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**SCIENTIFIC AND EXPLORATION DRILLING  
IN NORTHWESTERN MINNESOTA**

Lithological, geochemical, and geophysical results  
of drilling by the Minnesota Geological Survey,  
1991–1993, and a summary of other scientific and  
exploration test drilling

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**Minnesota Geological Survey**  
*D.L. Southwick, Interim Director*

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By

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University of Minnesota  
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## CONTENTS

	<u>Page</u>
INTRODUCTION.....	1
ACKNOWLEDGMENTS.....	1
BEDROCK GEOLOGY OF NORTHWESTERN MINNESOTA .....	1
Archean rocks .....	3
Wabigoon subprovince.....	3
Quetico subprovince.....	6
Wawa subprovince.....	7
Proterozoic dikes.....	7
Phanerozoic bedrock.....	7
Ordovician .....	8
Jurassic.....	8
Cretaceous.....	9
NW-SERIES DRILLING BY THE MINNESOTA GEOLOGICAL SURVEY, 1991-1993.....	9
Site selection and drilling methods.....	9
Explanation of MGS drilling records.....	9
Hole numbers .....	10
Location.....	10
Hole parameters.....	10
Lithologic logs.....	10
Petrographic descriptions.....	11
Geochemical data.....	11
Geophysical data (magnetic susceptibility, density, and gamma logs).....	12
REFERENCES CITED.....	12
MGS DRILLING RECORDS, NW-SERIES DRILL HOLES.....	14
SUMMARY OF ARCHIVED BEDROCK DRILLING DATA.....	60
Records of archived drill holes.....	62

## APPENDICES

Appendix A. Modal composition of plutonic rocks.....	96
Appendix B. Major and minor element geochemistry.....	97
Appendix C. Downhole gamma logs of NW-series drill holes.....	101

## ILLUSTRATIONS

Figure 1. Map of Minnesota showing locations of study area and previously published MGS drilling reports .....	2
2. Generalized bedrock geologic map of northwestern Minnesota showing locations of NW-series drill holes.....	4
3. First vertical derivative map of reduced-to-pole magnetic anomaly data, northwestern Minnesota .....	5
4. Illustration of the abbreviated Township-Range-Section subdivision system.....	10

## TABLE

Table 1. Logistical summary of drilling: NW-series drill holes.....	11
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## **INTRODUCTION**

Scientific test drilling in northwestern Minnesota was undertaken by the Minnesota Geological Survey (MGS) primarily to elucidate the geology of Precambrian and Phanerozoic bedrock in this area where the bedrock is buried beneath several hundred feet of Quaternary glacial sediment. The results of this drilling of 23 holes, and of selected logging, and analyses of the approximately 80 archived records and core from previous drilling, are presented in this report. These data, in conjunction with various geophysical maps, were utilized by the authors and others to construct a series of new geologic maps of northwestern Minnesota that are part of MGS Open-File Report 93-1A (Jirsa and others, 1993). Parts of that report will soon be published in the MGS Miscellaneous Map Series. An important secondary objective of this project is to describe the Quaternary deposits that overlie bedrock, though no systematic regional interpretation of those deposits has been undertaken to date.

This is the seventh information circular since 1980 to report the results of test drilling by the Minnesota Geological Survey. Figure 1 shows the areas covered by those earlier studies in relation to this study area in northwestern Minnesota.

## **ACKNOWLEDGMENTS**

Mapping and scientific test drilling were supported by the Minnesota Minerals Diversification Program administered by the Minerals Coordinating Committee of the Minnesota Legislature. Budget administration, editing, and geologic insight were provided to the authors by David Southwick of the MGS. Geophysical data were provided in part by funding from the Legislative Commission on Minnesota Resources.

Although the authors compiled this report, it was produced by the efforts of many MGS staff members whose names do not appear in the authorship: we acknowledge field geologists Emily Bauer, Alan Knaeble and Anthony Runkel for drill-site logging; John Mossler and Anthony Runkel for interpretation of cuttings and downhole geophysical data related to the Phanerozoic strata; Val Chandler for preparation of geophysical maps used in interpretation of the Precambrian geology; and Jane Cleland for compilation of geophysical (rock) properties data. We are grateful to the land owners who allowed us to drill on their property and to state and county government officials who assisted during drilling on public property. We also wish to acknowledge the efforts of the many exploration company geologists for careful selection of drill targets, core logging and analyses, and curation of drill cores and data, and the Minnesota Department of Natural Resources, Division of Minerals for archiving those cores and data and helping us retrieve them.

## **BEDROCK GEOLOGY OF NORTHWESTERN MINNESOTA**

The bedrock geology of northwestern Minnesota consists of Late Archean and Early Proterozoic rocks that are locally overlain by Paleozoic and Mesozoic strata. All of these bedrock units are covered by glacial deposits that vary in thickness from 180 to 535 feet. Because no exposures of the bedrock exist within the map area, the geology described below and generalized on Figure 2 is based on new drilling; on the archived records of nearly 400 drill holes; on geophysical maps such as that shown on Figure 3; and on extrapolation from better known and locally well exposed terrane which lies along strike.

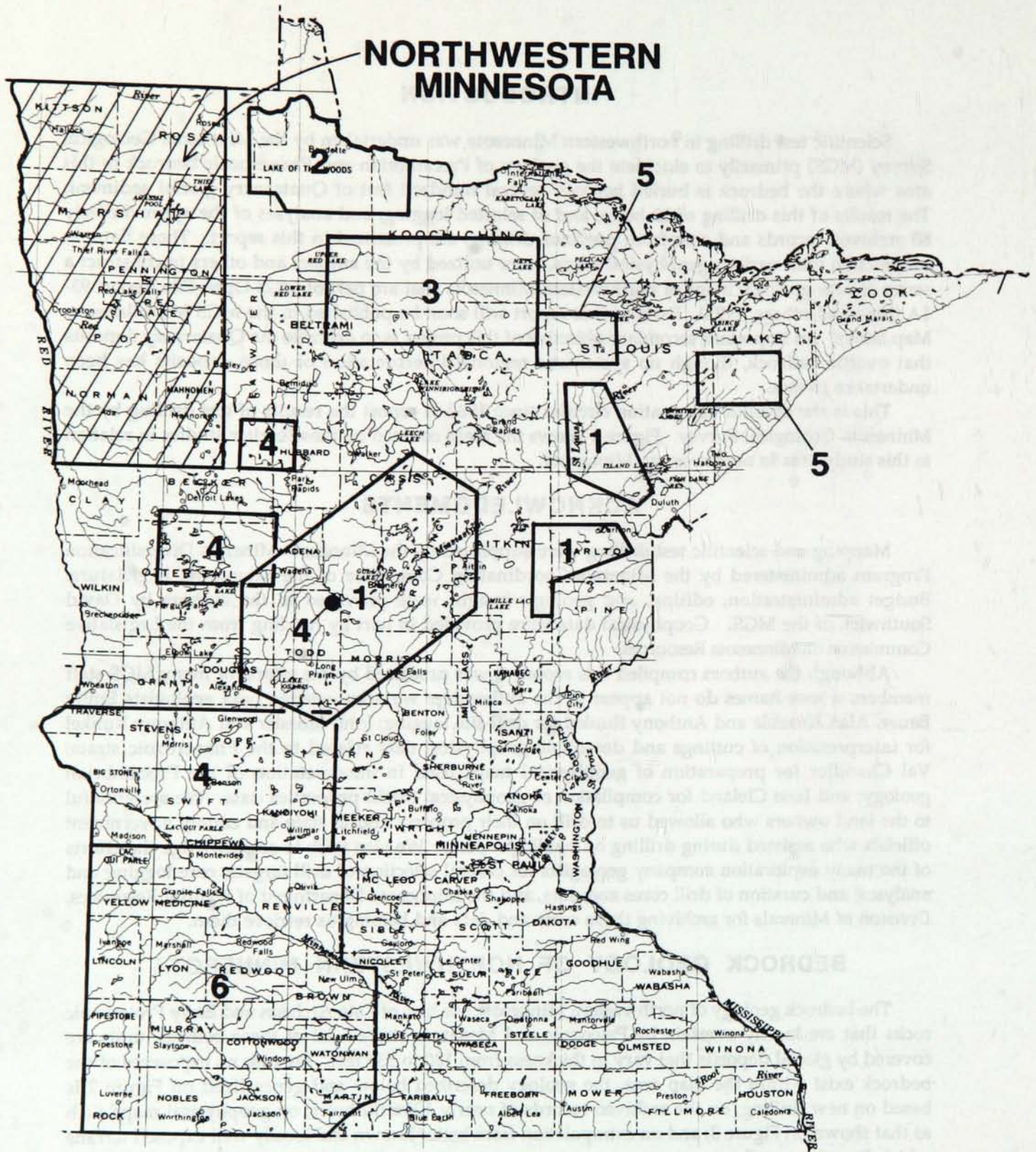


Figure 1. Map of Minnesota showing the location of this study (shaded), and of previously published MGS Information Circulars on drilling: 1. Southwick and others (1986); 2. Mills and others (1987); 3. Boerboom and others (1989); 4. Southwick and others (1990); 5. Meints and others (1993); and 6. Southwick and others (1993).



## Archean Rocks

The Archean geology of northwestern Minnesota includes parts of the Wabigoon, Quetico, and Wawa subprovinces of the Superior Province. The geology is further subdivided into six lithotectonic blocks (Fig. 2). The blocks have contrasting lithologic, structural, and metamorphic attributes, and are separated by major fault zones. The general characteristics of those lithotectonic blocks and their bounding faults are described below.

### Wabigoon subprovince

The internal part of the subprovince, blocks I-III on Figure 2, is made up of large elliptical to irregularly shaped, composite granitoid batholiths separated by subordinate cusped wedges and septa of supracrustal rocks that are metamorphosed to the middle to upper greenschist facies and locally to higher grades. Long, sinuous fault zones are common within the segments of supracrustal rocks. The southern part of the subprovince, block IV, is a distinctively linear belt which is parallel to the subprovince border and composed of lower greenschist-facies supracrustal rocks and relatively small elliptical plutons. This marginal zone is dissected by many nearly belt-parallel shear zones inferred from exposures to the east to have complex displacement histories that include both early dip-slip movement, and later, largely dextral strike-slip offsets.

Block I. Amphibolite- to granulite-facies biotitic paragneiss and granodioritic to tonalitic orthogneiss cut by post-tectonic granitic pegmatite dikes and larger granitoid plutons. Foliation locally is relatively shallow, on the order of 40-60°. Nearly pygmatic distribution of narrow magnetic highs (Fig. 3) is attributed to folded gneissic banding and large supracrustal xenolithic blocks. Gravity expression generally is higher and more variable than in block II.

*Lancaster fault.* Inferred to be an early fault structure which lies along a lithologic break separating rocks predominantly of plutonic protolith to the north from those of dominantly supracrustal source to the south.

Block II. Gneissic to strongly foliated and metamorphosed rocks which vary from mostly plutonic to the west, to mostly supracrustal to the east. The schists are metamorphosed to amphibolite grade and contain albite, biotite, quartz, garnet, and cordierite. Biotite schist of graywacke protolith along the northern part of the belt grades into amphibolite-grade interbanded volcanic and clastic rocks, and eventually to dominantly mafic volcanic rocks to the south and east. This southward and eastward direction of progressive change of protolith is inferred from scattered drill core to be generally stratigraphically down. The plutonic rocks are strongly but variably magnetic and show a decrease in magnetite content adjacent to inferred fault structures that appear from map distribution to be splays of the Vermilion fault. Alternatively, these magnetic lows may be earlier thrust features not related to the Vermilion fault.

*Vermilion fault.* Inferred to be a relatively late, dextral strike-slip fault that offsets contrasting metamorphic zones and earlier faults such as the Fourtown and Rainy Lake-Seine River faults.

Block III. Large, composite granitoid batholiths (Karlstad, Florian, and Snake River batholiths) separated locally by thin sequences of metavolcanic and metasedimentary rocks. Mafic volcanic rocks are dominant, and one drill core contains spinifex textured flows inferred to be komatiitic. The several cores that define a large anticline near Thief Lake contain an S<sub>1</sub> cleavage that is

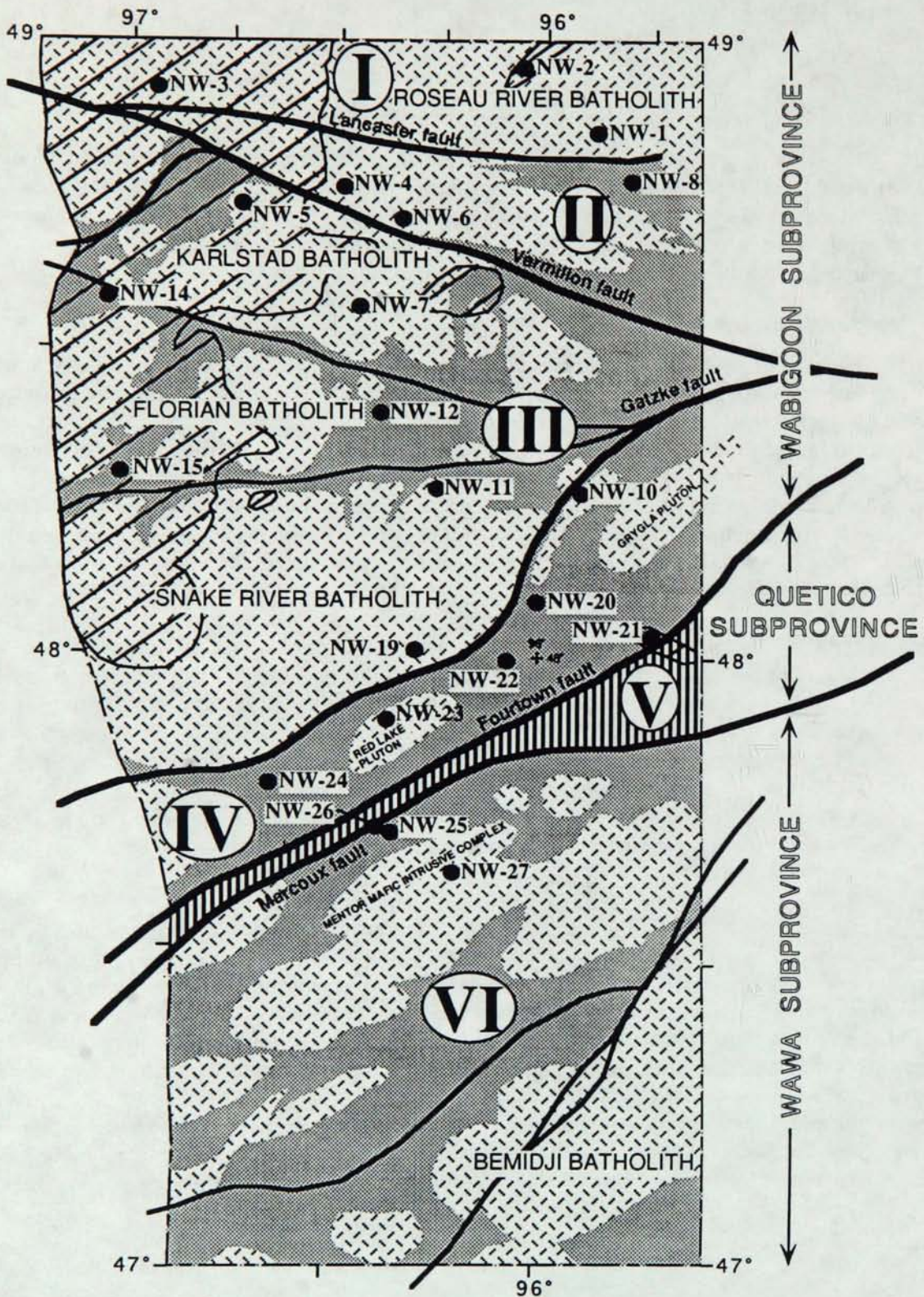


Figure 2. Generalized bedrock geologic map of northwestern Minnesota showing the subdivision of Archean subprovinces into lithotectonic blocks and the location of NW-series drill holes described in the text. The locations of archived drill holes are not shown, but the lithotectonic block in which they occur is given on the logs. Proterozoic dikes are omitted. Archean plutonic rocks are shown by the whisker pattern, supracrustal rocks are shaded. The Precambrian bedrock is overlain by Paleozoic and Mesozoic strata in the area shown by ruled pattern. Simplified from Jirsa and others (1993).



Figure 3. First vertical derivative map of reduced-to-pole magnetic anomaly data, northwestern Minnesota. The multitude of narrow, northwest-trending anomalies are produced by Proterozoic diabasic dikes that are not delineated on Figure 2. Scale is approximately the same as that of Figure 2 (1:1,131,000). Image produced by Val W. Chandler, Minnesota Geological Survey.

parallel to bedding and is cut by S<sub>2</sub> cleavage. This cleavage/bedding relationship implies that the anticline is an F<sub>2</sub> structure. Stratigraphic younging in supracrustal sequences is poorly constrained by drill holes, but tends to be away from batholiths. Metamorphic grade is dependent in part on proximity to the large batholiths, and varies from lower to upper greenschist facies.

*Gatzke fault and the southern boundary of the Snake River batholith. The fault locally offsets upper greenschist facies supracrustal rocks to the north, from lower greenschist facies (chlorite zone) rocks to the south. On this basis the fault is interpreted to have had a strong dip-slip, north-side-up sense of displacement, but strike-slip offset at different times is also a likelihood.*

**Block IV.** Narrow, linear, southern boundary zone of the Wabigoon subprovince. The zone consists of low metamorphic grade volcanic and clastic rocks containing many thin lenses of magnetite-quartz and graphitic, pyritic, and argillaceous iron-formation. Several relatively late (post-metamorphic), elliptical plutons of tonalitic to gabbroic composition occur within the zone, including the Grygla and Red Lake plutons. Stratigraphic younging determined from drill holes that lie within and east of the map area defines an antiform around the Grygla pluton, and elsewhere younging is toward the south where it can be determined.

*Fourtown fault. Inferred to be the continuation of the Rainy Lake-Seine River fault mapped farther to the east (Day and others, 1990a, 1990b), which is displaced about 40 km to the southeast by the Vermilion fault. Immediately east of the map area, the Fourtown fault separates rocks metamorphosed to the chlorite zone of greenschist facies to the north from amphibolite-grade metasedimentary rocks of the Quetico subprovince to the south. Movement, therefore, has been at least in part south-side-up and dip-slip; however, significant right-lateral displacement is recorded from mapping along the correlative Rainy Lake-Seine River fault system to the east.*

### **Quetico subprovince**

**Block V.** Schists of sedimentary protolith. Although no drill core of this unit exists from within the map area, cores to the east indicate that the rocks are biotite schist of graywacke protolith that contains thin layers and lenses of amphibolite. Gravity and magnetic expression are both low, though local banding can be discerned from derivative aeromagnetic maps. This eastward-striking banding is truncated by the northeast-trending Fourtown fault. The geophysical expression indicates that this part of the Quetico subprovince lacks the tonalitic to granodioritic plutonic intrusions that are typical of the eastern part of the subprovince (Bauer and others, 1992). Schist in drill cores from 50 km east of this map area near the southern boundary of the Quetico subprovince contains biotite, garnet, hornblende, plagioclase, and quartz. The drill holes nearest to the northern border lie 1-3 km east of the map area and contain approximately the same metamorphic mineral assemblage.

*Marcoux fault. A geophysical discontinuity that separates the low gravity and magnetic signature of Quetico subprovince schist to the north from rocks of relatively high gravity and magnetic expression in the Wawa subprovince to the south. Drill core east of the map area indicates that the discontinuity separates graywacke of moderate to high metamorphic grade to the north, from lower greenschist-facies (chlorite zone) volcanic, clastic, and plutonic rocks to the south. The subtle magnetic banding in Quetico rocks, which is subparallel to the Marcoux fault, implies that this boundary is a strata-parallel, faulted (up on the north) lithological*

*contact; however, no direct evidence exists in the map area for metamorphic contrast across the fault.*

## **Wawa subprovince**

Block VI. Volcanic and volcanoclastic rocks cut by large composite granitoid batholiths, and mafic and ultramafic intrusions, which vary from hypabyssal sills associated with the interdigitate volcanic rocks, to late, post-metamorphic and post-tectonic plutons. The Mentor mafic intrusive complex is considered to be the latter type of intrusion because it lacks evidence of metamorphism and deformation. The supracrustal rocks are composed of a northern sequence about which only a little is known from several drill holes which intersected interbedded volcanogenic graywacke having a large mafic clastic component and mafic volcanic rocks. The relatively thick sequence to the south in Norman County can be moderately well described from the numerous exploration drill cores. That sequence is consistently northward younging and "grades" progressively northward from dominantly mafic volcanic rocks adjacent to the Bemidji batholith on the south, to strata dominated by conglomerate of dacitic provenance on the north. Conglomeratic units locally contain sedimentary structures implying fluvial deposition, and are interlayered with variable amounts of dacitic tuff, dacitic graywacke, graphitic argillite, and thin units of magnetite-rich iron-formation. The dacite-dominated part of the sequence grades stratigraphically upward (northward) into strata of similar composition, but of finer grain size, implying deepening water and/or a decrease in dacitic volcanism with time. Although the apparent stratigraphic progression indicates a continuum in deposition, many geophysical discontinuities within the sequence may be faults that produced repetition of strata. The supracrustal rocks are metamorphosed to within the chlorite zone of greenschist facies, though slightly higher grade assemblages exist adjacent to intrusive rocks. The magnitude of deformation varies from minor to intense. Much of the conglomeratic, central part of the sequence contains well-preserved, delicate bedding features. Core samples from holes near large plutons and adjacent to "internal" fault zones are more intensely flattened, sheared, and metamorphosed.

## **Proterozoic Dikes**

Although not shown on Figure 2, diabasic to gabbroic dikes of the Kenora-Kabetogama swarm are abundant in northwestern Minnesota (see Jirsa and others, 1993). The dikes can be delineated from detailed aeromagnetic maps (Fig. 3), and groups of closely spaced dikes can locally be discerned on gravity anomaly maps. Several dikes were intersected in the exploration drill holes that are summarized in this report. Aeromagnetic maps indicate that dikes having both reversed and normal polarity occur within the area; however, polarity studies have not been completed to substantiate this inference.

## **Phanerozoic Bedrock**

Two Ordovician formations, shale and sandstone of Cretaceous age, and an intervening heterolithic unit of uncertain age (Jurassic?) subcrop beneath the Quaternary glacial deposits in extreme northwestern Minnesota. These rocks were deposited in marginal marine environments on the eastern shelf of the Williston basin. They therefore are the relatively thin, easternmost outlier of a much thicker Paleozoic and Mesozoic sequence that spans a wide range of ages in the Williston Basin in adjacent parts of Canada and North Dakota (Mossler, 1978). Because the inferred paleogeographic position of the Paleozoic and Mesozoic strata lies near the edge of the apparent depositional basin, differentiation between various components of the stratigraphic section is extremely complicated and is not well constrained by the available drilling information.

The following description summarizes what is known about those strata based on drill holes and to a lesser extent on correlation with better known districts in Manitoba and North Dakota.

### **Ordovician**

Two Ordovician units, the Winnipeg and Red River Formations, can be distinguished in drill holes. The Winnipeg Formation unconformably overlies Precambrian rocks. It is as much as 178 feet thick in the extreme northwestern corner of the study area, and thins to the east and south beneath the Red River Formation. It is less than 10 feet thick in two drill holes along the eastern edge of the Paleozoic subcrop. The Winnipeg typically consists of a thin basal unit of medium- to coarse-grained, quartzose sandstone consisting of well-rounded grains and overlain by as much as 150 feet of gray, green, and red shale containing sandstone and limestone interbeds. Brachiopod and bryozoan fossils are common. Sandstone and limestone beds are generally more abundant near the top of the formation, creating a transitional contact with the overlying Red River Formation.

The Red River Formation varies from partly dolomitized, bioclastic limestone, to slightly dolomitic, micritic limestone. The limestone is light gray, yellow, and tan; it commonly has pink and orange mottling and locally contains thin beds of red and green shale. The Red River is nearly 300 feet thick in the extreme northwestern part of the study area and thins to the south and east. Several drill holes indicate that the Red River Formation oversteps the Winnipeg Formation near its easternmost subcrop where it may lie directly on the Precambrian bedrock.

### **Jurassic**

A sequence of extremely heterolithic strata locally lies above the Winnipeg Formation and below shaly strata of Cretaceous age. These strata were informally named the Hallock red beds by Bayer (1959), although they have been recognized as a discrete unit since 1932 (Allison, 1932). The Hallock strata consist of (1) green, gray, brown, and red shale; (2) structureless to mottled, white to tan micritic limestone and dolomite; (3) calcareous shale; (4) red, brown, and white, fine- to coarse-grained sandstone and siltstone; and (5) nodules of chert and possibly gypsum. The origin and age of the Hallock red beds remain uncertain. Allison (1932) believed they were Paleozoic in age. Bayer (1959) suggested that these beds are a residuum of Red River Formation that weathered in Cretaceous time. Bayer (1959) also discussed the possibility that the Hallock beds are a southeastern outlier of marginal marine deposits of Jurassic age that occupy buried bedrock valleys in Manitoba and North Dakota. Those strata are much thicker than the Hallock of northwestern Minnesota and contain abundant evaporites. The Hallock red beds were tentatively assigned a Jurassic age by Mossler (1978) because of their stratigraphic position, because of their general similarity to Jurassic strata in adjacent parts of Manitoba and North Dakota, and because, unlike most Cretaceous regolith and marine strata in other parts of Minnesota, the shales in the Hallock are not rich in kaolinite.

Two of the NW-series holes penetrated beds that are tentatively assigned to the Hallock red beds. Study of the Hallock from these and previously drilled holes indicates that the stratigraphic setting of the Hallock differs somewhat from that of the Jurassic strata in North Dakota and Canada. The Hallock has been recognized only where it lies directly above the Winnipeg Formation, at an elevation and stratigraphic position identical to that of the Red River Formation in nearby drill holes. It has never been recognized directly overlying the Red River Formation. Additionally, it appears that the northernmost Hallock strata in Minnesota are surrounded by the Red River Formation at equal or higher elevations; however, deep drill holes are sparse in this area. These relationships indicate that the Hallock may be the fill of an internally drained basin, the regolith of weathered Red River Formation, or various combinations of both. If some of the Hallock is indeed a weathering residuum, its small kaolin content may

simply reflect the low kaolin content of the parent Red River Formation. We believe that strata assigned to the Hallock red beds probably were deposited on a weathered, possibly karsted carbonate terrain developed in the Red River Formation in Jurassic and possibly Cretaceous time. As such, they likely include in-situ weathered Red River Formation; fluviially transported, weathered residuum of the Red River Formation and detritus from the Winnipeg Formation; and perhaps nearshore marine deposits that accumulated near the edge of the Jurassic and/or Cretaceous seas. Better developed, thicker Jurassic rocks in Canada and North Dakota are possibly Hallock equivalents deposited in a more seaward environment.

