 94-123 ft	Browerville
215-232	Sandy clay till, gray; clasts of dolomite, basalt, granite, felsite	Meyer Lake
232-239	Sand and gravel	
239-255	Loamy till, greenish gray; clasts of dolomite, basalt, felsite, granite, and some wood chips	Meyer Lake
255-282	Sandy clay till, olive brown to gray; clasts of quartz, feldspar, granite, some basalt, dolomite	Elmdale
282-294	Sand and gravel	
REGOLITH ON PRECAMBRIAN ROCK		
294-380	Clay, greenish gray; scattered intervals of soft rock	
380-410	Variably decomposed rock with seams of greenish gray clay; derived from mylonite	

PETROGRAPHIC DESCRIPTION OF CORE

Principal rock type: Schistose mylonite.

Mineralogy: Plagioclase, quartz, muscovite, chlorite, green biotite; traces of opaque phases.

Texture: Shear-banded blastomylonitic fabric; porphyroclasts (as large as 2 mm) of plagioclase, lenses of polycrystalline quartz are embedded in a fine matrix of quartz, micaceous minerals. Matrix biotite has grown across neighboring grain boundaries, suggesting mineral growth after shearing. Porphyroclasts display crush trails and pressure shadows.

Structure: Strong shear banding.

Comments: Protolith not certain; may have been medium-grained granitoid rock.

CHEMICAL DATA

Rock type analyzed no analyses

Field number LV-13

Date Completed September 1, 1982

MGS unique number 233131

MGS lab number 1912

LOCATION (see map at right)

T-R-S 132-33-14 DCBCCA

County Todd

Quadrangle Browerville NE 7.5'

HOLE PARAMETERS

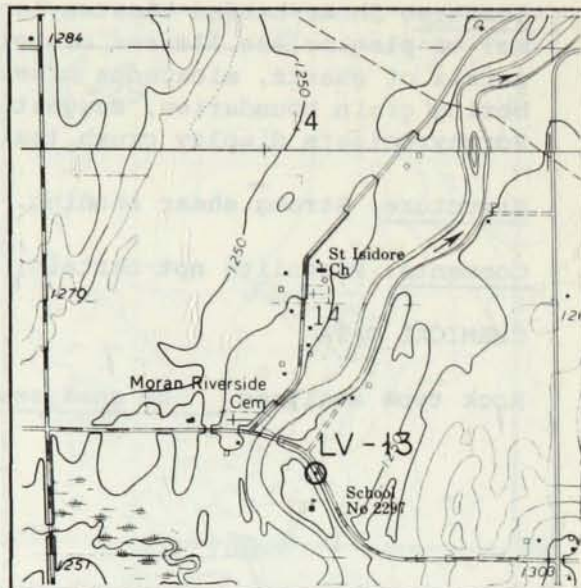
Surface elevation 1250 ft

Total depth 140.2 ft

Elevation, top of  
Precambrian rock 1125 ft

Core diam. 2.5"

Length of core run 130.6-140.2 Core recovered approx. 9.6 ft



ABBREVIATED LITHOLOGIC LOG (intervals recorded are depths in feet)

Interval	Description	Till unit of Meyer (1986)
QUATERNARY DEPOSITS		
0-58	Sand and gravel	
58-70	Silty till, olive gray to dark gray, calcareous; clasts of dolomite, mafic rocks, granite	Meyer Lake
70-74	Sandy clay till, dark brown, calcareous; some dolomite clasts	First Red
74-122	Clayey till, various shades of gray, pale olive, olive gray, dark gray; calcareous; dolomite clasts	Eagle Bend
122-125	Sand, medium to coarse, well sorted	
SOUND PRECAMBRIAN ROCK		
125-140	Epidotized, weakly gneissic leucotonalite	



PETROGRAPHIC DESCRIPTION OF CORE

Principal rock type: Hornblende tonalite, extensively altered.

Mineralogy: Quartz (15%), plagioclase, heavily sericitized (50%), dark-green igneous hornblende (10%); remainder of rock is secondary pale-blue-green amphibole, chlorite, epidote, sphene. Accessory apatite, opaque phases, carbonate, pyrite.

Texture: Allotriomorphic granular, modified by weak deformation and extensive growth of secondary minerals. Quartz is mostly reduced to subgrains. Original grain size 1-3 mm.

Structure: Basically massive with vague, streaky foliation. Numerous fractures; hairline veinlets of epidote, carbonate.

Comments: Abundant epidote; some may be primary but majority is late.

CHEMICAL DATA

Rock type analyzed no analyses



Field number P-5

Date Completed August 28, 1983

MGS unique number 234181

MGS lab number 1999

LOCATION (see map at right)

T-R-S 131-32-34 CADADA

County Todd

Quadrangle Lake Beauty 7.5'

HOLE PARAMETERS

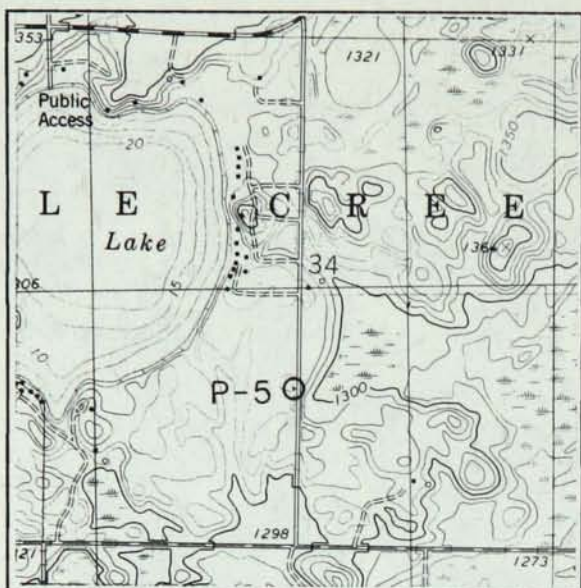
Surface elevation 1326 ft

Total depth 380 ft

Elevation, top of  
Precambrian rock 1094 ft

Core diam. 2.5"

