

MINNESOTA GEOLOGICAL SURVEY  
INFORMATION CIRCULAR 31

**SCIENTIFIC TEST DRILLING IN  
WEST-CENTRAL MINNESOTA**

Summary of Lithologic and Stratigraphic Results,  
1987-1988, and Some Preliminary Geological  
Conclusions

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Minnesota Geological Survey  
*Priscilla C. Grew, Director*

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Preliminary Geological Conclusions

By

D.L. Southwick, Dale R. Setterholm, and Terrence J. Boerboom

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**SCIENTIFIC TEST DRILLING IN WEST-CENTRAL MINNESOTA:  
SUMMARY OF LITHOLOGIC AND STRATIGRAPHIC RESULTS,  
1987–1988, AND SOME PRELIMINARY GEOLOGICAL CONCLUSIONS**

**By**

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**INTRODUCTION**

In 1980 the Minnesota Geological Survey (MGS) began a program of scientific test drilling designed to acquire a better understanding of the complex Precambrian bedrock of Minnesota. A research approach that combined selective test drilling with geophysical surveying of the Precambrian terrane was dictated by the fact that the Precambrian rocks are covered by substantial thicknesses of Quaternary glaciogenic sediment in most places and therefore are not amenable to standard mapping and sampling techniques. This circular is the fourth to report basic results from the drilling program. It contains data from four separate studies that were undertaken in central and western Minnesota in 1987–1988 (Fig. 1).

The drilling summarized here, like that in previous projects (Southwick and others, 1986; Mills and others, 1987; Boerboom and others, 1989), was closely coordinated with geophysical surveys, and the selection of drilling targets was guided by geophysics to the maximum extent practicable. Our standard procedure was to formulate regional interpretations of the buried Precambrian geology from the geophysical data and then drill to verify, modify, or otherwise constrain the geophysical interpretation. Earlier applications of this approach have contributed to regional-scale geologic maps of the Penokean orogen (Early Proterozoic) in east-central Minnesota (Southwick and others, 1988) and an Archean greenstone belt in north-central Minnesota (Jirsa and Boerboom, 1990); the data tabulated in this circular will eventually contribute to new geologic maps for west-central Minnesota.

The geophysical backbone of the drilling program is the detailed aeromagnetic survey begun in 1979 with funding from the Legislative Commission on Minnesota Resources. The drilling in west-central Minnesota was targeted on aeromagnetic features displayed in two major blocks of that survey that were flown in 1984–85 and 1986–87 (Chandler, 1985, 1987). Target selection was based on direct inspection of the contoured anomaly maps and various computer-enhanced derivative maps constructed from the digital aeromagnetic data. Gravity maps and their derivatives also contributed materially to the site-selection process.

Because the primary objective of this drilling project was to attain an enhanced understanding of regional geological features in the Precambrian basement of west-central Minnesota, we have drilled on geophysical anomalies of relatively large dimensions. Our intent has been to

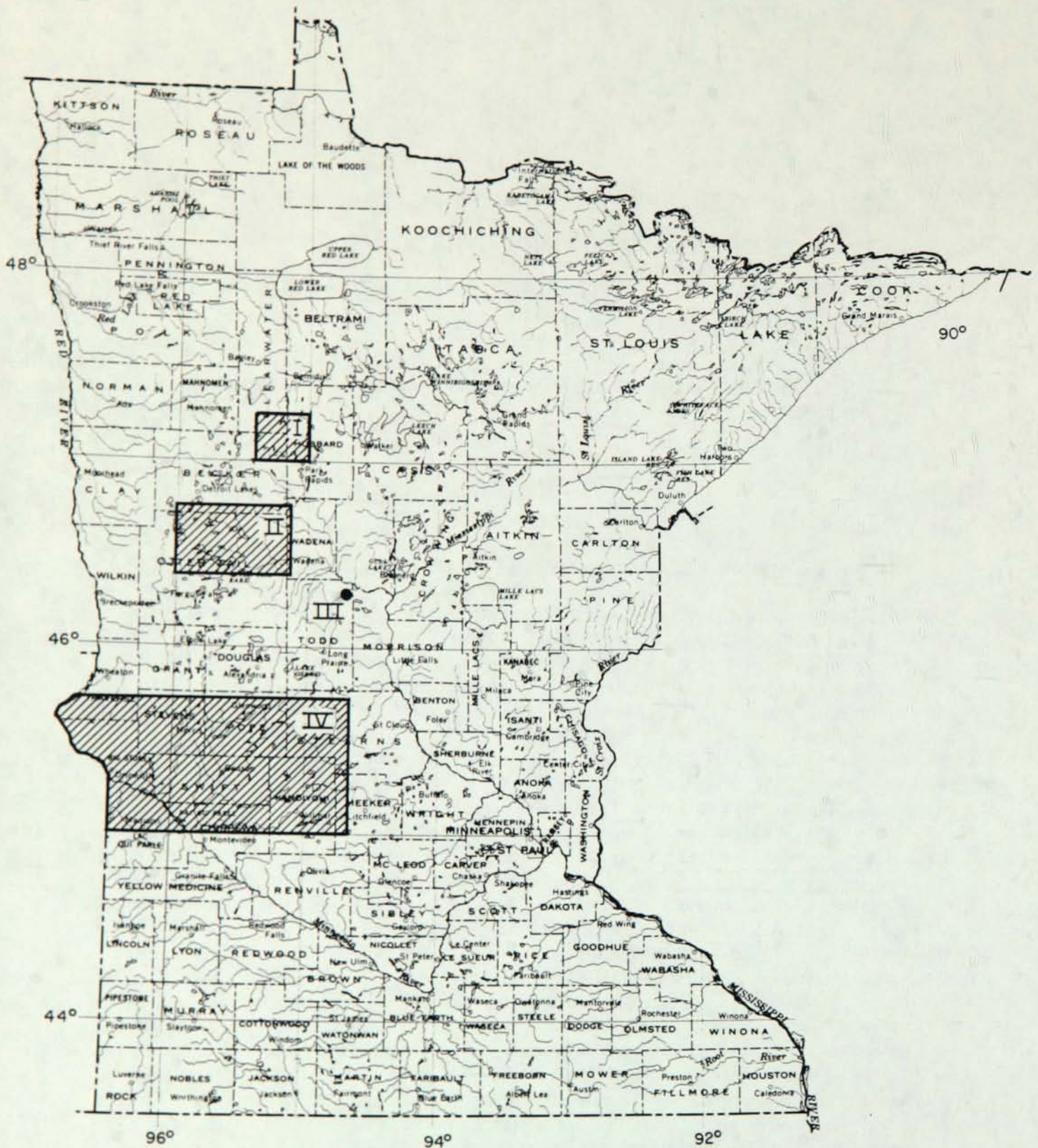


Figure 1. Map of Minnesota showing locations of project areas. I = Hubbard-Becker-Clearwater Counties area; II = northern Otter Tail County area; III = Philbrook area, northeastern Todd County; IV = area near Appleton geophysical lineament.



characterize the major rock units responsible for the first-order geophysical patterns of the region and develop geologic maps that show the most fundamental rock units with reasonable precision. Petrographic and geochemical work on recovered bedrock samples further characterizes rock units and aids in their geological interpretation.

Secondary but very important objectives of the drilling were to acquire subsurface data on the stratigraphy, composition, and thickness of the Upper Cretaceous sedimentary rocks that overlie Precambrian rocks in much of western Minnesota, and also to obtain subsurface data on the Quaternary surficial deposits in the region. The Cretaceous strata are of interest because they have attributes indicative of environments in which sedimentary manganese deposition may have been favored (Cannon and Force, 1983; Frakes and Bolton, 1984; Bolton and Frakes, 1985; Force and Cannon, 1988; Setterholm, 1989). The Quaternary materials contain most of the exploitable ground water in west-central Minnesota, and a proper three-dimensional understanding of their hydrogeologic parameters is essential to wise ground-water management. The data obtained on Quaternary materials in this study will contribute to ongoing hydrogeologic investigations by the MGS, the Minnesota Department of Natural Resources, and the U.S. Geological Survey.

## LOGISTICS AND DRILLING METHODS

Insofar as possible the drilling for this project was done on state land or within the right-of-way of public roads to avoid infringing on private property or disturbing area residents 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. 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-Upper 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 of size HQ (core diameter 2.5 inches or 6.35 cm) 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 375 feet (115 m) of rotary drilling in unconsolidated overburden and about 10 feet (3 m) of core drilling in sound rock. The drilling was done by the Thein Well Company of Spicer, Minnesota, and the Ben Ervin Well Company of Olivia, Minnesota.

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.

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. All cores and overburden samples are available for public examination at the MGS offices.

## PROJECT FOCUS AND RATIONALE

Three separate drilling projects that addressed geological problems in four different areas of the state were conducted in 1987–88. Each was funded from a different source. A project consisting of four holes was undertaken near the mutual corner of Hubbard, Becker, and Clearwater Counties (Fig. 1, area I) to investigate the sources of several sharp, subcircular to arcuate aeromagnetic anomalies that differ in form from the linear anomalies characteristic of the regional Archean greenstone-granite terrane. These holes, identified in the following descriptions by the prefix HB, were funded by a subcontract to the MGS from the Division of Minerals of the Minnesota Department of Natural Resources (MnDNR). A second project consisting of eight holes in northern Otter Tail County and two in northeastern Todd County (Fig. 1, areas II and III) was undertaken to investigate (1) the geological context of a horseshoe-shaped aeromagnetic pattern caused by a folded Archean iron-formation in the subsurface near Perham and New York Mills, and (2) the cause of sharp magnetic anomalies associated with Fe-Ti oxide variations in a diorite-gabbro plug near Philbrook (Boerboom, 1987, 1989). These holes, identified in the following descriptions by the prefixes HS and PBI, respectively, were drilled with funds provided by the Minerals Diversification Program of the Minnesota Legislature and administered by the MnDNR as a contract to the MGS. A third and regionally much larger project consisting of twenty-six holes was undertaken in a broad area of western Minnesota that extends from Lac Qui Parle and Big Stone Counties on the west to Meeker County on the east (Fig. 1, area IV). These holes were drilled to investigate the geological environs of the Appleton geophysical lineament, a marked linear discontinuity in both aeromagnetic and gravity data that apparently marks the boundary between two contrasting blocks of Archean gneissic crust (Southwick and Chandler, 1988; Southwick and others, 1989; Schaap, 1989). Holes drilled for the Appleton study are identified by the prefixes APL and BPL in the tabulated descriptions. Funds for their drilling were provided by the Legislative Commission on Minnesota Resources through their direct appropriation to the MGS for carrying out aeromagnetic surveying and follow-up studies.

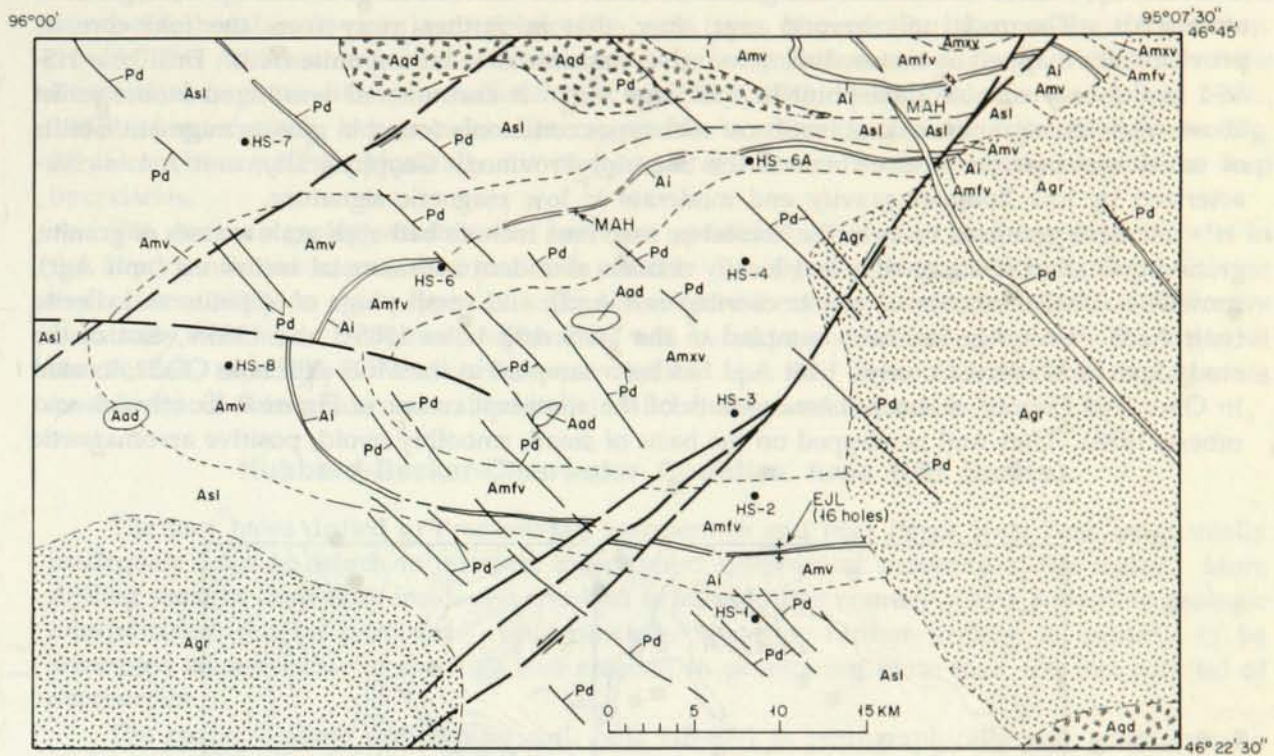
## SYNOPSIS OF RESULTS

### Northern Otter Tail County Area (“Horseshoe” Project; HS Series)

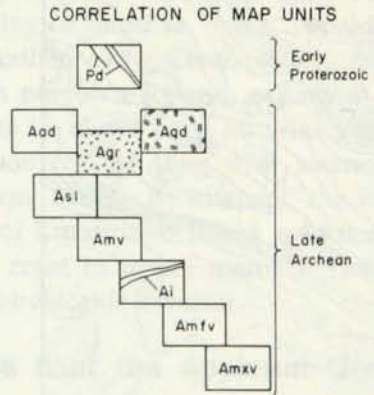
Figure 2 is a geologic map of the Precambrian rocks in the so-called “horseshoe” study area that is based on the geophysical and drilling results reported here, together with drilling data from earlier work by mineral exploration companies (MGS files; Anderson, 1957). Because drilling conditions in most of this area are very difficult, no further work is planned for the immediate future. Therefore, the interpretation presented in Figure 2, though poorly constrained, is likely to endure for some time.

The major structural element in the supracrustal rocks of the area is a moderately tight, steeply plunging fold outlined by cherty iron-formation (unit Ai). This fold closes to the west in a rounded hinge and is truncated on the east by intrusive granite; its shape is horseshoe-like in map view and in geophysical expression, and is particularly prominent on the color-enhanced aeromagnetic map (Chandler, 1987). The south limb of the fold dips about 70° south, as judged from a closely drilled transect at locality EJL (Fig. 2). It is not possible to say with present data whether the morphology of the fold is antiformal, synformal, or essentially neutral.

The core of the fold is occupied by a mixed sequence of volcanic and hypabyssal rocks that are predominantly of mafic composition. These are divided geophysically into two units, Amxv and Amfv, of which Amfv is the more dense and somewhat the more magnetic. Unit Amv,



EXPLANATION



- DESCRIPTION OF MAP UNITS**
- Pd Diabase dikes of Kenora - Kabetogama dike swarm
  - Aad Appinite, hornblende diorite, and lamprophyre
  - Aqd Hornblende - biotite quartz diorite, hornblende diorite, hornblende gabbro
  - Agr Granite, granodiorite, leucotonalite, locally with abundant mafic inclusions
  - Asi Biotite schist and metagraywacke injected to varying degrees by leucogranite
  - Amv Mafic metavolcanic rocks
  - Ai Laminated chert - magnetite - hematite iron - formation
  - Amfv Interstratified mafic and felsic metavolcanic rocks
  - Amxv Mixed unit consisting of mafic to intermediate flows, volcaniclastic and epiclastic sedimentary rocks, and hypabyssal intrusions

- MAP SYMBOLS**
- - - - - Inferred geologic contact
  - Inferred fault; inferred sense of displacement indicated by arrows
  - HS-3 Drill hole of HS-88-X series described in this report
  - + MAH M.A. Hanna Co. drill hole, 1954
  - + EJL E.J. Langyear Co. drill holes, 1909-1910

Figure 2. Highly generalized geologic map of Precambrian rocks in the northern Otter Tail County project area.



immediately outside the fold-defining iron-formation, is inferred to be relatively homogeneous metabasalt. The rock unit beyond unit Amv, that is, farther away from the fold core, is provisionally mapped as metasedimentary schist and intrusive leucogranite (Asl). Drill hole HS-88-1 is the only reliable data point in this large unit. It encountered weathered biotite schist above fresh leucogranite, a combination of rock types commonly found in grossly migmatitic units of schist and paragneiss elsewhere in the Superior Province. Geophysically, unit Asl is characterized by low Bouguer gravity and moderate to low magnetic signature.

Intrusive granitoid units in the horseshoe map area include batholith-scale masses of granite, granodiorite, and leucotonalite that locally contain abundant supracrustal inclusions (unit Agr), somewhat smaller masses of quartz diorite (unit Aqd), and small plugs of appinite and diorite (unit Aad). Unit Agr has been sampled in the MGS drill holes 1985-3 and 1985-4, east of the study area in Wadena County. Unit Aqd has been sampled in the MGS drill hole CC-32, located in Otter Tail County, a short distance south of the southeast corner of Figure 2 (Southwick and others, 1986). Unit Aad is mapped on the basis of small, smoothly ovoid, positive aeromagnetic

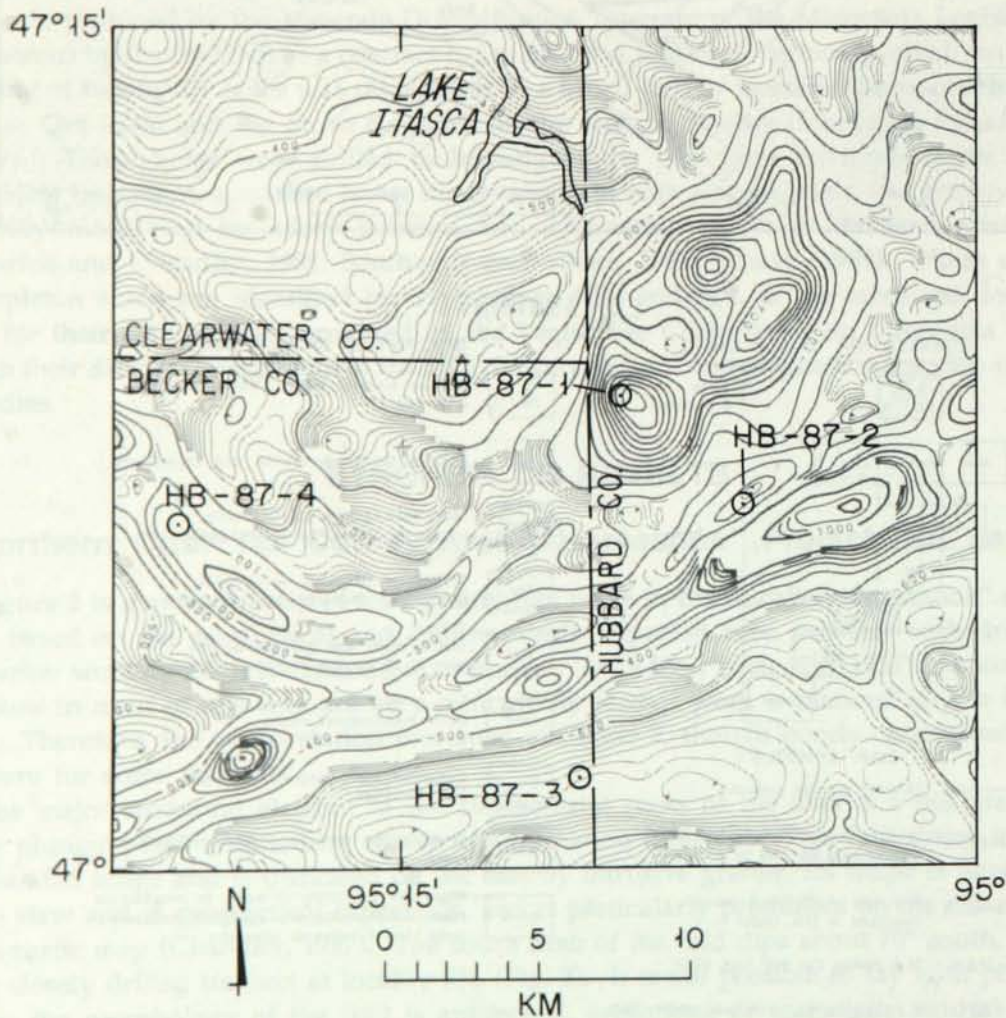


Figure 3. Aeromagnetic map (Chandler, 1985) of the Hubbard-Becker-Clearwater Counties project area with drill-hole locations superimposed. Contour interval is 10 nT.

anomalies; very similar anomalies have been drilled at several localities in central Minnesota and are due to hornblende-rich, lamprophyre-like rock types of generally intermediate composition.

All the Archean rock units are transected by Early Proterozoic diabase dikes (Pd) of the Kenora-Kabetogama dike swarm (Southwick and Day, 1983; Halls, 1986; Southwick and Halls, 1987). A particularly large master dike crosses the northeast quadrant of the study area (Fig. 2); it can be traced geophysically for many tens of kilometers along strike beyond the map boundaries.

The Archean geology of this area has clear parallels with that of other greenstone belts in the Superior Province, and therefore it is possible that significant gold deposits (e.g., Colvine and others, 1988) or other types of volcanic-hosted base-metal deposits (Sawkins, 1989) may eventually be found. However, exploration will be seriously hampered by very thick glacial overburden, especially in the northwestern half of the map area, and therefore an accurate assessment of subsurface mineral potential will be slow and expensive to develop.