## **Cretaceous**

Cretaceous strata occur mostly in the northwestern part of the map area where they unconformably onlap Hallock red beds, Ordovician strata, and Precambrian basement. The Cretaceous rocks in this area are as much as 115 feet thick and typically consist of a thin (<20 ft. ) basal unit of pebbly sandstone overlain by olive-gray, gray, and green silty claystone with lignite interbeds. Fossil coccoliths extracted from a gray shale that lies above the Hallock red beds in a test hole near the town of Hallock (Well A in T-R-S 161-49-13) indicate a Turonian or Coniacian age. Two outlying subcrops of Cretaceous rocks were penetrated in holes drilled for this project. These strata lie several miles east of the Paleozoic subcrop area and directly overlie Precambrian rocks in buried bedrock valleys. In contrast to Cretaceous deposits to the west, these outliers are composed mostly of fine to coarse, angular to subangular quartzose sandstone. Given the relatively small number of drill holes in this part of northwestern Minnesota, many other small outliers of Cretaceous strata are likely to exist.

# **NW-SERIES DRILLING BY THE MINNESOTA GEOLOGICAL SURVEY, 1991-1993**

## **Site Selection and Drilling Methods**

Drill hole locations were chosen on the basis of geophysical data to provide the best possible geologic framework by penetrating geophysical anomalies of broad regional extent. An effort was made to select locations on state, county or federally administered property to minimize impact to the public. Where it was necessary to drill on private property, permission was obtained from the owners and individual mineral rights were unaffected. Table 1 summarizes some of the drilling logistics. All drill holes in this series were drilled in a vertical orientation by standard rotary methods to the Precambrian bedrock, and cuttings were periodically retrieved from the drilling fluid. Cores were taken from the Precambrian bedrock where possible, and 10 feet of core was typically acquired at each drill site. No cores were taken of the Phanerozoic bedrock, in part because of the inherent difficulties of coring those relatively soft and clayey materials. Geologists from the MGS logged and sampled cuttings during drilling operations, and downhole geophysical logs were acquired from each drill hole to aid interpretation of the Quaternary sediment. Cores, rotary cutting samples, and the downhole geophysical logs are available at the Minnesota Geological Survey, St. Paul.

## **Explanation of MGS Drilling Records**

The drill hole records in this circular include geologic descriptions for each hole, together with geochemical and geophysical data where acquired. Elements of those records are described in more detail below.

### Hole Numbers

Drill holes described in this section are listed in order of increasing NW-series number. Hole numbers NW-9, 13, 16, 17, and 18 in the numerical sequence are missing, as not all sites initially selected were drilled. The smaller hole numbers generally lie to the north, and progressively larger-numbered holes occur toward the south. MGS lab number refers to the drill cuttings stored at the MGS Cuttings Library.

### Location

The holes are located by township, range, and section number (T-R-S). Precise locations within a legal section are specified by the ABCD system, which is a space-saving simplification of the "NE 1/4 SE 1/4. . ." system that traditionally has been used in legal land descriptions. In the ABCD system (Fig. 4), A is the NE 1/4, B is the NW 1/4, C is the SW 1/4, and D is the SE 1/4. In listing quarters, the *largest* subdivision is given first, followed by successively smaller subdivisions.

Quadrangle names are U.S. Geological Survey 7.5-minute topographic quadrangles (scale: 1:24,000).

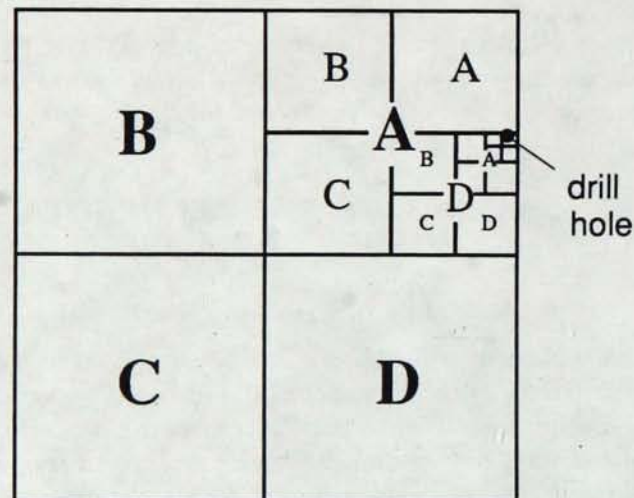


Figure 4. Diagram illustrating the method of locating a drill hole (dot) within a section using the abbreviated ABCD system. Hole location within the section in this example is described as ADAAAB. See explanation in text.

### Hole Parameters

All measurements are given in feet. Land surface elevations are estimated ( $\pm 5$  feet) from topographic contours on 1:24,000-scale quadrangle maps. The elevation of the top of Precambrian rock is the intersection of solid or weathered Precambrian bedrock. Thus in the footage calculations, locally thick saprolitic zones are included with the bedrock protolith. All NW-series holes were drilled vertically.

### Lithologic Logs

Most descriptions are generalized from the logs of field geologists, supplemented by subsequent interpretation of downhole geophysical logs, cuttings samples, and drill core.



Table 1. Logistical summary of drilling: NW-series drill holes

TOTAL PROJECT FOOTAGE		
Rotary drilling	9672.5'	
Core drilling	197.5'	19 of 23 holes were cored (82.6%)
Unrecovered casing	932'	Casing loss: 9.6% of total depth
<b>Total footage drilled</b> 9870'		
Total number of holes	23	
Total drilling time	20 weeks	Oct. 3-Nov. 21, 1991: 9 holes, NW #1-8 June 8-Aug. 23, 1992: 14 holes, NW #10-27
PARAMETER	RANGE (NW hole number)	AVERAGE
Hole depth	202' (#1) — 821' (#22)	429'
Depth to Precambrian	180' (#8) — 535' (#22)	371.4'
Drift thickness	180' (#8) — 535' (#22)	302.6'
Thickness of weathering residuum	0 —>286' (#22)	39.7'
NUMBER OF HOLES THAT INTERSECTED (NW hole number):		
Cretaceous rocks	4 (#2, #3, #15, #21)	
Hallock red beds	2 (#5, #15)	
Ordovician strata	4 (#3, #5, #14, #15)	
Red River Fm.	(#3, #14)	
Winnipeg Fm.	(#3, #5, #14, #15)	
Weathering residuum	16 (residuum not intersected in holes #1, #4A, #5, #7, #8, #11, #20)	
Precambrian rocks	23	

Contractor: Petersen Drilling, Virginia, Minnesota

### Petrographic Descriptions

These descriptions are based on detailed core logging and thin-section study. The percentages for relative abundance of individual minerals are based on visual estimates and point counts made from thin section. The rock type names are based on modal, rather than chemical composition, and the modal classification system of Streckeisen (1976) is applied to the plutonic rocks (Appendix A). The prefix "meta" is used inconsistently on rock names, but can be inferred for all of the supracrustal rocks of Precambrian age. "Meta" is typically applied to those plutonic rocks that show evidence for metamorphic recrystallization. Because the NW-series holes were drilled vertically, the attitudes of planar features are true dips from horizontal.

### Geochemical Data

The results of chemical analyses are listed with each NW drill hole record if acquired, and are summarized in Appendix B. A few analyses obtained from samples of archived cores are also reported, though a much larger database of geochemical data exists for those cores in the files of the Department of Natural Resources, Minerals Division, Hibbing, MN. Major and selected minor element analyses were performed by X-Ray Assay Laboratories, Ltd. using X-ray fluorescence for most oxides and minor elements, and wet chemical methods for CO<sub>2</sub> and FeO. Total iron content is given as Fe<sub>2</sub>O<sub>3t</sub>; the Fe<sub>2</sub>O<sub>3</sub> component was calculated and is included on the table as Fe<sub>2</sub>O<sub>3c</sub>. Minor element analyses were acquired from Activation Laboratories, Incorporated.

## Geophysical Data (magnetic susceptibility, density, and gamma logs)

In lieu of bedrock outcrops, geophysical data are critically important to deciphering the geology of northwestern Minnesota. With that in mind, magnetic susceptibility and gravity measurements were made of samples of the NW drill holes. Magnetic susceptibility was measured utilizing an EDA Instruments model K-2 magnetic susceptibility meter, and are recorded in  $10^{-3}$  cgs units (centimeter-gram-seconds). Measurements were taken at irregular intervals depending in large part on the relative variability of susceptibilities within a core. Magnetic susceptibility determinations should be regarded as approximate: an individual reading applies only to a very small volume of rock, and no corrections were made for core diameter. Measurements of density (specific gravity) were made with an Eberback Corporation Jolly balance, and the results are given in grams per cubic centimeter. Downhole geophysical logs, which record natural gamma radiation, are available for all of the NW-series drill holes and appear in simplified and reduced form in Appendix C, along with a crude interpretation of major stratigraphic boundaries. Typically, material that contains more potassic clay (clayey till, lacustrine clay, shale, and kaolinitic saprolite) reads higher than sandy strata or solid bedrock. Weathered bedrock, because of its large clay content, commonly shows anomalously high readings. Notice that the gamma logs commonly do not extend to the bottom of drill holes, and thus the depth to which the holes were gamma logged does not always correspond to the depth drilled as reported on the lithologic logs.

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Field number NW-1

Date finished 10-9-91

MGS unique number 247044

MGS lab number MGS 3220

LOCATION (see map at right)

T-R-S 162 - 41 - 15 ADAAB

County Roseau

Quadrangle Fox 7.5'

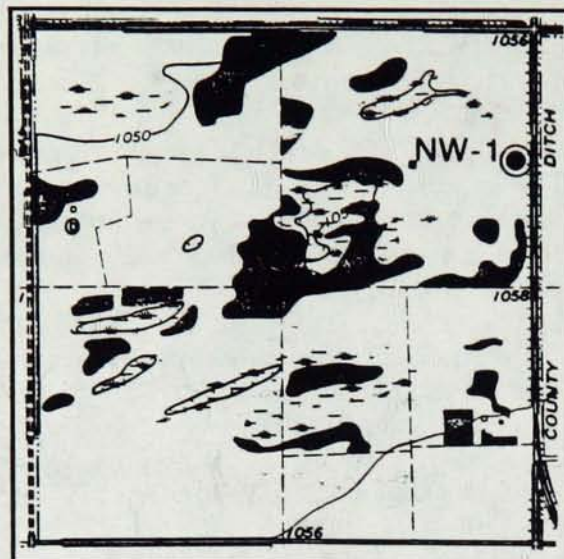
HOLE PARAMETERS (feet)

Surface elevation 1057'

Total depth 202'

Elevation, top of  
Precambrian rock 874'

Core interval 192'-202'



Hole azimuth:                      plunge: -90

Core recovered 100%

ABBREVIATED LITHOLOGIC LOG (intervals recorded are depths in feet)

Interval, feet	Description
<b>QUATERNARY DEPOSITS</b>	
0-2	Topsoil
2-18	Silt and clay; lacustrine, yellow and oxidized, mixed with wave-washed till, rare limestone pebbles.
18-26	Sandy clay similar to that above but containing a higher proportion of gravel.
26-40	Sandy till containing limestone and rare chert pebbles; gray
40-60	Sandy clay till as above; unoxidized. Dark gray lake clay near bottom of interval.
60-89	Sandy clay till; slightly oxidized, grayish-brown, pebbles of limestone, chert, basalt.
89-93	Clay till; greenish-gray .
93-150	Sandy till containing pebbles of limestone, chert, feldspar, and basalt, boulders at 97 and 137'.
150-160	Gravelly till, increasing proportion of sand with depth grading to sand below.
160-183	Clean sand.
<b>WEATHERING RESIDUUM ON PRECAMBRIAN ROCK</b>	
None encountered.	
<b>SOUND PRECAMBRIAN ROCK</b>	
183-202	Hornblende-pyroxene-biotite diorite to monzodiorite augen gneiss; pinkish-black, banded, lineated and cut by subcordant dikelets of medium- to coarse-grained, foliated, pink granite in sharp to diffuse contact with diorite. Younger, coarse-grained, undeformed granite dikelets are both concordant and discordant to foliation. Deformed feldspar phenocrysts (?) are scattered throughout the diorite.

PETROGRAPHIC DESCRIPTION OF CORE: NW-1

Principal Rock Type: Hornblende-pyroxene-biotite diorite to monzodiorite; Leucogranite.

Mineralogy: *Diorite/monzodiorite* - plagioclase, granoblastic (32-55%); orthoclase, granoblastic (0-12%); biotite, yellowish-brown pleochroism, subhedral, weakly foliated (19-27%); clinopyroxene, pale green, subhedral to granoblastic (5-20%); hornblende, sub- anhedral, brownish-green pleochroism, foliated (1-15%); opx (trace), mostly replaced by mat of fibrous greenish-brown biotite/chlorite/talc and granular oxides; accessory oxides, apatite, zircon, quartz.

*Granite* - plagioclase, granoblastic (30%); perthite, granoblastic to poikilitic (38%); quartz, large grains verging on mortar-texture (31%); accessory biotite, epidote, zircon, oxides, muscovite.

Texture: *Diorite/monzodiorite* - Variably lineated, medium-grained. Quartz, feldspars, and hornblende granoblastic, pyroxene granoblastic to subpoikilitic, biotite in subhedral books. Augen structures of ambiguous origin made up of granoblastic quartz and feldspar.

*Granite* - Weakly foliated, medium-grained. Plagioclase granoblastic, perthite granoblastic to poikilitic, quartz verging on mortar-texture.

Structure: Foliation dips 40-45° from horizontal.

CHEMICAL DATA

Rock Type Analyzed: Lineated augen (porphyritic?) hornblende monzodiorite; 196 - 198' interval

Major Elements (Wt. % oxides)	Minor Elements (ppm)	Minor Elements (ppm, Au=ppb)	Minor Elements (ppm)
SiO2 59.8	Rb 140	Au(ppb) <2	Cs 3.9
Al2O3 15.8	Sr 916	Ag <0.1	La 43.6
CaO 5.17	Ba 1260	Be 7	Ce 86
MgO 4.07	Zr 171	B 24	Ni 37
Na2O 4.27	Y 11	Sc 13.7	Sm 7.03
K2O 2.53	Nb 20	V 100	Eu 1.59
FeO 2.7		Cr 200	Tb 0.6
Fe2O3t 5.70		Co 23.0	Yb 1.14
MnO 0.11		Ni 91	Lu 0.16
TiO2 0.834		Cu 6.3	Hf 4.2
P2O5 0.50		Zn 106	Th 2.7
LOI 1.00		Pb 10	U 0.6
Total 100.1		Br 3.1	
Fe2O3 2.70			

MAGNETIC SUSCEPTIBILITY (depth in feet)

Depth	Reading (x 10 <sup>-3</sup> cgs units)	Depth	Reading (x10-3 cgs units)
192-193	0.22	197-198	0.17
193-194	0.14	198-199	0.28
194-195	0.07	199-200	0.03 - 0.15
195-196	0.07	200-201	0.12
196-197	0.14	201-202	0.20

DENSITY

Depth	Density
192.5	2.84 diorite
198.7	2.9 monzodiorite
201.5	2.63 granite

Field number NW-2

Date finished 10-8-91

MGS unique number 247041

MGS lab number MGS 3221

LOCATION (see map at right)

T-R-S 163 - 42 - 8 CDDADB

County Roseau

Quadrangle Badger NE 7.5'

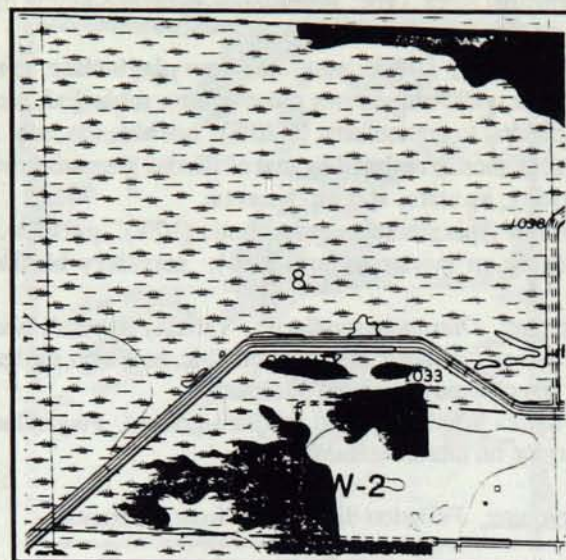
HOLE PARAMETERS (feet)

Surface elevation 1034

Total depth 306

Elevation, top of  
Precambrian rock 782

Core interval 296-306



Hole azimuth:                      plunge: -90

Core recovered 100%

ABBREVIATED LITHOLOGIC LOG (intervals recorded are depths in feet)

Interval, feet	Description
<b>QUATERNARY DEPOSITS</b>	
0-30	Silty till; gray, fine gravel component.
30-48	Sand and gravel.
48-98	Silty till; gray, fine gravel component.
98-160	Interlayered silty and sandy till; light gray. Gabbro, granite, basalt, metavolcanic rock cobbles are abundant from 98 - 102'.
160-185	Sand and gravel, sand is fine-grained, trace % wood fragments
<b>CRETACEOUS SEDIMENTARY ROCKS</b>	
185-204	Claystone; light olive-gray, silty.
204-252	Quartz arenite; very coarse-grained, well-sorted, subangular grains. Substantial % of detrital pyrite.
<b>WEATHERING RESIDUUM ON PRECAMBRIAN BEDROCK</b>	
252-278	Clay; green, white, and brown. Increasing component of residual biotite and feldspar below 277'.
<b>SOUND PRECAMBRIAN BEDROCK</b>	
278-306	Banded orthogneiss. Coarsely and diffusely banded, medium- to coarse-grained gneiss of enigmatic protolith. Banded via layers of neo-granitic material alternating with dark garnet-biotite restite. Garnet most abundant in dark layers but also present in lighter-colored granitic layers, which are composed of light gray to pink monzonite to granite.

PETROGRAPHIC DESCRIPTION OF CORE: NW-2

Principal Rock Type: Orthogneiss composed of light gray to pink, very coarse-grained, monzodiorite to granite intercalated with pinkish-black, medium-grained garnet-biotite schist (restite) with equilibrium granoblastic texture. Plagioclase is heavily saussuritized along late brittle fractures.

Mineralogy: *Neogranitic material* - perthite/antiperthite, large subequant grains (28-70%); plagioclase, small blocky crystals within perthite and larger interstitial grains myrmekitic with quartz (5-30%); quartz, large anhedral- interstitial equant grains recrystallized into coarse domains with shadowy extinction (25-25%); garnet, small euhedral grains within perthite, partially altered to chlorite and sericite (trace); biotite, deep red-brown strongly pleochroic (trace); calcite, in thin brittle fractures (trace); zircon, light yellow-brown, oval (trace). *Garnet-biotite schist:* garnet, pale yellow, 5mm in size, slightly altered to chlorite (13%); biotite, strongly pleochroic pale yellow to deep reddish-brown, rectangular books with abundant pleochroic haloes and rod to bleb shaped inclusions (35%); plagioclase, equant grains with equilibrium texture, fine polysynthetic twinning (52%); trace micropertthite and quartz.

Texture: Coarse-grained granoblastic texture in granite/monzodiorite; garnet-biotite schist has clean equilibrium prograde metamorphic texture of coarse granoblastic feldspar between idioblastic garnet and biotite; biotite is moderately well foliated.

Structure: Strong foliation in restite portion dips 45° from horizontal. Numerous tight brittle fractures with pyrite and chalky white clay linings dip 0-35° from horizontal.

CHEMICAL DATA

Rock Type Analyzed: None

MAGNETIC SUSCEPTIBILITY (depth in feet)

Depth	Reading (x 10 <sup>-3</sup> cgs units)
296-300	0.01
300-303	0.00
303-304	0.01
304-305	0.00

DENSITY

Depth	Density
302.5	2.63 neogranite
303	2.79 schist
306	2.63 neogranite

Field number NW-3

Date finished 11-17-91

MGS unique number 247048

MGS lab number MGS 3231

LOCATION (see map at right)

T-R-S 163 - 48 - 20 CCCBC

County Kittson

Quadrangle Orleans 7.5'

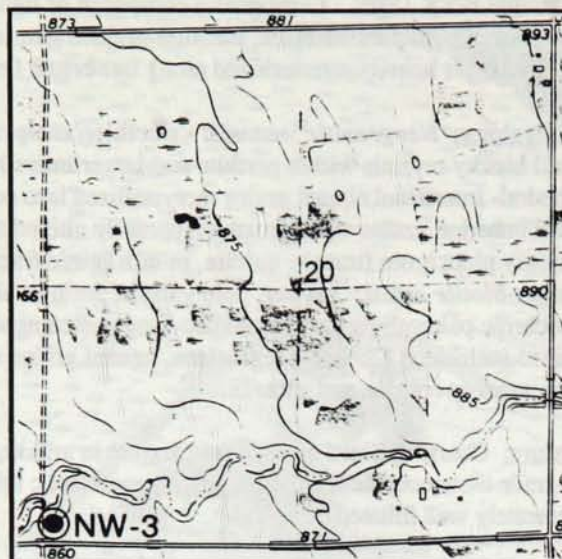
HOLE PARAMETERS (feet)

Surface elevation 855

Total depth 556

Elevation, top of  
Precambrian rock 327

Core interval 540-556



Hole azimuth: plunge: -90

Core recovered 100%

ABBREVIATED LITHOLOGIC LOG (intervals recorded are depths in feet)

Interval, feet	Description
<b>QUATERNARY DEPOSITS</b>	
0-20	Sandy to loamy till; grayish-brown and oxidized, contains limestone pebbles and one boulder at 6'.
20-38	Sandy to loamy till; as above but gray.
38-65	Sandy till; gray, silty.
65-135	Sand and gravel, large component of shale and limestone.
135-181	Sandy till with minor lignite; gray, layers of sand and gravel from 135-160'.
<b>CRETACEOUS SEDIMENTARY ROCKS</b>	
181-209	Silty shale; light to medium-gray, lignitic.
<b>ORDOVICIAN SEDIMENTARY ROCKS</b>	
209-350	Red River Formation - limestone; yellowish-brown to light olive-gray, dolomitic and fossiliferous.
350-434	Winnipeg Formation - sandstone; yellowish-gray fine- to medium-grained, minor siltstone near top.
434-520	Winnipeg Formation - shale; pale brown to grayish-green, gray at base.
520-528	Winnipeg Formation, Black Island Member - sandstone; light brownish-gray, medium- to very coarse-grained.
<b>WEATHERING RESIDUUM ON PRECAMRIAN ROCK</b>	
528-536	Clay-rich residuum with grains of quartz; gray.
<b>SOUND PRECAMBRIAN BEDROCK</b>	
536-556	Porphyritic quartz syenite to granodiorite; very coarse-grained, well-foliated and banded, pink and black. Deformed by brittle shear, with local silicification along larger shear planes.



**PETROGRAPHIC DESCRIPTION OF CORE: NW-3**

**Principal Rock Type:** Quartz syenite to granodiorite; pink and black, porphyritic to seriate-textured, weakly gneissic. Pink phenocrysts of K-feldspar as large as 2 cm.

**Mineralogy:** Perthite, pink, variable in size (10-78%); plagioclase, weakly sericitized, blocky grains (10-50%); quartz, elongate anhedral-interstitial masses, recrystallized, shadowy extinction (10-36%); biotite, greenish-brown pleochroism, small interstitial books aligned parallel to foliation (2-5%); muscovite, both secondary and primary (trace); accessory apatite, zircon, monazite, pyrite, calcite. Monazite unusually large and well-developed.

**Texture:** Brittle cataclastic texture is variably developed, silicified along one more intense zone of granulation. Foliation defined primarily by dark biotitic layers and by inequant feldspar, parallels locally developed gneissic banding.

**Structure:** Foliation and gneissic banding dip 45-70° from horizontal.

**Comments:** Chondrite-normalized REE patterns are very steep, 1000x light REE enrichment, 10x heavy REE enrichment (Appendix B).

**CHEMICAL DATA**

**Rock Type Analyzed:** Coarse-grained, microcline-porphyritic biotite granodiorite, 541.5-542' interval.

Major Elements (Wt. % oxides)		Minor Elements (ppm)		Minor Elements (ppm, Au=ppb)		Minor Elements (ppm)	
SiO <sub>2</sub>	68.7	Rb	110	Au (ppb)	<2	Cs	1.1
Al <sub>2</sub> O <sub>3</sub>	16.3	Sr	757	Ag	<0.1	La	318
CaO	2.11	Ba	1030	Be	4	Ce	533
MgO	0.61	Zr	890	B	39	Nd	170
Na <sub>2</sub> O	4.26	Y	11	Sc	2.18	Sm	23.3
K <sub>2</sub> O	4.62	Nb	18	V	24	Eu	1.64
FeO	0.9			Cr	8.5	Tb	1.3
Fe <sub>2</sub> O <sub>3t</sub>	1.40			Co	4.3	Yb	0.72
MnO	0.02			Ni	8	Lu	0.06
TiO <sub>2</sub>	0.172			Cu	9.4	Hf	24.0
P <sub>2</sub> O <sub>5</sub>	0.10			Zn	16.5	Th	130
LOI	0.90			Pb	26	U	4.2
Total	99.5			Br	10.0		
Fe <sub>2</sub> O <sub>3</sub>	0.40						

**MAGNETIC SUSCEPTIBILITY (depth in feet)**

Depth	Reading (x 10 <sup>-3</sup> cgs units)
540-544	0.00
544-545	0.01
545-556	0.00

**DENSITY**

Depth	Density
542	2.7 granodiorite
544.5	2.71 leucogranite
551.5	2.64 quartz syenite

Field number NW-4A

Date finished 10-21-91

MGS unique number 247046

MGS lab number MGS 3229

LOCATION (see map at right)

T-R-S 161 - 45 - 6 CDDAD

County Kittson

Quadrangle Skull Lake SE 7.5'

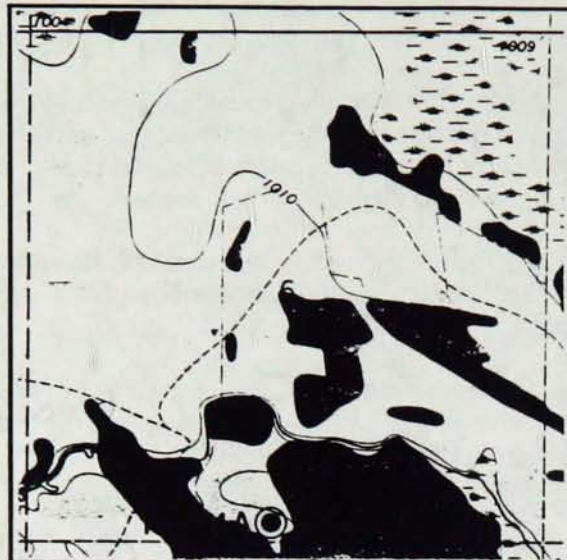
HOLE PARAMETERS (feet)

Surface elevation 1009

Total depth 359

Elevation, top of  
Precambrian rock 655

Core interval None



Hole azimuth:                      plunge: -90

Core recovered None

Lost cone off drill bit prior to coring; abandoned.