Length of core run 370-380 Core recovered 10 ft



ABBREVIATED LITHOLOGIC LOG (intervals recorded are depths in feet)

Interval	Description	Till unit of Meyer (1986)
QUATERNARY DEPOSITS		
0-43	Sandy silt to gravelly sand	
43-129	Gravelly, sandy till, dark grayish brown to olive gray; clasts of agate, felsite, mafic rocks. Dolomite clasts below 85 ft depth. Layers of sand and gravel, 62-67, 90-96, 102-106 ft	Pierz
129-159	Gravelly sand	
159-176	Sandy clayey till, dark gray to brown, calcareous; dolomite clasts	Wadena
176-232	Clayey till, pale olive to dark gray	Eagle Bend
REGOLITH ON PRECAMBRIAN ROCK		
232-368	Clay, variegated; intervals of soft rock	
SOUND PRECAMBRIAN ROCK		
368-380	Metagraywacke	

PETROGRAPHIC DESCRIPTION OF CORE

Principal rock type: Metagraywacke with prominent "rip-up" clasts of slate.

Mineralogy: Framework: Quartz, plagioclase, sparse K-feldspar; metamorphically recrystallized matrix is mainly chlorite, biotite, muscovite. Accessory tourmaline, Fe-Ti oxides; secondary hematite, leucoxene. Slate clasts are chiefly quartz, chlorite, sericitic muscovite.

Texture: Most framework sand grains are smaller than 0.3 mm; slate chips are as long as several centimeters. Original matrix is completely recrystallized and strongly foliated.

Structure: Strong, anastomosing cleavage verging on schistosity.

CHEMICAL DATA

Rock type analyzed metagraywacke

Major elements (wt.%)		Minor elements (ppm)	
SiO <sub>2</sub>	68.8	Ba	390
Al <sub>2</sub> O <sub>3</sub>	13.0	Be	1.3
Fe <sub>2</sub> O <sub>3</sub>	0.5	Sc	16.5
FeO	7.0	V	111
MgO	2.52	Cr	110
CaO	0.24	Co	48
Na <sub>2</sub> O	1.99	Ni	48
K <sub>2</sub> O	1.56	Cu	66
H <sub>2</sub> O <sup>+</sup>	n.d.	Zn	82
H <sub>2</sub> O <sup>-</sup>	n.d.	Rb	65
CO <sub>2</sub>	n.d.	Sr	100
TiO <sub>2</sub>	0.48	Y	16
P <sub>2</sub> O <sub>5</sub>	0.12	Zr	163
MnO	0.04		
TOTAL	96.3		

Anal. method DCAP/OES

Anal. method DCAP/OES

Analyst R. Knoche, Univ. of Minn.

Analyst R. Knoche, Univ. of Minn.



Field number P-6

Date Completed September 8, 1983

MGS unique number 234182

MGS lab number 2000

LOCATION (see map at right)

T-R-S 130-33-34 CDDDCD

County Todd

Quadrangle Browerville 7.5'

HOLE PARAMETERS

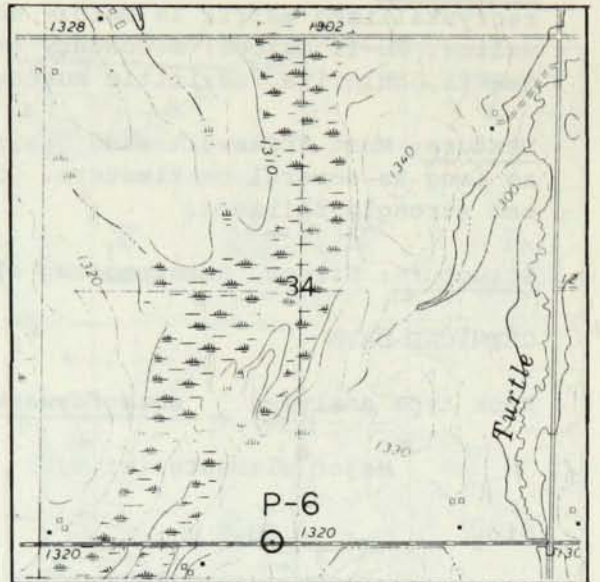
Surface elevation 1327 ft

Total depth 578.7 ft

Elevation, top of  
Precambrian rock 1019 ft

Core diam. 2.5"

Length of core run 572-578.7 Core recovered approx. 6.7 ft



ABBREVIATED LITHOLOGIC LOG (intervals recorded are depths in feet)

Interval	Description	Till unit of Meyer (1986)
QUATERNARY DEPOSITS		
0-9	Sandy till, olive yellow to light yellowish brown	Wadena
9-12	Gravelly sand	
12-72	Clayey till, dark gray; clasts of dolomite and Cretaceous limestone	Browerville
72-75	Clay loam, black; contains organic matter	
75-135	Silty till grading downward into clayey till. Greenish gray at top, grading to dark gray at base. Dolomite clasts. Contains scattered wood bits	Meyer Lake
135-146	Silt to silty clay to clay, light greenish gray	
146-170	Sandy clayey till, brown to dark gray with reddish tinge, calcareous. Clasts of dolomite and aphanitic red rock	First Red
170-174	Gravelly sand	
174-268	Clayey till, dark gray	Eagle Bend
268-308	Sandy clayey till, gray, dark grayish brown, and dark gray. Calcareous; clasts of dolomite and aphanitic red rock	Second Red
REGOLITH ON PRECAMBRIAN ROCK		
308-417	Clay, variegated	
417-559	Clay, variegated; intervals of soft slate	
SOUND PRECAMBRIAN ROCK		
559-579	Laminated slate	

PETROGRAPHIC DESCRIPTION OF CORE

Principal rock type: Slaty argillite, laminated to thin-bedded.

Mineralogy: Quartz, feldspar, chlorite, sericitic muscovite; graphite very abundant in some laminae. Granular opaques (amorphous carbon?) and leucoxene are widespread in small amounts; accessory tourmaline.