### **Hubbard-Becker-Clearwater Counties Area (HB Series).**

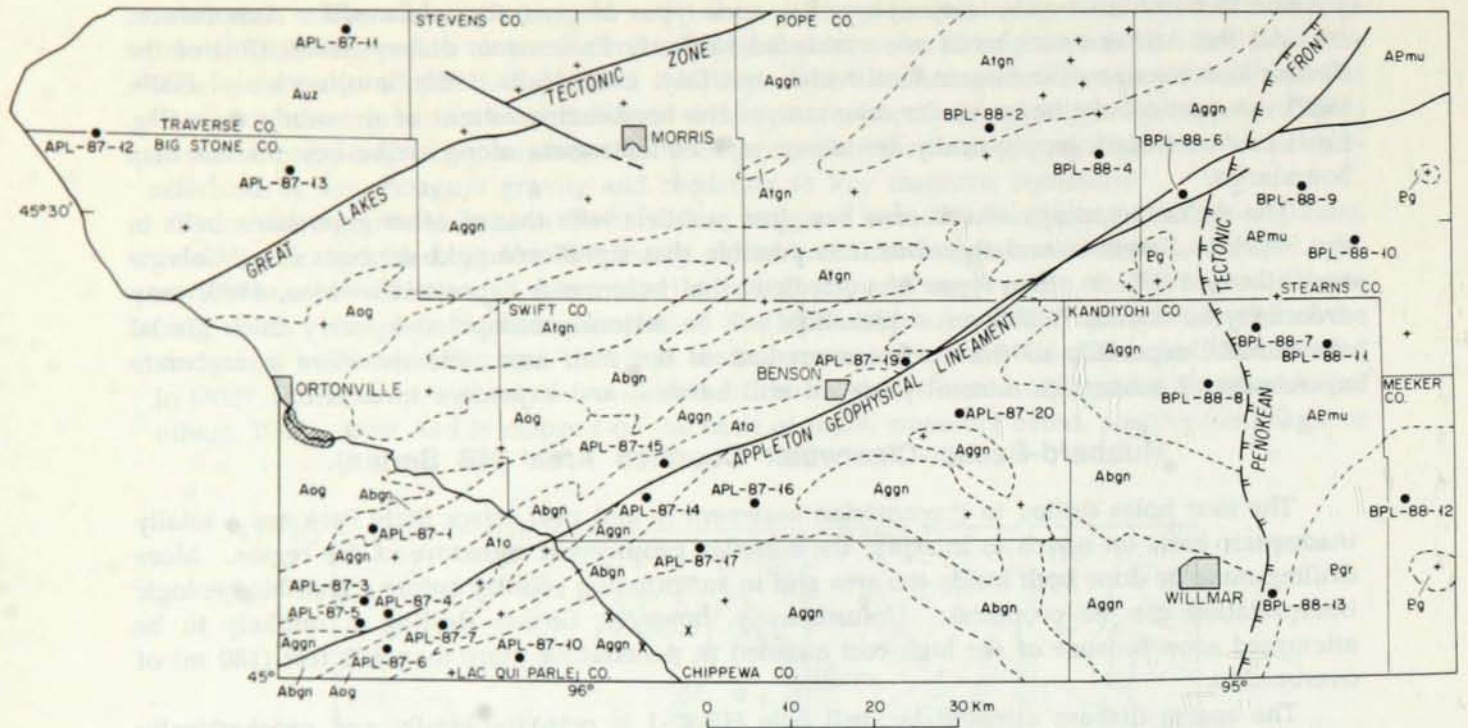
The four holes drilled to Precambrian basement in and near Itasca State Park are a totally inadequate basis on which to interpret the complex geophysical signature of the region. More drilling must be done both inside the area and in surrounding country before a credible geologic interpretation can be proposed. Unfortunately, however, further drilling is unlikely to be attempted soon because of the high cost entailed in penetrating more than 600 feet (180 m) of overburden.

The coarse diabase sampled by drill hole HB-87-1 is petrographically and geochemically similar to the diabase in Kenora-Kabetogama dikes (Southwick and Day, 1983; Southwick and Halls, 1987). This suggests that the ovoid magnetic and gravity highs on which HB-87-1 was sited (Fig. 3) are caused by an Early Proterozoic diabase-gabbro plug. The plug may be a large-scale analog of the dike "buds," or thick places of localized high magmatic flow rate, that have been described along Cenozoic and recent dikes at several localities (e.g., Delaney and Pollard, 1981). In northern Iceland, certain of the active shield volcanoes in the neo-volcanic zone are inferred to lie above large bud-like vertical conduits along a major rift. These volcanoes in turn are the sources for long dike swarms in associated rift structures at shallow crustal levels (Sigurdsson, 1987). By analogy, the Kenora-Kabetogama dike swarm may have been fed from a family of Proterozoic shield volcanoes that lay above vertical conduits to magma chambers in the deep crust or upper mantle. The plug at drill site HB-87-1 is a speculative candidate for such a subvolcanic conduit.

### **Area near the Appleton Geophysical Lineament (APL and BPL Series)**

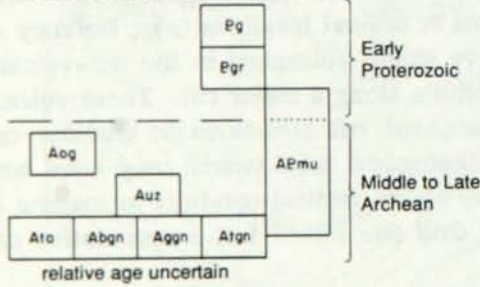
Drilling along the Appleton discontinuity has confirmed that it is a major brittle/ductile shear zone in the gneiss terrane of southwestern Minnesota (Fig. 4). In addition, geophysical analysis and follow-up drilling away from the discontinuity have contributed to new ideas on the late Archean assembly of the southern part of the Superior craton (for current interpretations and details, see Southwick and Chandler, 1988; Southwick and others, 1989; Schaap, 1989) and have broadly delineated the south-trending zone of Early Proterozoic plutons and supracrustal remnants that mark the deeply eroded foreland zone at the west margin of the Penokean orogen (Fig. 4; also Southwick and others, 1988, 1989). However, because the overall area of interest is large and complex, several more years' work will be needed before the schematic relationships shown on the sketch map of Figure 4 can be superseded by a more detailed and credible geologic map.





**EXPLANATION**

**CORRELATION OF MAP UNITS**



**DESCRIPTION OF MAP UNITS**

- Eg** Gabbro, troctolite, pyroxenite, and related rocks
  - Egr** Granite, megacrystic; resembles Rockville Granite at type locality (Morey, 1978)
  - AEmu** Metamorphic rocks, undivided; includes Proterozoic rocks & reworked Archean basement. Cut by Proterozoic granitoid plutons
  - Aoz** Odessa granite: red to maroon biotite granite
  - Auz** Undivided rocks of low metamorphic grade at the southern margin of the greenstone-granite terrane
  - Ato** Tonalite gneiss and amphibolite
  - Abgn** Biotite-bearing paragneiss
  - Aggn** Granitic to granodioritic gneiss, locally hypersthene-bearing
  - Atgn** Tonalitic to granodioritic gneiss, locally hypersthene-bearing
- } Units variably injected by foliated leucogranite

**MAP SYMBOLS**

- - - - - Inferred geologic contact
- Inferred brittle-ductile fault zone
- / / / / / Approximate tectonic front of Penokean orogen
- APL-87-4 MGS drill hole, this report
- + Other drill hole to Precambrian rock
- x Isolated outcrop of Precambrian rock
- ▨ Area of closely spaced bedrock outcrops

Figure 4. Preliminary and highly generalized geologic map of Precambrian rocks near the Appleton geophysical lineament with drill-hole locations superimposed.

Although the primary objectives of the ongoing geophysics and drilling project in southwestern Minnesota are to produce a geologic map and to understand the major lineaments (including the Appleton) that traverse the Archean gneiss terrane, the work has practical ramifications for mineral exploration and ground-water management as well. First, it is well established that crustal sutures and shear zones within very old Archean crust in other continents have controlled the emplacement of anorogenic igneous rocks, including kimberlite. Aeromagnetic anomalies suggestive of small anorogenic plugs and pipes are abundant near the Appleton feature, but they are widely scattered on either side of it and their genetic association with the suture zone is not proven. One such anomaly was drilled in 1983 in Morrison County, well east of the present study area (Southwick and others, 1986; Southwick and Chandler, 1987), and was found to be caused by a plug-like mass of biotite- and olivine-bearing clinopyroxenite of no special economic interest. Nevertheless, we continue to think that diamondiferous kimberlite pipes may occur in the Archean gneiss terrane of Minnesota, and that a key to finding them may well lie in understanding the relationship between deep crustal shear zones and kimberlite petrogenesis.

Secondly, recent studies have led to the recognition of potentially favorable conditions for sedimentary manganese deposition in the Upper Cretaceous marine strata that overlie unconformably the Precambrian basement in western Minnesota and eastern South Dakota (Setterholm and others, 1989, and references therein). In order to apply current thinking on manganese ore genesis to the specific case of Minnesota's Upper Cretaceous rocks, it is necessary to establish through drilling the vertical and lateral stratigraphic variations in the nearshore facies of the marine Cretaceous section that was deposited on Precambrian basement near the eastern edge of the Western Interior seaway. The drilling undertaken in the western part of the Appleton drilling project area has contributed significantly to the stratigraphic studies of the Cretaceous rocks, especially in Lac Qui Parle and Big Stone Counties. Good correlations have been developed between distinctive intervals of the previously undivided Cretaceous sequence in Minnesota and the standard Upper Cretaceous stratigraphic sequence as it is developed beneath the Great Plains. An understanding of the shoreward transitions of these strata is evolving.

In the Late Jurassic or early part of the Cretaceous, a thick saprolitic residuum developed on the Precambrian rocks of western Minnesota as a result of deep tropical weathering. This saprolitic material is locally rich enough in kaolinite to be a viable source of commercial kaolin (Setterholm and others, 1989). The saprolite layer varies laterally in its thickness and clay-mineral content, and also is covered by a variable thickness of Quaternary glacial and fluvial deposits. Therefore, the search for commercial-grade kaolin resources is basically a subsurface problem, and the economic viability of any particular deposit depends critically on the thickness, depth, and clay-mineral composition of the saprolitic layer. Such data have been a by-product of the present scientific drilling program.

Finally, the ground-water resources of the western part of the study area are highly variable in quantity and quality, and the three-dimensional stratigraphy of the major Quaternary aquifer systems is poorly understood. The data acquired on Quaternary materials in the present study will help in establishing the stratigraphic order and sedimentary history of these complex glaciogenic deposits—necessary steps toward understanding the hydrogeologic behavior of the Quaternary aquifers.

### **Overburden Conditions In the Itasca Moraine Complex**

Our drilling in the Hubbard-Becker-Clearwater and Otter Tail project areas (HB and HS holes, respectively) commonly encountered glacial drift thicknesses in excess of 500 feet (150 m). A large proportion of this thickness in both areas consists of water-saturated coarse sand and gravel. The great thickness of slump-prone sandy and gravelly outwash in these holes suggests that deep



drilling throughout the general area of the Itasca moraine complex (Wright, 1972; Hobbs and Goebel, 1982) is likely to be difficult and expensive, and that progress in solving problems of Precambrian geology there is likely to be slow. On the other hand, the thick sequences of buried outwash in the region constitute aquifer systems of unevaluated but potentially immense yield, and their hydrogeologic properties warrant further study.

## ORGANIZATION OF THE DATA

The main body of this circular contains 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. Some of the uncored holes produced clean cuttings of sound rock that were amenable to petrographic and chemical study.

The data are organized geographically by project. Hole locations are shown approximately on the project index maps. Detailed locations are given on each log in the abbreviated township-range-section (T-R-S) system (see below), and plotted on a topographic map of the legal section in which the hole was drilled.

### Explanation of the Abbreviated T-R-S System

Except for the eastern half of Cook County, in the extreme northeast corner of the state, all townships in Minnesota are north of a zero standard parallel and west of a zero principal meridian. Therefore, the great majority of Minnesota townships, including those in the present study areas, are described as T.(Y)N., R.(X)W. 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. 130 N. and R. 33 W., 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  $\frac{1}{4}$ , SE  $\frac{1}{4}$  . . ." system that traditionally has been used in legal land descriptions. In the ABCD system (Fig. 5), 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  $\frac{1}{4}$  of the SE  $\frac{1}{4}$  of the SW  $\frac{1}{4}$  of the NW  $\frac{1}{4}$  of section 29, Hartford Township, Todd County, would be described as 130-22-29 BCCDA.

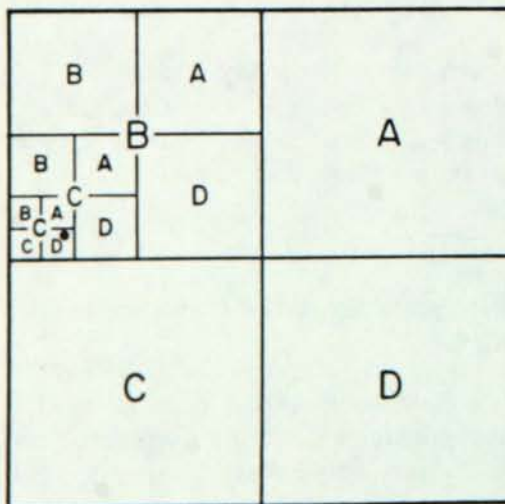


Figure 5. Diagram to illustrate the process of locating a drill hole (heavy dot) within a section by means of the abbreviated T-R-S system. See text for explanation.



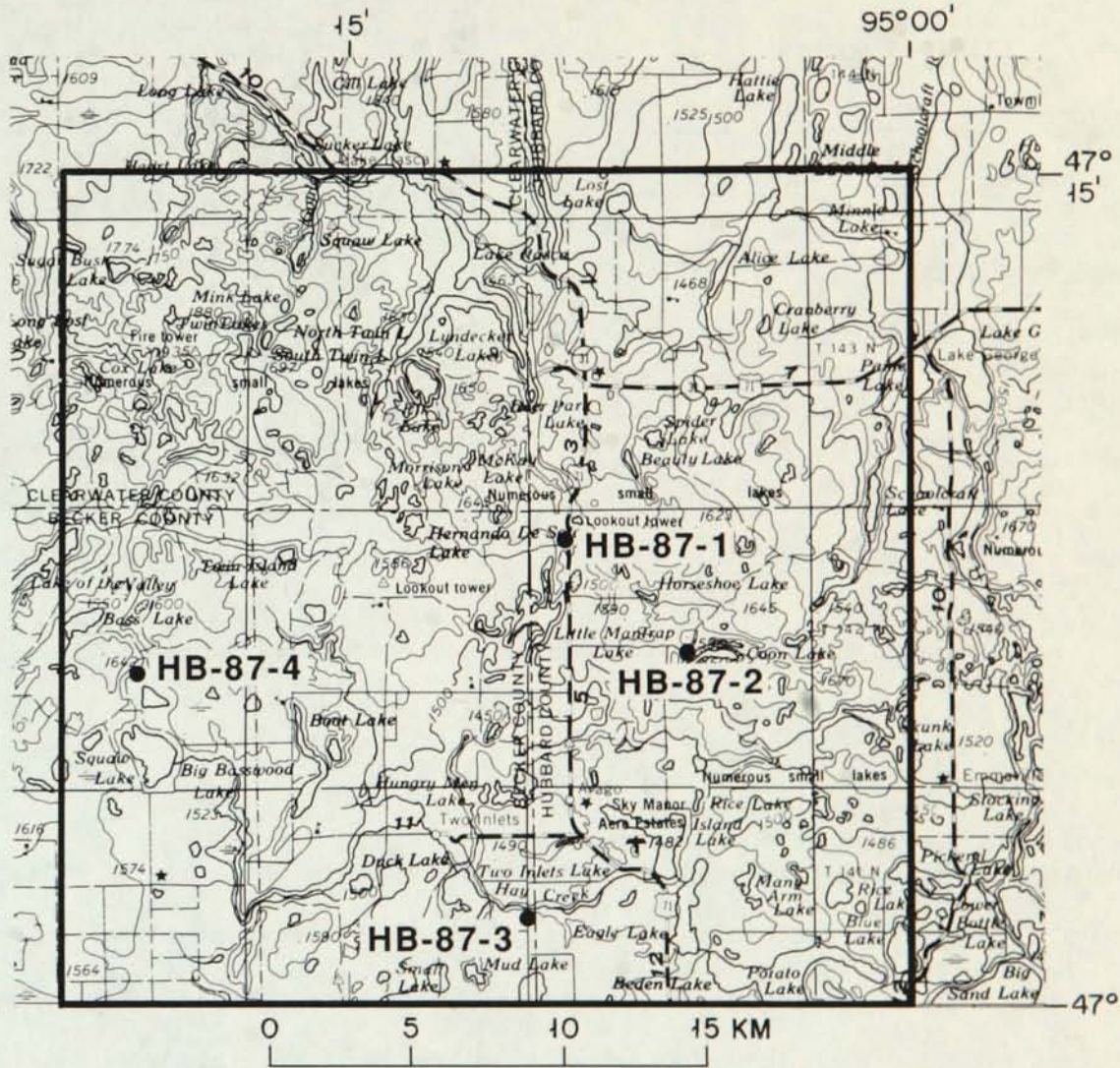


Figure 6. Locations of drill sites, Hubbard-Becker-Clearwater Counties project area.

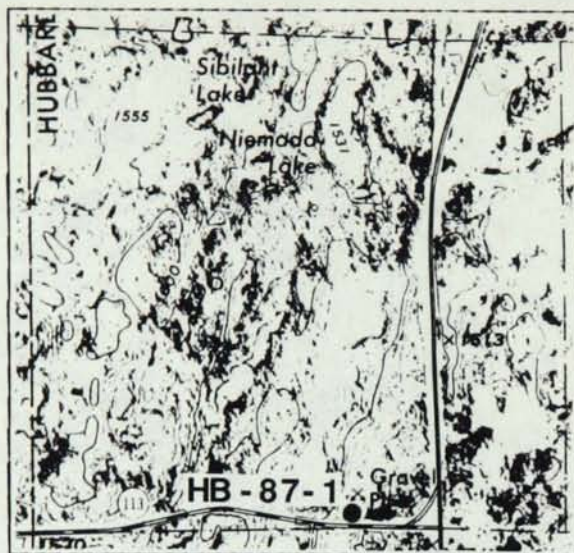


Field number HB-87-1Date completed June 1, 1987MGS unique number 420078MGS lab number 2619

LOCATION (see map at right)

T-R-S 142-35-6 DCCDCBCounty HubbardQuadrangle Lake Itasca 7.5'

## HOLE PARAMETERS

Surface elevation 1575 ± 5 ftTotal depth 680 ftElevation, top of  
Precambrian rock 938 ftCore interval 670-680 ftCore recovered 10 ft

## ABBREVIATED LITHOLOGIC LOG (intervals recorded are depths in feet)

Interval	Description
QUATERNARY DEPOSITS	
0-104	Sand, coarse sand, gravel
104-160	Mainly silty sand; gray; scattered layers or lenses of silty clay, coarse sand and gravel
160-373	Mainly sandy clay and silty sand; light brown to olive; interpreted as sandy till with interbeds of sand
373-410	Sand, coarse to fine, gray; abundant carbonate and black aphanitic grains
410-468	Clay and sandy clay, gray to olive-gray; possibly a lacustrine deposit
468-501	Mainly sand and coarse sand; contains wood fragments toward top of interval and wood chips plus gastropod shells near base
501-515	Till, sandy to clayey, medium gray
515-590	Sandy to clayey till, reddish-brown to brownish-gray; probably of Superior provenance

## CRETACEOUS SEDIMENTARY ROCKS (reworked regolith)

590-618 Clay shale, bluish-gray  
618-622 Coarse angular sand interbedded with white kaolin  
622-637 Clay shale, bluish-gray

## REGOLITH ON PRECAMBRIAN ROCK

637-649 Clay, blue-green; variable amounts of partly decomposed rock  
649-670 Mainly soft rock with zones of hard rock and very soft blue-green  
clay; rock is fine to medium grained, dark greenish gray

## SOUND PRECAMBRIAN ROCK

670-680 Coarse-grained diabase or fine-grained gabbro (near definitional  
boundary); numerous hairline fractures lined with chlorite

## PETROGRAPHIC DESCRIPTION OF CORE

Principal rock type: Coarse diabase or fine gabbro.

Mineralogy: Plagioclase, normally zoned in An<sub>45-55</sub> range (45-50%); clinopyroxene (40-50%); hornblende (2-3%); biotite (1-2%). Minor amounts of interstitial quartz, myrmekite, symplectite; accessory magnetite, apatite. Abundant development of secondary sericite, various green phyllosilicates, actinolite.

Texture: Equigranular diabasic; plagioclase laths (aspect ratio 1:4) are about 1-2 mm long and intergrown with prismatic clinopyroxene crystals of similar dimensions. Significant late alteration of clinopyroxene to actinolite, chlorite, biotite, and brownish clay-mineral species.

Structure: Essentially massive.

Comments: Rock is petrographically similar to interior portions of larger Kenora-Kabetogama dikes. See Southwick and Day (1983), Southwick and Halls (1987) for further details.