ABBREVIATED LITHOLOGIC LOG (intervals recorded are depths in feet)

Interval, feet

Description

QUATERNARY DEPOSITS

0-2	Topsoil; dark, organic-rich .
2-10	Sand; coarse, brown, chert boulder at base of unit.
10-18	Sandy till; gray, calcareous, contains pebbles of chert, limestone, greenstone, and granite.
18-34	Sand and gravel-rich interval in same till as above.
34-44	Clay till; dark gray.
44-55	Sand; fine to coarse, thin intercalated beds of light gray clay.
55-114	Sandy to gravelly till; light gray, calcareous. Granitic boulders at 75', 95', 113'.
114-165	Silty till; light gray and sandy, contains a few pebbles. Granite boulder at 131' depth.
165-173	Coarse sand with layers of chert- and limestone-rich gravel.
173-232	Sandy till; light gray . Wood fragments 207-209'.
232-260	Clayey till; gray, sticky. Pebbly 234'-235'.
260-278	Lacustrine clay; gray, dense, smooth. Thin, abrupt gravel layer at base of clay.
278-317	Clayey till; brownish-gray, cobble-free except at base of unit.
317-354	Sandy till; light gray with cobbles of limestone and dolomite.

WEATHERING RESIDUUM ON PRECAMBRIAN ROCK

354-355 Clay; pink and sandy with relict igneous texture.

SOUND PRECAMBRIAN ROCK

355-359 Granite; K-feldspar-rich, pegmatitic, salmon and gray-colored, possibly intrusive into gray gneiss. Cuttings consist of approximately 75% salmon-colored feldspar fragments with minor intergrown biotite. Other components are white (20%) myrmekitic feldspar, gray fine-grained feldspar and biotite and muscovite flakes.

PETROGRAPHIC DESCRIPTION OF CORE: NW-4A

Principal Rock Type: Granite; pegmatitic and gray gneiss; cuttings only.

CHEMICAL DATA

Rock Type Analyzed: None

MAGNETIC SUSCEPTIBILITY (depth in feet)

Depth	Reading ( $\times 10^{-3}$ cgs units)
	No readings obtained.

DENSITY

Depth	Density
	No readings obtained.

Field number NW-4B

Date finished 11-21-91

MGS unique number 247049

MGS lab number MGS 3234

LOCATION (see map at right)

T-R-S 161 - 45 - 9 CCCCCB

County Kittson

Quadrangle Juneberry Ridge

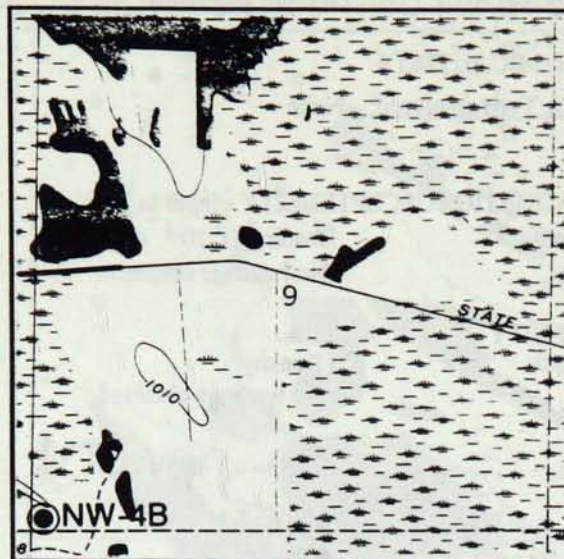
HOLE PARAMETERS (feet)

Surface elevation 1008

Total depth 340

Elevation, top of  
Precambrian rock 694

Core interval 330-340



Hole azimuth:                      plunge: -90

Core recovered 100%

ABBREVIATED LITHOLOGIC LOG (intervals recorded are depths in feet)

Interval, feet	Description
<b>QUATERNARY DEPOSITS</b>	
0-1	Topsoil; organic-rich.
1-12	Silty loam that grades to sand, then to gravel by 12'; oxidized, yellowish-brown.
12-21	Silty till; gray, sandy. Coarse sand component consists of quartz, basalt, dolomite, limestone.
21-28	Gravelly till; interlayered brown and gray.
28-52	Silty clay till.
52-60	Sandy and silty till; dense, gray. Pebbles of granite and carbonate rocks.
60-61	Paleosol; greenish-gray, organic-rich, contains wood fragments.
61-80	Till; brownish-gray, sandy, pebbly. Pebbles carbonate, granite, basalt, and quartz.
80-103	Till; sandy, pebbly.
103-166	Sandy and silty till; gray to light gray.
166-221	Lacustrine clay; greenish-gray, sandy, silty.
221-224	Sandy clay with a few pebbles.
224-243	Clay to silty clay; greenish-gray to gray, lacustrine.
243-248	Sandy clay with minor gravel.
248-294	Sandy till; brown, increasing proportion of gravel below 290', grades into unit below.
294-314	Silty till; gravelly.
<b>WEATHERING RESIDUUM ON PRECAMBRIAN BEDROCK</b>	
314-315	Clay; greenish-white.
315-324	Clay-rich residuum; red.
<b>SOUND PRECAMBRIAN BEDROCK</b>	
324-340	Hornblende granodiorite; grayish-pink to light gray, medium- to coarse-grained, weakly banded, moderately lineated and pervasively epidotized.

**PETROGRAPHIC DESCRIPTION OF CORE: NW-4B**

**Principal Rock Type:** Hornblende granodiorite; grayish-pink to light gray, medium- to coarse-grained, moderately lineated. Modal composition borders on tonalite (see Appendix B). Pervasive epidote alteration accompanied by pink staining of rock and crackle-veins filled with epidote. Late white carbonate-lined fractures cut epidote veins. A two-inch-wide band of more mafic rock is parallel to main rock fabric. Two narrow shear zones have produced intense retrograde alteration of rock.

**Mineralogy:** **Plagioclase**, stained by submicroscopic dusty material that may be incipient sericite, blocky subhedral grains elongate parallel to foliation with ragged, recrystallized edges (62%); **perthite**, small, clean, anhedral-interstitial grains (6%); **quartz**, very elongate (1:5 aspect ratio), anhedral grains with strong shadowy extinction; **hornblende**, subhedral to euhedral, pleochroic in shades of green to brown (10%); **sphene**, wedge-shaped to rounded, altered to leucoxene (0.5%); **apatite**, rounded (trace); **epidote**, scattered coarse, anhedral grains of secondary origin (trace). Mineral percentages determined from least-altered portion of core. In sheared, altered portions, plagioclase is altered to granular masses of grungy epidote, hornblende is altered to chlorite.

**Structure:** Foliation dips 50°.

**Texture:** Medium-to coarse-grained, moderate lineation defined by elongate grains of quartz and plagioclase, plus lineated prismatic hornblende.

**Comments:** Zones of low magnetic susceptibility are the result of retrograde-alteration along shear zones, due to breakdown of oxides.

**CHEMICAL DATA**

**Rock Type Analyzed:** Granodiorite/tonalite (338')

Major Elements (Wt.% oxides) 338' depth	Minor Elements (ppm) 338' depth	Minor Elements (ppm, Au=ppb) 338' depth	Minor Elements (ppm) 338' depth
SiO2 67.6	Rb 40	Au (ppb) <2	Cs 0.5
Al2O3 16.2	Sr 1110	Ag <0.1	La 7.8
CaO 2.95	Ba 1190	Be 4	Ce 17
MgO 1.15	Zr 92	B 66	Nd 9
Na2O 5.30	Y <10	Sc 3.25	Sm 1.96
K2O 3.08	Nb 15	V 39	Eu 0.57
FeO 0.8		Cr 11.0	Tb 0.2
Fe2O3t 2.38		Co 6.3	Yb 0.35
MnO 0.04		Ni 7	Lu 0.05
TiO2 0.322		Cu 11.6	Hf 2.9
P2O5 0.11		Zn 39.3	Th 2.4
LOI 0.90		Pb 5	U 1.4
Total 100.3		Br 4.7	
Fe2O3 1.49			

**MAGNETIC SUSCEPTIBILITY (depth in feet)**

Depth	Reading (x 10 <sup>-3</sup> cgs units)		
330-331	0.23	335-336	0.01
331-332	0.19	336-337	0.21
332-333	0.20	337-338	0.18
333-334	0.00	338-339	0.17
334-335	0.02	339-340	0.21

**DENSITY**

Depth	Density
337.3	2.63 granodiorite

Field number NW-5

Date finished 10-25-91

MGS unique number 247047

MGS lab number MGS 3228

LOCATION (see map at right)

T-R-S 161 - 47 - 30 CCB BBB

County Kittson

Quadrangle Enok 7.5'

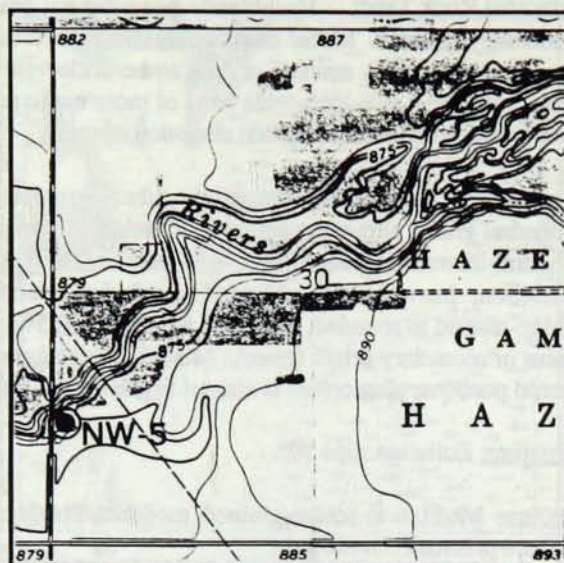
HOLE PARAMETERS (feet)

Surface elevation 872

Total depth 459

Elevation, top of  
Precambrian rock 872

Core interval None



Hole azimuth:                      plunge: -90

Core recovered None

Lost cone off drill bit prior to coring; abandoned.

ABBREVIATED LITHOLOGIC LOG (intervals recorded are depths in feet)

Interval, feet	Description
<b>QUATERNARY DEPOSITS</b>	
0-7	Fill.
7-12	Till; light brown with carbonate pebbles. Laminated clay and silt near top of interval.
12-21	Sandy till; gray, cobbles of predominantly granite and schist, lesser carbonate.
21-28	Lacustrine clay; gray, dense, laminated.
28-80	Sandy till; gray. Cobbles at 68' and 79 - 80'.
80-134	Clay till with thin sand lenses; dark brownish-gray. Pink cobbles and boulders at base of unit.
134-152	Lacustrine clay; gray. Contains black streaks and thin sand layers.
152-191	Clay till; gray, slightly sandier from 160-180'. Scattered clasts of granite, schist, and limestone.
191-240	Till; dark gray to olive-brown, very dense. Cobbles of weathered limestone. Sandier below 220'.
240-278	Sandy till; light to medium-gray. Granite boulder at 270-271'. Bottom 2' of interval contains pink sandy clay derived from underlying sedimentary rocks.
278-282	Boulder? of light pink, sandy dolomite of the Red River Formation.
<b>JURASSIC (?) SEDIMENTARY ROCKS (HALLOCK RED BEDS)</b>	
282-293	Shale; light brown to light grayish-red, silty.
293-314	Dolomite and chert; yellowish-gray to light gray, dense. Minor drusy quartz.
314-344	Shale and siltstone; light brown to gray with some interbedded shale as above.
344-356	Dolomite and chert; yellowish-gray, minor chalcedony.
356-437	Shale; red, light brown, and gray. Minor satin-spar gypsum.
437-440	Sandstone; fine- to coarse-grained, quartzose, grades into white clay weathering residuum of Winnipeg Formation.
<b>ORDOVICIAN SEDIMENTARY ROCKS (WINNIPEG FORMATION)</b>	
440-453	Siltstone; light brown with minor cemented sandstone.
<b>SOUND PRECAMBRIAN BEDROCK</b>	
453-459	Quartz- biotite ( $\pm$ hornblende)-feldspar schist/gneiss; fine- to medium-grained.

PETROGRAPHIC DESCRIPTION OF CORE: NW-5

Principal Rock Type: Quartz-biotite ( $\pm$ hornblende)-feldspar schist/gneiss; fine- to medium-grained. Cuttings only, no core obtained. Not examined in thin section.

CHEMICAL DATA

Rock Type Analyzed: None

MAGNETIC SUSCEPTIBILITY (depth in feet)

Depth	Reading ( $\times 10^{-3}$ cgs units)
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No readings obtained.

DENSITY

Depth	Density
-------	---------

No readings obtained.

Field number NW-6

Date finished 10-16-91

MGS unique number 247043

MGS lab number MGS 3222

LOCATION (see map at right)

T-R-S 160-44-6 BBABBC

County Roseau

Quadrangle Pelan 7.5'

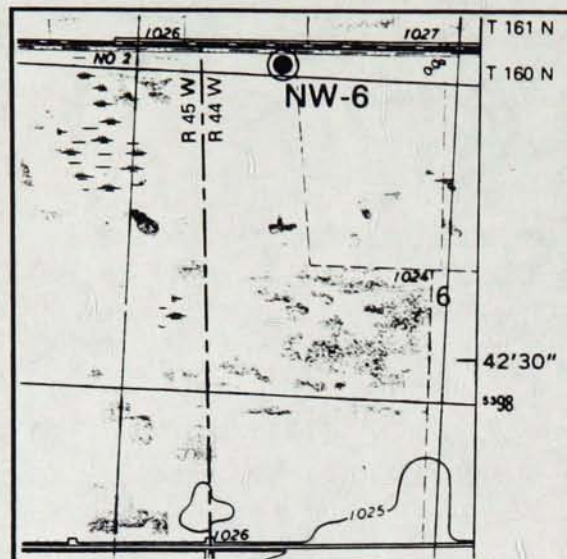
HOLE PARAMETERS (feet)

Surface elevation 1025

Total depth 366

Elevation, top of  
Precambrian rock 691

Core interval 356-366



Hole azimuth:                      plunge: -90

Core recovered 100%

ABBREVIATED LITHOLOGIC LOG (intervals recorded are depths in feet)

Interval, feet

Description

QUATERNARY DEPOSITS

0-6 Sandy till; yellow.  
6-17 Silty till; oxidized, sandy, with boulders.  
17-29 Silty till; gray, sandy. Granite cobbles at 19'.  
29-40 Silty till; gray and sandy as above, increased gravel content.  
40-58 Sand and gravel.  
58-65 Sandy till; gray, gravelly.  
65-72 Sand and cobbly gravel.  
72-146 Sandy till; gray with variable proportions of gravel.  
146-176 Silty till; gray with minor gravel.  
176-201 Silty to sandy till; dark greenish-gray, dense.  
201-232 Sandy till grading to sandy, silty till with gravel, cobbles and boulders.  
232-257 Sandy till; greenish-gray with cobbles and gravel. Color lightens with depth.  
257-264 As above but with increasing proportion and grain size of sand with depth.  
264-312 Sandy silty till. Cobbles below 297', limestone boulders below 305'.

WEATHERING RESIDUUM ON PRECAMBRIAN BEDROCK

312-334 Clay; greenish-white, sandy, possibly reworked into till. Sandy near base of interval.  
334-345 Clay; greenish-white.

SOUND PRECAMBRIAN BEDROCK

345-366 Diorite; dark greenish-gray, fine- to medium-grained, foliated. Cut by late-phase dikelets of pink diorite that range from straight to pygmatically folded.



PETROGRAPHIC DESCRIPTION OF CORE: NW-6

**Principal Rock Type:** Diorite; dark gray, fine- to medium-grained ( $\leq 1.5\text{mm}$ ), equigranular, foliated. Pink diorite dikelets may be a late differentiate, or may form "sweat out" veins, and are subcordant to foliation of host diorite. Pink, round bleb-like feldspar porphyroblasts or phenocrysts occur locally next to pink dikelets. Assemblage of chlorite and secondary oxides implies alteration of hornblende or biotite.

**Mineralogy:** *Dark gray diorite - plagioclase*, blocky angular grains with bent twinning (80%); **chlorite**, light green, pleochroic, irregular books anastomose around plagioclase (19%); **oxides**, small secondary scraps associated with chlorite; **apatite**, rounded subhedral grains, locally abundant (trace). **Pyrite** and bluish-black sulfide of unknown composition (trace).

**Texture:** Brittle shear fabric defined by oriented blades of chlorite that anastomose around plagioclase. Plagioclase is locally mortar-textured, in zones where brittle mylonitization is more complete.

**Structure:** Foliation dips consistently at  $65^\circ$  from horizontal. Late brittle fractures with chlorite slickensides dip  $40\text{-}85^\circ$ ; these are cut by later flat-lying fractures lined with a white carbonate mineral.

CHEMICAL DATA

**Rock Type Analyzed:** Dark gray diorite (360')

Major Elements (Wt. % oxides)		Minor Elements (ppm)		Minor Elements (ppm, Au=ppb)		Minor Elements (ppm)	
SiO <sub>2</sub>	58.5	Rb	<10	Au (ppb)	<2	Cs	<0.5
Al <sub>2</sub> O <sub>3</sub>	19.0	Sr	75	Ag	<0.1	La	13.9
CaO	0.23	Ba	73	Be	3	Ce	27
MgO	4.69	Zr	120	B	29	Nd	11
Na <sub>2</sub> O	9.01	Y	<10	Sc	7.47	Sm	2.03
K <sub>2</sub> O	0.20	Nb	13	V	70	Eu	0.44
FeO	3.6			Cr	29.0	Tb	<0.1
Fe <sub>2</sub> O <sub>3t</sub>	5.03			Co	17.0	Yb	0.58
MnO	0.10			Ni	44	Lu	0.10
TiO <sub>2</sub>	0.518			Cu	2.8	Hf	2.7
P <sub>2</sub> O <sub>5</sub>	0.15			Zn	99.7	Th	2.7
LOI	2.65			Pb	<2	U	0.6
Total	100.1			Br	10.0		
Fe <sub>2</sub> O <sub>3</sub>	1.03						

MAGNETIC SUSCEPTIBILITY (depth in feet)

Depth	Reading (x 10 <sup>-3</sup> cgs units)
356-366	0.00

DENSITY

Depth	Density
359.9	2.67 diorite
360.3	2.66 cataclastic diorite

Field number NW-7

Date finished 10-19-91

MGS unique number 247045

MGS lab number MGS 3230

LOCATION (see map at right)

T-R-S 159 - 45 - 16 CACBCC

County Kittson

Quadrangle Twistal Swamp 7.5'

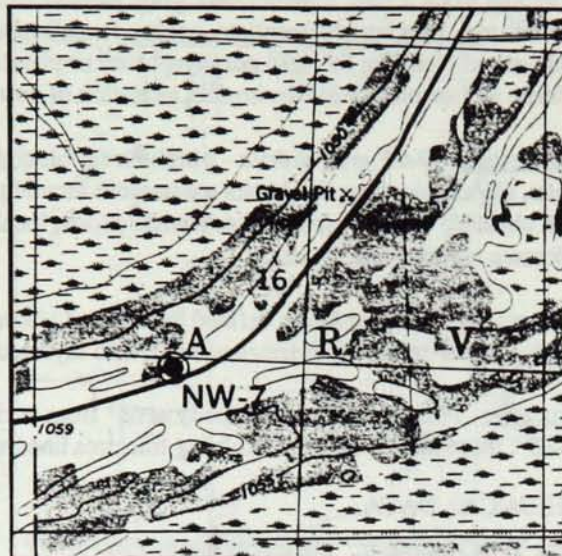
HOLE PARAMETERS (feet)

Surface elevation 1055

Total depth 407

Elevation, top of  
Precambrian rock 666

Core interval 397-407



Hole azimuth:                      plunge: -90

Core recovered 100%

ABBREVIATED LITHOLOGIC LOG (intervals recorded are depths in feet)

Interval, feet

Description

QUATERNARY DEPOSITS

0-12	Topsoil 0-2'; black; underlain by brown, medium to very coarse sand, possible beach deposit.
12-79	Calcareous till; gray. Contains fine to coarse sand and scattered pebbles of chert, granite, and dark mafic rocks. Sand; 42-45'.
79-84	Clay till; greenish-gray, calcareous.
84-94	Silty till; light gray, with fine sand and few pebbles.
94-97	Clay till; gray with pieces of lignite.
97-98	Sand.
98-101	Clay till; gray, slightly calcareous.
101-104	Clay; dark gray, pure, with minor lignite.
104-109	Sand; fine to medium, 1.5' boulder of white, amphibole-bearing crystalline rock at top.
109-116	Sandy till; gray with sand layers.
116-124	Clay till; gray, slightly sandy, calcareous. Pebbles of chert, granite, mafic rocks, carbonate rocks.
124-162	Till; gray, more sandy than above. Minor lignite, many cobbles of chert and carbonate rocks.
162-177	Lacustrine clay; dark gray with lignite.
177-282	Sandy till; light gray, with pebbles of chert and limestone; alternating layers of dark gray clay till.
282-321	Clay till; brownish-gray, calcareous.
321-357	Sandy till; light gray.
357-359	Clay; white and green, derived from a weathered boulder or reworked weathering residuum from below.
359-389	Sandy till; gray with white clay reworked from weathering residuum below.

WEATHERING RESIDUUM ON PRECAMBRIAN BEDROCK

389-395 Clay; green and white, mottled.

SOUND PRECAMBRIAN BEDROCK

395-407 Granodiorite gneiss; pinkish-gray, medium-grained, banded, cut by granite pegmatite.

PETROGRAPHIC DESCRIPTION OF CORE: NW-7

Principal Rock Type: Granodiorite gneiss; pinkish-gray, medium-grained, banded, cut by granite pegmatite.

Mineralogy: *Granodiorite* - **plagioclase**, equant, fresh, twinned (51%); **perthite**, anhedral-interstitial, generally equant in shape (10%); **quartz**, equant, anhedral, granoblastic (31%); **biotite**, greenish-brown, rectangular books, highly pleochroic (7%); **apatite** (trace).

*Granite* - crystals of opalescent **microperthite** up to 6 cm and 0.5 cm coarsely recrystallized **quartz** surrounded by ragged masses of fine-grained aplitic granite with blocky **plagioclase**, and anhedral quartz and K-feldspar. Scattered euhedral, pinkish-brown **garnets** and **oxidized Fe-oxides**. Quartz and feldspars occur in cotectic proportions.

Texture: *Granodiorite* - Medium-grained, moderate foliation defined by biotite, other minerals granoblastic.

*Granite* - Coarse graphic texture. Zonation within dikes consists of pink microcline crystals oriented perpendicular to dike margins, then coarse saccharoidal texture, to coarse albite and quartz, to a zone of graphic feldspars, to coarse blocky-textured pegmatite in core of dike.

Structure: Granodiorite foliation dips 30-60° from horizontal. Tight brittle fractures are relatively flat-lying, lined with bright green chlorite where they cross pegmatite. Granite was emplaced after deformation of granodiorite, crosses foliation.

CHEMICAL DATA

Rock Type Analyzed: Biotite granodiorite gneiss (401.5')

Major Elements (wt. % oxides)		Minor Elements (ppm)		Minor Elements (ppm, Au=ppb)		Minor Elements (ppm)	
SiO <sub>2</sub>	71.0	Rb	230	Au (ppb)	5	Cs	11.3
Al <sub>2</sub> O <sub>3</sub>	15.0	Sr	425	Ag	<0.1	La	9.5
CaO	1.84	Ba	981	Be	5	Ce	19
MgO	0.88	Zr	95	B	26	Nd	8
Na <sub>2</sub> O	5.16	Y	<10	Sc	1.75	Sm	1.69
K <sub>2</sub> O	3.11	Nb	21	V	19	Eu	0.32
FeO	1.0			Cr	10.0	Tb	0.2
Fe <sub>2</sub> O <sub>3t</sub>	1.91			Co	5.2	Yb	0.56
MnO	0.06			Ni	6	Lu	0.08
TiO <sub>2</sub>	0.296			Cu	5.8	Hf	2.6
P <sub>2</sub> O <sub>5</sub>	0.10			Zn	68.9	Th	1.7
LOI	0.45			Pb	9	U	3.5
Total	100.0			Br	2.9		
Fe <sub>2</sub> O <sub>3</sub>	0.80						

MAGNETIC SUSCEPTIBILITY (depth in feet)

Depth	Reading (x 10 <sup>-3</sup> cgs units)
397-407	0.00 - 0.01

DENSITY

Depth	Density
401.5	2.7 granodiorite
406.3	2.63 granite

Field number NW-8

Date finished 10-9-91

MGS unique number 247042

MGS lab number MGS 3223

LOCATION (see map at right)

T-R-S 161 - 40 - 12 CCDDCC

County Roseau

Quadrangle Roseau 7.5'

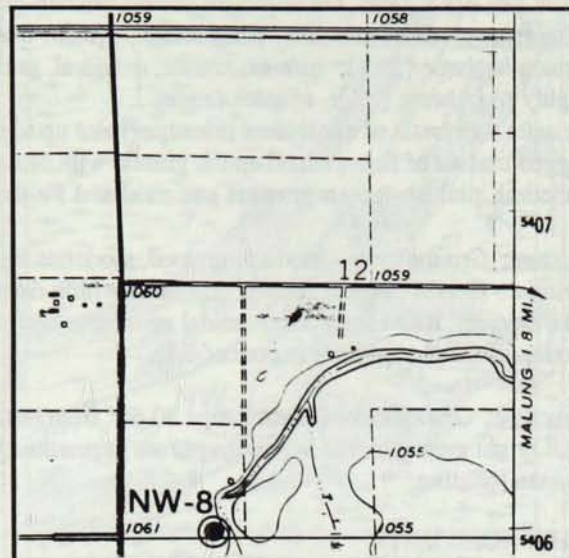
HOLE PARAMETERS (feet)

Surface elevation 1060

Total depth 228

Elevation, top of  
Precambrian rock 844

Core interval 195-202.5, 218-228



Hole azimuth:                      plunge: -90

Core recovered 100%

First core run - boulder overlying weathered bedrock.  
Second core run - sound bedrock.

ABBREVIATED LITHOLOGIC LOG (intervals recorded are depths in feet)

Interval, feet	Description
<b>QUATERNARY DEPOSITS</b>	
0-2	Topsoil; black, silty.
2-18	Lacustrine clay; light and dark gray, silty.
18-23	Lacustrine clay; light gray, sandy and silty.
23-50	Sandy till; light gray, contains pebbles of limestone and igneous rocks.
50-79	Sandy till; gray, gravelly with basalt pebbles. Granite boulder at 75'.
79-92	Sandy till; greenish-gray, scattered cobbles.
92-180	Sand and gravel.
180-195	Large boulders, including amphibolite and granitic rocks.
195-199	Till; light greenish-gray, contains large % of reworked weathered rock from below.
<b>WEATHERING RESIDUUM ON PRECAMBRIAN ROCK</b>	
199-216	Clay-rich weathering residuum, green, with bits of biotite and feldspar.
<b>SOUND PRECAMBRIAN ROCK</b>	
216-228	Garnet-cordierite(?) - biotite schist cut by deformed granitic pegmatite dikes.

PETROGRAPHIC DESCRIPTION OF CORE: NW-8

Principal Rock Type: Cordierite(?) - biotite schist; dark grayish-black, with small % of garnet. Intruded by pinkish-gray granitic pegmatite dikes which have been extensively deformed. Thin biotite-rich selvages occur in schist adjacent to pegmatite dikes.