Texture: Sedimentary texture strongly modified by deformation, recrystallization.

Structure: Slaty cleavage traverses bedding at high angle; cleavage is strongly bundled.

CHEMICAL DATA

Rock type analyzed no analyses



Field number 1985-5

Date Completed September 20, 1985

MGS unique number 236128

MGS lab number 2176

LOCATION (see map at right)

T-R-S 131-35-10 ABAAAB

County Todd

Quadrangle Eagle Bend 7.5'

HOLE PARAMETERS

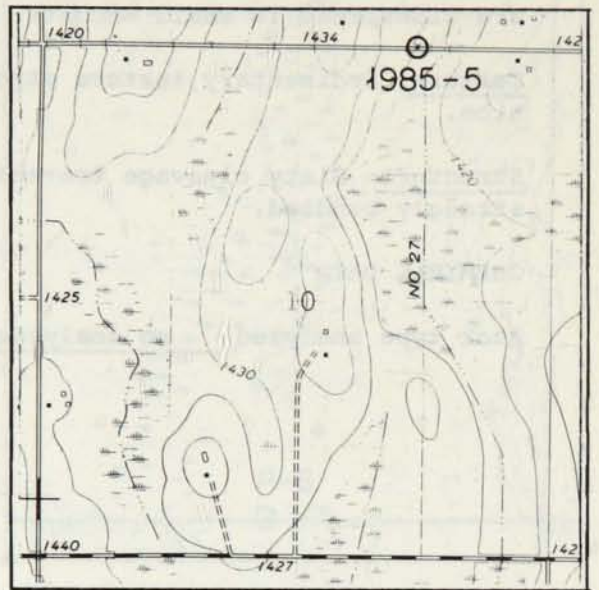
Surface elevation 1418 ft

Total depth 265.5 ft

Elevation, top of  
Precambrian rock 1179 ft

Core diam. 2.5"

Length of core run 257-265.5 Core recovered 8.5 ft



ABBREVIATED LITHOLOGIC LOG (intervals recorded are depths in feet)

Interval	Description	Till unit of Meyer (1986)
QUATERNARY DEPOSITS		
0-18	Sand and gravel	
18-58	Sandy till, gray; clasts of mafic rock, quartz, some carbonate. Layer of sand, 37-42 ft	Wadena
58-154	Clayey till, dark gray	Browerville
154-164	Sand	
164-183	Silty clayey till, dark gray; clasts of mafic rock and carbonate	Meyer lake
183-203	Clayey till, dusky red, to sandy clay till, light gray to gray	First Red
203-233	Sandy clay till, greenish gray; clasts of carbonate, mafic rock, minor red rock	Elmdale ?
233-239	Sand	
REGOLITH ON PRECAMBRIAN ROCK		
239-254	Gritty clay, greenish gray	
SOUND PRECAMBRIAN ROCK		
254-265.5	Metamorphically modified hornblende tonalite/diorite	

PETROGRAPHIC DESCRIPTION OF CORE

Principal rock type: Hornblende gneiss (derived from hornblende quartz diorite).

Mineralogy: Hornblende, pale-green (45%); plagioclase, sericitized, saussuritized (45%); quartz (10%). Secondary epidote is abundant. Accessory sphene, magnetite, apatite.

Texture: Dominantly neoblastic, weakly foliated, although vestiges of former granitic texture survive. Largest grains about 3 mm in diameter.

Structure: Inclined foliation readily visible in core.

Comments: Reasonable protolith would be a quartz diorite similar to that at site CC-32.

CHEMICAL DATA

Rock type analyzed hornblende gneiss

Major elements (wt.%)

not determined

Minor elements (ppm)

Ag	0.039	Te	<0.5
As	<1.0	Tl	<0.5
Au	<0.000	Zn	28.4
Bi	<0.5		
Cd	<1.0		
Cu	72.6		
Ga	0.79		
Hg	<0.5		
Mo	1.02		
Pb	2.79		
Pd	<0.25		
Pt	<0.5		
Sb	0.76		
Se	1.01		
Sn	<0.5		

Anal. method ICP/AES

Analyst Geochemical Services Inc.  
Torrance, California

Field number 1985-10

Date Completed October 11, 1985

MGS unique number 236133

MGS lab number 2181

LOCATION (see map at right)

T-R-S 130-35-28 DDDDBA

County Todd

Quadrangle Clotho 7.5'

HOLE PARAMETERS

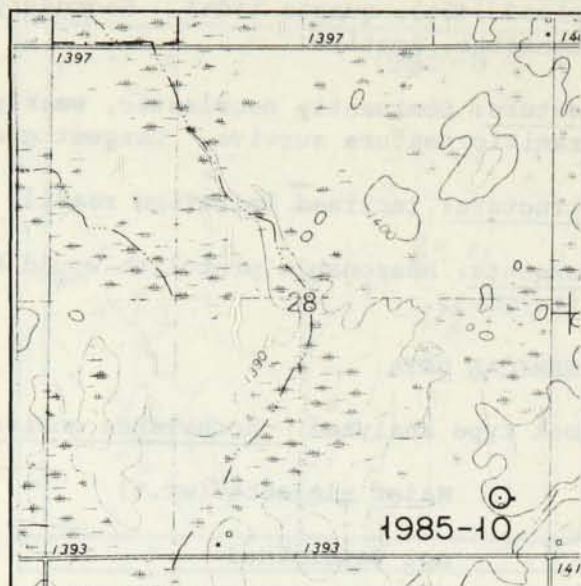
Surface elevation 1401 ft

Total depth 355.5 ft

Elevation, top of  
Precambrian rock 1110 ft

Core diam. 2.5"

Length of core run 345.5-355.5 Core recovered 10 ft



ABBREVIATED LITHOLOGIC LOG (intervals recorded are depths in feet)