## CHEMICAL DATA

Rock type analyzed: Coarse diabase (samples from depths 671 and 678 ft)

## Major elements (wt.%)

	HB-1-671	HB-1-678
SiO <sub>2</sub>	48.9	50.5
Al <sub>2</sub> O <sub>3</sub>	12.5	12.5
Fe <sub>2</sub> O <sub>3</sub> *	16.1	16.5
MgO	5.86	5.42
CaO	5.80	8.79
Na <sub>2</sub> O	2.51	2.16
K <sub>2</sub> O	1.06	0.50
TiO <sub>2</sub>	1.31	1.35
MnO	0.20	0.22
P <sub>2</sub> O <sub>5</sub>	0.13	0.14
H <sub>2</sub> O+	3.5	2.0
H <sub>2</sub> O-	2.6	0.6
CO <sub>2</sub>	0.12	0.01

\*Total Fe as Fe<sub>2</sub>O<sub>3</sub>Analytical method: XRF, DCP  
wet chemistry, NAAnalyst: X-ray Assay Labora-  
tories, Ltd., Don Mills, Ontario

## Minor elements (ppm)

	HB-1-671	HB-1-678
Cl	350	450
Ba	210	180
Zr	50	50
Cr	150	55
Y	20	30
Nb	30	20
Rb	25	30
Sr	120	100
Sc	49.3	54.5
Sb	<0.2	<0.2
Co	67.0	56.0
As	8	<2
Se	<3	<3
Br	2.1	2.1
Mo	<5	<5
Cs	0.9	1.5
Hf	1.5	2.1
Ta	<0.5	0.7
W	<3	<3
Th	0.9	1.2
U	<0.2	0.4
La	11.5	11.3
Ce	25	25
Nd	13	13
Sm	2.9	3.0
Eu	1.0	1.2
Tb	0.5	0.5
Yb	2.3	2.9
Lu	0.34	0.40

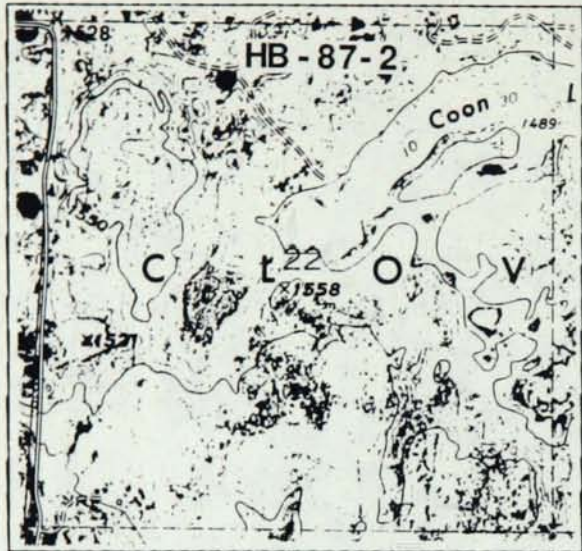


Field number HB-87-2Date completed June 5, 1987MGS unique number 420079MGS lab number 2620

LOCATION (see map at right)

T-R-S 142-35-22 BABDDACounty HubbardQuadrangle Skunk Lake 7.5'

## HOLE PARAMETERS

Surface elevation 1519 ± 5 ftTotal depth 702 ftElevation, top of  
Precambrian rock 888 ftCore interval no coreCore recovered 0; cuttings only

## ABBREVIATED LITHOLOGIC LOG (intervals recorded are depths in feet)

Interval	Description
QUATERNARY DEPOSITS	
0-18	Sandy till, sand, gravel, and silt; calcareous
18-42	Rocky, very sandy till; gravel lenses. Calcareous, yellow brown
42-58	Sand and gravel
58-78	Loamy, sandy till; calcareous, gray
78-151	Sand and gravel; minor silt and clay beds. Sands rich in lithic grains of black rock
151-163	Organic-rich silt; wood-bearing zone near top of interval; sand and gravel at base
163-176	Sandy till, greenish-gray, calcareous
176-216	Sand, coarse sand, fine gravel
216-274	Clayey silt, silt, very fine sand; abundant carbonate
274-413	Fine to medium sand; grades into overlying and underlying units
413-519	Coarse sand; layers or lenses of fine to coarse gravel. Some admixture of Superior rock types in gravel fraction
519-631	Predominantly gravel; clasts include some felsite, abundant basalt. Very coarse below 573 ft depth

## REGOLITH ON PRECAMBRIAN ROCK

631-697 Clay, green to greenish-gray; admixed chips of soft to moderately stiff phyllitic rock below 653 ft depth

## SOUND PRECAMBRIAN ROCK

697-702 Phyllite, chlorite- and muscovite-bearing. Poor recovery of cuttings



Field number HB-87-3Date completed June 15, 1987MGS unique number 420080MGS lab number 2621

LOCATION (see map at right)

T-R-S 141-36-13 DADABACounty BeckerQuadrangle Two Inlets 7.5'

## HOLE PARAMETERS

Surface elevation 1490 ± 5 ftTotal depth 760 ftElevation, top of  
Precambrian rock 776 ftCore interval no coreCore recovered 0; cuttings only

## ABBREVIATED LITHOLOGIC LOG (intervals recorded are depths in feet)

Interval	Description
QUATERNARY DEPOSITS	
0-56	Sand, coarse sand, gravel; calcareous; variegated tan colors
56-72	Till, very sandy, gray; abundant small pebbles of carbonate, aphanitic black rocks
72-85	Till, sandy; abundant cobbles of carbonate, granitoid rocks. Matrix is gray to bluish gray
85-114	Till, very sandy to loamy, light to medium gray, calcareous. Becomes more clay rich with depth
114-118	Silty clay, black; rich in organic matter
118-129	Coarse sand and gravel
129-165	Sandy till, light gray, calcareous
165-183	Sand and gravel, locally coarse
183-276	Sandy till, very carbonate-rich, gray
276-283	Coarse sand and gravel
283-305	Sandy till, calcareous, gray
305-344	Sand and gravel
344-384	Sandy till, calcareous, gray; oxidized zone, 353-355 ft
384-402	Coarse sand, fine- to medium-grained gravel



## CRETACEOUS SEDIMENTARY ROCKS

- 402-413 Clay, soft, dark gray to black  
413-419 Shale, dark greenish-gray; thin kaolinite-rich interbeds  
419-585 Clay shale, dark gray, waxy, noncalcareous; siltstone and sandstone beds become more numerous toward base  
585-714 Interbedded dark shale and kaolinitic sandstone; minor lignite

## REGOLITH ON PRECAMBRIAN ROCK

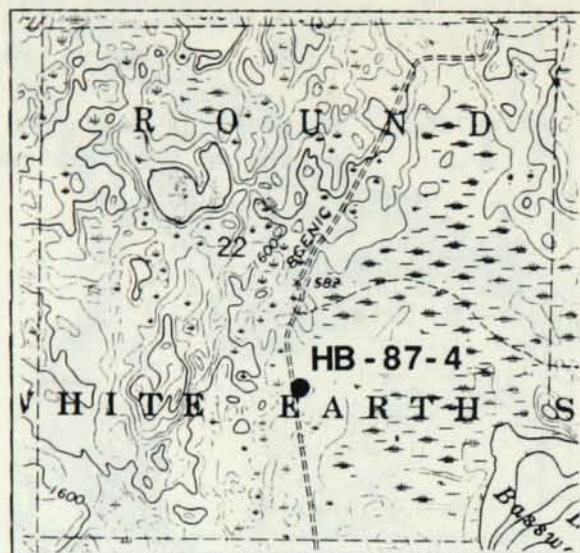
- 714-760 White, blue-green and green clay that contains angular, coarse grains of residual quartz. Granitoid protolith indicated

Field number HB-87-4Date completed June 22, 1987MGS unique number 420081MGS lab number 2622

LOCATION (see map at right)

T-R-S 142-37-22 DBCCBCCounty BeckerQuadrangle Big Basswood Lake

## HOLE PARAMETERS

Surface elevation 1592 ± 5 ftTotal depth 734 ftElevation, top of  
Precambrian rock 930 ftCore interval 724-734 ftCore recovered 10 ft

## ABBREVIATED LITHOLOGIC LOG (intervals recorded are depths in feet)

Interval

Description

## QUATERNARY DEPOSITS

0-21	Till, sandy and very bouldery, yellow-brown
21-68	Sand and gravel; variegated light colors
68-110	Clayey till; various shades of dark gray to bluish gray
110-144	Coarse sand, gravel
144-150	Clayey till
150-172	Sand and gravel; sparse interbeds of clay
172-223	Clay and silt, dark gray to greenish-gray; probably a lacustrine deposit
223-237	Sand and gravel
237-313	Loamy to sandy till, pale brown to dark gray
313-318	Sand
318-351	Loamy to sandy till, dark gray; lenses or layers of sand distributed throughout
351-361	Sand
361-418	Loamy to sandy till, dark gray
418-430	Sand, fine to coarse
430-493	Loamy to sandy till, dark gray
493-537	Interbedded sand, silt, sandy clay; abrupt color changes from green to pale brown to gray

## CRETACEOUS SEDIMENTARY ROCK

537-662 Clay shale; minor sandstone beds near base. Dark gray

## REGOLITH ON PRECAMBRIAN ROCK

662-718 Clay, pale gray to blue-gray; contains feldspar grit below 677 ft depth

718-722 Transition to fresh feldspathic rock

## SOUND PRECAMBRIAN ROCK

722-734 Hornblende monzodiorite speckled brick red and black

## PETROGRAPHIC CORE DESCRIPTION

Principal rock type: Hornblende monzodiorite.

Mineralogy: 65% plagioclase (An<sub>30</sub>) that contains abundant dusty inclusions of hematite and is therefore brick red in color; 25% amphibole that consists of two phases (one colorless to pale green and the other green to blue green), intimately intergrown; 9% microcline, chiefly as interstitial granules. Accessory phases are magnetite, sphene, apatite, and epidote.

Texture: Hypidiomorphic granular (grain size 0.5-3 mm). Narrow, discrete zones of brittle fracturing locally contain micromylonite. Some strain-induced recrystallization along grain boundaries.

Structure: Massive; faint suggestion of inclined foliation.

Comments: Rock termed a syenite in the field because of its strong red color. If fact, however, potassium feldspar is greatly exceeded by plagioclase and the correct rock name is monzodiorite.

## CHEMICAL DATA

Rock type analyzed: Hornblende monzodiorite (sample depth 724 ft)

## Major elements (wt.%)

HB-4-724

SiO <sub>2</sub>	59.8
Al <sub>2</sub> O <sub>3</sub>	15.1
Fe <sub>2</sub> O <sub>3</sub> *	6.11
MgO	3.18
CaO	3.94
Na <sub>2</sub> O	6.51
K <sub>2</sub> O	3.17
TiO <sub>2</sub>	0.66
MnO	0.13
P <sub>2</sub> O <sub>5</sub>	0.39
H <sub>2</sub> O+	0.9
H <sub>2</sub> O-	0.1
CO <sub>2</sub>	0.37

\*Total Fe as Fe<sub>2</sub>O<sub>3</sub>Analytical method: XRF, DCP  
wet chemistry, NAAnalyst: X-ray Assay Labora-  
tories, Ltd., Don Mills, Ontario

## Minor elements (ppm)

HB-4-724

Cl 100

Ba 435

Zr 170

Cr 36

Y 10

Nb 20

Rb 75

Sr 200

Sc 12.9

Sb &lt;0.2

Co 17.0

As 2

Se &lt;3

Br 6.9

Mo &lt;5

Cs 0.7

Hf 5.1

Ta &lt;0.5

W &lt;3

Th 7.5

U 1.9

La 50.5

Ce 96

Nd 43

Sm 8.0

Eu 2.7

Tb 0.8

Yb 1.9

Lu 0.28





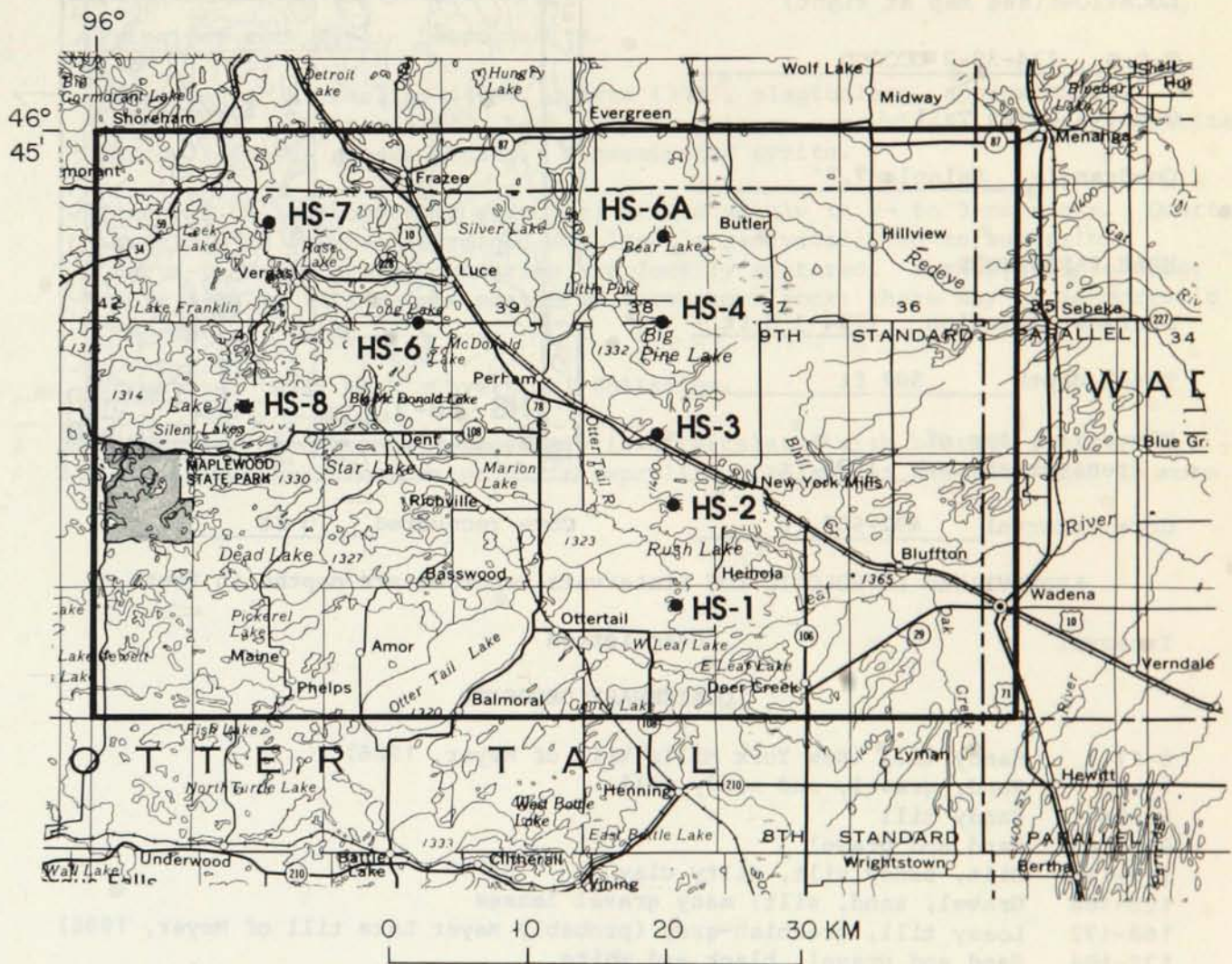


Figure 7. Locations of drill sites, northern Otter Tail County project area. Middle digits of hole numbers (88) have been omitted to reduce clutter.

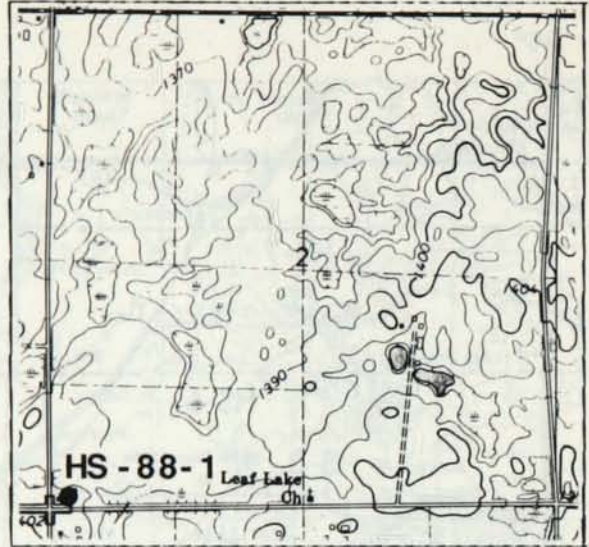


Field number HS-88-1Date completed May 19, 1988MGS unique number 242091MGS lab number 2743

LOCATION (see map at right)

T-R-S 134-38-2 CCCCCDCounty Otter TailQuadrangle Heinola 7.5'

## HOLE PARAMETERS

Surface elevation 1394 ± 5 ftTotal depth 502 ftElevation, top of  
Precambrian rock 1098 ftCore interval 492-502 ftCore recovered 10 ft

## ABBREVIATED LITHOLOGIC LOG (intervals recorded are depths in feet)

Interval

Description

## QUATERNARY DEPOSITS

0-11	Sandy till (New York Mills till of Meyer, 1986)
11-30	Sand, gravel, and sandy till
30-84	Sandy till
84-118	Sand and gravel
118-126	Silt, sandy silt, silty clay
126-168	Gravel, sand, silt; many gravel lenses
168-172	Loamy till, greenish-gray (probably Meyer Lake till of Meyer, 1986)
172-184	Sand and gravel, black and white
184-199	Loamy till, gray; sandy interbeds
199-233	Silt, silty clay, sand, and gravel
233-257	Clay and clayey till, dark gray
257-266	Loamy till, oxidized
266-296	Clay and clayey till, dark gray

## REGOLITH ON PRECAMBRIAN ROCK

296-304	Clay and gritty clay, light gray
304-310	Clay and gritty clay, red to red-brown
310-369	Gritty clay and soft rock chips; various hues of green
369-485	Clay, gritty clay; soft rock chips and numerous quartz veins; color is variegated green, gray, light gray



## SOUND PRECAMBRIAN ROCK

485-502 Mostly leucogranite; narrow (several cm) intervals of fine-grained schistose rock in cored interval

## PETROGRAPHIC DESCRIPTION OF CORE

Principal rock type: Leucogranite.

Mineralogy: Microcline (40%), quartz (30%), plagioclase, approximately An<sub>20</sub> (20%), chlorite (5%). Less than 1% primary muscovite. Accessory apatite, zircon, sphene, opaque phases. Disseminated pyrite.

Texture: Allotriomorphic granular; grains mainly in 2- to 3-mm range. Quartz is mildly to severely strained and locally recrystallized to subgrains. Quartz-feldspar grain boundaries are locally mortared. Megacrystic feldspar clots 5-10 mm in size are scattered throughout rock; these may be xenocrystic remnants.

Structure: Very weak subvertical foliation.

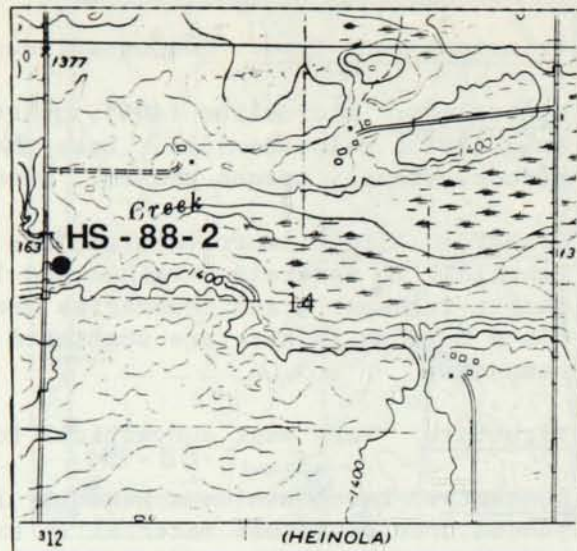
Comments: Leucogranite apparently is intercalated with biotite schist, as judged from schistose material in saprolite. No schist was recovered in core.

Field number HS-88-2Date completed May 13, 1988MGS unique number 242090MGS lab number 2744

LOCATION (see map at right)

T-R-S 135-38-14 BCCCBCounty Otter TailQuadrangle New York Mills West 7.5'

## HOLE PARAMETERS

Surface elevation 1372 ± 5 ftTotal depth 285 ftElevation, top of  
Precambrian rock 1132 ftCore interval 275-285 ftCore recovered 10 ft

## ABBREVIATED LITHOLOGIC LOG (intervals recorded are depths in feet)

Interval	Description
QUATERNARY DEPOSITS	
0-12	Sandy till, light brown
12-17	Clayey till, gray
17-62	Gravel and sand, coarse; thin clay-rich zone at 30-36 ft
62-81	Clayey till, gray, calcareous
81-158	Loamy to clayey till, very calcareous, gray, dark gray, and olive-gray. Abundant wood chips between 135 and 140 ft
158-168	Sandy till, brown to reddish-brown
168-240	Loamy to clayey till, calcareous; various shades of gray. Very clay rich and dark colored below 210 ft
REGOLITH ON PRECAMBRIAN ROCK	
240-273	Clay and gritty clay mixed with soft rock chips, greenish-gray
SOUND PRECAMBRIAN ROCK	
273-285	Felsic to intermediate metavolcanic rock, massive and coarsely clastic; aphanitic, dark gray, variably porphyritic and amygdaloidal

## PETROGRAPHIC DESCRIPTION OF CORE

Principal rock type: Felsic volcanoclastic rock, probably derived from hornblende dacite tuff-breccia.

Mineralogy: Quartz and untwinned plagioclase are principal constituents of recrystallized dacitic groundmass, together with small amounts of hornblende and biotite. Megacrysts (porphyroblasts that in some cases are replacements of igneous phenocrysts) include hornblende, cummingtonite, biotite, and sericitized plagioclase. Accessory opaque phases, apatite. Secondary carbonate, epidote, and clinozoisite occur in amygdules and also are distributed throughout rock.

Texture: Coarsely clastic; most clasts are metamorphosed porphyritic, amygdaloidal dacite that differ within a narrow range of texture and composition. Typical dacite groundmass consists of a neoblastic mosaic in which the crystals range between 0.01 and 0.1 mm in size. Megacrysts range up to 2 mm in largest dimension. Distinctive biotite-rich clasts (angular; 1-2 cm long) contain cummingtonite in place of hornblende and lack textural evidence of volcanic derivation.

Structure: Rock is essentially massive, without obvious bedding or foliation.

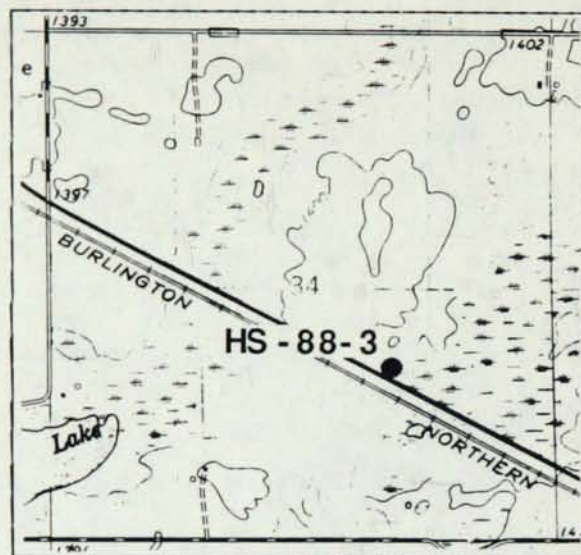


Field number HS-88-3Date completed May 9, 1988MGS unique number 242089MGS lab number 2745

LOCATION (see map at right)

T-R-S 136-38-34 DBDBDBCounty Otter TailQuadrangle New York Mills West 7.5'

## HOLE PARAMETERS

Surface elevation 1391 ± 5 ftTotal depth 436 ftElevation, top of  
Precambrian rock 1045 ftCore interval 426-436 ftCore recovered 10 ft

## ABBREVIATED LITHOLOGIC LOG (intervals recorded are depths in feet)

Interval	Description
QUATERNARY DEPOSITS	
0-36	Sandy to loamy till (New York Mills till of Meyer, 1986)
36-69	Sandy till, rocky at base (Wadena till of Meyer, 1986)
69-96	Sand and gravel; silt interbeds
96-114	Clayey till, dark gray, calcareous (Browerville till of Meyer, 1986)
114-157	Clayey to loamy till, greenish-gray to gray (Meyer Lake till of Meyer, 1986)
157-193	Silty clay, silt, fine sand; woody layers
193-209	Loamy to clayey till, gray; sandy interbeds
209-220	Cobbly sand and gravel
220-255	Loamy till, gray, calcareous
255-262	Sand, silt; clay-rich interbeds are possibly till
262-274	Loamy to clayey till; dark gray
274-283	Silt, sandy silt, fine sand
283-302	Clayey till, dark gray, calcareous (probably Eagle Bend till of Meyer, 1986)
302-332	Clay till and/or lacustrine silty clay, dark gray
332-346	Clayey till, dark gray

## REGOLITH ON PRECAMBRIAN ROCK

- 346-362 Smooth clay, orange-brown; gritty near base  
 362-399 Clay, gritty, locally pisolitic, orange-brown  
 399-424 Clay, gritty clay; soft rock chips near base. Olive green to turquoise green color

## SOUND PRECAMBRIAN ROCK

- 424-436 Speckled gray to greenish-gray porphyritic metadiabase or meta-andesite; mainly a porphyritic, fine-grained rock of hyababyssal aspect that contains meter-scale segregations of subpegmatitic diorite.

## PETROGRAPHIC DESCRITPION OF CORE

Principal rock type: Metamorphosed diabase porphyry that grades texturally into metagabbro and metadiorite.

Mineralogy: Blue-green hornblende, plagioclase in variable ratios; hornblende > plagioclase in most common porphyritic rock. Colorless clin amphibole present in subordinate amounts. Accessory opaque phases, sphene; secondary sericite, leucoxene, chlorite, carbonate in trace amounts.

Texture: Felted to decussate groundmass of actinolitic hornblende surrounds partially retrograded phenocrysts of plagioclase that are variably altered to granular clinozoisite, albite, and sericite. Phenocrysts range from 1 to 4 mm in length.

Structure: Weak, variable foliation primarily carried by oriented hornblende dips  $80^\circ \pm 5^\circ$ . Numerous semibrittle shear zones are diversely oriented throughout core. These are filled with partially recrystallized crushed material and introduced carbonate and range in thickness from 0.5 to 2 cm.