Mineralogy: Schist - cordierite (?), blocky equant sieve-textured grains mostly altered to very-fine-grained sericite/chlorite/clay, yellowish tinge and polysynthetically twinned where fresh, possibly plagioclase; biotite, rectangular laths with abundant pleochroic haloes and strong light brown to deep reddish-brown pleochroism; quartz and feldspar, granoblastic, elongate parallel to foliation; apatite, locally abundant (up to 2%), stout, stubby euhedral prisms; garnet, anhedral, minor proportions.

Granite - plagioclase, blocky, grain edges are granulated due to brittle cataclasis (37%); perthite, same crystal habit as plagioclase (24%); quartz, granoblastic but unfoliated (30%); muscovite, primary books and secondary shreds in zones of granulation between feldspars (6%); biotite, books and shreds, strongly pleochroic in shades of brown (2%); epidote, secondary granules (trace); opaques (trace).

Texture: Clean granoblastic, prograde metamorphic texture in biotite schist. Foliation defined by aligned biotite and elongate quartz plus feldspar. Granite dikes are folded and bulbous, weakly to strongly foliated, subcordant to schist foliation.

Structure: Foliation dips 30-40° from horizontal. Thin, brittle calcite-lined fractures parallel foliation. Relict bedding indicated by slight color variations within schist. Granitic portions are variably folded and deformed, affected by late brittle cataclastic deformation.

CHEMICAL DATA

Rock Type Analyzed: None

MAGNETIC SUSCEPTIBILITY (depth in feet)

Depth	Reading (x 10 <sup>-3</sup> cgs units)
218-222.5	0.00-0.01
222.5-224	0.02
224-228	0.00-0.01

DENSITY

Depth	Density
223	2.72 schist
223.5	2.63 granite
227.9	2.77 schist

Field number NW-10

Date finished 6-11-92

MGS unique number 247050

MGS lab number MGS 3316

LOCATION (see map at right)

T-R-S 155 - 41 - 3 DDCCDD

County Marshall

Quadrangle Gatzke SW 7.5'

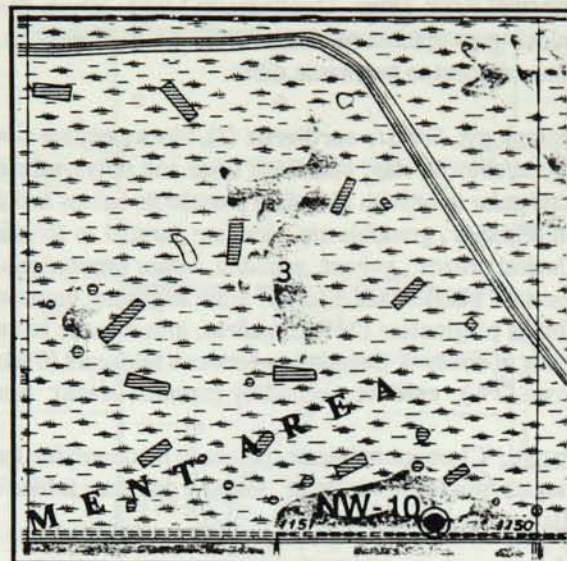
HOLE PARAMETERS (feet)

Surface elevation 1149

Total depth 291

Elevation, top of  
Precambrian rock 880

Core interval 281-291



Hole azimuth:                      plunge: -90

Core recovered 85%  
Lower 1.5' of core not retrieved.

ABBREVIATED LITHOLOGIC LOG (intervals recorded are depths in feet)

Interval, feet	Description
<b>QUATERNARY DEPOSITS</b>	
0-2	Topsoil; black.
2-13	Silty till; light yellowish-brown, clayey, with subangular pebbles of dolomite, granitic rocks and quartz; possibly lacustrine. Below 10' depth becomes darker brown and sandier.
13-19	Clay till; dark brown, dense and sandy. Contains sand grains 1-2mm in size. 6" cobble at base.
19-103	Sandy till; light to medium-gray, dense, slight layering via variable sand/clay ratios. Boulders of crystalline Precambrian rocks and dolomite (50:50 ratio).
103-127	Sand; gray, fine to coarse.
127-142	Sand and sandy till; interlayered, light and dark gray, respectively.
142-150	Clay; greenish-gray, possibly lacustrine.
150-160	Sandy till, gray, similar to that in 19-103' interval.
160-173	Clay till; gray, dense, with no sand.
173-178	Sandy till; gray.
178-190	Clay till; gray, dense.
190-209	Sandy till; gray.
209-220	Till; light greenish-gray, more sandy and pebbly than tills above.
220-259	Silty sand, sand, and gravel; interlayered, gray.
259-269	Sandy till; medium to dark gray with abundant pebbles of metabasalt and dark-colored schists.
<b>WEATHERING RESIDUUM ON PRECAMBRIAN BEDROCK</b>	
~269	Bedrock; broken and slightly weathered.
<b>SOUND PRECAMBRIAN ROCK</b>	
269-291	Granodiorite; sheared, quartz-rich and displaying porphyritic/porphyroclastic texture. Somewhat enigmatic origin. May be a small sill in supracrustal rocks, or sheared margin of a larger pluton.

PETROGRAPHIC DESCRIPTION OF CORE: NW-10

Principal Rock Type: Granodioritic porphyry; gray to pinkish-gray, sheared.

Mineralogy: **Plagioclase**, euhedral crystals (phenocrysts) up to 1mm, diffuse albite twinning, zoned, verging on antiperthite. Occurs both as individual euhedral crystals with quartz pressure shadows and in polycrystalline aggregates with minor perthite; (total phenocrysts = 10%); **groundmass**, very fine-grained granoblastic to mortar-textured, indistinguishable quartz and feldspar, includes elliptical clots of pure recrystallized quartz suggestive of primary quartz phenocrysts (82% total groundmass); **oxides**, very fine-grained dusty habit, define streaky banding which anastomoses around feldspar phenocrysts (5%); **stilpnomelane**, green, stellate, fibrous habit (3%); sphene, golden-brown granules disseminated throughout, but locally concentrated with stilpnomelane and oxides; **garnet**, pale yellow, rimmed by stilpnomelane and oxides; **pyrite and chalcopyrite**, blocky crystals (trace).

Texture: Foliated and lineated, foliation anastomoses around feldspar phenocrysts. Clear indications of shear texture.

Structure: Foliation dips 80° from horizontal. Minor calcite-chlorite veins dip variably. Thin, brittle oxidized fractures relatively flat-lying.

CHEMICAL DATA

Rock Type Analyzed: Sheared porphyry, 289' depth (Note that analyses were done by two analytical labs)

Major Elements (wt. % oxides) 289' depth	Minor Elements (ppm) 289' depth	Minor Elements (ppm Au=ppb) 289' depth	Minor Elements (ppm) 289' depth	Major and minor elements (ppm, except as indicated)
SiO2 72.1	Rb 20	Au (ppb) <2	Cs 0.5	Au (ppb) <5
Al2O3 11.3	Sr 70	Ag <0.1	La 76.6	Ag <5
CaO 0.91	Ba 506	Be 8	Ce 166	Ta 5
MgO 0.32	Zr 848	B 25	Nd 87	Sc 0.5
Na2O 5.37	Y 136	Sc 0.30	Sm 19.5	Ni <50
K2O 2.70	Nb 108	V <2	Eu 4.02	Zn 280
FeO 2.1		Cr 19.0	Tb 3.1	Hf 19
Fe2O3t 5.78		Co 1.8	Yb 9.12	Rb <30
MnO 0.08		Ni 3	Lu 1.32	Ba 410
TiO2 0.433		Cu 30.9	Hf 19.0	Fe (%) 3.41
P2O5 0.03		Zn 416	Th 7.2	Na 30700
LOI 0.90		Pb 2	U 2.8	Th 7.3
Total 100.1		Br 2.0		U 1.8
Fe2O3 3.45				Cs <2
				La 83
				Ce 180
				Nd 88
				Sm 18
				Eu 4.9
				Tb 3.5
				Yb 13.2
				Lu 1.9

MAGNETIC SUSCEPTIBILITY (depth in feet)

Depth	Reading (x 10 <sup>-3</sup> cgs units)	Depth	Reading (x10 <sup>-3</sup> cgs units)
281.0-281.5	1.8	284.0-284.5	1.9
281.5-282.0	2.6	284.5-285.0	0.25
282.0-283.0	1.2	285.0-285.5	1.7
283.0-283.5	1.9	285.5-287.5	3.17
283.5-284.0	3.0	287.5-289.5	3.7

DENSITY

Depth	Density
289	2.69

Field number NW-11

Date finished 6-13-92

MGS unique number 247051

MGS lab number MGS 3317

LOCATION (see map at right)

T-R-S 156 - 44 - 28 DDDADD

County Marshall

Quadrangle Newfolden 7.5'

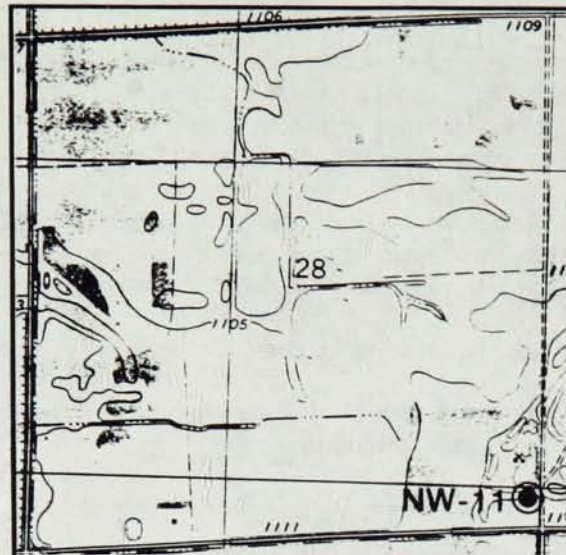
HOLE PARAMETERS (feet)

Surface elevation 1119

Total depth 330'

Elevation, top of  
Precambrian rock 807

Core interval 320-330



Hole azimuth:                      plunge: -90

Core recovered 100%

ABBREVIATED LITHOLOGIC LOG (intervals recorded are depths in feet)

Interval, feet	Description
<b>QUATERNARY DEPOSITS</b>	
0-6	Sand; gray, fine to very coarse, possibly fill. Hole placed in bottom of beach-deposit gravel pit.
6-30	Lacustrine clay; gray, weakly laminated.
30-40	Sand and very fine sand; gray, interbedded. 12" pink granite boulder at top of interval.
40-60	Very fine sand, silty sand, and clay; gray interbedded, all lacustrine sediments.
60-91	Silty till; gray, sandy. Pebbles predominantly granitic and dark, fine-grained rocks.
91-95	Sand.
95-102	Sandy till; gray, dense with cobbles.
102-142	Coarse sand, cobbles, and minor boulders. Possibly graded sequences in an outwash deposit.
142-195	Fine sand grading to coarse sand with depth, continuation of above outwash sequence. Granite boulder at 200' produces gamma response.
195-202	Very coarse sand with many cobbles and boulders; continuation of outwash sequence.
202-232	Cobbly till; medium to dark gray, dense. Cobbles of limestone, granodiorite, greenstone.
232-256	Till; similar to above, but more clay-rich and dark gray.
256-280	Till; gray, dense, sandy in upper part; more clay-rich below.
280-312	Sandy till; light gray and dense. Clasts of tonalite and granodiorite increase with depth.
<b>WEATHERING RESIDUUM ON PRECAMRIAN BEDROCK</b>	
312-320	Biotite granodiorite; weakly weathered, feldspars altered, mafic minerals altered to chlorite.
<b>SOUND PRECAMBRIAN ROCK</b>	
320-330	Hornblende-biotite tonalite to diorite.



**PETROGRAPHIC DESCRIPTION OF CORE: NW-11**

**Principal Rock Type:** Hornblende tonalite to diorite. Multiple mesocratic, porphyritic to melanocratic phases.

**Mineralogy:** **Plagioclase**, blocky-rectangular, subhedral, zoned, cores saussuritized, twinning mostly obliterated, some grains cataclastically broken (55%); **perthite**, anhedral-interstitial, locally myrmekitic against plagioclase (trace); **quartz**, coarsely-recrystallized grains with shadowy extinction, anhedral-interstitial, primary grain shape well-preserved (30%); **biotite**, brown-green pleochroism, both primary and secondary after hornblende, altered to chlorite (trace); **hornblende**, green, lineated-prismatic, subhedral, moderately pleochroic, twinned, locally altered to chlorite (12%); **chlorite**, secondary after hornblende, concentrated along shear planes (1%); **leucoxene**, **sphene**, **allanite**, **epidote** all occur as either primary or secondary accessory minerals.

**Texture:** Medium- to coarse-grained, slightly porphyritic, trachytic fabric defined by lineated hornblende. Slightly crushed by incipient brittle shear, concentrated along thin anastomosing, foliation-parallel shear zones. Vague modal banding but texture dominated by irregular mafic clots in mesocratic host.

**Structure:** Foliation dips 55-75° from horizontal, thin brittle shear planes parallel foliation.

**CHEMICAL DATA**

**Rock Type Analyzed:** Hornblende Tonalite, 325' depth

Major Elements (wt. % oxides)		Minor Elements (ppm)		Minor Elements (ppm, Au=ppb)		Minor Elements (ppm)	
SiO <sub>2</sub>	60.2	Rb	40	Au (ppb)	<2	Cs	1.7
Al <sub>2</sub> O <sub>3</sub>	14.8	Sr	394	Ag	<0.1	La	24.7
CaO	5.49	Ba	256	Be	5	Ce	52
MgO	4.58	Zr	97	B	39	Nd	24
Na <sub>2</sub> O	4.16	Y	<10	Sc	15.2	Sm	5.10
K <sub>2</sub> O	1.60	Nb	27	V	96	Eu	1.10
FeO	4.0			Cr	140	Tb	0.6
Fe <sub>2</sub> O <sub>3t</sub>	7.03			Co	24.0	Yb	1.38
MnO	0.14			Ni	120	Lu	0.20
TiO <sub>2</sub>	0.614			Cu	52.5	Hf	2.9
P <sub>2</sub> O <sub>5</sub>	0.14			Zn	112	Th	6.4
LOI	1.50			Pb	6	U	1.4
Total	100.3			Br	6.7		
Fe <sub>2</sub> O <sub>3</sub>	2.58						

**MAGNETIC SUSCEPTIBILITY (depth in feet)**

Depth	Reading (x 10 <sup>-3</sup> cgs units)
320-330	0.01 - 0.03

**DENSITY**

Depth	Density
323	2.78

Field number NW-12

Date finished 6-16-92

MGS unique number 247052

MGS lab number MGS 3318

LOCATION (see map at right)

T-R-S 157 - 44 - 24 BDBC center

County Marshall

Quadrangle Nelson Slough 7.5'

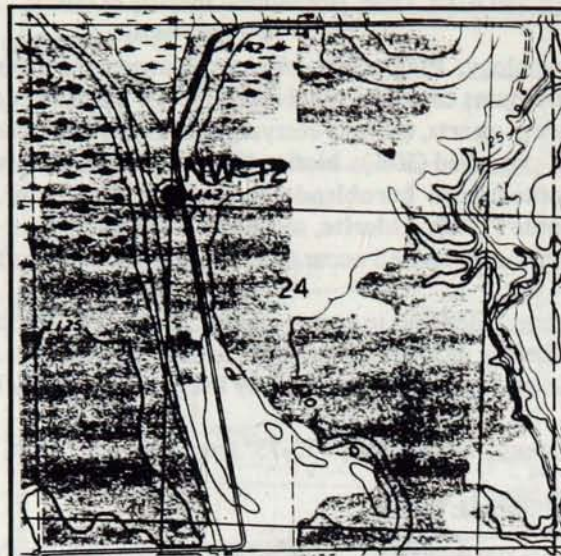
HOLE PARAMETERS (feet)

Surface elevation 1144

Total depth 490

Elevation, top of  
Precambrian rock 710

Core interval 480-490



Hole azimuth: plunge: -90

Core recovered 100%

ABBREVIATED LITHOLOGIC LOG (intervals recorded are depths in feet)

Interval, feet

Description

QUATERNARY DEPOSITS

0-1	Topsoil; dark brown.
1-26	Sand; yellowish-brown, coarse to very coarse, contains abundant dolomite pebbles.
26-45	Silty clay with rare pebbles, gray. Lacustrine origin or possible till.
45-65	Sandy and silty till; gray, with pebbles of dolomite, shale, and pink granite.
65-81	Clay till; dark gray, dense, sandy. Pebble assemblage as above but with higher proportion of shale.
81-94	Sand with abundant clasts of dark gray shale, granite, dolomite.
94-135	Sandy till; light brownish-gray, similar to above except for greater sand content.
135-193	Clay till; light brownish-gray, dense, clast-rich. Same clast types as above.
193-215	Sandy till; light gray, with abundant cobbles.
215-228	Sand and gravel, tightly compacted, abundant cobbles and boulders of granite and greenstone.
228-434	Clay till; light brownish-gray, dense, sandy, abundant cobbles and pebbles. Sand layers 298-304'.

WEATHERING RESIDUUM ON PRECAMBRIAN BEDROCK

434-465	Clay; soft, green, gray, and brown, a few thin zones of harder green clay.
465-480	Weathered metabasalt; dark green.

SOUND PRECAMBRIAN BEDROCK

480-490	Chlorite schist of basaltic protolith; dark green, weathered, strongly foliated. Cleavage wraps around deformed clots of hard, fine- to medium-grained dacite porphyry intrusion.
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PETROGRAPHIC DESCRIPTION OF CORE: NW-12

Principal Rock Type: Chloritic schist of basaltic protolith (70%); dark green, weathered, strongly cleaved; and intrusive dacite (30%); foliated, blocky-deformed, weakly retrograde altered.

Mineralogy: *Dacite* - plagioclase, forms two populations: 1.) small, euhedral, tabular, zoned crystals, 2.) larger (up to 1mm), more sericitized, poorly-twinned, subhedral equant grains (76% total); **quartz**, variably recrystallized but generally has retained its primary anhedral-interstitial shape; **biotite**, light brown, strongly pleochroic scraps and books, variably altered to chlorite (3%); **chlorite**, green (3%); **opaques**, some blocky pyrite altered to hydrous iron-oxides, other irregular fine-grained granules of unknown composition. *Basalt* - mostly chlorite.

Texture: Chlorite schist is strongly foliated, zones of epidote-altered feldspar or epidote-filled amygdules. Cleavage wraps strongly around more competent blocks of dacite, which is non-foliated but deformed in a brittle fashion.

Structure: Cleavage in mafic schist dips 65-90° from horizontal, cleavage dip varies along length of core due to strong wrapping of cleavage around dacite blocks.

CHEMICAL DATA

Rock Type Analyzed: Chlorite schist with dacite intrusion, 480-480.5' depth. Activation Laboratories, Inc.

Minor Elements (ppm, except as indicated)	
Au (ppb)	51
Ag	<5
As	4
Ta	<1
Sc	6.3
Co	14
Cr	10
Ni	56
Zn	50
Hf	3
Rb	34
Ba	510
Fe (%)	5.47
Na	4130
Th	1.8
U	<0.5
Cs	<2
La	21
Ce	46
Nd	25
Sm	4.0
Eu	1.7

MAGNETIC SUSCEPTIBILITY (depth in feet)

Depth	Reading (x 10 <sup>-3</sup> cgs units)
480-490	0.01-0.05, average 0.03

DENSITY

Depth	Density
485	2.59 dacite

Field number NW-14

Date finished 6-25-92

MGS unique number 247053

MGS lab number MGS 3319

LOCATION (see map at right)

T-R-S 159 - 49 - 22 DDDD

County Kittson

Quadrangle Donaldson 7.5'

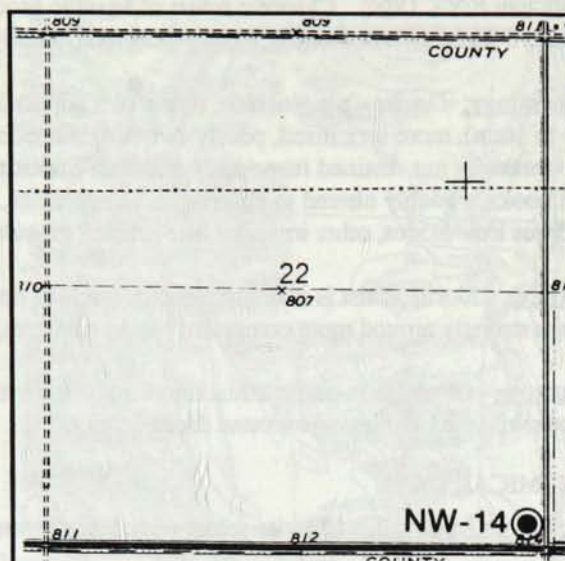
HOLE PARAMETERS (feet)

Surface elevation 814

Total depth 446

Elevation, top of  
Precambrian rock 398

Core interval 436-446



Hole azimuth:                      plunge: -90

Core recovered 100%

ABBREVIATED LITHOLOGIC LOG (intervals recorded are depths in feet)

Interval, feet

Description

QUATERNARY DEPOSITS

- 0-1            Topsoil; black, organic-rich and clayey.  
1-6            Lacustrine clay; dark gray.  
6-23          Lacustrine clay; olive-brown to gray, laminated.  
23-79        Lacustrine clay; gray, smooth.  
79-81        Sand and gravel, sand is coarse grained, gravel composed mostly of carbonate.  
81-183       Sandy till; gray, with numerous thin interlayered units of sand and gravel and rare cobbles.

ORDOVICIAN SEDIMENTARY ROCKS

- 183-248     Red River Formation - limestone; yellowish-gray, dense, micritic, slightly fossiliferous (brachiopods). Contains thin beds of red and light green shale and trace of light brown chert.  
248-261     Red River Formation - limestone; light olive-gray, with minor thin beds of shale.  
261-296     Winnipeg Formation - shale; pale red to grayish-green. Minor limestone. Brachiopod, crinoid fossils.  
296-416     Winnipeg Formation - shale; grayish-green, and quartz sandstone; yellowish-gray, medium to coarse grained, friable, well- rounded and sorted 296-306', 309-316', 321-325'; and limestone 363-370'.

WEATHERING RESIDUUM ON PRECAMBRIAN BEDROCK

- 416-428     Biotite schist; dark greenish-gray, weathered, clay-rich.  
428-436     Biotite schist; dark gray and green, slightly weathered.

SOUND PRECAMBRIAN BEDROCK

- 436-446     Quartzofeldspathic hornblende-biotite schist; dark gray to greenish-gray to black, with band of green amphibolite.

PETROGRAPHIC DESCRIPTION OF CORE: NW-14

Principal Rock Type: Quartzofeldspathic hornblende-biotite schist of graywacke protolith. Banding defined by variations in biotite and hornblende content represents primary compositional variation (bedding).

Mineralogy: **Biotite**, reddish-brown, strongly pleochroic, well-foliated, tiny books ( $\pm 15\%$ ); **plagioclase** and **quartz**, fine-grained granoblastic, weakly sericitized ( $\pm 72\%$  total); **hornblende**, dark green pleochroic, subhedral, confined to narrow bands, locally predominant (generally trace%); **sphene**, fine-grained subhedral granules aligned parallel to foliation ( $\pm 3\%$ ), **calcite** and **epidote**, fine-grained granoblastic (trace); **chlorite**, confined to late brittle fractures, after biotite and hornblende (trace); **pyrite**, irregular blocky grains disseminated throughout (up to 1%).

Texture: Strongly foliated, fine- to medium-grained, thoroughly recrystallized granoblastic texture with foliation defined primarily by oriented biotite.

Structure: Foliation dips  $80-85^\circ$  from horizontal. Vein of gray quartz is tightly folded. Minor calcite-chlorite fractures dip  $10-25^\circ$  from horizontal.

CHEMICAL DATA

Rock Type Analyzed: None

MAGNETIC SUSCEPTIBILITY (depth in feet)

Depth	Reading ( $\times 10^{-3}$ cgs units)
436-438	0.04-0.06
438-446	0.02

DENSITY

Depth	Density
437	2.74

Field number NW-15

Date finished 6-29-92

MGS unique number 247054

MGS lab number MGS 3320

LOCATION (see map at right)

T-R-S 156 - 50 - 35 BBBBAB

County Marshall

Quadrangle Big Woods 7.5'

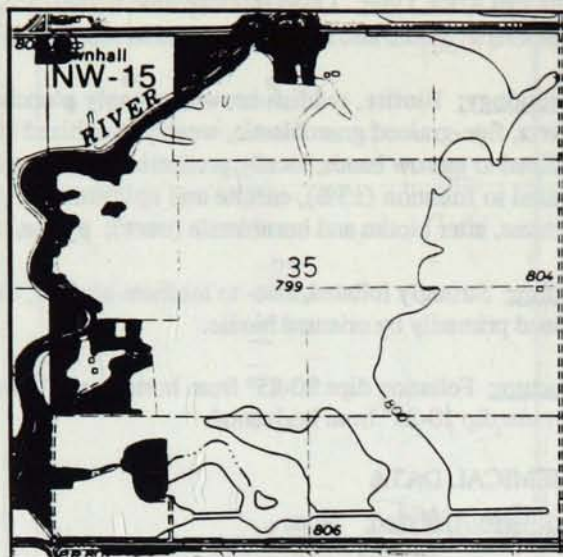
HOLE PARAMETERS (feet)

Surface elevation 800

Total depth 501

Elevation, top of  
Precambrian rock 316

Core interval 493-501



Hole azimuth:                      plunge: -90

Core recovered 100%

ABBREVIATED LITHOLOGIC LOG (intervals recorded are depths in feet)

Interval, feet	Description
<b>QUATERNARY DEPOSITS</b>	
0-8	Lacustrine clay; light yellowish-brown, silty.
8-17	Lacustrine clay; brown, silty.
17-150	Lacustrine clay; gray, laminated, sandier below 80' depth.
150-180	Silty till; gray, with abundant pebbles of granitic and mafic rocks.
180-298	Sandy till grading downward to clayey till.
<b>CRETACEOUS SEDIMENTARY ROCKS</b>	
298-319	Upper portion of black carbonaceous slate with lignite, light brownish-gray siltstone cemented with pyrite. Below 310' light gray, coarse-grained, pebbly sandstone with well-rounded, polished grains. Lignitic shale at base of section.
<b>JURASSIC SEDIMENTARY ROCKS</b>	
319-333	Hallock red beds - limestone; yellowish-gray, dense. Shale at base; brownish-red to white.
<b>ORDOVICIAN SEDIMENTARY ROCKS</b>	
333-470	Winnipeg Formation - shale; grayish-green to pale red, fossiliferous (Bryozoans and Brachiopods).
470-484	Winnipeg Formation, Black Island Member - Shale and fine-grained, well-rounded sandstone.
<b>WEATHERING RESIDUUM ON PRECAMBRIAN BEDROCK</b>	
484-488	Clay and weathered schist; soft, white and gray.
<b>SOUND PRECAMBRIAN BEDROCK</b>	
488-501	Tuffaceous wacke and argillite metamorphosed to gray, biotite-hornblende quartzofeldspathic schist.