Interval	Description	Till unit of Meyer (1986)
QUATERNARY DEPOSITS		
0-115	Sandy till, light olive brown to gray; clasts of mafic rock, carbonate, granite	Wadena
115-145	Sand, gravel, boulders	
145-170	Sandy till, light greenish gray; clasts of mafic rock, some carbonate	Sandy
170-204	Silty sandy to silty clay till, dark gray; contains wood fragments	Meyer Lake
204-261	Sand, gravel, silt; thin interbeds of clay	
261-283	Sandy till, dark grayish brown to dark gray	
283-291	Silty sand	
REGOLITH ON PRECAMBRIAN ROCK		
291-342	Sandy clay and soft rock	
SOUND PRECAMBRIAN ROCK		
342-355.5	Plagioclase-rich gneissose rock wholly altered to sericite, zoisite; interlayered with coarse garnet-biotite schist	

PETROGRAPHIC DESCRIPTION OF CORE

Principal rock type: Brecciated, highly altered sericite-zoisite-tremolite rock derived from coarse-grained, plagioclase-rich protolith.

Mineralogy: Sericitic muscovite, zoisite, tremolite predominate; lesser amounts of chlorite, epidote, biotite in rare pseudomorphs of coarse biotite flakes. Granular diopside suspected but unconfirmed.

Texture: Fine-grained, felted mat of secondary minerals; scattered partial pseudomorphs of coarse biotite flakes. (See comments below)

Structure: Formerly coarse-grained rock was fractured extensively prior to healing by pervasive hydrous alteration.

Comments: Lowermost 15 cm of core is very coarse garnet-biotite-quartz-plagioclase schist (grain size 7-15 mm), heavily altered to chlorite, sericite.

CHEMICAL DATA

Rock type analyzed Sericite-zoisite-tremolite rock (348.5, 355.5)

Major elements (wt.%)	Minor elements (ppm)					
	(348.5)	(355.5)	(348.5)	(355.5)		
not determined	Ag	<0.025	<0.025	Sb	0.57	<0.25
	As	3.47	1.53	Se	<1.0	<1.0
	Au	0.02	0.013	Sn	<0.5	<0.5
	Bi	<0.5	<0.5	Te	<0.5	<0.5
	Cd	<1.0	<1.0	Tl	<0.5	<0.5
	Cu	10.2	5.9	Zn	12.6	99.4
	Ga	<0.5	4.54			
	Hg	<0.5	<0.5			
	Mo	1.04	0.90			
	Pb	2.06	1.54			
	Pd	<0.25	<0.25			
	Pt	<0.5	<0.5			

Anal. method ICP/AES

Analyst Geochemical Services Inc.  
Torrance, California



Field number 1985-11

Date Completed October 16, 1985

MGS unique number 236134

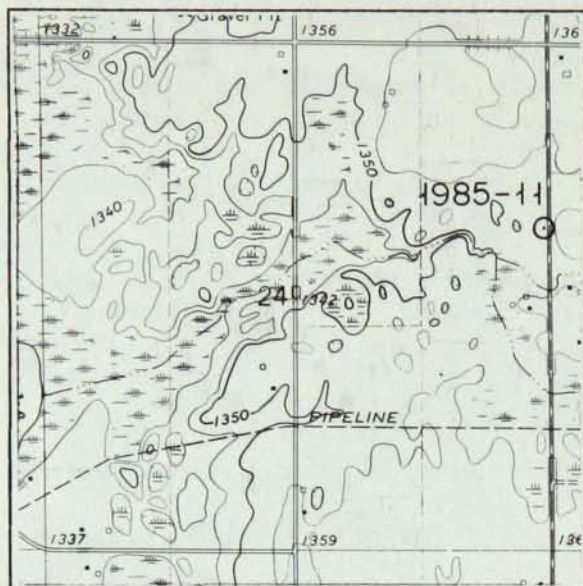
MGS lab number 2182

LOCATION (see map at right)

T-R-S 129-35-24 ADADDA

County Todd

Quadrangle Lake Osakis East 7.5'



HOLE PARAMETERS

Surface elevation 1355 ft

Total depth 344 ft

Elevation, top of  
Precambrian rock 1091 ft

Core diam. 2.5"

Length of core run 334-344 Core recovered approx. 9.9 ft

ABBREVIATED LITHOLOGIC LOG (intervals recorded are depths in feet)

Interval	Description	Till unit of Meyer (1986)
QUATERNARY DEPOSITS		
0-5	Sand and gravel	
5-8	Silty till, grayish brown	Des Moines
8-49	Sandy till, light brownish gray	Wadena
49-92	Gravelly sand, silt, silty clay	
92-104	Clayey till, dark gray to very dark gray	Browerville ?
104-179	Loamy to silty clay till, gray, brownish and greenish; abundant carbonate clasts, some wood fragments	Meyer Lake
179-195	Silty sand, sandy clay loam	
195-220	Clayey till, dark gray	
220-245	Clayey till, olive, changing to dark gray at base; carbonate clasts	Eagle Bend
245-257	Clayey till, olive to olive gray; Cretaceous limestone clasts	Elmdale
257-264	Reworked regolith. Silty sand, white and pink	
REGOLITH ON PRECAMBRIAN ROCK		
264-333	Gritty clay, reddish brown and greenish gray, and soft rock	
SOUND PRECAMBRIAN ROCK		
333-344	Mylonite	

PETROGRAPHIC DESCRIPTION OF CORE

Principal rock type: Mylonite derived from gabbroic protolith.

Mineralogy: Plagioclase, zoisite, both partially retrograded to fine-grained clinozoisite, albite; hornblende. Minor quartz; accessory magnetite, apatite of igneous derivation. Secondary talc, anthophyllite, sericitic muscovite, leucoxene.

Texture: Neoblastic, foliated; extensively masked by growth of fine-grained secondary phases.

Structure: Pronounced mylonitic foliation, lineation carried by elongate lenses of recrystallized plagioclase, zoisite.

Comments: Complex paragenesis interpreted to indicate shearing, mylonitization of gabbro under conditions conducive to annealing. Later hydrothermal overprinting.