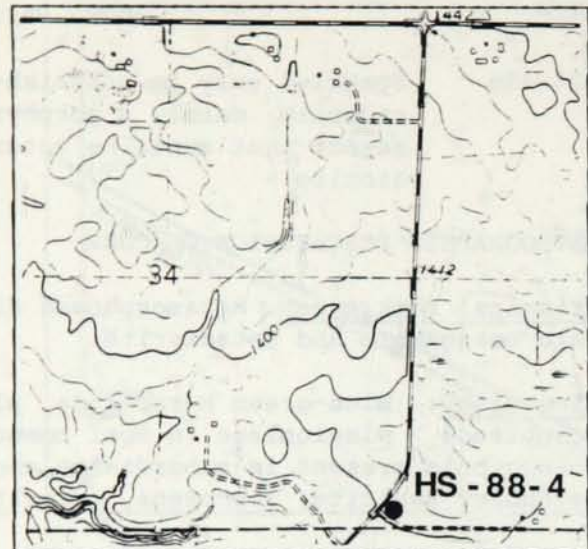


Field number HS-88-4Date completed June 28, 1988MGS unique number 242100MGS lab number 2746

LOCATION (see map at right)

T-R-S 137-38-34 DDDDCounty Otter TailQuadrangle New York Mills NW 7.5'

## HOLE PARAMETERS

Surface elevation 1400 ± 1 ftTotal depth 679 ftElevation, top of  
Precambrian rock 953 ftCore interval 669-679 ftCore recovered 10 ft

## ABBREVIATED LITHOLOGIC LOG (intervals recorded are depths in feet)

Interval	Description
QUATERNARY DEPOSITS	
0-18	Sandy till, brown to yellow-brown
18-56	Sandy, gravelly till; calcareous, gray
56-60	Well sorted and rounded gravel
60-109	Sandy clay, silty clay; sand interbedded. May be entirely braided river deposit or fluvial material intercalated with thin, sandy tills
109-217	Silty clay, soft, smooth, gray to faintly greenish-gray. Probably lacustrine deposit
217-221	Clayey to loamy till, stiff, calcareous, dark gray
221-296	Large block of variegated brown, green, and greenish-gray clay saprolite, presumably transported while frozen. Derived in part from coarse granitoid protolith
296-298	Coarse sand, well-sorted; clasts predominantly limestone
CRETACEOUS SEDIMENTARY ROCKS	
298-425	Clay shale, gray to dark gray; minor intercepts of silty shale, siltstone, fine sandstone

425-447 Clay shale interbedded with sandstone; sandstone becomes more abundant and coarser toward base

REGOLITH ON PRECAMBRIAN ROCK

447-486 Clay, white, pale gray, and pink

486-669 Clay; various shades of green and greenish gray; zones of variably weathered rock in clay below 527 ft

SOUND PRECAMBRIAN ROCK

669-679 Porphyritic metabasalt, dark greenish-gray; phenocrysts of plagioclase and clinopyroxene as large as 2 cm in greatest dimension

PETROGRAPHIC DESCRIPTION OF CORE

Principal rock type: Coarsely porphyritic metabasalt.

Mineralogy: Major minerals are plagioclase, clinopyroxene (two types; groundmass variety is browner, more birefringent than phenocryst variety), along with secondary green amphibole, chlorite. Minor minerals include brown hornblende, leucoxene, epidote (in part piemontite); carbonate and adularia occur in veins and amygdules. Apatite, sphene are very sparse accessories.

Texture: Modified intergranular groundmass is composed of plagioclase laths, granular clinopyroxene that is overgrown by secondary green amphibole. Clinopyroxene phenocrysts as large as 2 cm in diameter lack optical evidence of compositional zoning and are only slightly resorbed. Plagioclase phenocrysts are heavily sericitized and deeply embayed; their unzoned composition and their obvious disequilibrium with the groundmass liquid both suggest that they may be xenocrysts rather than magmatic crystals. Former olivine and/or orthopyroxene phenocrysts are totally replaced by deep green chlorite.

Structure: Rock is essentially massive and unfoliated. Nearly spherical amygdules contain piemontite, chlorite, and adularia.

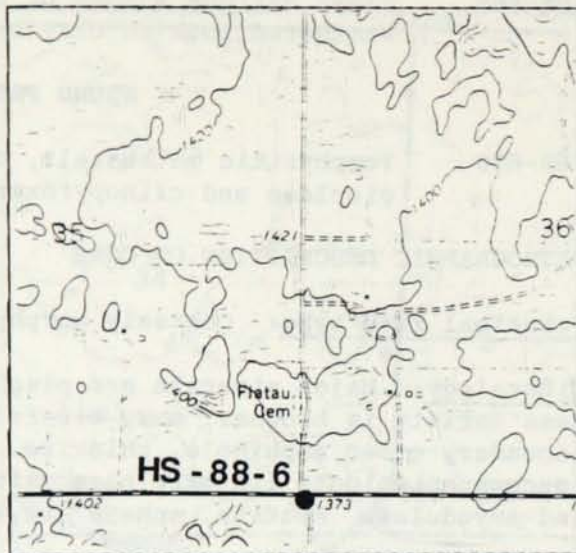
Comments: The texture and modal composition of this rock are similar to those of "Timiskaming" metabasalts in Canada.

Field number HS-88-6Date completed May 23, 1988MGS unique number 2748MGS lab number 242845

LOCATION (see map at right)

T-R-S 136-40-2 BAAAAACounty Otter TailQuadrangle Frazee 7.5'

## HOLE PARAMETERS

Surface elevation 1371 ± 3 ftTotal depth 237 ftElevation, top of  
Precambrian rock not reachedCore interval no coreCore recovered 0

## ABBREVIATED LITHOLOGIC LOG (intervals recorded are depths in feet)

Interval

Description

## QUATERNARY DEPOSITS

0-40	Loamy till, calcareous, gray
40-115	Sand, gravel, coarse gravel
115-151	Loamy to sandy till, calcareous; wood chips near base
151-172	Sand and gravel
172-178	Clayey till; stiff and slow drilling, greenish gray, calcareous
178-217	Sand and gravel
217-230	Loamy to sandy till, variably calcareous; wide color range from pale greenish gray to dark gray to brown
230-237	Pebbly to cobbly gravel, well-sorted, well-rounded, very permeable. Hole could not be maintained and was abandoned at 237 ft depth

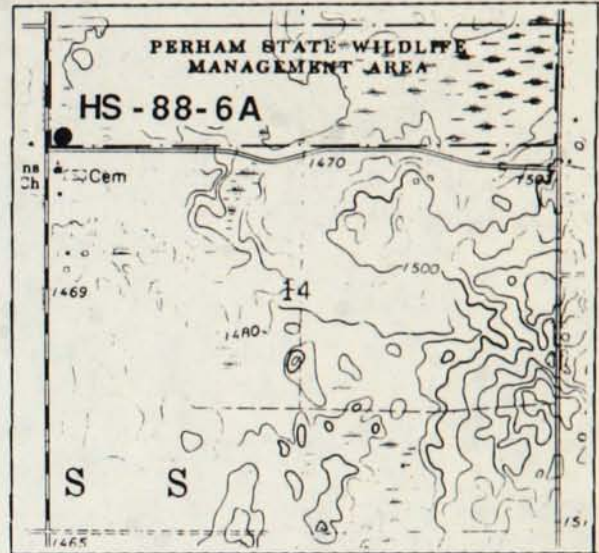


Field number HS-88-6ADate completed June 14, 1988MGS unique number 242212MGS lab number 2749

LOCATION (see map at right)

T-R-S 137-38-14 BCCCounty Otter TailQuadrangle New York Mills NW 7.5'

## HOLE PARAMETERS

Surface elevation 1478 ± 3 ftTotal depth 360 ftElevation, top of  
Precambrian rock not reachedCore interval no coreCore recovered 0

## ABBREVIATED LITHOLOGIC LOG (intervals recorded are depths in feet)

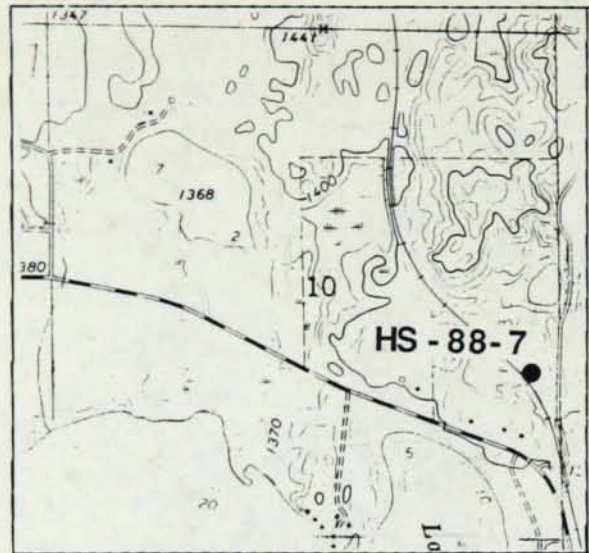
Interval	Description
QUATERNARY DEPOSITS	
0-40	Sandy, gravelly till, brown to yellowish-brown, calcareous
40-60	Sandy till, gray
60-78	Sand
78-82	Sandy till, gray
82-117	Interbedded sand, silty sand, silt, clay; possibly some thin layers of sandy till in sequence that is mainly fluvial
117-227	Loamy to sandy till with many thin layers or lenses of sand and gravel. Calcareous, generally gray
227-296	Loamy to sandy till, calcareous, gray to dark gray
296-360	Angular coarse sand with variable quantities of subangular to rounded pebbles and cobbles. Hole would not stand and was terminated at 360 ft

Field number HS-88-7Date completed June 3, 1988MGS unique number 242213MGS lab number 2750

LOCATION (see map at right)

T-R-S 137-41-10 DADBDCounty Otter TailQuadrangle Vergas 7.5'

## HOLE PARAMETERS

Surface elevation 1410 ± 2 ftTotal depth 657 ftElevation, top of  
Precambrian rock 942 ftCore interval no coreCore recovered 0

## ABBREVIATED LITHOLOGIC LOG (intervals recorded are depths in feet)

Interval

Description

## QUATERNARY DEPOSITS

0-17	Organic soil and gravelly till, yellow-brown, calcareous
17-37	Sandy till, gray, calcareous
37-50	Gravel and coarse sand, carbonate-rich
50-118	Sandy till, gray, very calcareous
118-137	Gravel and coarse sand
137-182	Fine silt, silty clay, clay, fine sand--possibly a lacustrine deposit
182-227	Loamy till, light to medium gray, calcareous
227-259	Medium to coarse sand, carbonate-rich; interbeds of silty clay and gravel, especially toward base
259-437	Mainly clay and silty clay with sandy interbeds
437-468	Till, clayey; bouldery toward top; gray to dark gray

## REGOLITH ON PRECAMBRIAN ROCK

468-484	Clay, brown, reddish-brown, pink, white; contains dispersed quartz granules
484-648	Clay; various shades of greenish gray, green, and pale green; variable quantities of quartz grit, kaolinized feldspar granules
648-657	Clay, bluish-green; small admixture of fine-grained soft rock chips. Hole collapsed and was terminated at 657 ft

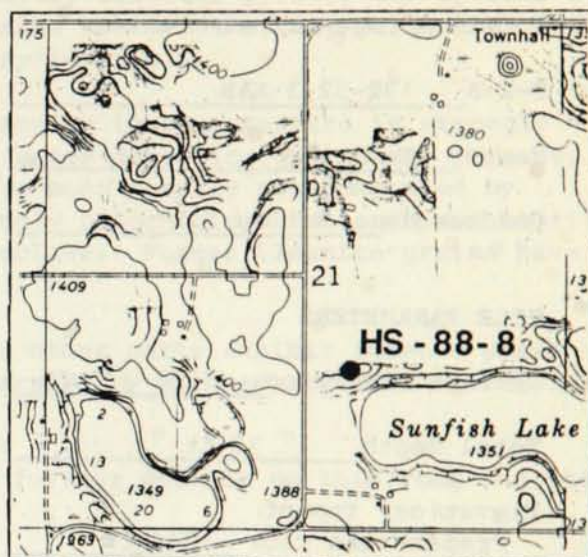


Field number HS-88-8Date completed May 27, 1988MGS unique number 2751MGS lab number 242846

LOCATION (see map at right)

T-R-S 136-41-21 DBCDBACounty Otter TailQuadrangle Star Lake 7.5'

## HOLE PARAMETERS

Surface elevation 1391 ± 3 ftTotal depth 430 ftElevation, top of  
Precambrian rock 996 ftCore interval no coreCore recovered 0; cuttings only

## ABBREVIATED LITHOLOGIC LOG (intervals recorded are depths in feet)

Interval	Description
QUATERNARY DEPOSITS	
0-302	Sand- and gravel-dominated outwash sequence. Intercepts composed of clayey silt and fine sand constitute about half the total thickness. They form layers generally thinner than 10 ft, which are intercalated among thicker layers of coarse sand, gravelly sand, and gravel. Entire sequence is calcareous
302-328	Clay and silty clay, greenish-gray. Possibly a lacustrine deposit
328-345	Loamy to sandy till, gray to bluish-gray, calcareous
345-381	Loamy to very sandy till, unusually rich in carbonate; gray
381-397	Loamy to clayey till, shale-rich; dark gray to greenish at base
REGOLITH ON PRECAMBRIAN ROCK	
397-425	Clay, grayish-green to blue-green
425-428	Fine-grained bedrock interspersed with zones of broken and partly decomposed rock
SOUND PRECAMBRIAN ROCK	
428-430	Cuttings from interval 428-430 ft are greenish-gray, aphanitic metabasalt ("greenstone")

Field number PBI-88-1Date completed June 30, 1988MGS unique number 242215MGS lab number 2739

LOCATION (see map at right)

T-R-S 132-32-3 AABCounty ToddQuadrangle Motley 7.5'

## HOLE PARAMETERS

Surface elevation 1265 ± 3 ftTotal depth 32 ftElevation, top of  
Precambrian rock 1244 ftCore interval 22-32 ftCore recovered 10 ft

## ABBREVIATED LITHOLOGIC LOG (intervals recorded are depths in feet)

Interval	Description
QUATERNARY DEPOSITS	
0-19.5	Gravel, well-sorted, brown; contains limestone clasts as well as abundant clasts of Superior affinity
19.5-22	Sandy clay, yellowish brown to gray
REGOLITH ON PRECAMBRIAN ROCK	
	None
SOUND PRECAMBRIAN ROCK	
22-32	Hornblende-rich gabbro or diorite



## PETROGRAPHIC DESCRIPTION OF CORE

Principal rock types: Oxide-rich ferrodiorite/hornblendite interlayered with plagioclase-rich ferrodiorite.

Mineralogy: Actinolite, hornblende, biotite, plagioclase, Fe-Ti oxides; accessory apatite, sphene; late-stage quartz, calcite, pyrite, and epidote in trace amounts. Plagioclase (An 30-50) makes up 15-65% of any particular layer and the proportions of mafic minerals vary inversely.

Texture: Medium-grained, massive-equigranular igneous texture is strongly modified by the growth of hydrous phases under deuteric conditions. Equant, subhedral grains of original pyroxene have been totally pseudomorphed by fibrous actinolite and overgrown by strongly pleochroic hornblende and biotite. The latter two also partly replace plagioclase. Former ilmenite grains have reacted to granular sphene and biotite.

Structure: Portions of core are massive; other parts exhibit igneous phase layering and igneous foliation that is carried by aligned crystals of tabular plagioclase.

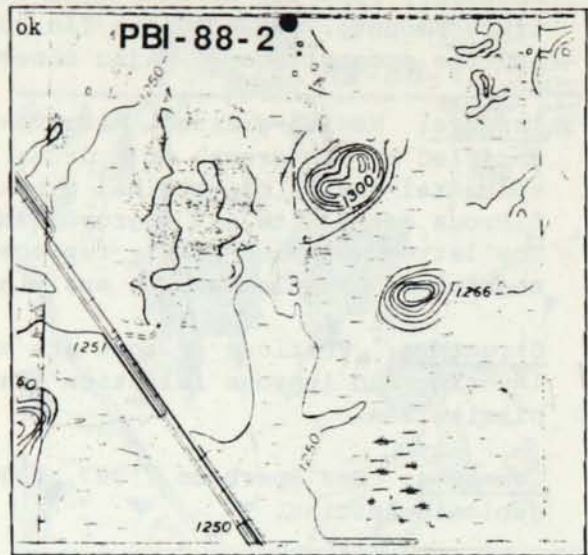
Comments: See Boerboom (1987, 1989) for further details on this rock and its geologic setting.

Field number PBI-88-2Date completed June 30, 1988MGS unique number 242214MGS lab number 2740

LOCATION (see map at right)

T-R-S 132-32-3 BAAAACounty ToddQuadrangle Motley 7.5'

## HOLE PARAMETERS

Surface elevation 1265 ± 1 ftTotal depth 38 ftElevation, top of  
Precambrian rock 1246 ftCore interval 28-38 ftCore recovered 10 ft

## ABBREVIATED LITHOLOGIC LOG (intervals recorded are depths in feet)

Interval	Description
QUATERNARY DEPOSITS	
0-12	Gravel, brown; clasts of limestone, various rocks of Superior affinity
12-19	Till, sandy; high gravel content; oxidized (yellow brown) in uppermost 2 ft, gray below
REGOLITH ON PRECAMBRIAN ROCK	
19-28	Weathered diorite or gabbro
SOUND PRECAMBRIAN ROCK	
28-38	Apatitic hornblende diorite or gabbro

## PETROGRAPHIC DESCRIPTION OF CORE

Principal rock type: Coarse-grained, opaque-rich melanocratic diorite.

Mineralogy: Plagioclase (64%), green hornblende (10%), actinolite (10%), apatite (8%), Fe-Ti oxides (5%), biotite (3%). Secondary quartz, carbonate in narrow veins; sericite, clinozoisite in alteration halos adjacent to veins.

Texture: Original equigranular igneous texture is all but obliterated by growth of decussate amphiboles that probably are of deuteritic origin. Apatite forms stout prisms intergrown with Fe-Ti oxides; polycrystalline apatite-oxide clusters appear to represent late-stage intercumulus crystallization that preceded growth by hydrous silicates.

Structure: Igneous foliation carried by aligned plagioclase crystals dips about 50°.

Comments: See Boerboom (1987, 1989) for further detail.





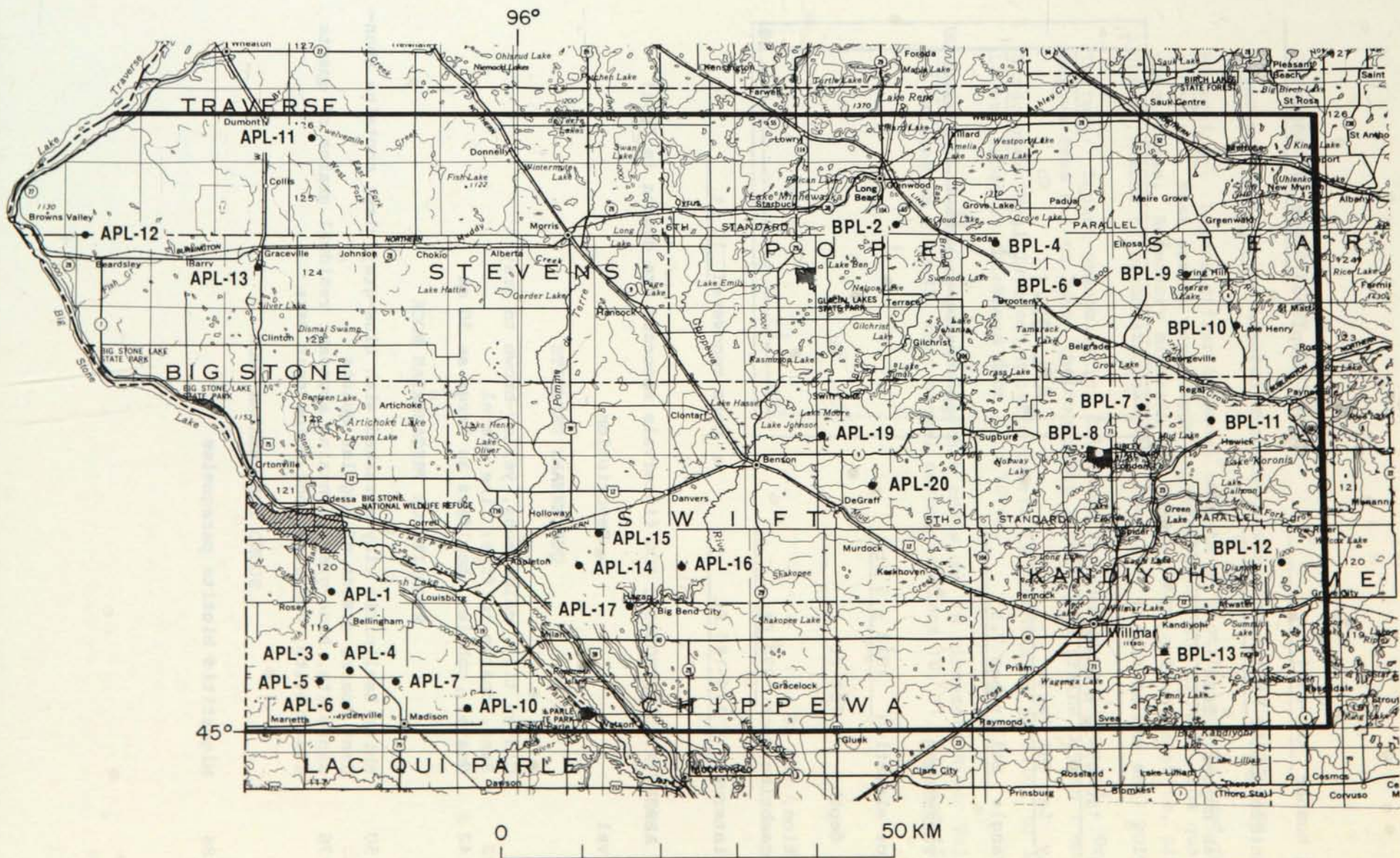


Figure 8. Locations of drill sites near the Appleton geophysical lineament and in adjacent tectonic domains. Middle digits of hole numbers (87 or 88) have been omitted to reduce clutter.