**PETROGRAPHIC DESCRIPTION OF CORE: NW-15**

Principal Rock Type: Biotite-quartz-plagioclase schist of andesitic crystal-lithic tuffaceous wacke protolith; light to medium-gray, banded, . Eye-shaped quartz and feldspar clots are presumed to be relict volcanic crystals.

Mineralogy: **Hornblende**, sieve-textured porphyroblasts up to 1mm which overprint foliation; **biotite**, brown, strongly pleochroic, irregular rectangular grains; **chlorite**, pale green; **quartz** and **feldspar**, very fine-grained groundmass, granoblastic shape modified by intergrowth with biotite; **calcite**, in veins with quartz and disseminated throughout; **epidote** and **magnetite**, fine grains disseminated throughout rock.

Texture: Clean prograde-metamorphic fabric, foliation defined by biotite, hornblende, and granblastic quartz and feldspar which are growth-controlled by biotite. Possible bedding and grading indicate topping direction is down. Quartz veins are folded and recrystallized.

Structure: Foliation and bedding are subparallel, dip 60-65° from horizontal.

**CHEMICAL DATA**

Rock Type Analyzed: Hornblende-biotite schist with disseminated pyrite (496'); pink, altered schist (501').

Minor elements (ppm, except as indicated) 496' depth		Minor elements (ppm, except as indicated) 501' depth	
Au (ppb)	<5	Au (ppb)	<5
Ag	<5	Ag	<5
Ta	<1	Ta	<1
Sc	11	Sc	9.8
Ni	120	Ni	<50
Zn	100	Zn	64
Hf	3	Hf	3
Rb	37	Rb	33
Ba	180	Ba	280
Fe %	4.57	Fe%	3.26
Na	22500	Na	26000
Th	3.2	Th	2.6
U	<0.5	U	<0.5
Cs	<2	Cs	<2
La	49	La	46
Ce	100	Ce	95
Nd	48	Nd	45
Sm	6.4	Sm	6.1
Eu	1.9	Eu	1.9
Tb	0.7	Tb	0.5
Yb	1.63	Yb	1.44
Lu	0.25	Lu	0.23

**MAGNETIC SUSCEPTIBILITY (depth in feet)**

Depth	Reading (x 10 <sup>-3</sup> cgs units)	Depth	Reading (x10 <sup>-3</sup> cgs units)
493.0-493.5	1.7	496.0-496.5	2.9
493.5-494.0	0.89	496.5-497.0	4.1
494.0-494.5	1.1	497.0-500.3	1.1 - 1.9
494.5-495.5	2.1 - 2.2	500.3-500.5	3.0
495.5-496.0	2.5	500.5-501.0	1.4

**DENSITY**

Depth	Density
496	2.8

Field number NW-19

Date finished 7-8-92

MGS unique number 247055

MGS lab number MGS 3321

LOCATION (see map at right)

T-R-S 152-44-9 AADDA

County Pennington

Quadrangle Viking SE 7.5'

HOLE PARAMETERS (feet)

Surface elevation 1090

Total depth 502

Elevation, top of  
Precambrian rock 700

Core interval 492-502



Hole azimuth:                      plunge: -90

Core recovered 100%

ABBREVIATED LITHOLOGIC LOG (intervals recorded are depths in feet)

Interval, feet

Description

QUATERNARY DEPOSITS

- 0-0.5 Topsoil
- 0.5-6 Sand and gravel; high proportion of sedimentary rocks in gravel.
- 6-67 Clay; dark gray, silty clay, and sandy clay. Gravel layers at 27.5-28.5', 50-51', 65.5-67' intervals.
- 67-126 Silty till; gray, sandy, with layers of dark gray clay till. Gravelly below 86' depth, to 100' depth.
- 126-137 Sand and gravel.
- 137-238 Sandy to gravelly till; gray. Numerous cobbles predominantly of granitic composition, encountered every 1-3 feet.
- 238-265 Clay till; dark greenish-gray, sandy to silty.
- 265-390 Sandy till; light gray, with abundant pebbles and cobbles.

WEATHERING RESIDUUM ON PRECAMBRIAN BEDROCK

- 390-430 Clay; white to greenish-white.
- 430-470 Clay; bluish-gray, gritty, with 1-2mm clots of white, medium blue, and dark greenish-blue clay and quartz grains in matrix of very light bluish-gray clay.

SOUND PRECAMBRIAN BEDROCK

- 470-502 Biotite tonalite; medium- to coarse-grained, greenish-pink, strongly foliated, sheared.



PETROGRAPHIC DESCRIPTION OF CORE: NW-19

Principal Rock Type: Biotite tonalite; medium- to coarse-grained, greenish-pink to gray, foliated.

Mineralogy: **Plagioclase**, weakly zoned, sericite-altered, primary blocky grain shapes rounded and broken by shear deformation, albite twinning mostly eradicated but carlsbad twinning well preserved (60%); **perthite**, anhedral-interstitial, locally granoblastic (2%); **quartz**, ribbon, mortar-textured to granoblastic, primary shape anhedral-interstitial (35%); **biotite**, subhedral shreds, foliated, may be secondary after hornblende, strongly pleochroic in shades of green, altered to chlorite (2%); **muscovite**, forms as secondary shreds in zones of high strain due to breakdown of feldspars (trace); **chlorite**, secondary after biotite, contains very fine-grained dusty oxides/leucoxene (1%); **sphene**, euhedral, altered to leucoxene along edges and fractures (trace); **epidote** and **allanite**, former rims latter, subhedral grains (trace).

Texture: Medium- to coarse-grained, primary igneous texture modified by semi-brittle cataclasis to a foliated rock. Foliation anastomoses around less deformed zones, resulting in augen-like texture. Local zones of more intense shear are more deeply weathered.

Structure: Shear foliation dips 65-75° from horizontal. Locally abundant brittle meso-faults dip more steeply than shear fabric.

CHEMICAL DATA

Rock Type Analyzed: None

MAGNETIC SUSCEPTIBILITY (depth in feet)

Depth	Reading (x 10 <sup>-3</sup> cgs units)
492-502	0.00-0.01

DENSITY

Depth	Density
494	2.6

Field number NW-20

Date finished 7-11-92

MGS unique number 247056

MGS lab number MGS 3322

LOCATION (see map at right)

T-R-S 153 - 42 - 15 ABBABB

County Pennington

Quadrangle Hazel 7.5'

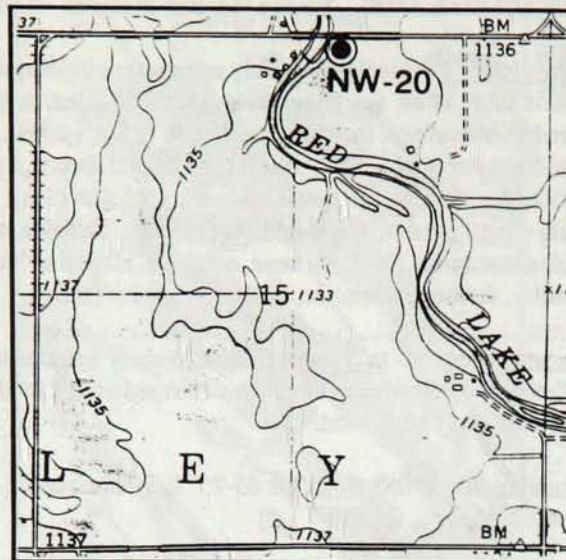
HOLE PARAMETERS (feet)

Surface elevation 1132

Total depth 529

Elevation, top of  
Precambrian rock 620

Core interval 520-529



Hole azimuth: plunge: -90

Core recovered 100%

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

Interval, feet	Description
<b>QUATERNARY DEPOSITS</b>	
0-17	Upper 2'; organic, brown topsoil, then loamy till; brown, gray below 12' depth. Gravel at base.
17-35	Sandy till; light gray, dense.
35-44	Clay till; dark gray, clasts predominantly dark-colored shale and slate.
44-76	Sandy till; light greenish-gray to gray, silty. Thin layers of gray clay till near base.
76-81	Sand grading downward to gravel with cobbles.
81-107	Sandy and silty till; gray.
107-125	Lacustrine clay; dark gray, with thin beds of sand and gravel.
125-133	Silty till; greenish-gray with abundant pebbles of dolomite.
133-159	Sandy till; light gray with several sand layers.
159-191	Clay till; gray.
191-230	Sandy till; light gray, minor sand layers near base of interval.
230-246	Coarse sand grading downward to fine sand.
246-270	Lacustrine clay; green to bluish-green, changes to brownish-gray, then to dark red color with depth.
270-289	Clay till; gray, sandy.
289-330	Clay till; dark gray, abundant cobbles and pebbles of dolomite, granite, shale, and metavolcanic rocks.
330-340	Sand; medium to coarse, minor cobble-rich intervals.
340-350	Clay till; gray, sandy.
350-376	Clay till; dense, contains clasts of red shale.
376-496	Sand; uniform, fine to medium, cobbles at base.
496-512	Clay till; light gray, with abundant cobbles of red shale, soft gray shale, dolomite, and granitic rocks.
<b>WEATHERING RESIDUUM ON PRECAMBRIAN BEDROCK</b>	
~512	Bedrock; slightly altered to clay along fractures in upper part of core.
<b>SOUND PRECAMBRIAN BEDROCK</b>	
512-529	Basalt; dark greenish-black, amygdaloidal, metamorphosed.

PETROGRAPHIC DESCRIPTION OF CORE: NW-20

Principal Rock Type: Basalt and basaltic flow top-breccia; amygdaloidal. Contains glomerophenocrysts of hornblende. Metamorphosed to chlorite-grade.

Mineralogy: (of massive portion of flow) **Hornblende**, primary? phenocrysts which range from individual crystals to glomeroporphyritic clusters of subhedral grains, fresh bluish-green crystals variably altered to fibrous mats of pale green chlorite; **plagioclase**, occurs in groundmass as fine-grained, lathy, trachytic crystals, trachytic alignment defines a flow fabric that bends around hornblende phenocrysts; **groundmass**, in addition to tiny plagioclase consists of mat of fine-grained **amphibole**, **chlorite**, **opaques** (leucoxene, oxides, and /or very fine-grained granular epidote), scattered euhedral **epidote** crystals of retrograde-metamorphic origin. Local **pyrite** and oxidized **pyrite** clots predate deformation.

Texture: Porphyritic, trachytic as described above. Flow top breccia in upper 2.5' of core contains 1mm-3cm, matrix-supported, angular clasts of fine-grained amygdaloidal basalt. Matrix rich in fine-grained chlorite, with crystals of altered feldspar and small hornblende grains.

Structure: Flow-top is moderately foliated (dips 80° from horizontal). Contact of massive portion with overlying flow-top breccia is abrupt, dips 40° from horizontal. Younging direction most likely is up-hole.

CHEMICAL DATA

Rock Type Analyzed: Basaltic flow-top breccia (522')

Major Elements (Wt. % oxides)	Minor Elements (ppm)	Minor Elements (ppm, Au=ppb)
SiO2 47.3	Rb <10	Au (ppb) <2
Al2O3 11.0	Sr 347	Ag <0.1
CaO 10.60	Ba 56	Be 7
MgO 8.72	Zr 108	B 16
Na2O 2.03	Y 12	Sc 33.3
K2O 0.14	Nb <10	V 275
FeO 10.9		Cr 610
Fe2O3t 16.20		Co 65.0
MnO 0.25		Ni 236
TiO2 1.730		Cu 73.4
P2O5 0.17		Zn 141
LOI 2.25		Pb <2
Total 100.5		Br 2.3
Fe2O3 4.09		

MAGNETIC SUSCEPTIBILITY (depth in feet)

Depth	Reading (x 10 <sup>-3</sup> cgs units)	Depth	Reading (x10 <sup>-3</sup> cgs units)
520-521.5	0.05	525.5-526.5	0.05
521.5-523.5	0.06-0.07	526.5-527.5	0.06
523.5-524.0	0.05	527.5-528.5	0.07
524.0-524.5	0.06	528.5-529.0	0.08
524.5-525.5	0.07		

DENSITY

Depth	Density
527	2.91 massive metabasalt

Field number NW-21

Date finished 7-15-92

MGS unique number 247057

MGS lab number MGS 3323

LOCATION (see map at right)

T-R-S 153 - 40 - 28 BBABAB

County Pennington

Quadrangle High Landing 7.5'

HOLE PARAMETERS (feet)

Surface elevation 1154

Total depth 601

Elevation, top of  
Precambrian rock 640

Core interval no core



Hole azimuth:                      plunge: -90

Core recovered None

Kink in well casing at 500' depth prevented coring.

ABBREVIATED LITHOLOGIC LOG (intervals recorded are depths in feet)

Interval, feet	Description
<b>QUATERNARY DEPOSITS</b>	
0-4	Topsoil; black, organic, clay-rich.
4-7	Gravel of fluvial origin. Pebbles predominantly dolomite.
7-20	Clay till; brownish gray, becomes grayer with depth. Dolomite, basalt, and granitic rock clasts.
20-144	Sandy till, silty till, and thin (1-5') sand layers; gray, interlayered.
144-227	Sand and gravel; fine to coarse with scattered cobbles and boulders, minor thin layers of till.
227-265	Silty till; gray, sandy, and layers of gravelly till. Silty clay till near base.
<b>CRETACEOUS SEDIMENTARY ROCKS</b>	
265-305	Quartz sandstone; gray, medium- to coarse-grained, contains large muscovite flakes. Lignite and thin layers of shale occur in the top 4' of interval.
305-311	Siltstone; gray.
311-362	Quartz sandstone; fine- to coarse-grained.
362-367	Shale; brown to maroonish-gray.
367-464	Quartz sandstone; clean, fine- to coarse-grained, well sorted. Muscovite-rich layer at 445'.
464-480	Quartz-rich sandstone with thin beds of white, silty clay.
480-514	Quartz sandstone, sand grains more angular than units above.
<b>WEATHERING RESIDUUM ON PRECAMBRIAN BEDROCK</b>	
514-597	Clay-rich residuum; white and light green with relict texture of schist.
<b>SOUND PRECAMBRIAN BEDROCK</b>	
597-601	Chlorite-quartz-sericite schist; white to pale green.

PETROGRAPHIC DESCRIPTION OF CORE: NW-21

Principal Rock Type: Chlorite-quartz-sericite schist; white to pale green, very fine-grained. Cuttings are crumbly and probably still slightly weathered.

CHEMICAL DATA

Rock Type Analyzed: None

MAGNETIC SUSCEPTIBILITY (depth in feet)

Depth	Reading ( $\times 10^{-3}$ cgs units)
	No readings obtained.

DENSITY

Depth	Density
	No readings obtained.

Field number NW-22

Date finished 7-28-92

MGS unique number 247058

MGS lab number MGS 3330

LOCATION (see map at right)

T-R-S 152 - 43 - 13 DADDD

County Pennington

Quadrangle Plummer 7.5'

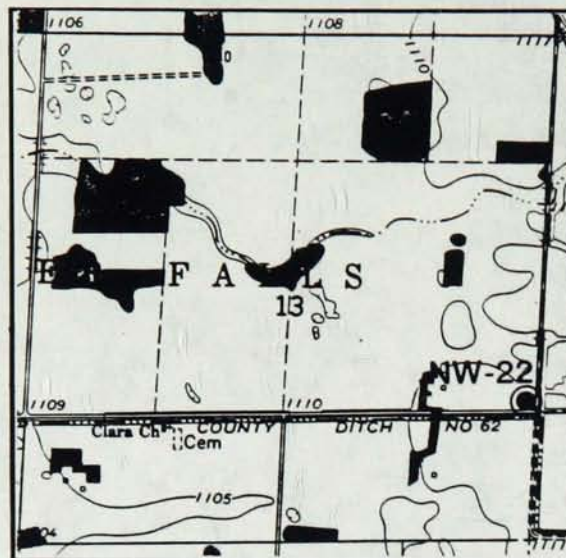
HOLE PARAMETERS (feet)

Surface elevation 1110

Total depth 821

Elevation, top of  
Precambrian rock 575

Core interval No core



Hole azimuth:                      plunge: -90

Core recovered None

Hole collapsed, drill rods stuck in hole, prevented drilling to sound rock, and coring.

ABBREVIATED LITHOLOGIC LOG (intervals recorded are depths in feet)

Interval, feet

Description

QUATERNARY DEPOSITS

0-2	Sand, gravel, clay; fill material.
2-15	Clay till; brown, oxidized. Clasts of limestone, granite, dark igneous rocks, metasedimentary rocks, and chert. Grades to sandy, gravelly till near base of unit.
15-80	Sandy till; gray. Layers of sand and gravel alternate with layers of silty to sandy till.
80-92	Sand; fine- to coarse-grained.
92-200	Sandy till; gray, with layers of sand and gravel. Layer of cobbles and boulders at 135'. Clasts of red granitic rock, dark-colored igneous rocks. Clasts of tan limestone are dominant below 197'.
200-213	Clay till; bluish-gray. Becomes sandier with depth and grades into underlying unit.
213-219	Sand, minor gravel.
219-236	Till; gray, contains minor layers of sandy till. Scattered limestone clasts, pieces of lignite near base.
236-260	Sandy till; brownish-gray, contains abundant fragments of wood.
260-265	Clay till; dark bluish-gray.
265-371	Sandy till; gray. Contains minor clasts, predominantly of limestone.
371-400	Till; gray, with layers of brown to greenish-blue clay till.
400-417	Till; gray, with clots of white clay.
417-535	Sandy till; gray, with clots of white clay.

WEATHERING RESIDUUM ON PRECAMBRIAN BEDROCK

535-586	Clay; brown grades to white, then to pale green with depth. Soft brownish-black clay 585-586'.
586-640	Clay; light green. Becomes harder 600 - 606', with some soft rock chips.
640-821	Alternating hard and soft zones of weathered rock and clay; light green. Sand grains at 679'.

SOUND PRECAMBRIAN BEDROCK

None obtained. Protolith of weathering residuum is apparently a fine-grained chlorite-sericite schist.

PETROGRAPHIC DESCRIPTION OF CORE: NW-22

Principal Rock Type: No competent bedrock samples obtained.

CHEMICAL DATA

Rock Type Analyzed: None

MAGNETIC SUSCEPTIBILITY (depth in feet)

Depth	Reading (x 10 <sup>-3</sup> cgs units)
	No readings obtained.

DENSITY

Depth	Density
	No readings obtained.

Field number NW-23

Date finished 8-7-92

MGS unique number 247059

MGS lab number MGS 3327

LOCATION (see map at right)

T-R-S 151 - 45 - 28 ADBABB

County Red Lake

Quadrangle Gentilly 7.5'

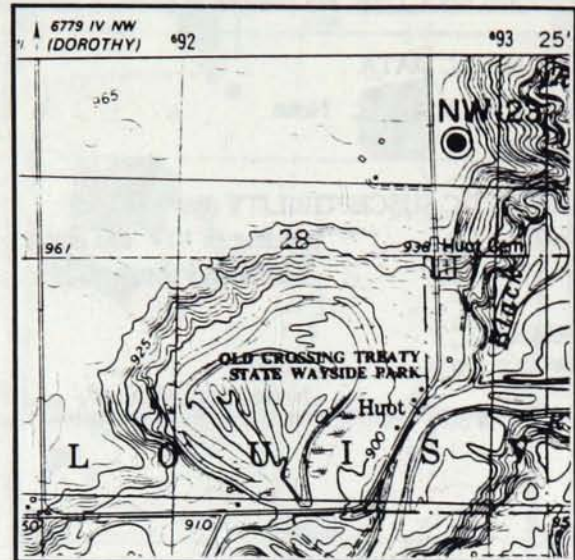
HOLE PARAMETERS (feet)

Surface elevation 962

Total depth 539

Elevation, top of  
Precambrian rock 598

Core interval 529-539



Hole azimuth:                      plunge: -90

Core recovered 100%

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

Interval, feet	Description
<b>QUATERNARY DEPOSITS</b>	
0-4	Clay; dark gray to black, organic-rich.
4-16	Lacustrine clay; light brown and gray.
16-109	Lacustrine clay; bluish-gray, unlaminated, with trace of sand and small pebbles.
109-152	Clay till; dark gray with thin sandy layers. Contains clasts of carbonate, minor lignite.
152-182	Sandy till; light brown to light gray, silty.
182-197	Clay till; sandy, cobbly, with abundant pieces of lignite.
197-214	Till similar to above but with fewer cobbles.
214-225	Layer of sand and cobbles.
225-230	Sandy, cobbly till.
230-244	Sand and gravel; high proportion of limestone in gravel.
244-270	Till; light gray, with sand, cobbles, and boulders of weathered Precambrian rocks.
270-325	Sandy till containing abundant clasts of chert, limestone, and Precambrian rocks.
325-348	Sandy, cobbly till; gray, with subordinate clay layers, including one of reddish-brown color.
348-364	Interbedded sandy till and clay till; scattered boulders, become more common near base.
<b>WEATHERING RESIDUUM ON PRECAMBRIAN ROCK</b>	
364-520	Clay; interlayered green and brown, minor white clay weathering residuum.
<b>SOUND PRECAMBRIAN ROCK</b>	
520-539	Biotite-hornblende tonalite; pinkish-gray, medium- to coarse-grained, massive to weakly porphyritic.



PETROGRAPHIC DESCRIPTION OF CORE: NW-23

Principal Rock Type: Biotite-hornblende tonalite; pinkish-gray, medium- to coarse-grained, massive to weakly porphyritic.

Mineralogy: Plagioclase, rectangular, euhedral, moderately zoned (cyclic), cores saussuritized (68%); quartz, anhedral-interstitial primary shape modified to ribbonry mortar-textured grains by brittle deformation (25%); biotite, subhedral, moderate brown to green pleochroism, altered to green color and to chlorite ( 2%); hornblende, subhedral prismatic, foliated, moderately pleochroic in shades of green, altered to chlorite when crossed by brittle shear plane (3%); chlorite, pale green, foliated, secondary after biotite and hornblende (2%); oxides, primary? anhedral grains (trace); leucoxene, anhedral granules, within biotite (trace); epidote, tiny secondary granular grains. Cut by a 2cm-thick, pink, coarse-grained granite dikelet which is subcordant to foliation of tonalite.

Texture: Weakly foliated via ribbonry quartz and aligned mafic minerals, due in part to brittle deformation to a protomylonitic, crushed texture. Primary texture is coarse-grained, locally vaguely porphyritic with 2 - 12mm blocky plagioclase crystals.

Structure: Foliation dips 55-65° from horizontal, may be primary trachytic fabric in part.

Comments: Drill hole placed over combined magnetic and gravity lows.

CHEMICAL DATA

Rock Type Analyzed: None

MAGNETIC SUSCEPTIBILITY (depth in feet)

Depth	Reading ( $\times 10^{-3}$ cgs units)
529-539	0.01 - 0.03, average 0.01.

DENSITY

Depth	Density
537	2.76

Field number NW-24

Date finished 8-9-92

MGS unique number 247060

MGS lab number MGS 3328

LOCATION (see map at right)

T-R-S 150-47-12 DBCAAD

County Polk

Quadrangle Crookston 7.5'

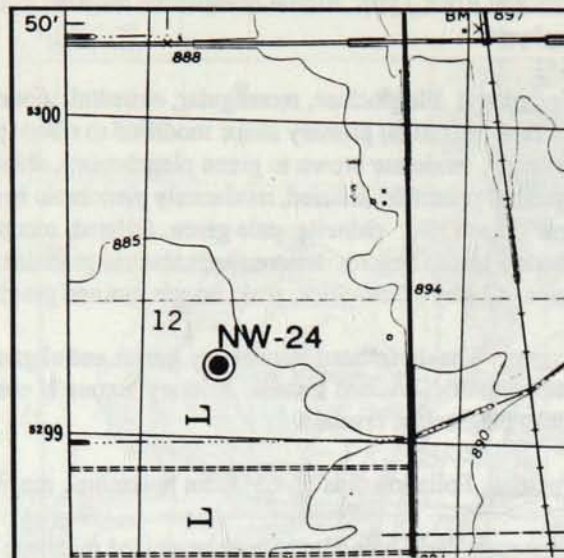
HOLE PARAMETERS (feet)

Surface elevation 885

Total depth 380

Elevation, top of  
Precambrian rock 580

Core interval 370-380



Hole azimuth:                      plunge: -90

Core recovered 100%

ABBREVIATED LITHOLOGIC LOG (intervals recorded are depths in feet)

Interval, feet

Description

QUATERNARY DEPOSITS

- 0-3            Topsoil; black, organic-rich.
- 3-18        Lacustrine clay; light brown to light gray. Becomes sandy below 12' depth.
- 18-75      Clay; gray, with fine sand and scattered pebbles of carbonate. May be lacustrine clay or clay till.
- 75-77      Sand and gravel.
- 77-82      Clay till; dense, with cobbles of carbonate rock.
- 82-142     Silt and very fine-grained fluvial sand with abundant fragments of carbonized wood.
- 142-305    Sandy to clayey till; interlayered, gray, contains pebbles of tan-colored carbonate rocks and pebbles to boulders of granitic Precambrian rocks.

WEATHERING RESIDUUM ON PRECAMBRIAN BEDROCK

- 305-331    Clay residuum: greenish-gray grading to dark olive-green, rare light brown clay.
- 331-335    Clay; green.
- 335-349    Clay; olive-green.
- 349-365    Clay; brown with green mottles, becomes uniformly green with increasing depth.
- 365-367    Clay; green and brown, with hard chips of greenstone.

SOUND PRECAMBRIAN BEDROCK

- 367-380    Chlorite schist of basaltic protolith; dark green, fine-grained, cut by early, deformed veins of calcite.

PETROGRAPHIC DESCRIPTION OF CORE: NW-24

Principal Rock Type: Chlorite schist of basaltic protolith; strongly cleaved, fine-grained, dark green. Contains zones and 2 - 15mm angular lithic fragments of calcite-filled and deformed amygdules: apparently a basaltic flow-top breccia.

Mineralogy: Mass of very fine-grained, dark green chlorite, disseminated calcite, and an unknown opaque dust comprised of leucoxene or very fine granular epidote/clinozoisite. The latter is concentrated along stringy zones which bend around carbonate grains and lithic fragments. Lithic fragments distinguished only by relative color differences (more chloritic or less chloritic) than matrix. Very fine-grained quartz (?) and feldspar in groundmass. Minor blocky pyrite associated with carbonate.

Texture: Foliation wraps around lithic fragments. Carbonate veins pinch and swell, and are extensively recrystallized to a fine-grained granoblastic mass.

Structure: Foliation dips 55-60° from horizontal. Clasts are lineated. Combined with deformation features of calcite veins, this implies that the rock has been sheared. Early calcite veins are very deformed and recrystallized, and amygdules are surrounded by asymmetric pressure shadows.

CHEMICAL DATA

Rock Type Analyzed: Chlorite schist with deformed carbonate veins.