CHEMICAL DATA

Rock type analyzed gabbroic mylonite

Major elements (wt.%)	Minor elements (ppm)			
not determined	Ag	0.046	Sn	<0.5
	As	<1.0	Te	<0.5
	Au	0.002	Tl	<0.5
	Bi	<0.5	Zn	18.4
	Cd	<1.0		
	Cu	100		
	Ga	1.12		
	Hg	<0.5		
	Mo	1.58		
	Pb	1.92		
	Pd	<0.25		
	Pt	<0.5		
	Sb	0.26		
	Se	<1.0		

Anal. method ICP/AES

Analyst Geochemical Services Inc.  
Torrance, California



Field number 1985-12

Date Completed October 24, 1985

MGS unique number 236135

MGS lab number 2183

LOCATION (see map at right)

T-R-S 128-34-16 CCCCCB

County Todd

Quadrangle Round Prairie 7.5'

HOLE PARAMETERS

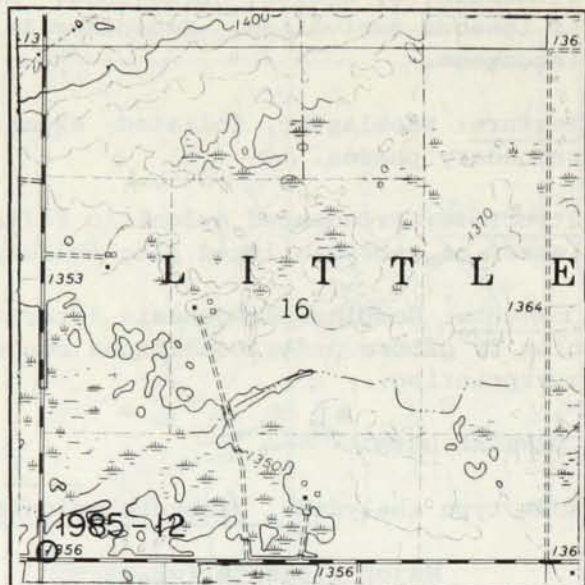
Surface elevation 1355 ft

Total depth 335.3 ft

Elevation, top of  
Precambrian rock 1111 ft

Core diam. 2.5"

Length of core run 325.1-335.3 Core recovered approx. 9.7 ft



ABBREVIATED LITHOLOGIC LOG (intervals recorded are depths in feet)

Interval	Description	Till unit of Meyer (1986)
QUATERNARY DEPOSITS		
0-61	Sandy till, olive to grayish brown to gray; pebbles of red granite	Wadena
61-97	Silty sand, silty clay	
97-135	Fine loamy till, pale olive to gray; abundant carbonate	Meyer Lake
135-141	Clayey till, dark gray	
141-213	Gravel, sandy silt, silty clay	
213-228	Sandy clay till, pale olive to gray; wood fragments at top	
228-236	Sandy till, reddish gray; pebbles of red sandstone, diabase	
236-239	Silty sand and gravel	
239-244	Sand and reworked regolith(?)	
REGOLITH ON PRECAMBRIAN ROCK		
244-247	Silty clay, light yellowish brown	
247-270	Clay, reddish, yellowish, greenish colors, soft greenish slate beds	
270-290	Sandy clay, white and light greenish gray, with abundant quartz grains (weathered gneiss)	
290-317	Silty clay, greenish gray (weathered mafic-rich gneiss or dike rock)	
317-322	Gritty clay, light greenish gray (weathered gneiss)	
SOUND PRECAMBRIAN ROCK		
322-335	Tonalite	

PETROGRAPHIC DESCRIPTION OF CORE

Principal rock type: Granodiorite (altered).

Mineralogy: Quartz (30%); plagioclase, heavily sericitized (55%); K-feldspar (10%). Secondary muscovite, carbonate, chlorite, opaque phases total the remaining 5%.

Texture: Hypidiomorphic granular, modified substantially by alteration. Former hornblende pseudomorphed by chlorite and carbonate and Fe-oxides; former biotite replaced by muscovite; quartz recrystallized to subgrains.

Structure: Essentially massive.

CHEMICAL DATA

Rock type analyzed granodiorite

Major elements (wt.%)

Minor elements (ppm)

Ag	<0.025	Te	<0.5
As	<1.0	Tl	<0.5
Au	0.001	Zn	14
Bi	<0.5		
Cd	<1.0		
Cu	2.94		
Ga	<0.5		
Hg	<0.5		
Mo	1.14		
Pb	6.64		
Pd	<0.25		
Pt	<0.5		
Sb	0.422		
Se	<1.0		
Sn	<0.5		

Anal. method ICP/AES

Analyst Geochemical Services Inc.  
Torrance, California



Field number 1985-13

Date Completed October 30, 1985

MGS unique number 236136

MGS lab number 2184

LOCATION (see map at right)

T-R-S 128-33-33 BAAAAA

County Todd

Quadrangle Ward Springs 7.5'

HOLE PARAMETERS

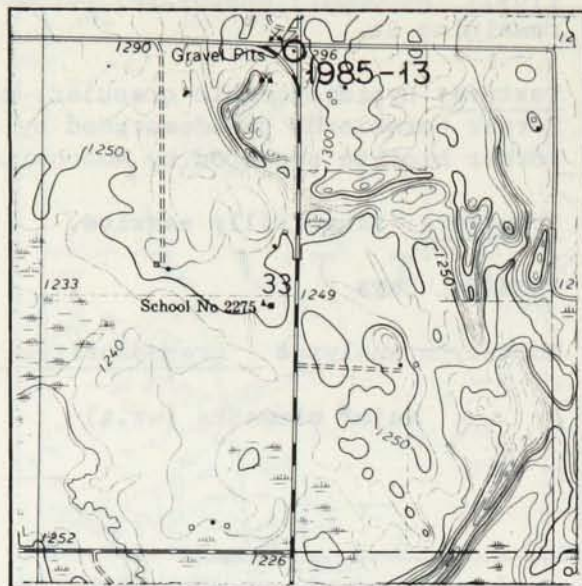
Surface elevation 1292 ft

Total depth 617 ft

Elevation, top of  
Precambrian rock 1064 ft

Core diam. \_\_\_\_\_

Length of core run no core Core recovered cuttings only



ABBREVIATED LITHOLOGIC LOG (intervals recorded are depths in feet)