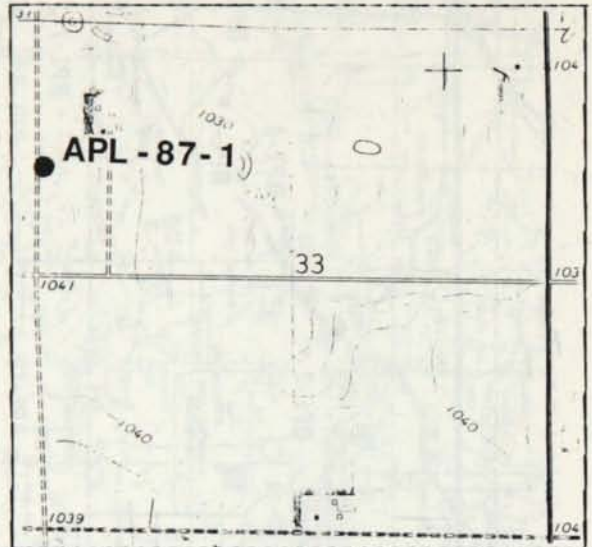


Field number APL-87-1Date completed Sept. 1, 1987MGS unique number 241416MGS lab number 2638

LOCATION (see map at right)

T-R-S 120-45-33 BCBBBCCounty Lac Qui ParleQuadrangle Bellingham 7.5'

## HOLE PARAMETERS

Surface elevation 1032 ± 5 ftTotal depth 186 ftElevation, top of  
Precambrian rock 890 ftCore interval 176-186 ftCore recovered 10 ft

## ABBREVIATED LITHOLOGIC LOG (intervals recorded are depths in feet)

Interval	Description
QUATERNARY DEPOSITS	
0-23	Clayey till, calcareous, yellow-brown to gray
23-132	Sand, coarse to fine; fine gravel
132-142	Gravel, cobbles, boulders as large as 30 cm
REGOLITH ON PRECAMBRIAN ROCK	
142-150	White kaolinitic clay streaked with blue-gray clay; contains abundant coarse grains of angular quartz
150-176	Saprolite, blue-gray; contains abundant residual grains of quartz and biotite; cohesive rock chips near base
SOUND PRECAMBRIAN ROCK	
176-186	Migmatitic biotite paragneiss

## PETROGRAPHIC DESCRIPTION OF CORE

Principal rock type: Layered biotite-quartz-plagioclase paragneiss.

Mineralogy: Layers differ in modal amounts of biotite, quartz, and plagioclase. Most common layer type contains about 20% biotite, 20% quartz, 60% plagioclase. Accessory minerals are opaque Fe-Ti oxides, apatite, zircon, epidote. Traces of secondary chlorite, hematite.

Texture: Equant granoblastic, foliated; thoroughly equilibrated. Grain size ranges from 0.1 to 2 mm; the commonest layers have grains 0.5 to 1 mm in size.

Structure: Well layered; biotite fabric is essentially parallel to layering. Layers range in thickness from 1 to 10 cm.

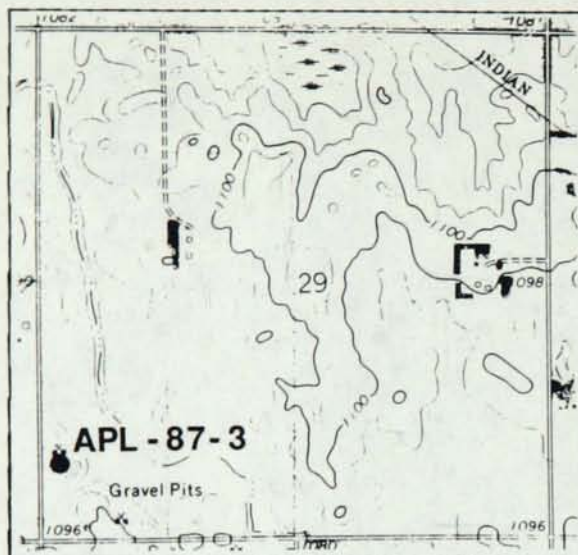
Comments: Resembles paragneiss that crops out in Minnesota River Valley north of Bellingham (120-45, near mutual corner sections 10, 11, 14, and 15).

Field number APL-87-3Date completed Sept. 2, 1987MGS unique number 241417MGS lab number 2639

LOCATION (see map at right)

T-R-S 119-45-29 CCBCDCCounty Lac Qui ParleQuadrangle Haydenville 7.5'

## HOLE PARAMETERS

Surface elevation 1084 ± 5 ftTotal depth 404 ftElevation, top of  
Precambrian rock 785 ftCore interval 394-404 ftCore recovered 10 ft

## ABBREVIATED LITHOLOGIC LOG (intervals recorded are depths in feet)

## Interval

## Description

## QUATERNARY DEPOSITS

0-38	Sandy till, calcareous; yellow brown except for basal 3-foot interval, which is gray. Thin bed of sand at 15 ft depth
38-46	Sand, medium to coarse; fine gravel
46-49	Till, clayey to loamy, dense, very calcareous, dark gray
49-54	Sand and fine gravel
54-66	Till, clayey to loamy, dense, very calcareous, medium gray

## CRETACEOUS SEDIMENTARY ROCKS

66-128	Lignitic silt, minor interbeds of fine sandstone and shale (Unit 6 of Setterholm, 1989)
128-235	Shale, soft, clay-rich, noncalcareous, medium-gray; becomes slightly finer, more silty, and weakly calcareous in basal 20-ft interval (Unit 5 of Setterholm, 1989)
235-248	Shale, hard, brittle, very calcareous, gray-brown to brown. Contains abundant <u>Inoceramus</u> shell fragments. (Units 3 and 4 of Setterholm, 1989)
248-300	Shale, siltstone, sandy shale; noncalcareous, various shades of gray (Unit 2 of Setterholm, 1989)



## REGOLITH ON PRECAMBRIAN ROCK

300-340 Clay, kaolinitic, white to pale gray; abundant residual muscovite  
340-394 Saprolitic clay, pale blue-gray grading to dark blue-gray; rock  
chips near base

## SOUND PRECAMBRIAN ROCK

394-404 Tonalite gneiss, medium-grained, strongly foliated

## PETROGRAPHIC DESCRIPTION OF CORE

Principal rock type: Tonalite gneiss.

Mineralogy: Plagioclase (45%), quartz (30%), hornblende (13%), biotite (11%), epidote (1%); accessory opaques, apatite, zircon. Zircon is euhedral and compositionally zoned.

Texture: Equant granoblastic, well foliated. Grain size ranges between 0.5 and 1.5 mm.

Structure: Strong foliation dips about 85°; carried by aligned biotite, hornblende, and shape fabric of quartz aggregates. Retrograded zone at bottom of core has textures, fabric indicative of shear.

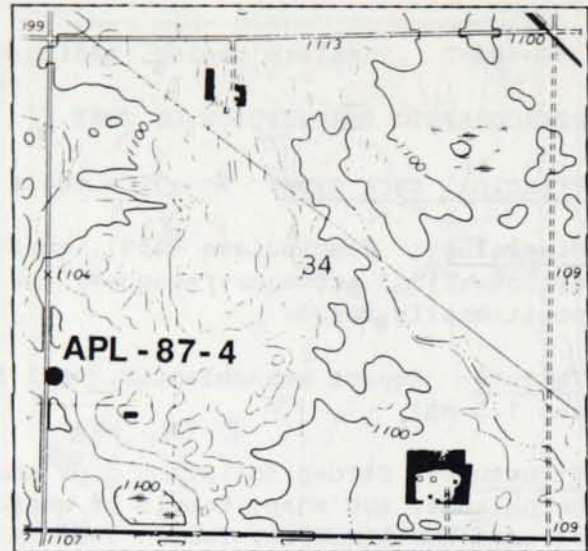
Comments: Homogeneous composition and texture suggest derivation from massive tonalite.

Field number APL-87-4Date completed Sept. 7, 1987MGS unique number 241418MGS lab number 2640

LOCATION (see map at right)

T-R-S 119-45-34 CBCBCCCounty Lac Qui ParleQuadrangle Haydenville 7.5'

## HOLE PARAMETERS

Surface elevation 1105 ± 5 ftTotal depth 391 ftElevation, top of  
Precambrian rock 782 ftCore interval 381-391 ftCore recovered 10 ft

## ABBREVIATED LITHOLOGIC LOG (intervals recorded are depths in feet)

Interval	Description
QUATERNARY DEPOSITS	
0-39	Clayey to loamy till, calcareous, yellow-brown, pebbly
39-46	Loamy till, stiff, calcareous, gray
46-51	Interbedded silty clay (till?) and sand; beds less than 1 foot thick
51-72	Sand, gravel, silty sand; coarsens upward
72-74	Boulders
74-130	Loamy to sandy till, calcareous, stiff, dark gray
130-138	Interbedded clay, sand, and gravel; gravel is rich in carbonate and granitoid clasts
CRETACEOUS SEDIMENTARY ROCKS	
138-220	Shale, noncalcareous, plastic, very smooth, gray (Unit 5 of Setterholm, 1989)
220-256	Shale, stiff, very calcareous, gray-brown. Abundant shell fragments (Units 3 and 4 of Setterholm, 1989)
256-323	Shale, siltstone, sandy shale, fine sandstone; noncalcareous to very weakly calcareous, various shades of gray (Unit 2 of Setterholm, 1989)

## REGOLITH ON PRECAMBRIAN ROCK

323-330 Clay, kaolin-rich, gritty, pinkish-white  
330-380 Saprolitic clay, variegated green, blue, white, pale gray; angular quartz grit

## SOUND PRECAMBRIAN ROCK

380-391 Hornblende tonalite gneiss

## PETROGRAPHIC DESCRIPTION OF CORE

Principal rock type: Tonalite gneiss, strongly foliated.

Mineralogy: Plagioclase (45%), quartz (30%), hornblende (21%), biotite (3%), epidote (1%); accessory opaque minerals, apatite, zoned zircon. Traces of secondary chlorite, sericite, hematite.

Texture: Medium grained granoblastic, strongly foliated. Ductile shear indicators include (1) augen-shaped aggregates (cm-scale) of plagioclase, quartz, and hornblende that are weakly foliated and rimmed by an envelope of well-foliated, finer grained hornblende and quartz; (2) flattened, recrystallized quartz augen that have mortared margins.

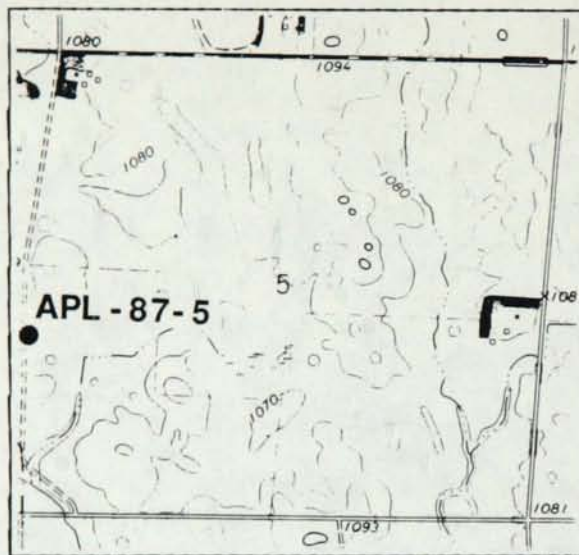
Structure: Foliation close to vertical. Local hornblende-rich lenses a few cm thick, elongate parallel to foliation; may be relict xenoliths within intrusive tonalite protolith.

Field number APL-87-5Date completed Sept. 9, 1987MGS unique number 241419MGS lab number 2644

LOCATION (see map at right)

T-R-S 118-45-5 CBCBBBCounty Lac Qui ParleQuadrangle Haydenville 7.5'

## HOLE PARAMETERS

Surface elevation 1079 ± 5 ftTotal depth 438 ftElevation, top of  
Precambrian rock 760 ftCore interval 426-436 ftCore recovered 10 ft

## ABBREVIATED LITHOLOGIC LOG (intervals recorded are depths in feet)

Interval	Description
QUATERNARY DEPOSITS	
0-4	Organic soil
4-14	Sand, fine to coarse
14-23	Loamy till, calcareous, fairly stiff, olive brown to olive gray
23-31	Sand, fine to coarse; variable color and composition
31-52	Loamy to clayey till, calcareous; lower half very shale-rich
52-58	Sand and gravel
58-77	Interbedded clay, silt, fine sand, olive gray to dark gray. May be lacustrine sequence
77-90	Loamy till, calcareous, gray
90-100	Thinly interbedded clay and silt grading downward to sand and gravel near base. Possible lacustrine sequence
100-110	Loamy till, calcareous, stiff; oxidized upper part. Dark gray to yellow green
110-114	Gravel
114-120	Thinly interbedded clay and silt
120-130	Loamy to clayey till, sticky, plastic, slightly calcareous, gray



## CRETACEOUS SEDIMENTARY ROCKS

- 130-203 Shale, dense, sticky, slightly calcareous (Unit 5 of Setterholm, 1989)
- 203-248 Shale, stiff, dense, very calcareous, gray-brown. Abundant shell fragments (mostly Inoceramus?) (Units 3 and 4 of Setterholm, 1989)
- 248-319 Shale, noncalcareous, gray; minor interbeds of siltstone and sandstone (Unit 2 of Setterholm, 1989)

## REGOLITH ON PRECAMBRIAN ROCK

- 319-352 Clay, kaolinitic, somewhat gritty; white to pink near base
- 352-408 Saprolitic clay, white to light gray; abundant grains of coarse feldspar as large as 5 mm
- 408-428 Saprolitic clay, blue-green; feldspar and quartz grit; rock chips near base

## SOUND PRECAMBRIAN ROCK

- 428-438 Strongly foliated hornblende tonalite gneiss

## PETROGRAPHIC DESCRIPTION OF CORE

Principal rock type: Tonalite gneiss, strongly foliated.

Mineralogy: Plagioclase (75%), hornblende (15-20%), quartz (5-10%), minor biotite (<1%). Plagioclase contains tiny inclusions tentatively identified as clinopyroxene. Local evidence for formation of retrograde epidote through hydrous reaction of plagioclase, hornblende. Accessory minerals: sphene, apatite, opaque Fe-Ti oxides; traces of secondary chlorite, green biotite, sericite.

Texture: Medium grained granoblastic, strongly foliated. Evidence for ductile shear is present but less well developed than in core APL-87-4.

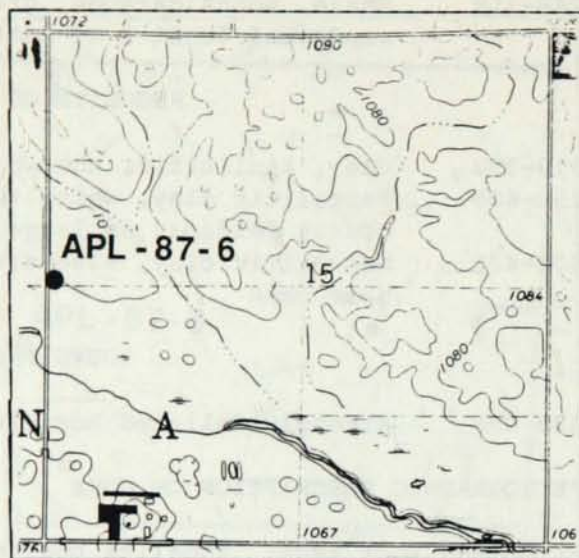
Structure: Strong foliation dips about 85°; carried by aligned hornblende, recrystallized quartz augen, and oriented layers, inclusions, or segregations of hornblende-rich rock.

Field number APL-87-6Date completed Sept. 11, 1987MGS unique number 241420MGS lab number 2645

LOCATION (see map at right)

T-R-S 118-45-15 BCCCCCounty Lac Qui ParleQuadrangle Haydenville 7.5'

## HOLE PARAMETERS

Surface elevation 1069 ± 5 ftTotal depth 425 ftElevation, top of  
Precambrian rock 726 ftCore interval 420-425 ftCore recovered 5 ft

## ABBREVIATED LITHOLOGIC LOG (intervals recorded are depths in feet)

Interval	Description
QUATERNARY DEPOSITS	
0-18	Loamy till, calcareous, stiff; oxidized yellow brown above 14 ft, gray below
18-20	Sand and gravel
20-34	Loamy to clayey till, gray and gray-tan
34-74	Sand and gravel, minor interbeds of clay or till
74-79	Loamy till, noncalcareous, stiff, gray
CRETACEOUS SEDIMENTARY ROCKS	
79-120	Lignitic siltstone and shale, noncalcareous; locally contains concretions, sharks' teeth (Unit 6 of Setterholm, 1989)
120-195	Noncalcareous shale, plastic, clay-rich, medium dark-gray (Unit 5 of Setterholm, 1989)
195-248	Shale, very calcareous, brittle, brown-gray; abundant shell fragments ( <u>Inoceramus?</u> ) near base (Units 3 and 4 of Setterholm, 1989)

- 248-322 Shale, noncalcareous, dark gray; minor interbeds of siltstone, sandstone (Unit 2 of Setterholm, 1989)
- 322-343 Sandstone, poorly lithified; composed mainly of angular quartz, kaolinitic cement. Minor interbeds of dark, clay-rich shale (Unit 1 of Setterholm, 1989)

## REGOLITH ON PRECAMBRIAN ROCK

- 343-370 Clay, gritty to smooth; white, light gray, tan, and black. Probably saprolitic material that has been transported locally and might therefore be interpreted as a Cretaceous sedimentary rock
- 370-420 Saprolitic clay, kaolinite-rich; abundant residual grains of angular quartz; angular feldspar grains are abundant also in basal 10 ft

## SOUND PRECAMBRIAN ROCK

- 420-425 Biotite granite, brick-red and gray

## PETROGRAPHIC DESCRIPTION OF CORE

Principal rock type: Granite.

Mineralogy: Plagioclase (33%), perthitic microcline (33%), quartz (31%), very dark brown biotite (1%), muscovite (<1%). Accessory opaques, apatite, sphene, epidote, zircon. Traces of secondary sericite, chlorite, hematite.

Texture: Hypidiomorphic granular; grain size, 3-4 mm. Quartz reduced to subgrain mosaics that have sutured boundaries; plagioclase twin lamellae and biotite cleavage traces are locally bent and kinked.

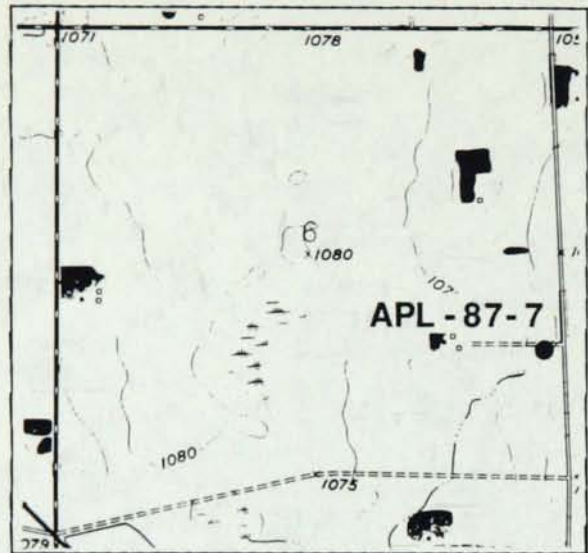
Structure: Massive, nonfoliated. Textural evidence for weak strain (see above).

Field number APL-87-7Date completed Sept. 15, 1987MGS unique number 241421MGS lab number 2646

LOCATION (see map at right)

T-R-S 118-44-6 DADAAACounty Lac Qui ParleQuadrangle Madison 7.5'

## HOLE PARAMETERS

Surface elevation 1060 ± 5 ftTotal depth 393 ftElevation, top of  
Precambrian rock 725 ftCore interval 383-393 ftCore recovered 6.5 ft

## ABBREVIATED LITHOLOGIC LOG (intervals recorded are depths in feet)

Interval	Description
QUATERNARY DEPOSITS	
0-5	Organic-rich soil
5-37	Loamy till, calcareous, brownish-gray; oxidized to yellow brown at top
37-43	Gravel
43-75	Loamy till, calcareous; minor lenses or interbeds of gravel. Color is olive gray; uppermost 10 ft oxidized to dark yellow brown
75-85	Cobbly gravel; very rich in carbonate clasts
85-91	Clayey till, calcareous, shale-bearing, olive-gray

## CRETACEOUS SEDIMENTARY ROCKS

91-135	Lignitic siltstone and shale, noncalcareous to weakly calcareous, dark gray (Unit 6 of Setterholm, 1989)
135-190	Noncalcareous shale, clay-rich; local siltstone interbeds; dark gray (Unit 5 of Setterholm, 1989)
190-235	Shale, very calcareous, fissile; abundant shell fragments; brownish gray (Units 3 and 4 of Setterholm, 1989)



- 235-302 Shale, noncalcareous, dark gray; minor interbeds of siliceous siltstone, very fine sandstone (Unit 2 of Setterholm, 1989)
- 302-335 Sandstone, poorly lithified; quartz grains in coarse sand to granule range, very angular (Unit 1 of Setterholm, 1989)

## REGOLITH ON PRECAMBRIAN ROCK

- 335-383 Saprolitic clay, gritty; rich in kaolinite and quartz; white, grading downward to pink and buff

## SOUND PRECAMBRIAN ROCK

- 383-393 Biotite granite, brick-red and gray

## PETROGRAPHIC DESCRIPTION OF CORE

Principal rock type: Granite.

Mineralogy: Plagioclase (33%), perthitic microcline (33%), quartz (31%), intense dark brown biotite (1%). Accessory Fe-Ti oxides (relatively abundant), apatite, epidote, sphene, zircon. Traces of secondary muscovite, sericite, chlorite, epidote, carbonate, and hematite.

Texture: Hypidiomorphic granular, weakly porphyritic. Main mass of rock has grain size of 3-4 mm; scattered microcline megacrysts are as large as 1.5 cm. Textural evidence for slight strain same as described for core APL-87-6.

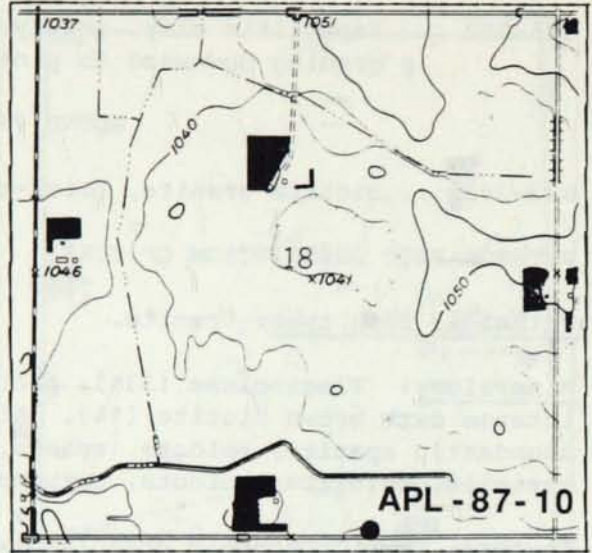
Structure: Essentially massive but very weakly strained.

Field number APL-87-10Date completed Sept. 17, 1987MGS unique number 241422MGS lab number 2647

LOCATION (see map at right)

T-R-S 118-43-18 DCDCCCounty Lac Qui ParleQuadrangle Cerro Gordo 7.5'

## HOLE PARAMETERS

Surface elevation 1042 ± 5 ftTotal depth 344 ftElevation, top of  
Precambrian rock 784 ftCore interval 334-344 ftCore recovered 10 ft

## ABBREVIATED LITHOLOGIC LOG (intervals recorded are depths in feet)

Interval	Description
QUATERNARY DEPOSITS	
0-37	Loamy till, calcareous; abundant cobbles and boulders of carbonate, various basaltic rocks. Oxidized to depth of 35 ft; color olive gray in basal 2 ft
37-131	Sand, coarse sand, gravel of varying texture. Interval from 112 to 131 ft is coarse gravel; carbonate rich, with interbeds of soft gray clay
CRETACEOUS SEDIMENTARY ROCKS	
131-180	Shale, noncalcareous to weakly calcareous, clay-rich, dark gray; traces of lignite (Unit 5 of Setterholm, 1989)
180-195	Shale, very calcareous, fissile; abundant <u>Inoceramus</u> shell fragments; brownish gray (Units 3 and 4 of Setterholm, 1989)
195-258	Shale, noncalcareous, dark gray. Abundant lignite in basal 13 ft. (Unit 2 of Setterholm, 1989)

## REGOLITH ON PRECAMBRIAN ROCK

258-281 Clay, soft, kaolin-rich, white. May be transported material  
281-334 Saprolite; white to yellowish-white in upper part, grading to  
greenish gray near base. Coarse residual quartz throughout;  
feldspar toward base

## SOUND PRECAMBRIAN ROCK

334-344 Biotite granite, red and gray

## PETROGRAPHIC DESCRIPTION OF CORE

Principal rock type: Granite.