Minor elements  
(ppm, except as  
indicated) 371' depth

Au (ppb)	7
Ag	<5
As	10
Ta	<1
Sc	35
Ni	<50
Zn	104
Hf	1
Rb	<30
Ba	120
Fe (%)	10.8
Na	5660
Th	<0.5
U	<0.5
Cs	<2
La	2
Ce	6
Nd	<5
Sm	1.4
Eu	0.7
Tb	<0.5
Yb	2.69

MAGNETIC SUSCEPTIBILITY (depth in feet)

Depth	Reading (x 10 <sup>-3</sup> cgs units)
370-380	0.03-0.07, average 0.05

DENSITY

Depth	Density
371	2.83

Field number NW-25

Date finished 8-19-92

MGS unique number 247334

MGS lab number MGS 3347

LOCATION (see map at right)

T-R-S 149 - 45 - 28 DDCCDD

County Polk

Quadrangle Harold 7.5'

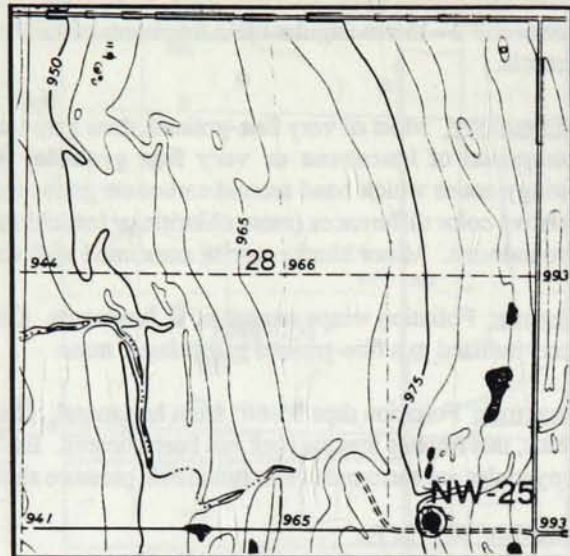
HOLE PARAMETERS (feet)

Surface elevation 980

Total depth 360

Elevation, top of  
Precambrian rock 728

Core interval 350-360



Hole azimuth:                      plunge: -90

Core recovered 100%

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

Interval, feet	Description
<b>QUATERNARY DEPOSITS</b>	
0-1	Topsoil; black, cobbly.
1-6	Sand, cobbles, and boulders. Carbonate and granitic rock types.
6-20	Sandy till; light brown, with cobbles and boulders.
20-34	Sand; with minor proportion of pebbles and cobbles.
34-37	Lacustrine clay; bluish-gray, silty.
37-39	Sand.
39-52	Lacustrine clay with minor silt.
52-63	Sand.
63-72	Cobbles and boulders of granite and carbonate, in sand. Mafic boulders near base of unit.
72-252	Till; gray, sandy to cobbly. Clasts consist of Precambrian rock types as well as carbonate rocks. Granite cobble at 120' produces gamma response.
<b>WEATHERING RESIDUUM ON PRECAMBRIAN BEDROCK</b>	
252-350	Clay; green, locally with brown and white mottles. Drill bit passes in and out of harder zones of green, fine-grained greenstone-type rock.
<b>SOUND PRECAMBRIAN BEDROCK</b>	
350-360	Interbedded graywacke and argillite; medium-grained, light greenish-gray, moderately foliated.

PETROGRAPHIC DESCRIPTION OF CORE: NW-25

Principal Rock Type: Graywacke; greenish-gray, medium-grained, interbedded with argillite; gray to greenish-gray. Graded beds are common. Graywacke beds as thick as five feet contain pristine unit quartz and feldspar grains and lithic fragments. Argillite is thinly laminated, in beds one to three feet thick, with moderately well developed, bedding-parallel cleavage. Thin-section examination indicates that the rock is a reworked crystal-lithic tuff of dacitic to andesitic composition.

Mineralogy: *Graywacke* - plagioclase, angular, albite-twinned, incipiently replaced by calcite; quartz, subangular unit grains with sharp to shadowy extinction, coarse sand to silt-sized, some with radial rims of quartz and mica; hornblende, greenish-brown, diamond-shaped, of detrital origin; actinolite, light green tabular prisms to needles interpreted as metamorphic in origin; sphene, euhedral; epidote, scattered crystals and granular clots after an earlier mafic mineral or clasts of unknown character; pyrite, ubiquitous, very fine-grained; lithic clasts, defined by clusters of feldspar crystals or by fine-grained "cherty"-textured masses, some altered to carbonate.

Texture: Weak foliation in graywacke defined by fine-grained fibrous actinolite, elongate quartz, and stringy concentrations of opaque minerals.

Structure: Foliation is parallel to bedding, both dip 70° from horizontal. Foliation wraps around lithic fragments and crystals. Minor foliation-parallel pinch-and-swell quartz veins. Graded bedding indicates younging is up-hole.

CHEMICAL DATA

Rock Type Analyzed: Volcanogenic graywacke (360'), both analyses.

Major elements (wt. % oxides)		Minor Elements (ppm)		Minor Elements (ppm, Au=ppb)		Minor elements (ppm, except as indicated)	
SiO <sub>2</sub>	64.2	Rb	50	Au (ppb)	<2	Au (ppb)	13
Al <sub>2</sub> O <sub>3</sub>	15.0	Sr	297	Ag	<0.1	Ag	<5
CaO	1.87	Ba	663	Be	4	Ta	<1
MgO	3.02	Zr	128	B	33	Sc	14
Na <sub>2</sub> O	3.64	Y	14	Sc	11.4	Ni	<50
K <sub>2</sub> O	2.25	Nb	16	V	102	Zn	96
FeO	4.0			Cr	120	Hf	4
Fe <sub>2</sub> O <sub>3t</sub>	6.18			Co	21.0	Rb	53
MnO	0.10			Ni	72	Ba	480
TiO <sub>2</sub>	0.623			Cu	40.3	Fe (%)	5.1
P <sub>2</sub> O <sub>5</sub>	0.16			Zn	107	Na	17800
LOI	2.75			Pb	8	Th	7.3
Total	99.9			Br	2.6	U	<0.5
Fe <sub>2</sub> O <sub>3</sub>	1.73					Cs	3
						La	20
						Ce	41
						Nd	16
						Sm	2.8
						Eu	1
						Tb	0.6
						Yb	1.55
						Lu	0.25

MAGNETIC SUSCEPTIBILITY (depth in feet)

Depth	Reading (x 10 <sup>-3</sup> cgs units)
350-360	0.01-0.03 average 0.02

DENSITY

Depth	Density
360	2.75

Field number NW-26

Date finished 8-22-92

MGS unique number 247335

MGS lab number MGS 3348

LOCATION (see map at right)

T-R-S 149 - 45 - 28 BBBB

County Polk

Quadrangle Harold 7.5'

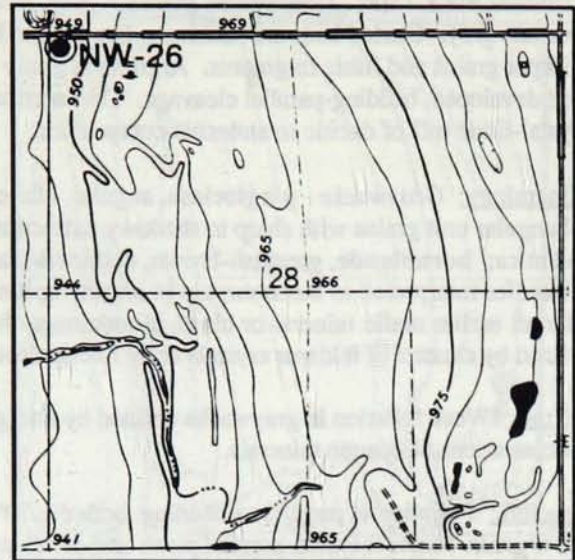
HOLE PARAMETERS (feet)

Surface elevation 949

Total depth 439

Elevation, top of  
Precambrian rock 666

Core interval 430-439



Hole azimuth:                      plunge: -90

Core recovered 100%

ABBREVIATED LITHOLOGIC LOG (intervals recorded are depths in feet)

Interval, feet	Description
<b>QUATERNARY DEPOSITS</b>	
0-4	Topsoil; black, organic-rich.
4-8	Sandy till; light brown with pebbles of carbonate rock.
8-20	Clay; dark gray, possibly lacustrine.
20-49	Sandy till; light gray with abundant clasts of granitic and mafic Precambrian rocks, and carbonate.
49-198	Sandy till; light gray with thin layers of sand and clay. Contains cobbles and boulders.
198-211	Clay till; gray, sandy.
211-223	Sand with layers of sandy till.
223-232	Clay till; dark gray.
232-253	Sandy till; light gray, contains abundant wood fragments.
253-272	Till as above but with less sand.
272-279	Sand, boulders.
279-283	Sandy clay till with cobbles.
<b>WEATHERING RESIDUUM ON PRECAMBRIAN ROCK</b>	
283-430	Clay; brick red, gray, green, and white. Harder and fresher rock of greenstone affinity occurs in some zones. Color variations range from one to four feet in thickness.
<b>SOUND PRECAMBRIAN BEDROCK</b>	
430-439	Pyrite-ankerite-sericite schist of graywacke protolith; mostly uniform texture, brown-spotted green.

## PETROGRAPHIC DESCRIPTION OF CORE: NW-26

Principal Rock Type: Pyrite-ankerite-sericite (fuchsite?) schist of probable volcanogenic graywacke protolith. Sericite is pale green color under microscope, and imparts green color to core.

Mineralogy: Quartz eyes, elliptical unit grains with shadowy extinction (5%); 'ankerite' clots, altered to Fe-hydroxides and calcite (8%); 'pyrite' clots, altered to Fe hydroxides (10%); **groundmass** of subequal quartz and sericite (77%). Sericite is pale green color in thin section (i.e. fuchsite).

Texture: Phyllitic, matrix is locally granular with feldspar or rock fragments up to 1mm. Elliptical 0.5mm clots of altered ankerite, deformed clots of altered pyrite, elliptical grains of unit quartz enclosed in a fine-grained matrix of strongly foliated sericite and granoblastic quartz. The fuchsitic sericite forms long sinewy grains which anastomose around ankerite and pyrite clots and quartz eyes. The strong dichotomy in grain size between the unit quartz grains and the matrix quartz implies the 'eyes' are volcanic (reworked or not) in origin.

Structure: Foliation dips 75-80° from horizontal, is parallel to bedding. Deformed veins of quartz + ankerite ± chlorite are 0.5mm to 2.5mm thick, subcordant to cleavage.

## CHEMICAL DATA

Rock Type Analyzed: Green quartz-sericite schist with brown clots of oxidized ankerite and pyrite. 436' depth.

Minor Elements (ppm, except as indicated)	
Au (ppb)	<5
Ag	<5
As	39
Ta	<1
Sc	17
Ni	89
Zn	80
Hf	3
Rb	42
Ba	280
Fe (%)	4.77
Na	11200
Th	2.9
U	<0.5
Cs	<2
La	12
Ce	26
Nd	13
Sm	2.2
Eu	0.9
Tb	<0.5
Yb	1.64

## MAGNETIC SUSCEPTIBILITY (depth in feet)

Depth	Reading ( $\times 10^{-3}$ cgs units)
430-439	0.00 - 0.01

## DENSITY

Depth	Density
437	2.71

Field number NW-27

Date finished 8-12-92

MGS unique number 247336

MGS lab number MGS 3329

LOCATION (see map at right)

T-R-S 148 - 44 - 16 ABAABB

County Polk

Quadrangle Dugdale 7.5'

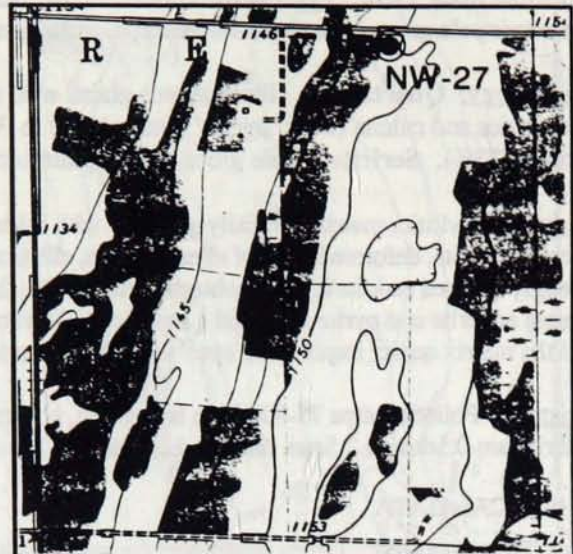
HOLE PARAMETERS (feet)

Surface elevation 1149

Total depth 418

Elevation, top of  
Precambrian rock 754

Core interval 410-418



Hole azimuth:                      plunge: -90

Core recovered 70%

ABBREVIATED LITHOLOGIC LOG (intervals recorded are depths in feet)

Interval, feet	Description
<b>QUATERNARY DEPOSITS</b>	
0-3	Topsoil; black, organic.
3-15	Sand and gravel; pebbles predominantly granitic in composition, with lesser carbonate rocks.
15-41	Silty clay; gray, with minor sand or pebbles, possibly lacustrine.
41-51	Clay till; gray, silty, with carbonate pebbles.
51-62	Clay till; dark gray, with carbonate pebbles.
62-68	Sand and cobbly gravel; with minor interbedded light gray sandy clay.
68-88	Clay till; dark gray, with carbonate cobbles, carbonized wood fragments, dark gray shale.
88-106	Sandy till; light gray, interlayered with silty sand. Granite cobbles or boulders 98-100' interval.
106-120	Sand. Granite boulder at 112-113' has high response on gamma log.
120-157	Sand; light gray, with layers of gray, sandy till, and cobbles.
157-176	Coarse sand and gravel with cobbles and boulders of Precambrian rocks, and carbonate rocks.
	Clay till; gray, calcareous, with clasts of gray Cretaceous shale and carbonized wood chips.
176-212	Sandy till; gray, variations in sand/clay ratios occur over 5-10' intervals.
212-328	Clay till; gray, greasy.
328-352	Sand and boulders of carbonate rock.
352-355	Clay till; gray to locally greenish-gray, with sand and pebbles of carbonate and Precambrian rocks.
355-379	Clay till; gray.
379-397	Clay till; gray, with abundant reworked pink, white, and brown weathering residuum from below.
<b>WEATHERING RESIDUUM ON PRECAMBRIAN BEDROCK</b>	
397-406	Clay; white (predominant) and green (minor), gradually becomes more coherent with depth.
<b>SOUND PRECAMBRIAN BEDROCK</b>	
406-418	Gabbroic anorthosite; light greenish-white, very coarse-grained, deuterically-altered.



PETROGRAPHIC DESCRIPTION OF CORE: NW-27

Principal Rock Type: Gabbroic anorthosite; pegmatitic, white, heavily retrograde-altered. Microscopically consists of fine-grained mat of quartz, sericite or talc, (clino)zoisite, epidote, and an unknown bladed, fibrous mineral such as amphibole or wollastonite (?).

Mineralogy: Quartz, clean, anhedral-granular grains form groundmass to other minerals; (clino)zoisite, anhedral-granular, anomalous blue birefringence; colorless amphibole?, bladed-prismatic, fibrous, hackly cross-fractures and weak diamond-shaped cleavage and cross-sections, some are twinned, form a felty mat; chlorite, colorless to very pale green with brownish-green birefringence; sericite or talc, felty mats of curved wispy grains.

Texture: Very coarse-grained, pegmatitic. Secondary assemblage of fine-grained granular minerals has completely overprinted primary texture in thin section, macroscopically visible relict feldspar crystals as large as 5cm. Massive, unfoliated.

Structure: Massive, cut by an apparently ductile shear zone 1 to 2 cm wide which dips steeply at a low angle to core axis, reverse sense of shear indicated.

CHEMICAL DATA

Rock Type Analyzed: Coarse-grained, altered, anorthosite (436' depth)

Minor Elements (ppm, except as indicated)	
Au (ppb)	<5
Ag	<5
Ta	<1
Sc	4.5
Ni	74
Zn	<50
Hf	<1
Rb	<30
Ba	140
Fe (%)	1.52
Na	14500
Th	<0.5
U	<0.5
Cs	<2
La	<1
Ce	<3
Nd	<5
Sm	0.2
Eu	0.3
Tb	<0.5
Yb	0.29
Lu	<0.1

MAGNETIC SUSCEPTIBILITY (depth in feet)

Depth	Reading (x 10 <sup>-3</sup> cgs units)
410-418	0.00

DENSITY

Depth	Density
410	3.05

## SUMMARY OF ARCHIVED BEDROCK DRILLING DATA, NORTHWESTERN MINNESOTA

This summary describes selected drill holes from northwestern Minnesota that intersected Precambrian bedrock, together with some holes that intersected Paleozoic, Jurassic or Cretaceous strata which locally overlie the Precambrian basement. These data are summarized from the files of the Minnesota Geological Survey (MGS) and the Department of Natural Resources (DNR), Minerals Division, Hibbing. It should be noted that many logs in this section are reinterpreted and therefore differ significantly from the original ones in the files. The holes were drilled in the area shown in Figure 2 which is bounded by latitudes 47°00' and 49° 00' and longitudes 95°30' and 97°15'. They lie within Townships 141-164 N. and Ranges 39-51 W., in all of Kittson, Marshall, Norman, Pennington, and Red Lake Counties and parts of Clay, Polk and Roseau Counties. Some were drilled in adjacent parts of North Dakota.

The drill logs are listed in order of Township-Range-Section and also are referenced by both the Minnesota Unique Number (**MN UNIQUE NO.**) and by the company or agency **HOLE NAME**. The method of abbreviating the hole location is the same as that described in the preceding section of this report. The **MN UNIQUE NO.** is either a unique 6-digit number assigned by MGS or the Minnesota Department of Health or a 5-digit unique number from abandonment reports of the Health Department. These logs are part of the Minnesota Geological Survey County Well Index (Wahl and Tipping, 1991), the state's major computerized data base of subsurface geological information.

Listed beneath **MN UNIQUE NO.** are the references for the sources of the data presented here, including the name of the exploration company, government agency, or individual for whom the hole was drilled; the date that drilling occurred; the attitude of the drill hole (azimuth/angle of plunge). The line beneath that shows the storage location of core (MGS or DNR), the core footage and the type of analytical work done by MGS: TS=thin section, WR=whole rock geochemistry, ASSAY=analytical package of 15 or more minor elements, dominantly metals. Analyses by R. Clark in 1990 are in unpublished files of the U.S. Geological Survey CUSMAP Program.

The lithologic logs are generalized from the original company, agency, or drillers log, and from subsequent relogging of most cores by the authors. The footnote symbols (1,2,3) as in LITHOLOGIC LOG<sup>1</sup> indicate the bases for lithologic descriptions given here, and should direct the reader to the appropriate repository of additional information on specific drill holes. The footnote symbols indicate the following:

1. Core and log are on file at DNR. Core was relogged by the authors and the lithologic log given here is simplified from that relogging. The log may therefore differ from that on file with DNR.
2. Core and/or cuttings are on file at DNR but were not relogged by MGS. The lithologic description is simplified from logs on file at DNR that were made by the company or agency for whom the hole was drilled.
3. Core and cuttings (if they exist) and descriptive log are on file at MGS. The lithologic log shown here is simplified from that on file.

Because many of the lithologic descriptions of holes relogged by us differ from the original logs, those original data sources should be consulted if more detail is required. In addition, more detailed information may exist in the files that are indicated by the footnote symbol. The types of additional data from some holes include downhole geophysical logs, geochemical analyses acquired by the original hole owner or by other firms and agencies, and more detailed descriptions of the Quaternary deposits available from the DNR from some Exmin Corporation drill holes, such as that in 141-48-2 (hole number 21735), and downhole geophysical data acquired by the U.S. Geological Survey are available at MGS, such as hole number 219963 in 156-46-2.

The Roman numerals after PRECAMBRIAN BEDROCK DATA refer to the lithotectonic blocks I-VI that are shown in Figure 2.

MAGNETIC SUSCEPTIBILITY measurements were routinely made of all cores relogged by MGS and are recorded in  $10^{-3}$  cgs units (centimeter-gram-seconds). DENSITY (specific gravity) measurements were taken by MGS for some samples and are recorded in grams per cubic centimeter.

Abbreviations in the descriptions:

CA=core axis

nd=no data

f.g.=fine grained

m.g.=medium grained

c.g.=coarse grained

v.c.g.=very coarse grained

bif=banded iron-formation

mv=metavolcanic rocks

bio=biotite

clor=chlorite

cpx=clinopyroxene

cpy=chalcopyrite

ep=epidote

feld=feldspar

hb=hornblende

opx=orthopyroxene

plag=plagioclase

po=pyrrhotite

px=pyroxene

py=pyrite

qtz=quartz

serp=serpentine

## RECORDS OF ARCHIVED DRILL HOLES

**MN UNIQUE NO. 21735    141-48-2 DDB, Clay Co. HOLE NAME 239 108/R1**

Exmin, 10/86    vertical    Rotasonic

Relogged, MGS sample @ 208'

LITHOLOGIC LOG<sup>1</sup>

0-197'    Drift

97-316'    Olivine-rich gabbro and peridotite; f.g., locally highly fractured and serpentinized

PRECAMBRIAN BEDROCK DATA VI

Structure

No penetrative linear or planar fabric. Two vein sets: earlier anastomosing serp-talc-chlorite veins dip 65° and display steeply plunging slickenfibers; later white asbestiform and serpentine veins dip 5-25° in opposing direction.

Mineralization, Alteration, Metamorphism

Serpentinized, local control by multiple thin veinlets. Trace % pyrite along serp-talc-chlorite veins.

Magnetic Susceptibility

Average 2.4, range 0.25-8.0. No obvious relationship of susceptibility to macroscopic features.

Density

2.55 @ 208'

**MN UNIQUE NO. 232327    142-44-29 ADBCBC, Clay Co. HOLE NAME SL-1**

Exxon, 6/81    143° / -50°

Relogged core 427-1003' at DNR

LITHOLOGIC LOG<sup>1</sup>

0-410    Drift

410-427'    Rotary in bedrock

427-647'    Metabasalt to meta-andesite flow; minor amygdaloidal zones, cut by fine-grained, hornblende-phyric dikes 483-485', 554-560', and 623-626"

647-689'    Meta-andesite(?); more chaotic, banded and veined downward. Local pillow breccia, all bleached

689-692'    Tuffaceous, graphitic argillite

692-790'    Intermediate flows and tuffs(?); massive, v.f.g., dk gray

790-819'    Mafic tuff, tuff-breccia, and banded magnetite-chert iron-formation

819-1003'    Intermediate tuff, flows and interbedded siliceous and graphitic argillite, hb porphyry intrusion @841-861'

PRECAMBRIAN BEDROCK DATA VI

Structure

Foliation defined by bedding contacts and subparallel fabric dips 45-50° to CA, inferred to be 80° N. Stratigraphic younging from grading and contacts at 890-910' to the north.

Mineralization, Alteration, Metamorphism

Both disseminated and local veins of py <2%. Metamorphism to low-medial greenschist facies (no TS)

Magnetic Susceptibility

427-480'(mv)=0.03-0.05	623-684'=0.03
480-554'(mv)=0.1.-0.24	684-689'=0.07-0.1
554-560'(mv)=0.10	689-790'=0.05
560-609'=0.03	790-800'(BIF)=1.7-12.0
609-623'(mv+dike)=0.48-1.1	800-1003'=0.00-0.01

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MN UNIQUE NO. 21709 143-44-18 ABACDB, Norman Co. HOLE NAME 239-60/2 P1  
Exmin, 10/86 vertical Rotasonic  
Company log at DNR, cuttings only  
LITHOLOGIC LOG <sup>2</sup>

- 0-299' Drift (excellent detailed log of drift; some indication of weathering residuum in till, but no apparent thick saprolitic zone)  
299-309' Gabbro, diorite, or coarse-grained meta-andesite to metabasalt; green

NO OTHER DATA AVAILABLE VI

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MN UNIQUE NO. unknown 143-44-34 ACBDAC, Norman Co. HOLE NAME HL-1  
Exxon, 11/81 320° / -55°  
Relogged core 403-1003' at DNR  
LITHOLOGIC LOG <sup>1</sup>

- 0-350' Drift  
350-403' Weathering residuum, no recovery  
403-458' Saprolitic metavolcanic rock of intermediate composition, relict trachytic texture  
458-580' Meta-andesite; f.g., massive, gray, some relict flow banding, locally saprolitic  
580-820' Meta-andesite; uniformly f.g.  
820-831' Flowtop breccia composed of angular blocks of aphanitic volcanic rocks as above in graphitic matrix, down-hole decrease in % and size of clasts, and increase in degree of rounding  
831-938 Graphitic argillite and interbedded felsic tuff; with zones of semi-massive pyrite; local pyrite balls  
938-1003' Meta-andesite; 944-963 pillowed with graphitic argillite interpillow hash

PRECAMBRIAN BEDROCK DATA VI

Structure

Bedding and subparallel tectonic fabric including localized shear dips 25-50° to CA, inferred to be dipping 85° N to vertical. Younging via grading in sedimentary breccia and contacts in lower part of core are down-hole (to the N). Most brecciation appears to be syn-depositional. Argillite contains strong cleavage, but no folds are evident.

Mineralization, Alteration, Metamorphism

Disseminated and local semi-massive sulfide (py and minor cpy) having indications of syn-depositional origin. Waxy gray-brown color and strong fabric in the interval 645-655' may be shear and carbonate-alteration. Metamorphism=greenschist.

Magnetic Susceptibility

- 403-458'=0.00  
458-1003'=0.00-0.04, avg=0.01

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MN UNIQUE NO. 21254 143-45-5 BBADD, Norman Co. HOLE NAME W-1  
Exxon, 8/82 113° / -55 to 46°  
Relogged core 438-1724' at DNR MGS TS @ 638'  
LITHOLOGIC LOG <sup>1</sup>

- 0-418' Drift  
418-438' Saprolite (no core)  
438-1668' Interbedded tuffaceous graywacke and sandstone, f.g. tuff, argillite, and conglomerate. Moderately weathered in zones to 775'. Conglomerate composed of white to light green dacitic volcanic clasts in varied matrix, mostly matrix-supported. Well developed graded bedding and nearly pristine depositional features, even at the contacts between units of contrasting competencies. Much appears to be alluvial-fluvial in origin. The

- dominant clast type is dacite that consists of m.g. feldspar and hb in aphanitic, siliceous groundmass. Other clasts are porphyritic dacite, uniformly fine-grained felsite, graphitic argillite, and rounded mafic clasts with aphanitic to diabasic texture.
- 1668-1710' Metabasalt: dark green, aphanitic to med. grained, contains small chlorite amygdules. Coarsens down-hole to m.g. trachytic basalt, then fines again, but lacks amygdules to 1710'.
- 1710-1724' Metabasalt flow unit identical with that above; capped by 10' thick flowtop breccia.

**PRECAMBRIAN BEDROCK DATA VI**

Structure

Well-developed and consistently dipping bedding at 30-40° to CA, inferred to dip vertically to 80° S. Unequivocal younging up-core to north. Cleavage is not apparent, though conglomeratic matrices may obscure tectonic fabric. No obvious shear features.