Interval	Description	Till unit of Meyer (1986)
QUATERNARY DEPOSITS		
0-6	Sandy till, brown	Pierz
6-19	Silt, light brown	
19-53	Sand and gravel	
53-61	Sandy clay till, brown	Wadena
61-80	Sand and gravel	
80-96	Clayey till, dark gray. Layer of carbonate-rich sand and gravel, 82-84 ft	
96-108	Silt to sand	
108-130	Sandy clay till, dark gray	Sandy ?
130-151	Loamy till and clay loam till, dark gray	Meyer Lake
151-162	Sandy till, reddish gray	First Red
162-185	Clayey till, light yellowish to olive brown	Eagle Bend
185-224	Clayey till, dark to very dark gray. Fragments of regolith and interbeds of sand near base	Elmdale
224-228	Sand	
REGOLITH ON PRECAMBRIAN ROCK		
228-617	Clay, white, green, brown, gray, reddish brown; mixed with intervals of soft and hard rock	
SOUND PRECAMBRIAN ROCK		
617	Slate to phyllite	

PETROGRAPHIC DESCRIPTION OF CORE

Principal rock type: Slate or phyllite; rock not examined petrographically.



Field number 1985-13A

Date Completed November 8, 1985

MGS unique number 236137

MGS lab number 2185

LOCATION (see map at right)

T-R-S 128-33-27 DBBAAA

County Todd

Quadrangle Ward Springs 7.5'

HOLE PARAMETERS

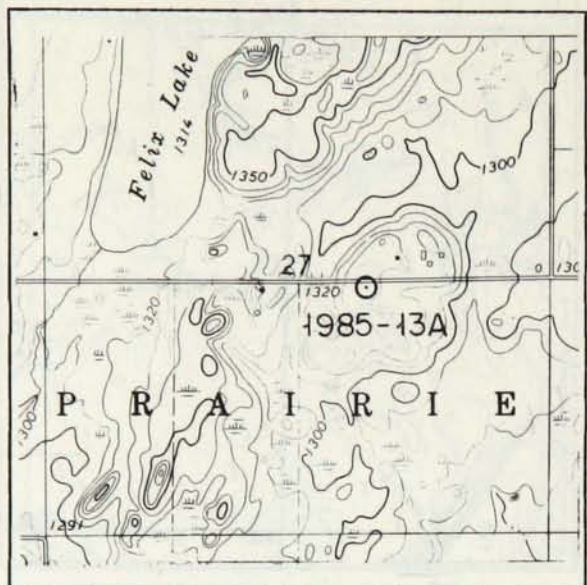
Surface elevation 1330 ft

Total depth 624 ft

Elevation, top of  
Precambrian rock 1046 ft

Core diam. 2.5"

Length of core run 614-624 Core recovered 10 ft



ABBREVIATED LITHOLOGIC LOG (intervals recorded are depths in feet)

Interval	Description	Till unit of Meyer (1986)
QUATERNARY DEPOSITS		
0-54	Silt, clay, coarse sand, gravel	
54-95	Sandy gravelly till, dark grayish brown; clasts of rhyolite, granite, and black and dark-green fine-grained rocks	Pierz
95-128	Sandy till, olive to olive gray; carbonate clasts. Layer of sand, 103-105 ft	Wadena
128-130	Clay, brown	
130-150	Sandy till, gray; clasts of granite, basalt, iron-formation	Red Sandy
150-185	Sandy clay till, dark gray; clasts of carbonate, basalt; wood at base	Meyer Lake
185-200	Sandy clay till, gray	First Red
200-246	Clayey till, olive gray to dark gray; carbonate clasts	Eagle Bend
CRETACEOUS SEDIMENTARY ROCKS		
246-272	Clayey to sandy shale and siltstone	
272-284	Kaolinite-cemented quartz sandstone	
REGOLITH ON PRECAMBRIAN ROCK		
284-600	Clay, red and green, and soft phyllitic slate	
SOUND PRECAMBRIAN ROCK		
600-624	Phyllitic metagraywacke-siltstone	

PETROGRAPHIC DESCRIPTION OF CORE

Principal rock type: Phyllite, derived from fine-grained graywacke-siltstone.

Mineralogy: Framework grains: quartz, plagioclase, K-feldspar, muscovite; lithic fragments of polycrystalline quartz, fine-grained quartz-carbonate rock. Matrix: sericitic muscovite, chlorite, granular carbonate; also comminuted quartz and feldspar.

Texture: Poorly sorted, poorly rounded graywacke; texture modified somewhat by cleavage development and recrystallization of matrix.

Structure: Strong slaty cleavage ( $S_1$ ) is subhorizontal; quartz-carbonate concretions flattened in  $S_1$  plane. Weak crenulation cleavage ( $S_2$ ) nearly normal to  $S_1$  on conjugate trends;  $S_2$  approaches morphology of kink bands. Prominent thin calcite veinlets throughout rock.