Mineralogy: Plagioclase (35%), perthitic microcline (30%), quartz (25%), intense greenish-brown biotite (10%). Accessory opaques, sphene, apatite, zircon; latter is euhedrally zoned about small, round, pink cores, and rounded externally. Traces of secondary chlorite, leucoxene, hematite.

Texture: Allotriomorphic equigranular; grain size, 2-4 mm. Quartz strained, partially recrystallized. Partial myrmekitic rims around microcline grains indicate tendency toward "rapikivi" texture.

Structure: Massive.



Field number APL-87-11Date completed Oct. 12, 1987MGS unique number 241462MGS lab number 2650

LOCATION (see map at right)

T-R-S 126-45-29 BABBBACounty TraverseQuadrangle Graceville NE 7.5'

## HOLE PARAMETERS

Surface elevation 1054 ± 5 ftTotal depth 399 ftElevation, top of  
Precambrian rock 797 ftCore interval 389-399 ftCore recovered 10 ft

## ABBREVIATED LITHOLOGIC LOG (intervals recorded are depths in feet)

Interval

Description

## QUATERNARY DEPOSITS

0-5	Organic topsoil
5-29	Clay and silty clay, smooth, plastic, yellow-tan to gray. Probably lacustrine
29-93	Till, clayey to sandy, calcareous, gray. May be two till units
93-108	Gravel and coarse sand grading downward to fine sand at base
108-158	Till, loamy, calcareous, gray
158-168	Gravel and sand; cobbly to bouldery at base

## CRETACEOUS SEDIMENTARY ROCKS

168-252	Shale, noncalcareous, gray; minor interbeds of siltstone, fine sandstone toward base (Unit 2 of Setterholm, 1989)
252-257	Sandstone, very coarse but poorly sorted, well-rounded; many grains in granule range. Dominantly quartz (Unit 1 of Setterholm, 1989)

## REGOLITH ON PRECAMBRIAN ROCK

- 257-265 Variegated clay that contains angular quartz, much muscovite; probably a transported deposit
- 265-380 Saprolite; clay rich at top; increasing content of residual quartz and muscovite with depth; blue gray
- 380-386 Saprolite and soft rock

## SOUND PRECAMBRIAN ROCK

- 386-399 Biotite schist; veins of quartz/muscovite/potassium-feldspar pegmatite

## PETROGRAPHIC DESCRIPTION OF CORE

Principal rock type: Metamorphosed feldspathic wacke or reworked crystal tuff.

Mineralogy: Plagioclase (retrograded), quartz, biotite (retrograded), chlorite, epidote, garnet (retrograded); accessory apatite, opaque Fe-Ti oxides (two generations), zircon. Dusty clinozoisite is distributed throughout.

Texture: Predominantly granoblastic and foliated, but with vestiges of primary clastic textures preserved. Plagioclase-rich layers consist of grains 1-2 mm long that are well sorted and tend toward prismatic shape. Finer grained layers (0.5- to 1-mm grains) contain larger proportion of quartz and phyllosilicates; quartz, plagioclase grains are augen shaped and surrounded by anastomosing phyllosilicate films.

Structure: Original layering (bedding) dips 70-75°; beds are a few cm to a few dm in thickness. Foliation is essentially parallel to layering.

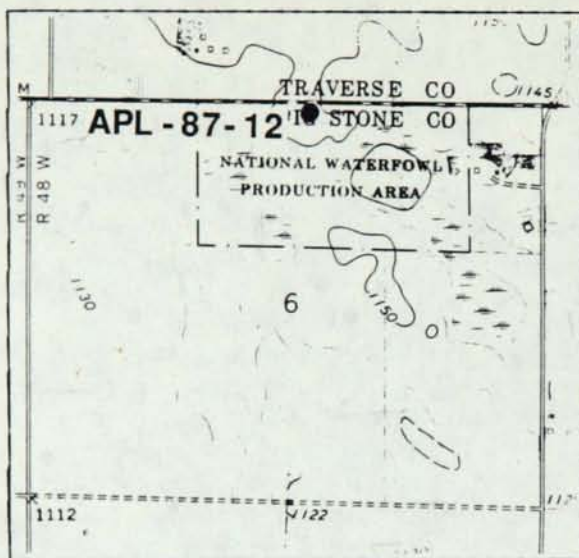
Comments: Rock shows clear evidence of prograde-retrograde metamorphic history. Prograde event produced a schist composed of oligoclase/andesine, quartz, biotite, and garnet. During the retrograde event, garnet and biotite were partly reacted to chlorite, and intermediate plagioclase was partly reacted to albite, epidote, and clinozoisite.

Field number APL-87-12Date completed Oct. 8, 1987MGS unique number 241463MGS lab number 2649

LOCATION (see map at right)

T-R-S 124-48-6 ABBBACCounty Big StoneQuadrangle Beardsley 7.5'

## HOLE PARAMETERS

Surface elevation 1151 ± 5 ftTotal depth 640 ftElevation, top of  
Precambrian rock 646 ftCore interval 630-640 ftCore recovered 10 ft

## ABBREVIATED LITHOLOGIC LOG (intervals recorded are depths in feet)

Interval	Description
QUATERNARY DEPOSITS	
0-1.5	Organic soil
1.5-76	Sandy to clayey till, calcareous, medium gray-brown; uppermost 19 ft oxidized
76-97	Sand, very fine; lesser amounts of silt
97-139	Sand, coarse to very coarse; rich in shale and dolomite clasts; lenses of gravel
139-182	Sand, very fine; grades downward into silt and clay
182-184	Sand, coarse; contains abundant carbonate
CRETACEOUS SEDIMENTARY ROCKS	
184-276	Sandstone and siltstone, poorly cemented, probably interbedded; contains scattered fragments of carbonized wood (probably Unit 6 of Setterholm, 1989, although not completely typical)
276-320	Shale, slightly calcareous, fissile, dark gray to gray-brown (Unit 5 of Setterholm, 1989)



- 320-385 Shale, very calcareous; abundant shell debris (Inoceramus?); dark gray brown (Units 3 and 4 of Setterholm, 1989)
- 385-505 Shale, noncalcareous, stiff, waxy, dark gray. Minor zones of lignite, somewhat silty or sandy shale. (Unit 2 of Setterholm, 1989)

## REGOLITH ON PRECAMBRIAN ROCK

- 505-565 Clay mixed with abundant residual muscovite and oxybiotite; silvery white
- 565-630 Saprolite; mainly micaceous, somewhat gritty clay; narrow zones rich in coarse feldspar, quartz; pale gray

## SOUND PRECAMBRIAN ROCK

- 630-640 Biotite schist (metagraywacke)

## PETROGRAPHIC DESCRIPTION OF CORE

Principal rock type: Biotite-quartz-plagioclase schist.

Mineralogy: Oligoclase (40%), quartz (35%), biotite (25%); accessory apatite, zircon, epidote, monazite. Traces of secondary chlorite after biotite.

Texture: Medium fine grained granoblastic, well foliated. Foliation carried by biotite and biotite-rich films that tend weakly to anastomose.

Structure: Foliation dips about 80°, virtually parallel to poorly defined bedding.

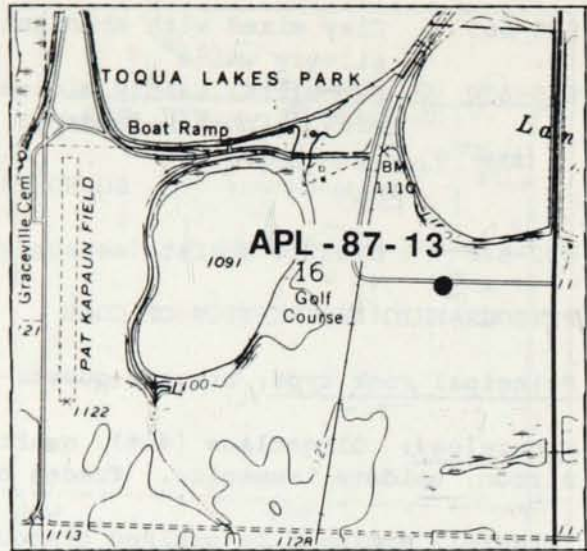
Comments: Protolith interpreted to have been a feldspathic graywacke.

Field number APL-87-13Date completed Oct. 1, 1987MGS unique number 241464MGS lab number 2651

LOCATION (see map at right)

T-R-S 124-46-16 DABBBACounty Big StoneQuadrangle Graceville 7.5'

## HOLE PARAMETERS

Surface elevation 1123 ± 2 ftTotal depth 502 ftElevation, top of  
Precambrian rock 643 ftCore interval 492-502 ftCore recovered 10 ft

## ABBREVIATED LITHOLOGIC LOG (intervals recorded are depths in feet)

Interval	Description
QUATERNARY DEPOSITS	
0-2	Organic soil
2-49	Loamy till, calcareous, gray; oxidized to depth of 32 ft
49-51	Sand, coarse, variegated
51-140	Clayey till; various shades of gray and greenish-gray. May be three till units superimposed: 51-71 ft, 71-95 ft, and 95-140 ft
140-192	Clay, bluish-gray; grades downward into silt and silty sand
192-210	Clay or very clay-rich till, dark gray, very stiff
210-219	Sand, gravel, cobbly gravel
219-295	Clay, sandy clay; possibly a lacustrine sequence of interbedded clay, sand, silt
295-320	Sand, gravelly sand, lesser amounts clay and silt; contains abundant fossil wood
320-350	Silt and fine sand, gray
350-372	Silty clay, gray

## CRETACEOUS SEDIMENTARY ROCKS

372-480 Shale, noncalcareous, variegated, with interbedded siltstone, silty sandstone, kaolinitic sandstone; carbonized wood near base (Unit 2 of Setterholm, 1989)

## REGOLITH ON PRECAMBRIAN ROCK

480-487 Micaceous clay, pale gray-green

## SOUND PRECAMBRIAN ROCK

487-502 Biotite-bearing, weakly gneissose quartz diorite

## PETROGRAPHIC DESCRIPTION OF CORE

Principal rock type: Gneissose quartz diorite (see comments below).

Mineralogy: Plagioclase, oligoclase-andesine range, moderately well-twinned (60%); quartz (25%); biotite (15%). Accessory zircon, apatite. Traces of secondary chlorite, hydrobiotite, sericite after biotite.

Texture: Most of rock is a granoblastic mosaic of anhedral crystals in 0.1- to 0.5-mm size range; moderately developed foliation is carried by aligned biotite flakes and cm-size biotite clots. Scattered about are anhedral megacrysts and compound megacrysts of plagioclase; these are in 2- to 3-mm size range and are interpreted as relict features of coarse-grained protolith. No indication that rock has been sheared. Grain size reduction seems to be consequence of metamorphic recrystallization.

Structure: Foliation dips about 70-80°.

Comments: Hole was targeted near the crest of a sharp, positive magnetic anomaly and was expected to intersect iron-formation or associated supracrustal rocks. The protolith of the gneiss encountered probably was a plutonic quartz diorite. However, a protolith that was a hypabyssal silt or some sort of dacitic crystal tuff cannot be completely ruled out.

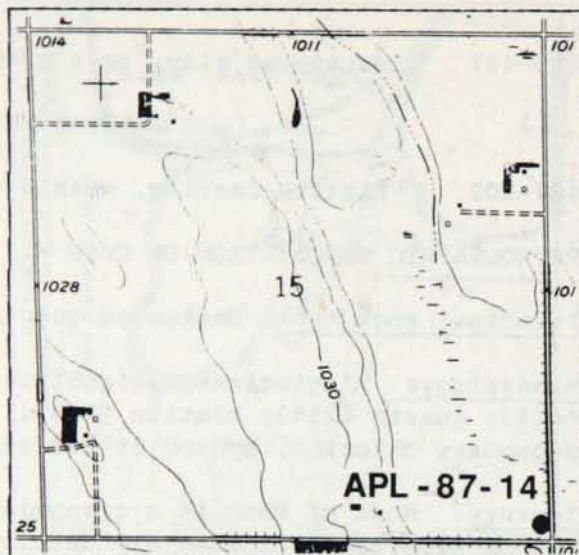


Field number APL-87-14Date completed Oct. 14, 1987MGS unique number 241470MGS lab number 2652

LOCATION (see map at right)

T-R-S 120-42-15 DDDDDACounty SwiftQuadrangle Milan NW 7.5'

## HOLE PARAMETERS

Surface elevation 1009 ± 2 ftTotal depth 353 ftElevation, top of  
Precambrian rock 726 ftCore interval 343-353 ftCore recovered 10 ft

## ABBREVIATED LITHOLOGIC LOG (intervals recorded are depths in feet)

Interval	Description
QUATERNARY DEPOSITS	
0-12	Gravel and sand
12-31	Till, loamy, calcareous; pebbles of limestone, shale; olive gray
31-38	Sand and gravel; cobbly at base
38-105	Till, loamy, calcareous, olive-gray
105-182	Till, loamy, calcareous; olive gray except for 10-ft oxidized zone at top
182-235	Sand and gravel, minor intervals of clay and silt. Abundant cobbly to bouldery gravel toward base
CRETACEOUS SEDIMENTARY ROCKS	
235-283	Shale and claystone, noncalcareous; layers of sandstone, siltstone interbedded with shale below 276 ft depth (probably Unit 2 of Setterholm, 1989)
REGOLITH ON PRECAMBRIAN ROCK	
283-341	Saprolite, gritty and quartz-rich, white to very light gray

## SOUND PRECAMBRIAN ROCK

341-353 Granite, weakly porphyritic, pink and gray

## PETROGRAPHIC DESCRIPTION OF CORE

Principal rock type: Granite.

Mineralogy: Plagioclase, oligoclase range (40%); microcline, perthitic (28%); quartz (27%); biotite, intense olive brown (5%). Accessory apatite, sphene, zircon, opaque oxides, epidote. Traces of secondary chlorite, leucoxene, hematite, and sericite.

Texture: Coarse allotriomorphic granular, weakly porphyritic. Most grains in 3- to 5-mm size range; scattered microcline crystals are approximately twice as large.

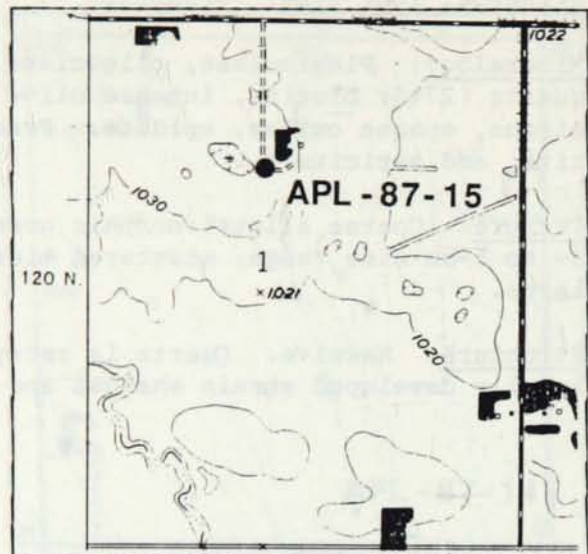
Structure: Massive. Quartz is recrystallized to subgrains; plagioclase shows locally developed strain shadows and strain lamellae.

Field number APL-87-15Date completed Oct. 22, 1987MGS unique number 241478MGS lab number 2655

LOCATION (see map at right)

T-R-S 120-42-1 BDAADACounty SwiftQuadrangle Big Bend City 7.5'

## HOLE PARAMETERS

Surface elevation 1032 ± 5 ftTotal depth 306 ftElevation, top of  
Precambrian rock 767 ftCore interval 296-306 ftCore recovered 10 ft

## ABBREVIATED LITHOLOGIC LOG (intervals recorded are depths in feet)

Interval	Description
QUATERNARY DEPOSITS	
0-4	Organic topsoil
4-48	Till, loamy, calcareous, gray to light gray; top 11 ft oxidized
48-55	Sand, fine- to medium-grained
55-90	Till, loamy, calcareous, gray
90-93	Gravel and coarse sand
93-126	Till, loamy, calcareous, gray; numerous thin lenses of sand or very sandy till
126-142	Interbedded sand, gravel, silt, and clay; contains fragments of fossil wood
CRETACEOUS SEDIMENTARY ROCKS	
142-148	Clay shale, lignitic, noncalcareous, black
148-265	Shale, noncalcareous, sticky, gray; interbeds of siltstone, fine sandstone become more abundant with depth (probably correlates with Unit 2 of Setterholm, 1989)



## REGOLITH ON PRECAMBRIAN ROCK

265-295 Saprolite; clay, somewhat gritty, light bluish-gray to dark greenish-gray

## SOUND PRECAMBRIAN ROCK

295-306 Amphibolite cut by hairline carbonate veins, brittle crush zones

## PETROGRAPHIC DESCRIPTION OF CORE

Principal rock type: Amphibolite.

Mineralogy: Plagioclase, oligoclase-andesine range, well-twinned (70%); hornblende, deep green (23%); quartz (3%); biotite (2%); magnetite (2%). Accessory apatite, sphene. Secondary chlorite, sericite in crush zones. Carbonate in veins.

Texture: Well-recrystallized, medium-grained granular mosaic. No discernable fabric. Clean, equilibrium texture.

Structure: Seemingly massive; cut by hairline-thin veinlets of carbonate and brittle crush zones that are about one cm thick.

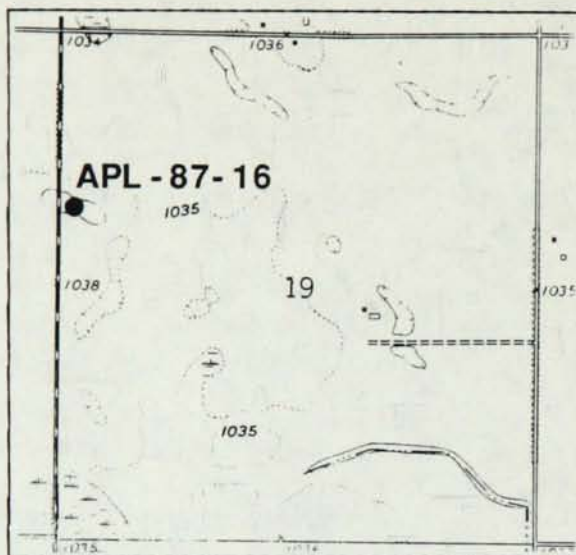
Comments: Brittle crush zones contain comminuted particles that range in size from smaller than 0.01 mm to about 1 mm. Hornblende is crushed the least but is partly converted to chlorite and shows evidence of internal slip along cleavage planes. Rebreakage is indicated by fragments of cataclastite that have been fractured, rotated by later displacements.

Field number APL-87-16Date completed Oct. 20, 1987MGS unique number 241477MGS lab number 2654

LOCATION (see map at right)

T-R-S 120-40-19 BCBCBACounty SwiftQuadrangle Gracelock NW 7.5'

## HOLE PARAMETERS

Surface elevation 1040 ± 5 ftTotal depth 422 ftElevation, top of  
Precambrian rock 754 ftCore interval 412-422 ftCore recovered 10 ft

## ABBREVIATED LITHOLOGIC LOG (intervals recorded are depths in feet)

Interval	Description
QUATERNARY DEPOSITS	
0-2	Organic topsoil
2-44	Till, loamy, calcareous, gray; topmost 23 ft oxidized
44-56	Sand and pea gravel, variegated
56-96	Till, loamy to sandy, calcareous, bluish-gray
96-98	Sand
98-151	Till, loamy to sandy, calcareous; abundant clasts of red granite and carbonate rocks. Gray except for uppermost oxidized interval of 7 ft, which is greenish gray to olive
151-169	Clay, silty clay, and silt; basal 7 ft consist of interbedded clay and mature quartz sand. Probable lacustrine deposit
CRETACEOUS SEDIMENTARY ROCKS	
169-202	Shale, noncalcareous, gray
202-240	Fine sandstone, poorly sorted, lithic, gray-brown; locally contains abundant fossil fish scales
240-286	Shale, some siltstone; noncalcareous, gray. Interval 244-255 ft contains bentonitic material in one or more layers

## REGOLITH ON PRECAMBRIAN ROCK

286-314 Kaolinitic clay, somewhat gritty; various shades of light gray, bluish gray, and white; may be transported in part  
 314-360 Saprolite, clay-rich but gritty, gray and greenish-gray  
 360-412 Saprolite, clay-rich; residual quartz, mica, and feldspar

## SOUND PRECAMBRIAN ROCK

412-422 Biotite paragneiss

## PETROGRAPHIC DESCRIPTION OF CORE

Principal rock type: Biotite paragneiss, somewhat migmatitic.

Mineralogy: Paleosome is about 60% plagioclase, 25% quartz, 15% biotite; Leucosome is about 50% plagioclase, 45% quartz, 5% biotite. Accessory apatite, zircon, sphene, granular opaques, monazite; traces of secondary chlorite, sericite, epidote.

Texture: Granoblastic, foliated; grain size, 0.1-0.3 mm in paleosome, 1-2 mm in leucosome.

Structure: Compositional layering and schistosity are parallel and dip moderately. Rock contains thin veinlets and brittle shear zones that are essentially concordant with the main foliation. Veins contain quartz, albite, and epidote.

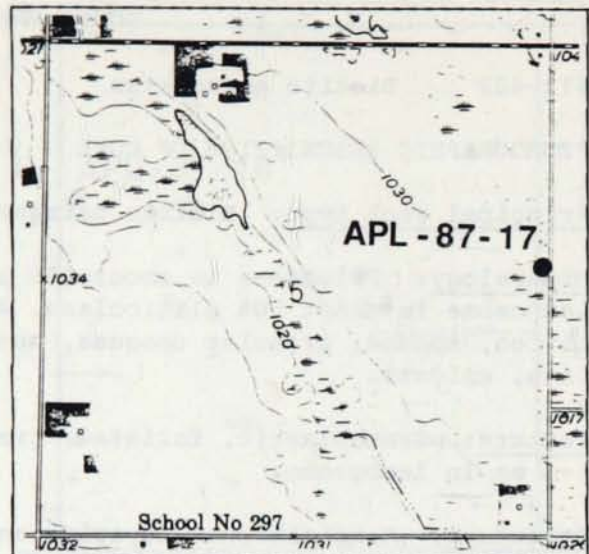


Field number APL-87-17Date completed Oct. 16, 1987MGS unique number 241469MGS lab number 2653

LOCATION (see map at right)

T-R-S 119-41-5 ADDADDCounty ChippewaQuadrangle Big Bend City 7.5'

## HOLE PARAMETERS

Surface elevation 1020 ± 2 ftTotal depth 347 ftElevation, top of  
Precambrian rock 848 ftCore interval 337-347 ftCore recovered 10 ft

## ABBREVIATED LITHOLOGIC LOG (intervals recorded are depths in feet)

Interval	Description
QUATERNARY DEPOSITS	
0-1	Organic topsoil
1-45	Till, loamy, calcareous, olive-gray, shale-bearing. Uppermost 20 ft oxidized
45-50	Clayey silt grading downward into sand and sandy gravel
50-78	Till, loamy, calcareous; abundant limestone cobbles. Medium gray; uppermost 6 ft oxidized
78-112	Clay or very clayey till poor in sand, gravel components. Olive gray; uppermost 3 ft oxidized. Wood chips in depth interval 100-105 ft
112-128	Till, loamy, with abundant cobbles in uppermost 4 ft; remainder is very poor in sand and gravel components
CRETACEOUS SEDIMENTARY ROCKS	
128-172	Clay shale and claystone; variegated in shades of olive gray and greenish gray; minor intervals of fine sandstone

## REGOLITH ON PRECAMBRIAN ROCK

- 172-245 Clay, somewhat gritty; variegated in shades of very light gray to medium gray. Upper part of interval may be transported
- 245-337 Saprolite consisting of core stones and weathered septa; former are variably cohesive gneissose rock; latter are predominantly clay, light to medium gray

## SOUND PRECAMBRIAN ROCK

- 337-347 Migmatitic biotite paragneiss

## PETROGRAPHIC DESCRIPTION OF CORE

Principal rock type: Biotite paragneiss, somewhat migmatitic.