Mineralization, Alteration, Metamorphism

Trace % of py, cpy and po. Metamorphism=low greenschist, some biotite is present locally. Local epidote and chlorite clots and amygdule fillings occur.

Magnetic Susceptibility

uniform 0.00-0.03

Density

2.7 @ 638'

**MN UNIQUE NO. 23597 143-45-14 BDBCCC, Norman Co. HOLE NAME BCH-91-1**

Noranda, 2/91 360° / -55°

Relogged core 358-818' at DNR

**LITHOLOGIC LOG<sup>1</sup>**

- 0-338' Drift
- 338-358' Weathering residuum, green (no core)
- 58-400' Volcanic rocks; light green, weathered
- 400-580' Porphyritic, dacitic flow (?); green-gray, weathered in zones. Phenocrysts of feldspar >> quartz. Local brecciated zones containing graphitic matrix.
- 580-706' Dacitic tuff, tuff-breccia and graphitic argillite, moderately to intensely weathered. Local tuff-breccia contains dacite, graphitic argillite and pyrite clasts. Unit grades down-core to graphitic argillite.
- 706-790' Dacitic tuff; fine-grained, graphitic interlayers decrease in abundance down core. Graded beds.
- 790-818' Dacitic crystal tuff; visible feldspar and quartz grains, laminae of tourmaline and pyrite.

**PRECAMBRIAN BEDROCK DATA VI**

Structure

Moderately developed cleavage parallel to bedding dips ~30° to CA, vertical to 85°N. Stratigraphic younging based on contacts and grading in grainy tuff is down-hole to the N.

Mineralization, Alteration, Metamorphism

Greenschist grade. Generally sulfide-poor to 682', pyrite abundant below 682' in graphitic strata and is syn-depositional (evidenced by py clasts). Cubes of pyrite having asymmetric pressure shadows occur in tuff 790-818' associated with tourmaline laminae.

Magnetic Susceptibility

0.00-0.03

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MN UNIQUE NO. unknown 143-45-20 ABCCCB, Norman Co. HOLE NAME RK-1  
Exxon, 3/79 163°/-56°

Relogged core 260-863' at DNR

LITHOLOGIC LOG<sup>1</sup>

- 0-251' Drift  
251-260' Weathering residuum, no core  
260-377' Saprolite; locally well preserved primary textures in clayey saprolite derived from metabasalt  
(260-364') and thinly banded, f.g. wacke and argillite (364-377').  
77-531' Interbedded, f.g. graywacke and graphitic argillite.  
531-863' Meta-andesite(?); gray, pristine-textured amygdaloidal flows (at least 3 units). Upper 15' is dk-green chlorite-py unit inferred to be tuffaceous cap on flow. Locally flow banded below 546'.

PRECAMBRIAN BEDROCK DATA VI

Structure

Bedding is well-preserved and dips 55-65° to CA, inferred to be about 70° N. Grading and contacts indicate N-younging. Weak and localized cleavage dips 30-35° to CA, inferred to be vertical to 85° S. No obvious folds exist, and amygdules are relatively spherical, implying minor tectonism.

Mineralization, Alteration, Metamorphism

Trace % py. Metamorphism to greenschist facies (no TS)

Magnetic Susceptibility

0.00-0.02

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MN UNIQUE NO. 23599 143-45-29 ACACDD, Norman Co. HOLE NAME BE-91-1  
Noranda, 2/91 342° / -55°

Relogged core 200-800', MGS dike sample @ 677'

LITHOLOGIC LOG<sup>1</sup>

- 0-160' "Overburden"  
160-200' Weathering residuum; green  
200-800' Mafic-intermediate metavolcanic rocks. Composed of several massive to pillowed flows having autobrecciated and amygdaloidal flowtops and separated by thin graphitic interflow strata. Diabasic dikes inferred to be Proterozoic occur 646-652' and 653-688' cut the flow fabric and have aphanitic chill contacts.

PRECAMBRIAN BEDROCK DATA VI

Structure

Bedding defined by flow bands and interflow sedimentary strata dips 30-40° to CA, i.e., about vertical. Stratigraphic younging vaguely to the north (down-core). Irregular and weak penetrative fabric, no obvious flattening of amygdules or pillows. Well preserved autobrecciation textures.

Mineralization, Alteration, Metamorphism

Metamorphic grade ~ chlorite zone of greenschist facies. Rare disseminated pyrite. Local veins contain py, cpy and quartz and pre-date weak cleavage. Local quartz-epidote alteration occurs, particularly in flow 774-800'. Minor clots of py in chill of diabase dike.

Magnetic Susceptibility

200-300'=0.02-0.03

300-350'=0.07-0.17 (med crystalline flow)

350-800'=0.00-0.03 except 646-688'=0.03-0.32, avg 0.08 in Proterozoic-like diabase dike

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MN UNIQUE NO. 21257 143-46-12 DDABCD, Norman Co. HOLE NAME W-1

Exxon, 11/81 293° / -55°

Relogged core 225-1213' at DNR

LITHOLOGIC LOG<sup>1</sup>

- 0-200' Drift
- 200-225' Weathering residuum
- 225-1213' Interbedded andesitic tuff, tuffaceous and more argillaceous graywacke, and thin beds of laminated jasperoid chert. Strongly to moderately weathered to 290'. Much of core is remarkably uniform, f.-v.f.g. argillite that varies from green to dk gray.

PRECAMBRIAN BEDROCK DATA VI

Structure

Bedding locally well-preserved and dips variably from 20-50° (inferred to be 80° N). Local contortions of bedding may in part be soft sediment: for example, broken jello-like features. Grading is consistent throughout and indicates younging down-hole to the north. Cleavage is not distinct. Thin, locally clayey fault gouge occurs (287-292'), and fractured rubbly zones exist.

Mineralization, Alteration, Metamorphism

Pyrite locally disseminated and some jasperoid units contain clots of py. Carbonate veining common. Greenschist facies metamorphism.

Magnetic Susceptibility

225-350' (graywacke)=0.01-0.03

350-1213' (wacke and jasperoid rock)=typically f.g., gray units contain euhedra of magnetite and have greater susceptibility (0.60-4.1) than greenish-gray units (0.03-0.75) of the same approximate grain size.

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MN UNIQUE NO. 23600 143-46-23 ACBDDC, Norman Co. HOLE NAME BW-91-1

Noranda, 2/91 360° / -55°

Relogged core 281-798' at DNR

LITHOLOGIC LOG<sup>1</sup>

- 0-260' Drift
- 260-281' Weathering residuum, green—no core
- 281-369' Tuffaceous metasedimentary rocks. Intensely weathered to approximately 350'. Plagioclase and lithic fragments in clayey green matrix. Dacitic protolith.
- 369-501' Interbedded multilithic conglomerate and c.g.f.g. feldspathic sandstone. Clasts are rounded and dominantly of dacitic feldspar porphyry. Conglomerate grades down-core to sandstone.
- 501-602' Siltstone and shale
- 602-798' Interbedded argillite and feldspathic sandstone. Well-graded sequences, local ball-and-pillow and flame structures.

PRECAMBRIAN BEDROCK DATA VI

Structure

Bedding dips 45-55° to CA, i.e. 70°, not obviously cleaved. No evidence for major folds and bed contacts are pristine. Minor contorted bedding in argillaceous strata can be attributed to soft sediment slump. Overall sequence becomes finer grained and more argillaceous down-core, yet grading and bed contacts show stratigraphic younging up-core to the south (in contrast to all other cores in this area!)

Mineralization, Alteration, Metamorphism

Weathering is intense to 350', feldspars altered to clays variably to 450'. Rare pyrite nodules and finer grained disseminated pyrite in shale at ~500-600'. No other alteration or sulfides.

Magnetic Susceptibility

0.00-0.01



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MN UNIQUE NO. 21259 144-44-9 ADACCC, Norman Co. HOLE NAME E-1  
Exxon, 9/82 347° / -55°

Company log in DNR files

LITHOLOGIC LOG<sup>2</sup>

- 0-368' Drift
- 368-386' Weathered bedrock (no core)
- 86-864' Dacitic crystal-lithic tuff, tuff-breccia and volcanic conglomerate containing thin interbeds of graphitic and pyritic argillite.

PRECAMBRIAN BEDROCK DATA VI

Structure

Bedding and weak bed-parallel cleavage dips 20-30° to CA (inferred to be 80° N). Local indication of younging down-hole to the N.

Mineralization, Alteration, Metamorphism

Minor disseminated py, local silicification, chlorite alteration

Magnetic Susceptibility--nd.

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MN UNIQUE NO. 21264 144-44-9 AACCC, Norman Co. HOLE NAME E-2  
Exxon, 11/83 125° / -55°

Company log in DNR files

LITHOLOGIC LOG<sup>2</sup>

- 0-364' Drift
- 364-381' Weathered bedrock (no core)
- 381-503' Greenish gray saprolite of metabasaltic protolith
- 503-843' Crystal tuff with interbeds of graphitic argillite that locally contain large % of pyrite.

PRECAMBRIAN BEDROCK DATA VI

Structure

Bedding and bedding-parallel local cleavage dips 50-60° to CA (inferred to be 65-70° N). Minor contortions of bedding occur in graphitic beds.

Mineralization, Alteration, Metamorphism

Pyrite is abundant; in some zones is semi-massive, in most of core in trace amounts. Minor cpy and carbonate and silica alteration is reported.

Magnetic Susceptibility--nd.

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MN UNIQUE NO. 21253 144-46-1 CDCBAB, Norman Co. HOLE NAME K-1  
Exxon, 7/82 270° / -60°

Relogged core 435-1004' at DNR,

LITHOLOGIC LOG<sup>1</sup>

- 0-402' Drift
- 402-435' Weathering residuum (no core)
- 435-1004' Biotite granodiorite porphyry containing mafic xenoliths or phases (?). Varies from equigranular with subhedral plag, anhedral bio, possible hb in siliceous-looking mesostasis; to coarsely porphyritic with 2-5 mm plag and smaller bio in same mesostasis; to c.g. and containing 3-6 mm feld and interstitial bio, chlor, ep, and rare qtz grains. Mafic zones 2-20' thick consist largely of bio and/or chlorite together with feldspar and qtz, and have contacts that vary from gradational to abrupt

PRECAMBRIAN BEDROCK DATA VI

Structure

Moderately well developed banding that appears mostly igneous in origin and dips 35-40° to CA (inferred vertical to 85° E).

Mineralization, Alteration, Metamorphism

Tr % py, local epidote alteration, local calcite veins associated with py mineralization in wall rocks.

Magnetic Susceptibility

0.00-0.02

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MN UNIQUE NO. 247555 144-47-10 DDD, Norman Co. HOLE NAME 247555

Frederickson Well Co., 4/65 vertical

Drillers log

LITHOLOGIC LOG<sup>3</sup>

0-241' Drift

241-243' Decomposed "granite"; green

NO OTHER DATA VI

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MN UNIQUE NO. 247554 144-48-22 CBC Norman Co. HOLE NAME 247554

Frederickson Well Co. vertical

Drillers log

LITHOLOGIC LOG<sup>3</sup>

0-344' Drift; 272-344 described as blue clay, may be weathering residuum?

344-347' "Decomposed granite"

NO OTHER DATA VI

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MN UNIQUE NO. unknown 145-43-7 CB, Norman Co. HOLE NAME GD-1

Exxon 11/8 0° / -50°

Relogged core 495-1165' at DNR

LITHOLOGIC LOG<sup>1</sup>

0-495' Drift

495-1165' Interbedded graphitic argillite, f.g. graywacke and tuffaceous graywacke. Variably weathered. Some graywacke units contain visible graphitic argillite clasts and feldspar as grains: qtz grains are relatively rare. Cut by thin (7-15') dacitic to andesitic dikes.

PRECAMBRIAN BEDROCK DATA VI

Structure

Well preserved bedding, grading, and contacts; remarkable considering the large % of graphitic material in the rock. Beds dip 20-30° to CA (75° N), and grading indicates younging to the north. Minor syn-depositional breccias occur locally.

Mineralization, Alteration, Metamorphism

Trace to local zones of as much as 7% pyrite and local chlorite alteration. Deflected argillaceous laminae around pyrite balls imply that pyrite predates deformation.

Magnetic Susceptibility

0.00 throughout

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MN UNIQUE NO. 23656 145-43-10 CABCDC, Norman Co. HOLE NAME NOR76-91-1

Noranda, 11/91 325° / -67°

Relogged core 443-896' at DNR MGS sample @ 474', ASSAY (see Appendix B-1)

LITHOLOGIC LOG<sup>1</sup>

- 0-390' Drift
- 390-443' Weathered greenstone
- 443-896' Dacitic to latitic conglomerate and feldspathic sandstone. Clasts are coarse to f.g. dacite composed of blocky micropertthite phenocrysts up to 1.5 cm, white plagioclase laths as large as 1 cm, and finer subhedral hornblende and biotite in dk-gray siliceous groundmass. Texture is coarser than volcanic rock; infer hypabyssal plutonic source. Clasts are rounded to subrounded and locally as large as 25 cm.

PRECAMBRIAN BEDROCK DATA VI

Structure

Very weak penetrative fabric, though bedding and grading are well displayed. Bedding dips 10-15° to CA, i.e., 75-80° N. Grading occurs on large scale affecting units as thick as 50 feet. Younging consistently down-core to the north.

Mineralization, Alteration, Metamorphism

Moderately weathered to 472'. Pyrite is disseminated in conglomerate matrix and as much as 2 % in some clasts. Metamorphism inferred to be biotite zone of greenschist facies.

Magnetic Susceptibility

0.01-1.5; average ~ 0.51. Larger porphyry clasts 0.42-1.5; moderate susceptibility is anomalous for dacite

Density

2.76 @ 473' in latite porphyry

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MN UNIQUE NO. 23651 145-44-13 ABCAAC, Norman Co. HOLE NAME SP 91-1

Noranda, 2/91 325° / -55°

Relogged core 452-672' at DNR

LITHOLOGIC LOG<sup>1</sup>

- 0-452' "Overburden"
- 452-672' Metagraywacke and slate. Thinly interbedded, slate-wacke.

PRECAMBRIAN BEDROCK DATA VI

Structure

Well preserved, relatively untectonized bedding contacts, pristine load structures, and thin bedding and laminae. Bedding not significantly folded, but dips vary from 0° to 10° to CA, i.e. ~60° north. Although younging direction is internally consistent, the shallow dip angle relative to CA produces younging that varies from up-core to down-core.

Mineralization, Alteration, Metamorphism

Low metamorphic grade (chlorite zone of greenschist). Trace % of disseminated pyrite. Pyrite and calcite veins are late, brittle and dip 65° to CA.

Magnetic Susceptibility

452-530'=0.00-0.02

530-630'=0.05-0.25, average 0.09

630-672'=0.01-0.04

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MN UNIQUE NO. 236563 145-44-15 DBBBBD, Norman Co. HOLE NAME ST-1  
Exxon, 9/79 0° / -61 to 52°

Company log

LITHOLOGIC LOG<sup>2</sup>

- 0-405' Drift  
405-446' Weathering residuum and broken rock (no core)  
446-495' Saprolitic meta-argillite, siltstone and chert  
495-1005' Interbedded f.g. felsic tuff, tuffaceous wacke, and graphitic and more siliceous argillite. Local sedimentary breccias have sulfide-rich matrices. Graphitic po-py beds read from log like sulfide-facies iron-formation. Cut by several intermediate dikes intruded locally into breccia zones, and dikes are not brecciated, implying brecciation pre-dates intrusion.

PRECAMBRIAN BEDROCK DATA VI

Structure

Bedding dips 20-25° to CA (inferred to be 70-80°N), but in one zone at 500-540' it decreases to 0-5° to CA. Contains several zones of disrupted bedding: younging is questionable, but most is down-hole to the north.

Mineralization, Alteration, Metamorphism

Po>py>>cpy. Po locally as much as 60% in argillite bands associated with graphite

Magnetic Susceptibility.- nd

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MN UNIQUE NO. 236564 145-44-15 ACDACB, Norman Co. HOLE NAME ST-2  
Exxon, 10/79 0° / -56-42°

Company log at DNR

LITHOLOGIC LOG<sup>2</sup>

- 0-425' Drift  
425-530' Strongly weathered, dk green, basalt to intermediate to mafic tuff  
530-1515' Tuff, lapilli tuff and tuff breccia of intermediate to felsic composition; greenish gray. Most is moderately massive and fine grained. Cut by several mafic dikes and thin feldspar porphyry dikes. Local breccia zones are sulfidic.

PRECAMBRIAN BEDROCK DATA VI

Structure

Bedding and contacts dip 20-40° to CA. Stratigraphic younging not determined. Mafic dikes dip 20° to CA, feld-porphyry dikes dip 60-90° to CA

Mineralization, Alteration, Metamorphism

Py and po locally abundant, as much as 15%. In one zone, py forms matrix to sedimentary breccia, implying syn-depositional origin for some.

Magnetic Susceptibility

Mafic dikes are variably magnetic according to company log, remainder is unknown.

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MN UNIQUE NO. 236565 - 145-44-15 ADDCDD, Norman Co. HOLE NAME ST-3  
Exxon, 11/800° / -55 to 60°

Relogged core 465-1295' at DNR MGS dike sample at 887' for polarity measurements and at 492' for geochemical analyses.

LITHOLOGIC LOG<sup>1</sup>

- 0-465' "Overburden" (no indication from log of weathering residuum)  
465-1295' Dacitic crystal tuff and tuffaceous graywacke interbedded locally with thin graphitic strata.

Cut by several dikes:

- 1.) 561-575' f.g. basaltic dike
- 2.) 600-887' m.-c.g. diabasic dike having 15' wide chill at both contacts that is identical to small dike above. Both dikes are moderately to strongly magnetic, particularly at chills, and both are inferred to be Proterozoic.
- 3.) 1038-1050' and 1230-1240' dacite porphyry dikes, sharp-walled contacts

#### PRECAMBRIAN BEDROCK DATA VI

##### Structure

Bedding dips 10-20° to CA; 75-80° N. Minor contortions of beds are inferred to be the result of soft sediment deformation as dacitic dikes cut small fold structures, yet lack any evidence of being folded and are nearly identical looking in composition to the sedimentary rocks they intrude. Younging can be determined at many places and is consistently down-hole (northward) even in and across thin breccia and fold zones. Soft-sediment deformation has produced asymmetrical folds and small faults, which have consistent N-side-up kinematic sense. Dike has all attributes of Proterozoic, including chilled margin and medium-grained diabasic-textured central portion containing saussuritized plagioclase and fresh pyroxene. Proterozoic dikes have sharp, irregular contacts at about 45° to CA, one contact similar in orientation to the host fabric, the other opposing it.

##### Mineralization, Alteration, Metamorphism

Trace to 5% py locally. Veining and alteration are conspicuously lacking.

##### Magnetic Susceptibility

Diabase dike=0.03-0.69, average 0.35

Sedimentary rocks= 0.00-0.03 except local zones of dark argillite in zone from 1020-1050' where values of 0.08-0.14 occur.

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#### MN UNIQUE NO 23655 145-44-18 BCDCBA, Norman Co. HOLE NAME NOR-58-91-1

Noranda, 11/91 348° / -60°

Relogged core 390-705' at DNR

##### LITHOLOGIC LOG<sup>1</sup>

0-370'	Drift
370-390'	Weathering residuum, green and clayey
390-450'	Metagabbro, dark green, f.-m.g., contains mafic minerals now mostly amphibole.
450-463'	Monzonite to monzodiorite, m.g., green and pink rock composed of oxidized red brown biotite and hornblende, and odd mottling of saussuritized plagioclase clots slightly larger than mafic minerals.
463-559'	Diabase dike; inferred to be Proterozoic: has chilled contacts
559-569'	Altered plutonic rock, most is aphanitic, red to green and contains 2-8 mm chloritic clots. Locally the unit has an equigranular-granitic texture (unit was inferred by company as metasedimentary).
569-631'	Metagabbro, similar to 390-450'. Contains aphanitic zones and is K-altered in irregular zones below 625'.
631-705'	Metagabbro to metaperidotite, dark green though variably altered to red color by brittle multiple veins that contain pink (K-spar) fill. May be altered ultramafic as it becomes black and talcose downward. No macroscopically visible olivine, but high magnetic susceptibility and serpentine imply peridotite may have been protolith.

#### PRECAMBRIAN BEDROCK DATA VI

##### Structure

Foliation defined by vague banding and by contacts dips 20-30°, 80° N to vertical. Tectonic fabric is weak to moderate.

Mineralization, Alteration, Metamorphism

Saprolitic in zones to 405'. Px retrograde metamorphosed to hb, actinolite, and chlorite. Pink to salmon-colored alteration zones occur irregularly and adjacent to veins, and are inferred to be feldspathic. Disseminated py is associated with the alteration.

Magnetic Susceptibility

390-450'=0.02-0.03, metagabbro  
450-463'=0.00, monzonite  
463-559'=0.32-2.0, average 1.1, greatest in central part of diabasic dike  
559-631'=0.02-0.17, average 0.04, metagabbro  
631-705'=0.45-12.0, average 7.4 in peridotite

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**MN UNIQUE NO. 236567 145-45-8 DACAAB, Norman Co. HOLE NAME GM-1**

Exxon, 3/79 180° / -55°

Relogged core 326-789' at DNR

**LITHOLOGIC LOG<sup>1</sup>**

0-300' Drift  
300-326' Weathered, chloritic-looking metabasalt  
326-440' Mafic flows and tuffaceous rocks  
440-523' Interbedded f.g. felsic tuff and lapilli tuff, cut by intermediate dike  
523-789' Interbedded graywacke, graphitic argillite, chloritic mafic tuff and lighter felsic tuff.  
Cut by andesitic (plag, hb, bio) dikes

**PRECAMBRIAN BEDROCK DATA VI**

Structure

Bedding and moderate to strong cleavage dips 30-40° to CA (vertical to 85° N). Cleavage locally is strong and flattening intense, locally askew bedding by 10° to an attitude of vertical to 85° S. Grading and contacts show younging up-core, to the north. Cleavage-bedding lineation plunges 25° to CA in the cleavage plane. Many qtz veins are boudinaged symmetrically in the cleavage plane.

Mineralization, Alteration, Metamorphism

Py as abundant as 5% locally, trace % cpy; both commonly associated with graphitic layers and appear primary and pre-cleavage. Trace % also of tourmaline and po. Graphitic zone 522-620' appears to be conductor. Upper greenschist facies metamorphism is indicated by bio, actinolite-hb(?), and garnet in mafic layers; grade looks higher than most holes to south.

Magnetic Susceptibility

0.00-0.05, averages about 0.01 .

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**MN UNIQUE NO. 236568 145-45-14 BDBADB, Norman Co. HOLE NAME FL-1**

Exxon, 1/80 330° / -56° at top to -35° at bottom

Relogged core 364-1233' at DNR

**LITHOLOGIC LOG<sup>1</sup>**

0-350' Drift  
350-364' Core of drift; brown-gray, clay-rich till, abrupt contact with saprolite at 364'  
364-511' Saprolite derived from mafic intrusion or flow. Banded chert-jasperoid iron-formation  
419-421'  
511-630' Metabasalt or mafic intrusion, moderately weathered; dk green, chloritic  
630-678' Amygdaloidal basalt flow  
678-1233' Tuffaceous graywacke, granular intermediate (?) tuff, and graphitic argillite. Zone from  
808-909' lacks clastic texture, is pervasively silicified (or silicic), likely is dacitic to  
andesitic flow.

## PRECAMBRIAN BEDROCK DATA VI

### Structure

Locally cleavage is steeper (smaller angle to CA) than bedding. Bedding averages 75° S to vertical, and moderate to strong cleavage dips vertical to 60° S. Local zones contain multiple shear discontinuities, especially 909-934' and at 983'. Stratigraphic younging established by grading in tuff-wacke/argillite units is down-core, toward the north. Shearing consistently indicates south-side up sense.

### Mineralization, Alteration, Metamorphism

Tr-2% py. Metamorphism to upper greenschist facies as local garnet porphyroblasts exist.

### Magnetic Susceptibility

350-364'=0.04-0.09 in drift core

364-419'=0.00

419-422'=0.23-0.54 in thinly banded quartz-magnetite iron-formation

422-1233'=0.01-0.03

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**MN UNIQUE NO. 23652    145-45-20 ACCBCD, Norman Co. HOLE NAME JO-91-1**

Noranda, 3/91    335°/-55°

Relogged core 362-914' at DNR

### LITHOLOGIC LOG<sup>1</sup>

- 0-320'    Drift
- 320-362'    Weathering residuum; dk green
- 362-914'    Metasedimentary rocks intruded by intermediate and mafic intrusions. Metasedimentary strata are biotite plagioclase schists that retain bedding even though metamorphically recrystallized. Protoliths include dacitic wacke, siliceous argillite and graphitic argillite. Dacite porphyry intrusions occur at 375-381', 384-386', 412-424' and 574-584'. Locally porphyritic, hb-px-bio diorite to monzodiorite occur at 832-838' and 872-881'

## PRECAMBRIAN BEDROCK DATA VI

### Structure

Foliation and bedding dip 45-50° to CA, ~75° south. Grading is poorly developed in the mostly argillaceous strata and is poorly preserved due to recrystallization, but indicates younging is likely down-core, i.e., to the north. Most dacite porphyry intrusions are semi-concordant, though they contain the regional penetrative fabric. Monzodiorite sills lack tectonic fabric and have sharp walls.

### Mineralization, Alteration, Metamorphism

Metamorphism indicated by recrystallization, locally producing large porphyroblasts of biotite, indicates upper greenschist facies and is inferred to be a contact phenomena related to granitoid body lying immediately to the north. Pyrite and chalcopyrite occur as pre-cleavage folia and in later vein-related features as great as 5%.

### Magnetic Susceptibility

sedimentary rocks and dacitic dikes=0.00-0.02

monzodioritic dikes vary from 0.13 to 0.54.

argillite at 870-872' adjacent to monzodiorite is 0.50

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**MN UNIQUE NO. 224270    145-47-15 CBBDBA, Norman Co. HOLE NAME RRVD-26**

Moore, W.L., 1979    vertical

Relogged core at MGS    MGS TS @ 392 and 394'

### LITHOLOGIC LOG<sup>3</sup>

- 0-309'    Drift
- 309-373'    Weathering residuum, gray-green clay
- 373-394'    Biotite-bearing granodiorite to quartz monzonite; m.g., massive, hypidiomorphic, equigranular. Weathered to 391'. Biotite and other Fe-Mg minerals altered to ep, chlor,

sphene, and sericite.

PRECAMBRIAN BEDROCK DATA VI

Structure

Massive

Mineralization, Alteration, Metamorphism

Fe-Mg minerals altered to chlorite and others. Feldspar is saussuritized and locally weathered to kaolinite.