CHEMICAL DATA

Rock type analyzed no analyses



Field number 1985-14

Date Completed November 21, 1985

MGS unique number 236138

MGS lab number 2186

LOCATION (see map at right)

T-R-S 127-32-27 BCBAAB

County Todd

Quadrangle Burtrum 7.5'

HOLE PARAMETERS

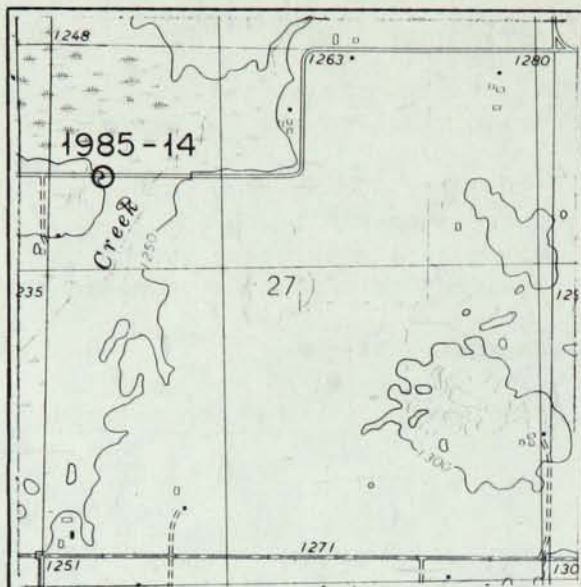
Surface elevation 1249 ft

Total depth 185.7 ft

Elevation, top of  
Precambrian rock 1119.5 ft

Core diam. 2.5"

Length of core run 180-185.7 Core recovered 5.7 ft



ABBREVIATED LITHOLOGIC LOG (intervals recorded are depths in feet)

Interval	Description	Till unit of Meyer (1986)
QUATERNARY DEPOSITS		
0-7	Sandy till, light yellowish brown; clasts of carbonate, granite	Pierz
7-28	Sandy clay till, dark gray	Wadena ?
28-30	Sandy till, grayish brown	Red Sandy ?
30-46	Silty sand	
46-70	Sandy till, olive gray; clasts of carbonate, red sandstone, mafic rocks, slaty rocks	
70-108	Sandy clay till, olive gray	Meyer Lake ?
108-114	Fine sandy till, reddish brown	First Red
114-126	Clayey till, olive	Eagle Bend
126-130	Silty sand and reworked regolith	
REGOLITH ON PRECAMBRIAN ROCK		
130-167	Micaceous clay, olive gray	
167-174	Gritty clay, dark grayish green	
SOUND PRECAMBRIAN ROCK		
174-185.7	Granite with schist inclusions	

PETROGRAPHIC DESCRIPTION OF CORE

Principal rock type: Coarse leucogranite.

Mineralogy: Quartz (30%), plagioclase (35%), microcline (33%); former biotite (2%) pseudomorphed by fine-grained aggregate of muscovite, chlorite, secondary green biotite, and sphene. Accessory apatite, allanite, epidote, zircon.

Texture: Allotriomorphic granular, modified by mild deformation. Quartz is moderately strained and locally has developed subgrains; plagioclase shows bent twin lamellae, some fracturing. Average primary grain size about 15 mm.

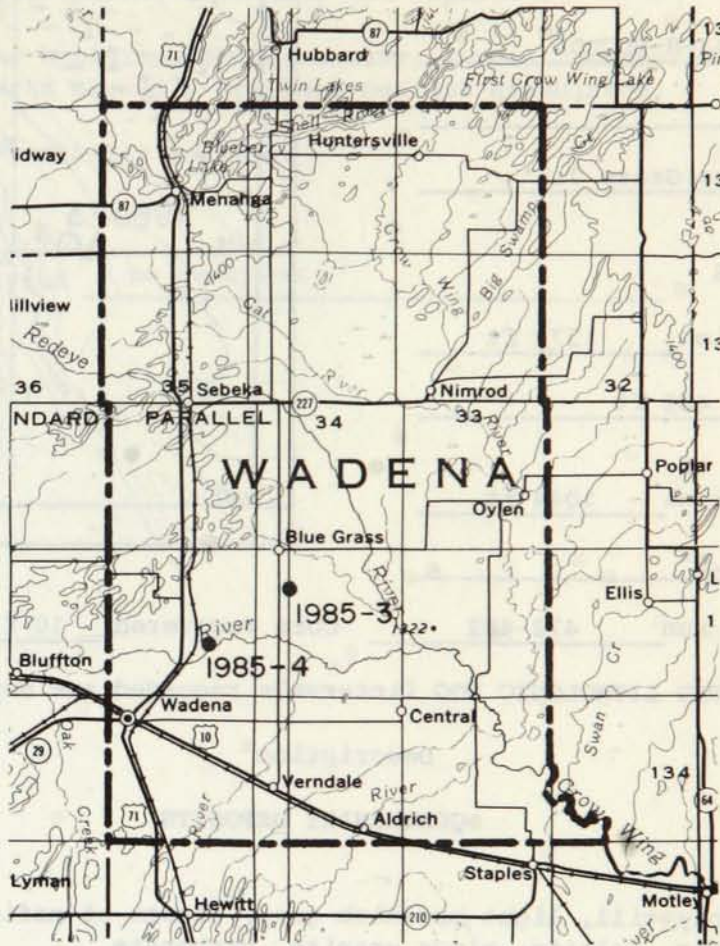
Structure: Weak megascopic foliation.

Comments: Contains amphibolite xenoliths. Petrographically resembles Archean granitoids.

CHEMICAL DATA

Rock type analyzed no analyses







Field number 1985-3

Date Completed September 12, 1985

MGS unique number 236126

MGS lab number 2174

LOCATION (see map at right)

T-R-S 135-34-8 BDCDDD

County Wadena

Quadrangle Blue Grass 7.5'

HOLE PARAMETERS

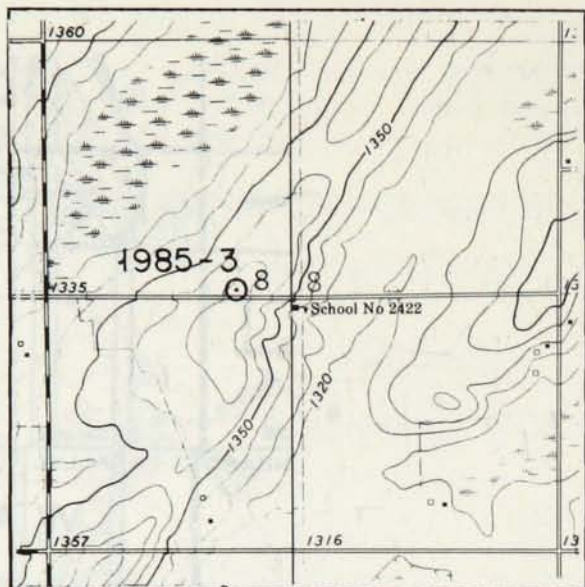
Surface elevation 1372 ft

Total depth 482 ft

Elevation, top of  
Precambrian rock 1044 ft

Core diam. 2.5"