Mineralogy: Plagioclase, quartz, and biotite in varying proportions from layer to layer; garnet, pseudomorphs of unknown porphyroblast mineral occur in most micaceous layers. Accessory apatite, zircon (compositionally zoned; subrounded), opaque phases.

Texture: Texture varies gradationally from finer grained (<0.5 mm), biotite-rich layers to coarser grained (1-3 mm), biotite-poor layers. Overall, the rock is granoblastic and well foliated; widely dispersed plagioclase megacrysts deflect the schistosity. More aluminous layers contain small porphyroblasts of garnet and an unknown, highly sieved mineral (staurolite? cordierite?) that has been replaced entirely by fine-grained white mica and chlorite.

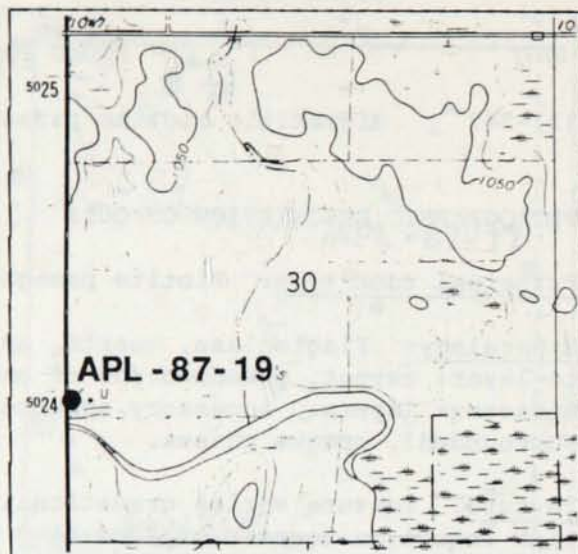
Structure: Well-developed layer-parallel schistosity dips at moderate angle.

Field number APL-87-19Date completed Nov. 3, 1987MGS unique number 241501MGS lab number 2657

LOCATION (see map at right)

T-R-S 122-38-30 CBCCBCounty SwiftQuadrangle De Graff 7.5'

## HOLE PARAMETERS

Surface elevation 1043 ± 2 ftTotal depth 268 ftElevation, top of  
Precambrian rock 817 ftCore interval 245-248 and 258-268 ftCore recovered 12.5 ft

## ABBREVIATED LITHOLOGIC LOG (intervals recorded are depths in feet)

Interval	Description
QUATERNARY DEPOSITS	
0-77	Till, loamy to sandy, calcareous, gray; uppermost 15 ft oxidized. Minor sand lenses; abundant limestone and shale pebbles
77-80	Gravel, variegated
80-143	Till, loamy, calcareous; many pebbles of limestone and basaltic rock. Olive gray
143-226	Outwash sand and gravel layers (each 3 to 20 ft thick) intercalated with thin till sheets (each 5 to 10 ft thick). Latter are loamy, calcareous, olive gray
REGOLITH ON PRECAMBRIAN ROCK	
226-234	Clay, dark greenish-gray
234-258	Broken hard rock, dark gray; alternates with seams, thicker intervals of green clay
SOUND PRECAMBRIAN ROCK	
258-268	Porphyritic diabase, relatively coarse-grained



## PETROGRAPHIC DESCRIPTION OF CORE

Principal rock type: Porphyritic diabase, locally altered.

Mineralogy: Fresh diabase: Plagioclase (typically zoned), clinopyroxene, orthopyroxene, biotite (deep red-brown), Fe-Ti oxides; accessory apatite. Secondary biotite (green), amphibole, chlorite locally have replaced pyroxene. Altered diabase: Blue-green amphibole has replaced all pyroxene, most groundmass plagioclase, and embayed the margins of plagioclase megacrysts.

Texture: Groundmass of fresh diabase is composed of plagioclase laths 1-2 mm long, granular, anhedral pyroxene crystals about 1 mm in diameter, and much smaller crystals of granular oxides. Biotite is interstitial and invariably associated with oxides. Phenocrysts and xenocrysts of zoned plagioclase (see comments below) range between 5 and 10 mm in size. The groundmass of the altered diabase is a decussate aggregate of fibrous to prismatic blue-green amphibole.

Structure: Massive. Megacrysts are unevenly distributed, suggesting that their distribution may have been controlled by magmatic flowage phenomena.

Comments: The plagioclase megacrysts in this rock are of three types:

1. Individual crystals that have large, homogeneous, calcic cores and narrow, strongly zoned rims.
2. Polycrystalline clots of optically unzoned calcic crystals that have a narrow zoned rind around the entire clot.
3. Polycrystalline clots made up of several zoned crystals that are identical to the individual crystals of type 1.

The clots of type 2 are interpreted as xenocrysts, whereas those of type 3 are interpreted as glomeroporphyritic aggregate of possibly xenocrystic crystals that collected after receiving a magmatic overplating of near plagioclase.

The diabase probably is from a Proterozoic dike.

Field number APL-87-20Date completed Oct. 27, 1987MGS unique number 241502MGS lab number 2658

LOCATION (see map at right)

T-R-S 121-38-14 CBBCBBCounty SwiftQuadrangle De Graff 7.5'

## HOLE PARAMETERS

Surface elevation 1076 ± 1 ftTotal depth 350 ftElevation, top of  
Precambrian rock 769 ftCore interval 340-350 ftCore recovered 10 ft

## ABBREVIATED LITHOLOGIC LOG (intervals recorded are depths in feet)

Interval	Description
QUATERNARY DEPOSITS	
0-5	Organic soil and muck
5-15	Till, loamy, calcareous, gray; abundant carbonate pebbles. Top 5 ft is oxidized
15-27	Coarse sand that grades downward into pea gravel
27-50	Till, loamy, calcareous, gray; carbonate pebbles, cobbles greatly predominate
50-307	Complex outwash sequence composed of sand, gravel, lesser amounts of silt and clay. Interval from 266-280 ft is chiefly silt and silty clay; otherwise the section is medium to coarse sand interbedded with layers and lenses of gravel
REGOLITH ON PRECAMBRIAN ROCK	
307-317	Clay, white, kaolinitic; contains abundant quartz grit
317-340	Saprolitic grus derived from granitoid rock

## SOUND PRECAMBRIAN ROCK

340-350      Leucogranite gneiss; incipiently weathered zones interspersed with and grade into zones of fresh rock

## PETROGRAPHIC DESCRIPTION OF CORE

Principal rock type: Leucogranite gneiss.

Mineralogy: Oligoclase, perthitic orthoclase, and quartz in roughly equal amounts; no more than 1% biotite that is partly altered to chlorite, muscovite, and Fe-Ti oxides. Accessory allanite (metamict).

Texture: Recrystallized xenomorphic; grains typically have embayed, sutured, interlocking boundaries but locally exhibit mosaic textures indicative of reequilibration. Grain size in 0.1- to 1.0-mm range.

Structure: Weakly foliated.

Comments: Probably belongs with adamellite-1 group of granitic intrusions as defined by Wooden and others (1980). Aplitic protolith is likely.

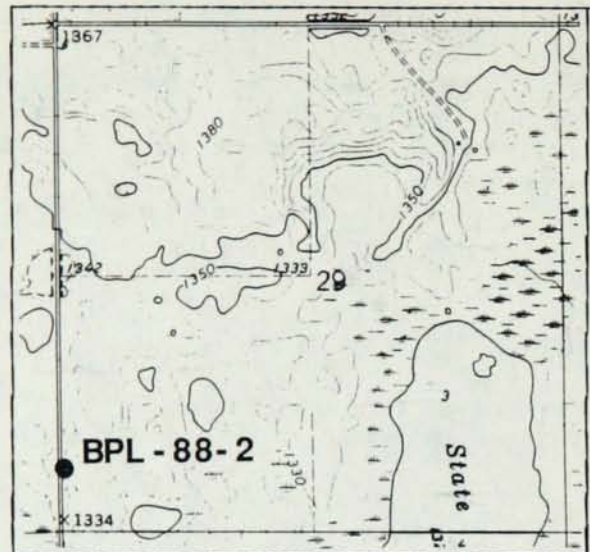


Field number BPL-88-2Date completed Sept. 8, 1988MGS unique number 242398MGS lab number 2839

LOCATION (see map at right)

T-R-S 125-37-29 CCCBCCounty PopeQuadrangle Terrace 7.5'

## HOLE PARAMETERS

Surface elevation 1335 ± 5 ftTotal depth 466 ftElevation, top of  
Precambrian rock 933 ftCore interval 456-466 ftCore recovered 9.9 ft

## ABBREVIATED LITHOLOGIC LOG (intervals recorded are depths in feet)

Interval	Description
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## QUATERNARY DEPOSITS

(NOTE: The Quaternary intersection is long and complex, and its description is greatly generalized for brevity. Further details are available on request from the MGS)

0-2	Organic soil, dark brown
2-16	Till, sandy to loamy, calcareous, oxidized
16-21	Sand and gravel
21-42	Till, sandy to clayey, calcareous, gray; several lenses of sand
42-61	Sand
61-100	Till, loamy to clayey, calcareous, gray
100-129	Sand, silt; minor gravel and clay
129-216	Till, generally loamy, calcareous, various shades of gray; scattered interbeds of sand
216-286	Till, clayey to loamy, calcareous, shale-bearing; various shades of greenish gray
286-328	Till, sandy, somewhat calcareous; various shades of reddish or brownish gray. Some admixture of Superior provenance sand, gravel

- 328-383 Till, clayey to loamy, calcareous, shale-bearing, gray to very dark gray  
 383-388 Mainly sand, dolomitic; contains fossil wood  
 388-399 Till, clay-rich, shaly; calcareous but less so than tills above  
 399-405 Sand, coarse gravel, rock rubble; contains fossil wood

## REGOLITH ON PRECAMBRIAN ROCK

- 405-413 Broken granitoid rock with minor zones of white to light green kaolinitic clay  
 413-450 Clay-rich saprolite; content of angular quartz grit increases downward

## SOUND PRECAMBRIAN ROCK

- 450-466 Granite gneiss

## PETROGRAPHIC DESCRIPTION OF CORE

Principal rock type: Hornblende granulite gneiss derived from granite.

Mineralogy: Perthitic microcline (35%), antiperthitic oligoclase (30%), quartz (22%), hornblende (7%), biotite (2%), orthopyroxene (1%), clinopyroxene (1%), epidote (1%); accessory apatite, calcite, sphene, magnetite, hematite, zircon. The sphene is partly decomposed into magnetite, rutile, and calcite.

Texture: Granoblastic but strongly bimodal. Larger crystals are perthitic microcline and antiperthitic oligoclase, anhedral, size range 1.5-7 mm. These are set in a finer matrix (0.1-0.3 mm) of quartz, potassium feldspar, plagioclase, and mafic phases. Apatite crystals are large and well formed.

Structure: Weak inclined foliation carried by preferred orientation of poly-mineralic, granoblastic clots of mafic minerals.

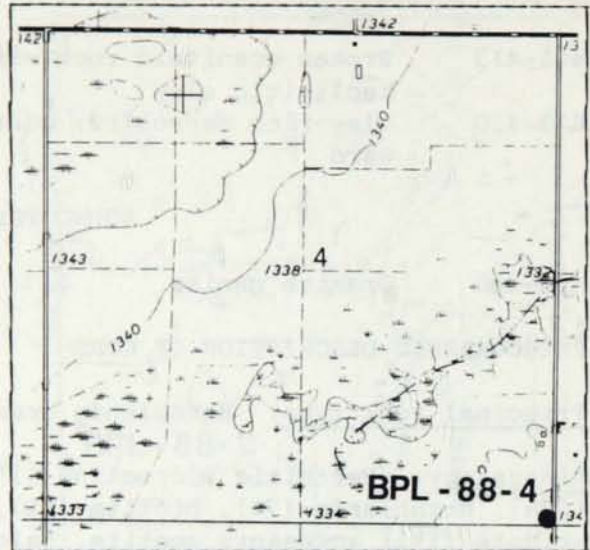
Comments: Textures suggest that this gneiss is an incompletely recrystallized coarse-grained granitoid rock that was metamorphosed under conditions of the lower granulite facies. Primary igneous minerals were quartz, microcline, plagioclase, hornblende (1) and biotite (1). This assemblage reacted to orthopyroxene + biotite (2) + hornblende (2) + clinopyroxene + sphene (in the presence of quartz, potassium feldspar, and plagioclase) at high metamorphic grade. Subsequently, retrograde reactions produced epidote, calcite, magnetite, and rutile through the hydration and carbonitization of prograde mafic phases and sphene.

Field number BPL-88-4Date completed Sept. 13, 1988MGS unique number 242399MGS lab number 2840

LOCATION (see map at right)

T-R-S 124-36-4 DDDDDDCounty PopeQuadrangle Sedan 7.5'

## HOLE PARAMETERS

Surface elevation 1340 ± 2 ftTotal depth 340 ftElevation, top of  
Precambrian rock 1053 ftCore interval 330-340 ftCore recovered 10 ft

## ABBREVIATED LITHOLOGIC LOG (intervals recorded are depths in feet)

Interval	Description
QUATERNARY DEPOSITS	
0-2	Organic topsoil, dark brown
2-45	Till, calcareous, shaly, gray; uppermost 12 ft oxidized
45-53	Gravel, rich in dolomite pebbles
53-160	Till, loamy, calcareous, gray
160-170	Gravel and coarse sand interbedded with clay; gravel is dominantly dolomite
170-222	Till, loamy, calcareous, gray
222-225	Pea gravel, very calcareous
225-235	Till, loamy to silty, calcareous, gray
235-238	Pea gravel, very calcareous
238-245	Till, loamy to pebbly, calcareous, gray
245-255	Till, loamy to sandy; abundant small pebbles of basalt and dolomite. Light brown to reddish brown
255-287	Till, loamy, calcareous, gray, very stiff



## REGOLITH ON PRECAMBRIAN ROCK

- 287-304 Saprolitic clay; grades from light gray at top to greenish gray toward base
- 304-326 Granular grus-like saprolite that contains variable amounts of residual quartz, potassium feldspar

## SOUND PRECAMBRIAN ROCK

- 326-340 Biotite tonalite gneiss and quartz/potassium-feldspar pegmatite

## PETROGRAPHIC DESCRIPTION OF CORE

Principal rock type: Streaky gray and pink gneiss composed of an older tonalitic component and a younger granitic component.

Mineralogy: Tonalitic component: plagioclase, quartz, biotite. Granitic component: microcline, quartz, plagioclase, biotite. Accessories: zircon, apatite, rutile, epidote, opaque Fe-Ti oxides. Alteration minerals (traces); sericite muscovite, chlorite, carbonate.

Texture: Tonalitic component: Neoblastic granular; grain-size range, 0.7-1.5 mm. Plagioclase grains coherent, unstrained, unzoned, well twinned; locally they display vestiges of igneous subhedral shape but most grains are anhedral and tend toward ovoid form. Quartz grains are reduced to subgrains. Granitic component: Microcline megacrysts as large as 10 mm enclose amoeboid aggregates of finer grained quartz, plagioclase, and biotite. Megacrysts typically are separated by irregular zones of tonalitic composition, but locally coalesce.

Structure: Foliation carried primarily by oriented biotite flakes, quartz aggregates in tonalitic part of rock.

Comments: Rock is very fresh and contains abundant zircon; therefore it is an unusually attractive prospect for radiometric dating.

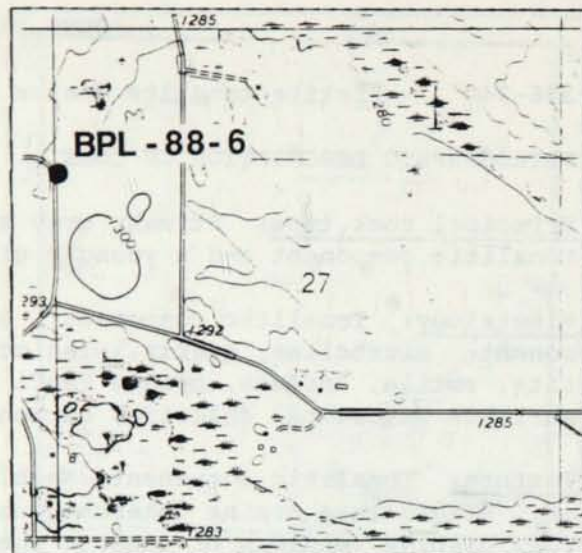


Field number BPL-88-6Date completed Sept. 15, 1988MGS unique number 242400MGS lab number 2841

LOCATION (see map at right)

T-R-S 124-35-27 BCBBBCounty StearnsQuadrangle Padua 7.5'

## HOLE PARAMETERS

Surface elevation 1290 ± 5 ftTotal depth 313 ftElevation, top of  
Precambrian rock 1019 ftCore interval 303-313 ftCore recovered 10 ft

## ABBREVIATED LITHOLOGIC LOG (intervals recorded are depths in feet)

Interval

Description

## QUATERNARY DEPOSITS

0-2	Organic soil, dark gray-brown
2-41	Coarse sand and gravel; interbedded in lower half with silty clay; unusually rich in basaltic clasts
41-77	Till, loamy to sandy, calcareous; rich in basaltic pebbles, gray
77-111	Sand, calcareous; dolomite is predominant constituent
111-158	Till, clayey to loamy, very calcareous, dark gray
158-164	Sand, medium to coarse
164-188	Thin till sheets or silty clay layers (gray) interstratified with layers or lenses of sand. All calcareous
188-202	Till; clayey at top to very sandy near base. Weakly calcareous; color grades from yellow at top to reddish brown
202-242	Till, loamy to sandy, very stiff, calcareous, dark gray. Top 3 ft weakly oxidized
242-258	Coarse sand, gravel; minor clay interbeds

## REGOLITH ON PRECAMBRIAN ROCK

- 258-271      Kaolinitic clay, silty clay, fine sand; bedded, redeposited saprolitic material  
 271-300      Saprolite; white and green mottled clay that grades into hard rock

## SOUND PRECAMBRIAN ROCK

- 300-313      Metadiabase, weakly schistose

## PETROGRAPHIC DESCRIPTION OF CORE

Principal rock type: Somewhat schistose metadiabase, fine- to very fine-grained.

Mineralogy: Plagioclase, part relict with twinning, part recrystallized (25%); actinolitic hornblende (65%); epidote, both granular and prismatic (5%); ilmenite, as large skeletal crystals (4%). Accessory apatite, sphene, biotite, hematite. Veins contain various combinations of epidote, tremolite, chlorite, carbonate, and adularia.

Texture: Relict plagioclase laths about 0.5 mm long suggest original diabasic texture; this primary texture has been strongly overprinted by granular to decussate growth of metamorphic amphibole and epidote.

Structure: Relatively weak schistosity carried mainly by oriented sheaves of fibrous amphibole. Conspicuous hairline veins are mostly small shear zones that have a central dilatant crack in which the vein minerals have grown normal to the walls.

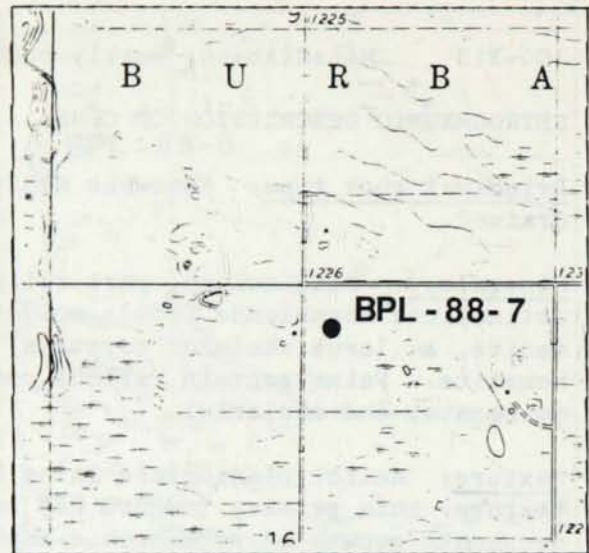
Comments: Coarse crystals of potassium feldspar, pink to brick-red, were encountered in saprolite above the cored interval. This suggests that the metabasalt either is cut by granitic dikes or is a large inclusion in granite.

Field number BPL-88-7Date completed Oct. 8, 1988MGS unique number 242801MGS lab number 2821

LOCATION (see map at right)

T-R-S 122-34-16 ABBCACounty KandiyohiQuadrangle Georgeville 7.5'

## HOLE PARAMETERS

Surface elevation 1230 ± 1 ftTotal depth 291 ftElevation, top of  
Precambrian rock 970 ftCore interval 285.5-290.7 ftCore recovered 5.2 ft

## ABBREVIATED LITHOLOGIC LOG (intervals recorded are depths in feet)

Interval	Description
QUATERNARY DEPOSITS	
0-39	Gravel, coarse sand; calcareous throughout, shale chips present near base
39-60	Till, loamy to sandy, calcareous, dark olive-gray
60-66	Sand, coarse to fine; thin interbeds of clay, silt
66-93	Till, sandy, somewhat calcareous, olive-gray
93-98	Gravel, carbonate-rich
98-107	Till, loamy, somewhat calcareous, gray to dark gray
107-111	Fine sand
111-160	Till, loamy, stiff, calcareous, olive-gray
160-182	Gravel and sand, carbonate-rich
182-216	Till, loamy to sandy; calcareous toward top; interval 193-210 is carbonate poor and reddish brown; interval 210-216 is weakly calcareous and gray
216-232	Sand and silty sand; rich in angular quartz, feldspar, and detrital mica; thin interbeds of silt
232-260	Silty clay, silty fine sand, and clay; mica rich in coarser fraction; variegated in shades of gray, green gray, and brown

## REGOLITH ON PRECAMBRIAN ROCK

260-285 Clay and grus, silvery gray, greenish-gray and pink. Grades downward to sound quartzofeldspathic rock

## SOUND PRECAMBRIAN ROCK

285-291 Biotite granite, massive, coarse-grained, porphyritic

## PETROGRAPHIC DESCRIPTION OF CORE

Principal rock type: Porphyritic granite.

Mineralogy: Microcline (35%), plagioclase (30%), quartz (30%), biotite (4%); accessory sphene, apatite, zircon, and opaque Fe-Ti oxides. Minor alteration minerals include sericite, chlorite, and hematite.

Texture: Strongly bimodal; abundant phenocrysts of microcline, plagioclase, and quartz in size range 5-15 mm are set in an allotriomorphic granular ground-mass of microcline, plagioclase, quartz, and biotite, in which the crystals are mainly 0.5 mm or smaller in size. Microcline phenocrysts are Carlsbad-twinned, perthitic, and some have partial Rapikivi rims; plagioclase phenocrysts are intricately zoned and display multiple, oscillatory composition cycles; quartz phenocrysts are anhedral but tend toward bipyramidal shape.

Structure: Massive.

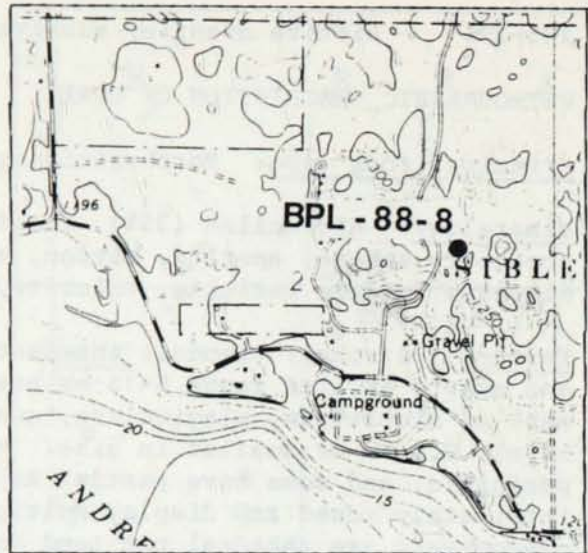


Field number BPL-88-8Date completed Oct. 12, 1988MGS unique number 242802MGS lab number 2812

LOCATION (see map at right)

T-R-S 121-35-2 ADCCACounty KandiyohiQuadrangle Mount Tom 7.5'

## HOLE PARAMETERS

Surface elevation 1255 ± 5 ftTotal depth 494 ftElevation, top of  
Precambrian rock 785 ftCore interval 484-494 ftCore recovered 10 ft

## ABBREVIATED LITHOLOGIC LOG (intervals recorded are depths in feet)

Interval Description

## QUATERNARY DEPOSITS

(NOTE: The Quaternary intersection is long and complex, and its description is greatly generalized for brevity. Further details are available on request from the MGS)

0-49	Sand, gravel, minor clay interbeds. Abundant carbonate
49-100	Till, loamy to sandy, calcareous, olive-gray; several interbeds or lenses of sand, gravel; probably more than one till sheet
100-110	Sand and clay, silt
110-173	Till, sandy to loamy, very calcareous; much shale, some lignite in lower half
173-178	Coarse dolomite gravel
178-233	Till, sandy to clayey, calcareous, gray and greenish-gray
233-277	Coarse sand and gravel; interbeds of silt, clay increase in abundance, thickness with depth
277-392	Complex section composed of several thin till sheets interstratified with bedded clay, sand, gravel, and silt. Generally calcareous and gray, but colors vary abruptly
392-470	Sand, coarse sand, and gravel; minor silt and clay

## REGOLITH ON PRECAMBRIAN ROCK

470-478 Saprolitic clay, pale gray-green; abundant rock chips

## SOUND PRECAMBRIAN ROCK

478-494 Granitoid gneiss, extensively epidotized

## PETROGRAPHIC DESCRIPTION OF CORE

Principal rock type: Granodiorite gneiss, extensively epidotized.

Mineralogy: Plagioclase (55%), heavily altered to sericite, clinozoisite; microcline (10%), quartz (25%); chlorite-muscovite-sphene replacement of biotite (5%). Secondary epidote constitutes about 4% of the rock and accessory allanite, apatite, sphene, and magnetite together account for 1-2%.

Texture: Original equigranular, medium-grained igneous texture modified to weakly foliated, partly recrystallized mosaic by metamorphism. Relict grains of twinned, generally undeformed plagioclase have sutured to weakly recrystallized margins; microcline forms both relict crystals and smaller recrystallized grains. Quartz aggregates consist entirely of subgrains.

Structure: Weak foliation carried by preferred orientation of retrograded biotite and long dimensions of recrystallized quartz. Rock is cut by numerous fracture-filling veins.

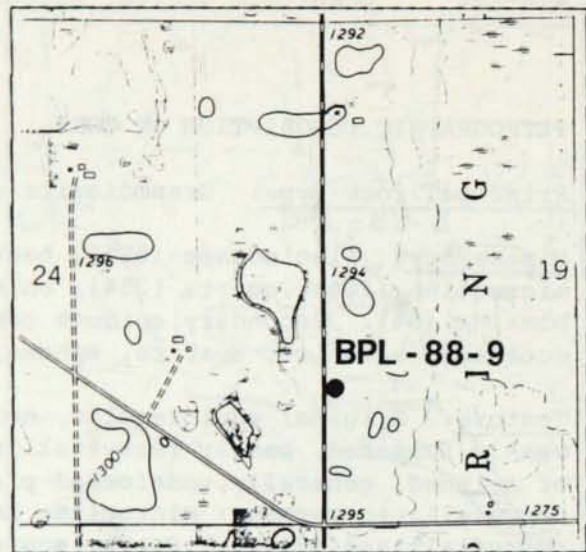
Comments: Rock is similar to epidotized gneiss that crops out in Ashley Township, Stearns County (126-35-17 BC and 18 AD: Raymond Lake 7.5' quadrangle).

Field number BPL-88-9Date completed Sept. 19, 1988MGS unique number 242803MGS lab number 2842

LOCATION (see map at right)

T-R-S 124-33-19 CBCCCCCounty StearnsQuadrangle Elrosa 7.5'

## HOLE PARAMETERS

Surface elevation 1295 ± 5 ftTotal depth 398 ft<sup>317</sup>Elevation, top of  
Precambrian rock 978 ftCore interval 394-398 ftCore recovered 4 ft

## ABBREVIATED LITHOLOGIC LOG (intervals recorded are depths in feet)

Interval	Description
QUATERNARY DEPOSITS	
0-2	Organic topsoil, dark brown
2-49	Till, clayey to loamy, calcareous, gray
49-63	Sand, fine sand, and clay; latter is soft and gray or tan
63-115	Till, clayey to loamy, calcareous, gray to greenish-gray
115-119	Clay, stiff and uniform, dark brown
119-150	Till, clayey to sandy, calcareous, gray to greenish-gray
150-152	Sand, coarse
152-167	Till, sandy to loamy, calcareous, shaly, very dark gray
167-228	Fine sand, silt, clay, thinly interbedded
228-238	Silty, clayey till or stiff, silty clay; gray
238-258	Fine sand, silt, clay; thinly interbedded; coarse multicolored gravel at base
258-275	Till, loamy, calcareous; gray with brown zones
275-297	Till, calcareous, loamy, stiff, dark gray; topmost foot is strongly oxidized. Contains admixed clasts of Superior provenance
297-312	Clay, plastic; various colors
312-317	Coarse sand and gravel



## REGOLITH ON PRECAMBRIAN ROCK

317-392 Saprolitic clay, greenish-gray; increasing proportion of partly decomposed rock with increasing depth below 322 ft

## SOUND PRECAMBRIAN ROCK

392-398 Greenstone of intermediate to mafic composition, closely fractured; difficult drilling

## PETROGRAPHIC DESCRIPTION OF CORE

Principal rock type: Microporphyrritic greenstone

Mineralogy: Plagioclase (relict microphenocrysts and recrystallized groundmass), chlorite, epidote; relatively minor muscovite and biotite. Accessory apatite, magnetite, ilmenite.

Texture: Relict porphyritic, strongly modified by low-grade metamorphic recrystallization, fabric development, late-stage brittle fracturing. Original plagioclase phenocrysts (to 1 mm in size) are largely replaced by sericite and albite. Original hornblende phenocrysts, recognized from relict crystal morphology, are totally replaced by chlorite and epidote. Groundmass is a tangle of fine-grained chlorite, epidote, and recrystallized sodic plagioclase.

Structure: Foliation inclined at a dip of 45° is carried primarily by flattened sheaves of chlorite and epidote.

Comments: Protolith interpreted to have been a hyababysal intrusion or massive flow of hornblende andesite. Minor disseminated pyrite.

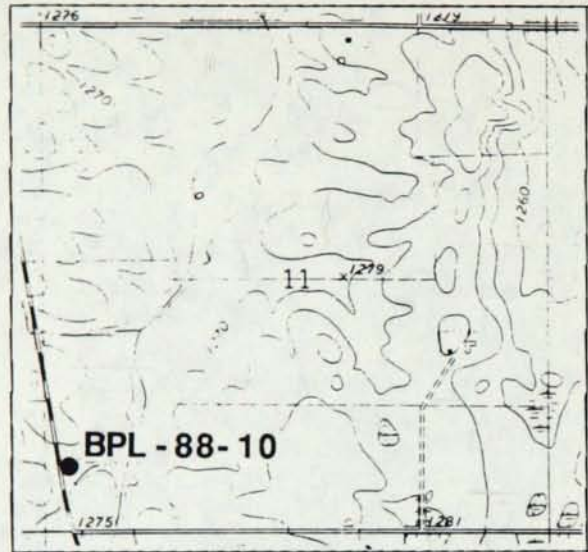


Field number BPL-88-10Date completed Sept. 21, 1988MGS unique number 242804MGS lab number 2843

LOCATION (see map at right)

T-R-S 123-33-11 CCBCCCCounty StearnsQuadrangle Lake Henry 7.5'

## HOLE PARAMETERS

Surface elevation 1275 ± 5 ftTotal depth 259 ftElevation, top of  
Precambrian rock 1075 ftCore interval 249-259 ftCore recovered 10 ft

## ABBREVIATED LITHOLOGIC LOG (intervals recorded are depths in feet)

Interval	Description
QUATERNARY DEPOSITS	
0-3	Organic topsoil
3-34	Till, clayey, calcareous, gray with brownish zones
34-38	Gravel and coarse sand
38-43	Till, clayey, calcareous, gray
43-67	Sand and gravel
67-90	Till, loamy, calcareous, gray
90-93	Sand and gravel
93-128	Till, clayey, calcareous; considerable basalt, granite in coarse fraction. Color changes downward from olive gray to very dark gray
128-150	Coarse sand and gravel; abundant clasts of basalt, granite
150-180	Till, loamy to very sandy, calcareous; abundant basalt, graywacke-slate, somewhat less carbonate
180-186	Coarse cobbly gravel
186-200	Till, sandy to clayey near base; very dark gray

## REGOLITH ON PRECAMBRIAN ROCK

200-225 Saprolitic clay, gray-green  
 225-249 Saprolitic clay with abundant residual biotite; grades downward into increasingly fresh rock

## SOUND PRECAMBRIAN ROCK

249-259 Staurolite-garnet-biotite schist, porphyroblastic

## PETROGRAPHIC DESCRIPTION OF CORE

Principal rock type: Staurolite-garnet-biotite schist.

Mineralogy: Quartz, plagioclase (untwinned, unzoned, slightly sericitized), biotite, garnet, staurolite; accessory sphene, tourmaline, apatite, zircon, and opaque Fe-Ti oxides. Zircons are small, rounded, pale pink, and rather abundant.

Texture: Main mass of rock is an equilibrium mosaic of quartz, plagioclase, and biotite composed of grains about 0.3-1.0 mm in size. Highly sieved porphyroblasts of garnet (1.0-1.5 mm) and staurolite (10-15 mm) are randomly superimposed on the foliated mosaic. Neither garnet nor staurolite is optically zoned, and neither shows evidence of rotation.

Structure: Bedding dips at angle of approximately 50°, schistosity at about 60° in same sense. Strong schistosity is defined primarily by oriented biotite.

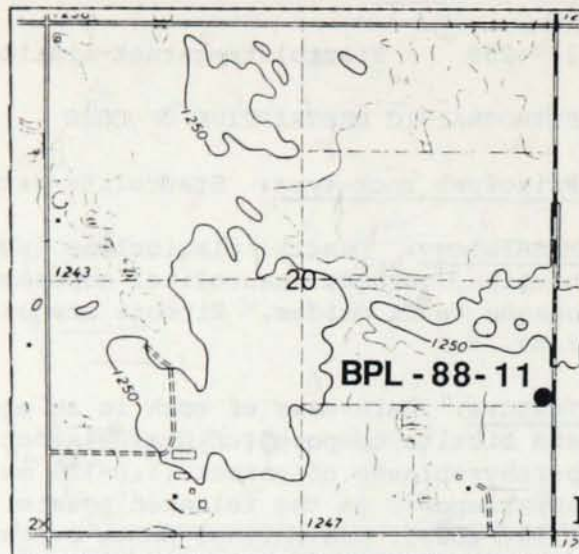
Comments: Beds range in composition between pelitic and semipelitic, and in thickness between a few cm and a few tens of cm. The semipelitic layers are richer in quartz and plagioclase than the pelitic, but are sufficiently aluminous to contain garnet and staurolite.

Field number BPL-88-11Date completed Sept. 23, 1988MGS unique number 242805MGS lab number 2790 and 2844

LOCATION (see map at right)

T-R-S 122-33-20 DDAAACounty KandiyohiQuadrangle Hawick 7.5'

## HOLE PARAMETERS

Surface elevation 1245 ± 5 ftTotal depth 413 ftElevation, top of  
Precambrian rock 995 ftCore interval 403-413 ftCore recovered 10 ft

## ABBREVIATED LITHOLOGIC LOG (intervals recorded are depths in feet)

Interval	Description
QUATERNARY DEPOSITS	
0-3	Topsoil, loamy, dark brown
3-36	Gravel and sand, medium to coarse
36-55	Till, sandy to loamy, calcareous, gray
55-58	Sand and gravel
58-120	Till, sandy to loamy, calcareous, gray
120-163	Till, clayey, calcareous, gray
163-169	Clay, plastic, dark gray-brown
169-217	Till, clayey to loamy, calcareous; olive gray above 195 ft; grades to brownish gray and is sandier below 195 ft
217-228	Sand, very coarse, variegated; abundant mafic grains, quartz, relatively sparse carbonate
228-235	Till, loamy, pale yellow-brown
235-250	Interbedded sequence of silt, fine to coarse sand, gravel

## REGOLITH ON PRECAMBRIAN ROCK

250-260 Saprolitic clay, kaolinitic, white to pale green  
260-374 Saprolitic clay and grus; residual grains of quartz, potassium  
feldspar  
374-403 Grus and partly decomposed granitic rock

## SOUND PRECAMBRIAN ROCK

403-413 Granite, very coarse-grained; somewhat weathered above 410 ft

## PETROGRAPHIC DESCRIPTION OF CORE

Principal rock type: Very coarse granite.

Mineralogy: Plagioclase, heavily sericitized (35%); quartz (30%), microcline (30%), biotite intergrown with muscovite (4%). Biotite is extensively altered to chlorite, vermiculite(?), Fe-Ti oxide. Accessory sphene, zircon.

Texture: Very coarse hypidiomorphic granular; grain size 0.5-2 cm.

Structure: Massive.

Comments: Recovered core is slightly weathered.

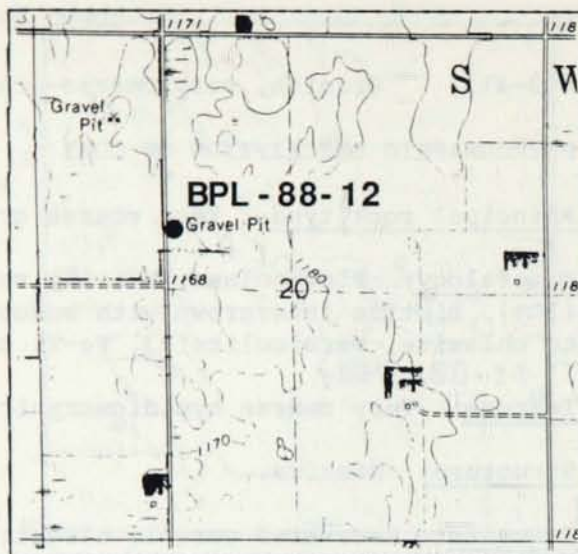


Field number BPL-88-12Date completed Oct. 15, 1988MGS unique number 242806MGS lab number 2845

LOCATION (see map at right)

T-R-S 120-32-20 BDCBBCounty MeekerQuadrangle Grove City 7.5'

## HOLE PARAMETERS

Surface elevation 1170 ± 5 ftTotal depth 384 ftElevation, top of  
Precambrian rock 814 ftCore interval 374-384 ftCore recovered 9.5 ft

## ABBREVIATED LITHOLOGIC LOG (intervals recorded are depths in feet)

Interval	Description
QUATERNARY DEPOSITS	
0-1	Topsoil, pebbly, black
1-16	Gravel and sand, carbonate-rich, yellow-brown
16-49	Till, loamy to clayey, very calcareous, gray; oxidized in topmost foot
49-131	Till, loamy to sandy, calcareous and shale-bearing; gray to dark gray. May consist of more than one till unit
131-153	Sand, fine to coarse, and gravel. Carbonate clasts predominant
153-183	Till, loamy, calcareous, gray to dark gray. Zone 173-177 ft is green and interpreted to be weakly oxidized
183-197	Gravel, coarse sand; contains abundant basalt, felsite, quartz; relatively sparse carbonate
197-202	Till, sandy-loamy, felsite-bearing, carbonate-poor, brownish-gray
202-210	Interbedded gravel, coarse sand, stiff, clayey silt; brownish gray
210-225	Till, sandy-loamy, felsite-bearing; some carbonate and shale. Brownish gray
225-259	Till, clayey; contains abundant carbonate, shale; traces of red felsite. Gray to dark gray
259-270	Till, sandy-loamy; numerous cobbles in lower half. Brownish gray

## REGOLITH ON PRECAMBRIAN ROCK

270-314	Saprolitic clay, kaolinitic, white, pale pink, pale green
314-325	Saprolitic clay, pale to dark greenish-gray
325-356	Saprolitic clay, greenish-gray; residual quartz and feldspar locally abundant
356-374	Grus and partly decomposed rock

## SOUND PRECAMBRIAN ROCK

374-384	Granite of "Rockville" type; coarsely porphyritic
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## PETROGRAPHIC DESCRIPTION OF CORE

Principal rock type: Coarse-grained megacrystic granodiorite.

Mineralogy: Megacrysts: plagioclase (delicately zoned in oligoclase range), microcline (strongly perthitic, Carlsbad-twinning). Groundmass: oligoclase (45%), quartz (20%), biotite (20%), microcline (16%). Accessory sphene, apatite, monazite, zircon; traces of secondary sericite, chlorite. Fe-Ti oxides very sparse.

Texture: Groundmass is allotriomorphic granular; grain size, 1-4 mm. Plagioclase megacrysts include individual complete crystals, broken crystals, and glomeroporphyritic clots. Microcline megacrysts have anhedral, embayed margins. Megacrysts (both compositions) are typically 1-1.5 cm in length.

Structure: Massive.

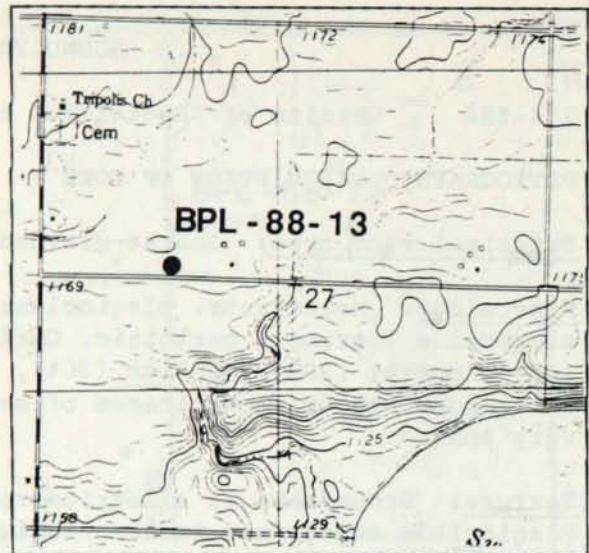
Comments: Resembles the Rockville Granite of Morey (1978).

Field number BPL-88-13Date completed Oct. 20, 1988MGS unique number 242807MGS lab number 2846

LOCATION (see map at right)

T-R-S 119-34-27 BDCCCCCounty KandiyohiQuadrangle Little Kandiyohi Lake 7.5'

## HOLE PARAMETERS

Surface elevation 1172 ± 5 ftTotal depth 653 ftElevation, top of  
Precambrian rock 641 ftCore interval 643-653 ftCore recovered 10 ft

## ABBREVIATED LITHOLOGIC LOG (intervals recorded are depths in feet)

Interval Description

## QUATERNARY DEPOSITS

(NOTE: The Quaternary intersection is long and complex, and its description is greatly generalized for brevity. Further details are available on request from the MGS)

0-3	Organic topsoil, black
3-17	Clay, plastic and very sticky, olive-gray
17-62	Till, clayey-loamy, calcareous, dark gray; topmost 13 ft somewhat oxidized
62-92	Interbedded sand, gravel, silt, and silty clay
92-118	Till, sandy-loamy, calcareous, dark gray
118-124	Silt, fine sand; gravel at base
124-158	Till, loamy-sandy, calcareous, gray
158-200	Gravel, coarse, dolomitic, interbedded with fine to coarse sand
200-281	Till, clayey-loamy, calcareous; upper half gray, lower half greenish gray to green
281-291	Interbedded sand and soft clay
291-309	Till, clayey-loamy, calcareous, shale-bearing, dark gray
309-316	Interbedded sand and silt
316-358	Till, loamy, calcareous, shale-bearing, olive-gray to dark gray



- 358-377 Clay, silt, fine sand; coarsens downward to gravel near base. Contains red felsite, rather little carbonate; wood chips present toward top
- 377-412 Till, sandy to loamy, felsite-bearing, carbonate-poor, red-brown
- 412-424 Till, loamy, shale-rich, very stiff, gray
- 424-432 Silt and fine sand, gray; contains wood
- 432-442 Till, clayey to loamy, shale-rich but with minor felsite; gray to brown
- 442-531 Coarse sand, fine sand, silt, clay, and gravel

## REGOLITH ON PRECAMBRIAN ROCK

- 531-565 Saprolitic clay, blue-green to greenish-gray
- 565-638 Saprolitic clay with zones of sparse residual quartz. Abrupt transition to sound rock at base

## SOUND PRECAMBRIAN ROCK

- 638-653 Pink granitoid gneiss

## PETROGRAPHIC DESCRIPTION OF CORE

Principal rock type: Granitoid gneiss

Mineralogy: Oligoclase, moderately sericitized (40%); quartz (30%); microcline, variably perthitic (20%); biotite (9%). Accessory apatite, sphene, epidote, zircon, opaque Fe-Ti oxides; traces of secondary sericite, chlorite, epidote, carbonate.

Texture: Relict equigranular, coarse-grained igneous texture is partially overprinted by metamorphic recrystallization, fabric development. Large feldspar grains (1-7 mm) have partly recrystallized and mortared rims but are not recrystallized or deformed internally. Quartz grains of comparable size are reduced to sub-grains and dimensionally flattened. Zones of more intense granulation (discontinuous size reduction of both feldspar and quartz) anastomose around less deformed lenses that are 5-10 mm thick, and define the foliation.

Structure: Well developed foliation dips at approximately 50°.



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