Length of core run 472-482 Core recovered 10 ft



ABBREVIATED LITHOLOGIC LOG (intervals recorded are depths in feet)

Interval	Description	Till unit of Meyer (1986)
QUATERNARY DEPOSITS		
0-4	Sand	
4-76	Sandy till, light brownish gray; clasts of mafic rocks, felsite; minor granite, carbonate	Wadena
76-181	Clayey till, dark gray; clasts of carbonate, mafic rocks	Browerville
181-184	Gravel	
184-216	Clayey till, dark gray; abundant carbonate clasts	Meyer Lake ?
216-228	Sandy clay till, reddish brown	First Red
228-273	Clayey till, light yellow brown to dark gray	Eagle Bend
273-290	Clayey till, dark gray to gray; slightly more sandy than overlying interval	Elmdale ?
290-306	Clay, gray (Cretaceous sediments)	
CRETACEOUS SEDIMENTARY ROCKS		
306-322	Kaolinitic sand, white	
322-328	Clay, dark gray and black	
REGOLITH ON PRECAMBRIAN ROCK		
328-400	Sandy clay, white to pale green	
400-469	Sand and clay, pale green; clasts of quartz and feldspar	
SOUND PRECAMBRIAN ROCK		
469-482	Granite	

PETROGRAPHIC DESCRIPTION OF CORE

Principal rock type: Granite, weakly deformed.

Mineralogy: Subequal amounts of quartz, plagioclase, perthitic microcline; original biotite, hornblende, and magmatic epidote have been altered extensively to various assemblages of chlorite, green amphibole, secondary epidote, magnetite, sphene, sericite, and carbonate.

Texture: Coarse hypidiomorphic granular; largest grains about 8 mm in diameter. Quartz markedly strained but not granulated.

Structure: Essentially massive.

CHEMICAL DATA

Rock type analyzed no analyses

Field number 1985-4

Date Completed September 17, 1985

MGS unique number 236127

MGS lab number 2175

LOCATION (see map at right)

T-R-S 135-35-23 CBBBBC

County Wadena

Quadrangle Verndale 7.5'

HOLE PARAMETERS

Surface elevation 1302 ft

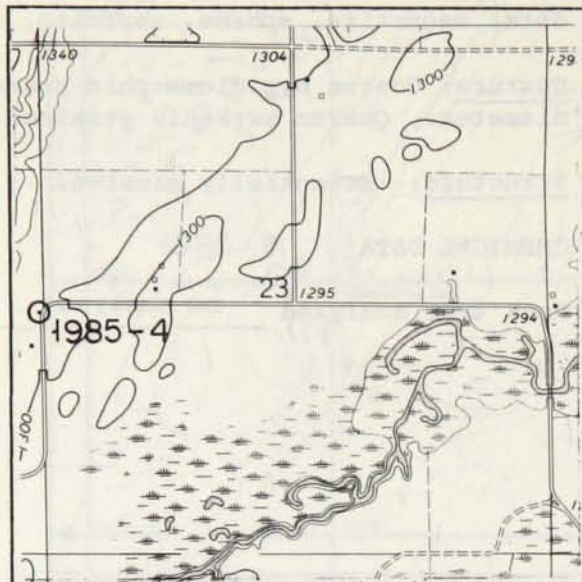
Total depth 334 ft

Elevation, top of  
Precambrian rock 1066 ft

Core diam. 2.5"

Length of core run 324-334

Core recovered 10 ft



ABBREVIATED LITHOLOGIC LOG (intervals recorded are depths in feet)

Interval	Description
QUATERNARY DEPOSITS	
0-128	Sand and gravel; minor layers of clay
128-158	Silty sandy till, light olive brown; carbonate clasts
158-162	Silt and sand
162-219	Clayey till, dark gray, to sandy clayey till, very dark greenish gray. Mafic and carbonate clasts
CRETACEOUS SEDIMENTARY ROCKS	
219-236	Silt and sand, abundant quartz clasts
REGOLITH ON PRECAMBRIAN ROCK	
236-308	Gritty clay, light gray to greenish gray
308-321	Soft rock
SOUND PRECAMBRIAN ROCK	
321-334	Brecciated leucotonalite

PETROGRAPHIC DESCRIPTION OF CORE

Principal rock type: Leucotonalite with mafic inclusions.

Mineralogy: Leucotonalite consists of quartz (35%), plagioclase (60%), altered biotite (5%), microcline (<1%). Secondary phases include chlorite, epidote, sericitic muscovite, clinozoisite, and sphene; accessory minerals are apatite, tourmaline. Mafic inclusions contain blue-green hornblende (40%), plagioclase (30%), and epidote (30%).

Texture: Leucotonalite is allotriomorphic granular, slightly modified by shearing; quartz is highly strained and locally granulated; some plagioclase is mortared. Inclusions are fine-grained, neoblastic, metamorphic rocks.

Structure: Essentially massive, but cut by innumerable brittle fractures. Fractures include simple cracks, shear fractures, and millimeter-scale quartz-epidote veins.

CHEMICAL DATA

Rock type analyzed no analyses



#### ACKNOWLEDGMENTS

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Because successful drilling depends absolutely on skilled drillers, it is a pleasure to acknowledge the skill and patience of drillers Ed Pilarski, Al Donabauer, Melvin Backowski, and especially Doug Ervin. We also thank Robert Beltrame, Bruce Bloomgren, Terry Boerboom, James Dalsin, Mark Jirsa, Peter McSwiggen, James Poppe, Dale Setterholm, and James Simonet for their tours of duty as site geologists and mud loggers.

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