Magnetic Susceptibility

0.00 throughout

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MN UNIQUE NO. 23813 146-44-32 ABBDCC, Norman Co. HOLE NAME SH-91-1

Cominco American, 3/91 180° / -45°

Relogged core 684-1197', 12/92

LITHOLOGIC LOG<sup>1</sup>

- 0-684' Drift? compared to other holes in region (e.g. GA-1) this is deep, possibly incorporates weathering residuum in basal 100' or more
- 684-833' Dacite porphyry, likely a hypabyssal intrusion as no obvious flow features exist. Contains plagioclase and hornblende phenocrysts in white to light green groundmass. Basal part is zone of multiple foliation parallel shears.
- 833-910' Dacite porphyry sill, similar to that above, with the exception of having larger plag. phenocrysts and grayer, more siliceous looking groundmass.
- 910-923' Andesitic sill, equigranular, f-mg, foliated and contains xenoliths of dacitic porphyry like that above and below.
- 923-1054' Dacite porphyry, like 833-910'.
- 1054-1197' Interbedded graphitic argillite and fine grained wacke containing variable % of graphitic matrix. Thinly bedded.

PRECAMBRIAN BEDROCK DATA VI

Structure

Moderate penetrative fabric and several shear discontinuities parallel bedding and dip 35-20° to CA, i.e., 65-80° south. Stratigraphic younging is poorly indicated near base of core as up-core to the north.

Mineralization, Alteration, Metamorphism

Rock is moderately weathered to 735'. Shear zones contain sericite, calcite, chlorite, and pyrite. Disseminated py cubes occur in amounts less than 1% 923-1054'.

Magnetic Susceptibility

0.00-0.01 throughout

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MN UNIQUE NO. 236566 146-44-36 DDBAAB, Norman Co. HOLE NAME GA-1

Exxon, 12/79 348° / -56°

Relogged core 500-1113' at DNR MGS sample 997'

LITHOLOGIC LOG<sup>1</sup>

- 0-475' Drift (depth approximated)
- 475-500' No core
- 500-542' Altered ultramafic rock; talc-serpentine-sericite-chlorite schist, mottled texture implies intrusive origin
- 542-624' Altered syenite, sheared and strongly brecciated
- 624-806' Altered ultramafic rock, talc-serp-ser-chlor-calc silicate schist
- 806-835' Altered ultramafic rock, local granular texture akin to syenite above, implies the two are co-magmatic
- 835-970' Talc schist inferred to be altered ultramafic rock.



- 970-1050' Calc-silicate rock containing bands of graphitic argillite
- 1050-1113' Metabasalt containing interflow autobreccias with graphitic matrix
- 1113-1143' Strongly sheared meta-andesite flow or flowtop breccia, sulfide-rich

**PRECAMBRIAN BEDROCK DATA VI**

Structure

Foliation dips 35-40° to CA (vertical to 85° S). Shearing locally intense.

Mineralization, Alteration, Metamorphism

Ultramafic intrusive or extrusive rocks altered to talc, serpentine, chlorite and sericite. Pyrite occurs in trace % to 1%. Analyses for Cu, Sn, Cr, Ag, and Au: Au up to 0.21 ppm in metasedimentary rocks at 973'

Magnetic Susceptibility

Extreme variability:

- 500-530'=0.50-2.5, ave. 0.96    820-857'=0.50-1.9
- 530-785'=0.02-0.07, ave 0.04    857-970'=0.02-0.07
- 785-820'=0.42-0.50    970-1143=0.01-0.03

Density

2.98 @ 997' in calc-silicate rock

**MN UNIQUE NO. 22001    146-44-36 DCBCBB, Norman Co. HOLE NAME GA-2**

Newmont, 12/88    350° / -60°

Relogged core 499-982' at DNR

**LITHOLOGIC LOG<sup>1</sup>**

- 0-480' "Overburden"
- 480-499' Bedrock (no core)
- 499-530' Meta-andesite to dacite flows, amygdaloidal
- 530-539' Dacitic porphyry dike; salmon-colored, aphanitic groundmass, feld and hb phenocrysts
- 539-691' Meta-andesite flow (identical to 499-530). Porphyritic flows with irregular zones of plag phenocrysts and local qtz-and calcite-filled amygdules. Sharp-walled dike 625-628' of hb-bio-plag diorite, equigranular and crosses weak flow banding in flow.
- 691-732' Hornblende diorite dike, chilled upper and lower contacts. Local planar and linear fabric, together with zones of multiple quartz veins, imply it is not Proterozoic.
- 732-982' Meta-andesite flows; plag-phyric, local amygdaloidal flowtops and interflow autobreccias.

**PRECAMBRIAN BEDROCK DATA VI**

Structure

Foliation 30° to CA, infer vertical to 85° N. No obvious flattening of amygdules. Stratigraphic younging based on flow contacts is down-core, i.e., to the north. Dike at 691' has sharp contacts dipping 70° to CA.

Mineralization, Alteration, Metamorphism

Small % py, po, cpy, local silica and ankerite alteration. Chlorite, epidote, and quartz fill fractures. Au=15-17 ppb in zones 530-540' (dacite), and 970-980' (meta-andesite).

Magnetic Susceptibility

0.00-0.03, average=0.01, except for diorite dike at 691-732'=0.02-0.10, average=0.04

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MN UNIQUE NO. **unknown 148-45-19 DB, Polk Co.** HOLE NAME **P4-B**  
Ridge, 10/74 155° / -55°

Reloged core 298-592' at DNR

LITHOLOGIC LOG<sup>1</sup>

- 0-298' Drift  
298-554' Metabasalt to andesite; green, f.g., lacks flow bands. Amygdaloidal zone 309-315' is capped (up-core) by slightly coarser volcanic rock.  
554-592' Oxide-rich mafic intrusion; green-black, m.g., massive, magnetic.

PRECAMBRIAN BEDROCK DATA VI

Structure

Weak fabric dips 20-30° to CA. Irregular contact at 554' dips 30-35° to CA. Younging may be up-hole to N judged from zone 309-315'.

Mineralization, Alteration, Metamorphism

Altered oxides abundant in intrusion, also local zones of 1-2% py and cpy. Cpy occurs mostly near calcite veins 563-565'. Analyses performed by exploration company (not reported here) show high vanadium.

Magnetic Susceptibility

298-546.2' = 0.00-0.07, avg. 0.04.

546-592' = 0.64-57.0; extreme variability, largest at semi-massive oxide zone containing magnetite and pyrite veins normal to CA.

Comments

Hole was drilled along narrow, ENE-trending magnetic anomaly.

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**MENTOR PROPANE STORAGE CAVERN 149-43-26 DABBAB, Polk Co.**

This mined storage facility, excavated in 1961-62 for the Solar Gas Company, is a rectangular cavern 400'X350' wide, and 25' high. Its floor is 530' below the land surface. Approximately 17,000 tons of rock were removed and about half of that material was taken from the site for use as rip-rap, aggregate and fill. The remaining pile contains blocks large enough to determine relationships between components of the rock. Holes L-2, L-3, and L-4, described below, were presumably drilled to determine engineering characteristics prior to cavern construction. The following description is based on samples from the waste pile.

The rock is mineralogically enigmatic due in part to intense alteration, and has been variously described as dolomitic marble, conglomerate, clinozoisite, and "Erskinite" (named by the workers after the nearby town of Erskine). It is generally a saussuritized and locally magmatically brecciated anorthosite and gabbroic anorthosite. The dominant phase is very coarse grained anorthosite containing sub- to euhedral, blocky to tabular and alteration-mottled relicts of plagioclase up to 12 cm, in a mesostasis of finer relict plagioclase and chlorite. An irregularly distributed phase of brecciated porphyritic gabbroic anorthosite contains white, relict plagioclase crystals as large as 5 cm in a dark- to light-green altered mesostasis. Breccia matrices are composed of altered, euhedral plagioclase and various altered mafic minerals and appear to have a magmatic origin. All gradations exist between these two rock types. Both contain planar bands of fine-grained feldspathic material that appear to be semi-fluid (magmatic?) shear zones, as they never cut large feldspar crystals. All rock types are cut by sharp-walled, pink leucotonalite dikes. Rock fabric typically is massive, except in dikes where margin-parallel banding occurs.

Mineralogically, the rock is composed of as much as 90% of clinozoisite (confirmed by X-ray diffraction). Locally fresh plagioclase is oligoclase (An 10-15). The Fe-Mg minerals, locally having pyroxene morphology, are mostly altered to chlorite, serpentine and talc. Because alteration minerals are so widely distributed and not obviously related to breccia zones or any tectonic fabric, alteration is assumed to be deuteric. Sulfide minerals (py>cpy) occur in late segregations in gabbroic anorthosite associated with an as yet unknown brown interstitial mineral. A few samples contain calcite-qtz and serpentine-chlorite veins;

both lack sulfide minerals.

**MENTOR MAFIC INTRUSIVE COMPLEX (informal new name)**

Hole NW-7 was drilled about 8 mi. west of the Mentor facility in an area of similar gravity and magnetic character. It intersected white, altered anorthosite identical with the main intrusive phase at Mentor. The magnetic and oxide-rich gabbro in P4-B (described above) is texturally and mineralogically similar to gabbroic phases in the L-2 and L-4 cores from Mentor, and presumably is related. Hole P4-B was drilled on a narrow magnetic high that irregularly encircles the ovoid gravity high and magnetic low associated with the anorthosite; this magnetic pattern implies that the gabbro is a magnetic border phase of a single intrusion or group of comagmatic intrusions here named the Mentor mafic intrusive complex. Based on geophysical data, the complex is an elongate body 6-8 mi. wide at its widest (N-S), and 25-30 mi. long (WSW-ESE). The narrow magnetic phase is most prominent on the north, east and west sides; the southern boundary is defined largely by gravity data.

It is interesting to note that cores STAR-3 (155-39-1), G-1 (157-39-3), and the SC-series (158-43) from the Wabigoon belt to the north locally contain mafic rocks that are texturally and mineralogically similar.

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**MN UNIQUE NO. D12785 149-43-26 DABBAB, Polk Co. HOLE NAME L-2**

Solar Gas, 1961 vertical

Relogged core 496-599 at DNR MGS sample @ 499'

**LITHOLOGIC LOG<sup>1</sup>**

0-496' Unknown  
496-599' Altered anorthosite, plutonic "breccia", and diabase. Anorthosite consists of mottled and altered white plagioclase blocks (relict single and aggregate crystals) in light green chloritic groundmass. Metadiabase is uniformly f.g., variably epidotized, and contains altered plag microlites.

**PRECAMBRIAN BEDROCK DATA VI**

Structure

Vague modal and textural banding dips 0 to 75°. No obvious penetrative tectonic fabric exists. Brecciation and much of the alteration appears to have been synchronous with cooling.

Mineralization, Alteration, Metamorphism

Alteration to epidote and chlorite is pervasive. "Triple points" created by junction of aggregates of large plag pseudomorphs are filled with unknown pink-brown mineral and as much as 3% cpy, py and Fe-oxides, all of which appear magmatic in origin.

Magnetic Susceptibility

0.00-0.05, largest in metadiabase 551-558'.

Density

2.9 @ 499'

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**MN UNIQUE NO. D12786 149-43-26 DABBAB, Polk Co. HOLE NAME L-3**

Solar Gas, 1961 vertical

Relogged core 503-593' at DNR

**LITHOLOGIC LOG<sup>1</sup>**

0-503' Unknown  
503-593' Anorthosite; altered, white to light green and coarsely mottled. Contains large, equant plag crystal aggregates up to 10 cm in a groundmass of 1-3 mm plag crystals, chlorite and epidote. Moderately weathered to 536'.

**PRECAMBRIAN BEDROCK DATA VI**

Structure

Vague alternations between slightly different mode or texture dip 60°.

Mineralization, Alteration, Metamorphism

Epidote, chlorite, sericite, no visible sulfides though some oxidized spots occur.

Magnetic Susceptibility

0.00-0.02

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**MN UNIQUE NO. 12787    149-43-26 DABBAB, Polk Co. HOLE NAME L-4**

Solar Gas, 1961    vertical

Relogged core 476-594' at DNR    MGS TS @ 535'

**LITHOLOGIC LOG<sup>1</sup>**

- 0-476'    Unknown
- 476-534'    White, coarsely mottled and altered anorthosite similar to L-3. Cut by c.g. gabbro 518-522' that is ophitic to subophitic containing oikocrysts of uralitized pyroxene. Similarities in composition, texture, and alteration, and the occurrence of identical gabbroic phases in anorthosite imply that the two are comagmatic.
- 534-553'    Pegmatitic anorthosite; large subhedral altered plag clots up to 8 cm surrounded by green amphibole after pyroxene(?).
- 553-594'    Mixed, coarsely mottled, vaguely brecciated, and pegmatitic anorthosite

**PRECAMBRIAN BEDROCK DATA VI**

Structure

Banding is indistinct, contacts dip 40-55°. No penetrative fabric. All textures appear primary, even breccia zones, as they contain the same mineral assemblage as non-brecciated rock.

Mineralization, Alteration, Metamorphism

Trace-1% py. Variably weathered in zones throughout.

Magnetic Susceptibility

476-518'= 0.00

518-522'= 0.05

22-594'= 0.03

Density

3.12 @ 535'

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**MN UNIQUE NO. 224271    150-44-10 CCDBD, Red Lake Co. HOLE NAME RRVD-28**

Moore, 1979    vertical

Relogged core at MGS    MGS TS @ 393' and 394', ASSAY @ 386'

**LITHOLOGIC LOG<sup>1</sup>**

- 0-378'    Drift
- 78-394'    Pyrite-sericite-ankerite(?) - quartz schist, cut by several pre-shear qtz-sericite-py veins. Eye-shaped to angular qtz grains up to 7 mm occur in micaceous folia. Protolith may be quartzose graywacke, although shear fabric precludes unequivocal interpretation. Generally too quartzose for granitoid protolith.

**PRECAMBRIAN BEDROCK DATA VI**

Structure

Foliation dips 80-85°.

Mineralization, Alteration, Metamorphism

1-8% py, <1% cpy. Assay shows 45 ppb Au (Appendix B).

Magnetic Susceptibility

0.00-0.02

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**MN UNIQUE NO. 224269 152-49-11 DCDAAD, Polk Co. HOLE NAME RRVD-27**

Moore, 1979 vertical

Relogged core 279-321' at MGS TS @ 301', 309', 313', and 320'

**LITHOLOGIC LOG<sup>1</sup>**

- 0-279' Drift
- 279-291' Ordovician, Winnipeg Fm., Icebox Mbr.; vari-colored shale
- 291-299' " " " Black Island Mbr.; sandstone, c.-v.c.g., well-sorted
- 299-321' Quartz-plag-bio-hb gneiss (qtz-dioritic composition), cut by c.g. pegmatite dikes

**PRECAMBRIAN BEDROCK DATA III**

Structure

Well foliated gneiss; modal banding and micaceous fabric dips 55-60°. Contacts with pegmatite are irregular, lack selvages, and pegmatite contains small xenoliths of foliated gneiss having erratic orientations indicating that gneissosity predates pegmatite emplacement.

Mineralization, Alteration, Metamorphism

Chlor after bio. As much as 1% magnetite euhedra occur in gneiss. Gneissic fabric inferred to be metamorphic.

Magnetic Susceptibility

- 296-313'=0.00-0.04 in gneiss and pegmatite
- 313-320'=0.04-0.26 in gneiss
- 320-321'=0.44 in gneiss

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**MN UNIQUE NO. 219996 154-48-1 BBBCCB, Marshall Co. HOLE NAME Warren #1**

MGS cutting #2485, no core, drilled 6/54 samples missing below 250'

USGS log

**LITHOLOGIC LOG<sup>3</sup>**

- 0-259' Drift?
- 259-279' Shale
- 279-280' Granite; qtz, bio and hb

**PRECAMBRIAN BEDROCK DATA III**

Structure--nd

Mineralization, Alteration, Metamorphism--nd

Magnetic Susceptibility--nd

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**MN UNIQUE NO. unknown 155-39-1 CDDAD, Marshall Co. HOLE NAME STAR-3**

Lehman (Occidental Minerals), 7/77 vertical

Relogged core 235-495' at DNR MGS TS @ 474'

**LITHOLOGIC LOG<sup>1</sup>**

- 0-235' Drift
- 235-495' Very coarse grained magmatic breccia of gabbroic composition. Thin section of oxide olivine gabbro contains c.g., cumulus olivine (talc and granular oxides), partly uraltized subophitic pyroxene, poikilitic oxides, and small amounts of hb, bio, and chlorite. Most breccia matrix is finer grained gabbroid.

**PRECAMBRIAN BEDROCK DATA IV**

Structure

Entire core lies within magmatic breccia zone: no penetrative fabric or obvious modal banding.

Mineralization, Alteration, Metamorphism

Mafic minerals are variably to strongly altered (talc, serpentine). Breccia matrix rarely consists of pyrite. Pyrite and cpy locally 5%. Rare oxide-rich zones occur.

Magnetic Susceptibility

Extremely variable 0.04-48.0, Avg=3.5, most fall in range of 0.85-13.0, local oxide zones as at 379'=22.0-48.0

Density

3.11 @ 474'

Comments

Hole was drilled on strong magnetic and gravity anomaly.

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**MN UNIQUE NO. unknown 155-39-4 BBBBD, Marshall Co. HOLE NAME STAR-2**

Lehman 7/77 vertical

Relogged core 250-357' at DNR MGS sample @ 267

**LITHOLOGIC LOG<sup>1</sup>**

- 0-250' "Overburden"
- 250-357' Hornblende leucodiorite (Grygla pluton); lineated, quartz-poor, plagioclase-rich. Consistent medium grain size. No evidence of tectonism or metamorphism, but differs from most of the quartz-poor intrusions common in the belt by being finer grained overall and plagioclase-rich.

**PRECAMBRIAN BEDROCK DATA IV**

Structure

Linear and planar fabric is vague; finer grained gray zones dip steeply, almost parallel to CA (i.e. vertical). Lination defined by hb and bio dips 70-75°.

Mineralization, Alteration, Metamorphism

Minor Qtz-carbonate veining, trace % py. No obvious metamorphism.

Magnetic Susceptibility

0.00-0.01 throughout

Density

3.0 @ 267'

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**MN UNIQUE NO. 244858 155-39-34 AAAAAC, Marshall Co. HOLE NAME MPL3-B2**

MGS test hole, 12/81 vertical

Relogged core 170-175' at DNR MGS TS @ 174.5' ASSAY by Clark, 1990 (MGS cuttings #1784)

**LITHOLOGIC LOG<sup>1,3</sup>**

- 0-167' Drift
- 167-170' Rock (no core)
- 170-172' Porphyritic granodiorite, banded via local, vaguely bounded segregations of mafic minerals
- 172-175' Hornblende tonalite. Thin section contains 72% plag + antiperthite, and 25% quartz. Small amounts of hornblende, apatite, epidote and monazite. Contact with unit above is intrusive, sharp, and lacks selvage. Both units appear compositionally similar, and may be approximately comagmatic.

**PRECAMBRIAN BEDROCK DATA IV**

Structure

The relationship between the trend of modal banding in tonalite which dips 45°, and the contact with monzogranite which dips more steeply is unclear, but monzogranite may crosscut banding in tonalite. Modal banding and lination of feldspars in porphyry appears magmatic.

Mineralization, Alteration, Metamorphism

Not obviously metamorphosed, most fabric and composition consistent with igneous origin.

Magnetic Susceptibility

0.02-0.54, most in the range of 0.11-0.37, slightly higher at contact zone

Density

2.65 @ 174'

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**MN UNIQUE NO. unknown 155-41-5 BAACAD, Marshall Co. HOLE NAME STAR-1**

Lehman, 7/77 vertical

Relogged core 413-615' at DNR

**LITHOLOGIC LOG<sup>1</sup>**

0-406' Drift

406-413' Rock (no core)

413-615' Bio-hb monzodiorite to syenite; some zones of mafic concentrations of bio, hb, sphene.

**PRECAMBRIAN BEDROCK DATA IV**

Structure

Weak linear and vague planar fabric that may be in part tectonic (local augen-like structures) dips consistently parallel to CA (i.e vertical).

Mineralization, Alteration, Metamorphism

No veining, no obvious metamorphic minerals, remarkably pristine mineralogy. Minor serpentine or talc along fractures.

Magnetic Susceptibility

0.04-0.20, avg=0.05

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**MN UNIQUE NO. 219930 155-44-2 DAAACD, Marshall Co. HOLE NAME J-6A**

USGS test hole, no core

**LITHOLOGIC LOG<sup>3</sup>**

0-399' Drift

399-407' Bedrock or boulder; red granite cuttings

**NO OTHER DATA III**

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**MN UNIQUE NO. 219921 155-45-2 CCCACC, Marshall Co. HOLE NAME H-4A**

USGS test hole, no core

USGS log, MGS cutting # 2383

**LITHOLOGIC LOG<sup>3</sup>**

0-433.5' Drift

433.5-435' Greenstone?

**NO OTHER DATA III**

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**MN UNIQUE NO. 21737 155-48-10 BCABDA, Marshall Co. HOLE NAME 238105/2R1**

Exmin, 1/90 vertical

Relogged core 345-405' MGS TS @ 395'

**LITHOLOGIC LOG<sup>1</sup>**

0-272' Drift

272-? Limestone (no core)

?-350' Conglomerate in core 345-350' although depth of contact is imprecisely known. Conglomerate not well represented in core, but contains several Precambrian clast types including white bio granite, red c.g. granite, and f.-m.g. weathered "diabase" in matrix of red f.g. quartz sandstone. Most clasts strongly weathered, as is matrix sand, implying incorporation of pre-Paleozoic saprolite.

350-405' Foliated biotite granodiorite; pink to gray, c.g.

### PRECAMBRIAN BEDROCK DATA III

#### Structure

Foliation defined by weak modal bands dips 25-30°

#### Mineralization, Alteration, Metamorphism

Minor foliation-parallel, qtz-healed shears contain trace % py. Granite is variably weathered, most strongly between 350 and 360'.

#### Magnetic Susceptibility

0.00 throughout

#### Density

2.73 @ 395'

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MN UNIQUE NO. D12566 156-42-31 ACAAAA, Marshall Co. HOLE NAME GS-1

Exxon, 10/79 0° / -60° (top) to 40° (bottom)

Relogged core 415-919' at DNR

#### LITHOLOGIC LOG<sup>1</sup>

0-415'	"Overburden"
415-435'	Saprolite
435-504'	Tuffaceous wacke to graywacke, interbedded chloritic mafic tuff, all intruded by hb-bio-plag-qtz porphyry dikes of a few cm to 30 cm thick that have sharp, discordant contacts
504-520'	Mafic flow ?
520-533'	Dacite porphyry dike
533-919'	Interbedded mafic tuff (hb-rich), f.g. tuffaceous graywacke and argillite; thinly bedded, poorly graded, local lapilli tuff units, all intruded by dacite porphyry dikes, particularly below 873'.

### PRECAMBRIAN BEDROCK DATA III

#### Structure

Bedding is parallel to a weak to moderate cleavage dipping 30-40° to CA; vertical to 80° S. Local disturbed and folded beds occur.

#### Mineralization, Alteration, Metamorphism

Metamorphic minerals include bio, amphibole, chlorite, and garnet (the latter in mafic layers). Minor alteration, trace % py near some porphyry dikes.

#### Magnetic Susceptibility

0.00-0.03 except 0.10 occurs from 440-500'

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MN UNIQUE NO. 21736 156-43-35 DDBABB, Marshall Co. HOLE NAME 238109/2R1

Exmin, 1/90 vertical

Relogged core 342-380' at DNR

#### LITHOLOGIC LOG<sup>1</sup>

0-340'	Drift
340-342'	Bedrock (no core)
342-380'	Banded pyroxene-biotite diorite (meta-lamproite); similar to SC-2; f.g. chlor, px, bio and magnetite bands alternate with c.g., euhedral, partly uralitized pyroxene in a finer, dk-green groundmass. One zone of semi-fluid (magmatic) brecciation is infilled with c.g. pyroxenite.

### PRECAMBRIAN BEDROCK DATA III

#### Structure

Enigmatic fabric; strong cleavage in f.g. units, locally brecciated and infilled with c.g. rock implies most fabric is magmatic. Fabric dips consistently vertical to 80°. Multiple, low angle calcite-chlor-epidote-plag veinlets occur.



Mineralization, Alteration, Metamorphism

Uralite and low grade, possibly deuteritic alteration.

Magnetic Susceptibility

342-345= 0.53-0.40

345-380= 0.06 (average of 10 measurements)

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**MN UNIQUE NO. 219963 56-46-2 CDCCBD, Marshall Co. HOLE NAME G-8**

USGS test hole, MGS cuttings # 2372, no core

USGS log

LITHOLOGIC LOG<sup>3</sup>

0-365' Drift

365-366' Greenstone, hard and fine-grained, may be a boulder

NO OTHER DATA III

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**MN UNIQUE NO. 244718 156-49-4 BCBDDA, Marshall Co. HOLE NAME 244718**

Water well log on file-MGS, no core vertical

LITHOLOGIC LOG<sup>3</sup>

0-320' Drift

320-489' Interbedded limestone and shale

489-496' "Crystalline rock"

NO OTHER DATA III

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**MN UNIQUE NO. unknown 156-51-8 B, North Dakota HOLE NAME RRVD-18**

Moore, 1979 vertical

LITHOLOGIC LOG<sup>3</sup>

0-276' Drift

276-386' Cretaceous sandstone>shale (black)

386-537 Jurassic (?), shale, limestone (gray-white)

537-644' Ordovician, Winnipeg, Icebox member, shale (orange-yellow)

644-659' Granodiorite; gray, m.g., epidotized, gneissic

NO OTHER DATA III

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**MN UNIQUE NO. 21039 157-39-2 CCB, Marshall Co. HOLE NAME MR-1**

Texasgulf, 1/84 30° / -45°

Company log

LITHOLOGIC LOG<sup>2</sup>

0-303' Drift

303-430' Weathered greenstone

430-583' Interbedded dacitic-looking crystal tuff, tuffaceous wacke, and graphitic and siliceous argillite.

PRECAMBRIAN BEDROCK DATA III

Structure

Thinly bedded, beds dip 10-30° to CA.

Mineralization, Alteration, Metamorphism

Py occurs in "balls" (primary?) and disseminated up to 5%

Magnetic Susceptibility

0.00-0.1, company data, units of measurement unknown, though other logs indicate this is 0.01

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MN UNIQUE NO. 21040 157-39-2 CB, Marshall Co. HOLE NAME MR-2

Texasgulf, 1/84 150° / 45°

Relogged core 310-883' at DNR

LITHOLOGIC LOG<sup>1</sup>

- 0-310' Drift, may include weathering residuum
- 310-418' Volcanogenic wacke, siltstone and lapilli-rich tuff of intermediate (dacitic) volcanic composition
- 418-424' Hematitic shale and fine-grained wacke
- 424-477' Fine-grained wacke
- 477-521' Graphitic argillite, pyrite- and calcite-rich
- 521-544' Conglomerate containing clasts of dacitic volcanic rock, pyritic graphitic argillite, and wacke.
- 544-843' Interbedded graphitic argillite and tuffaceous argillite and conglomerate
- 843-883' Andesite flow, massive, amygdaloidal at 855', bleached at up-hole contact.

PRECAMBRIAN BEDROCK DATA III

Structure

Bedding dips 45-50° to CA, 70-80° N. Moderate to strong flattening; however, bedding contacts are preserved. Younging is down-hole to the south. Fragmental graphite breccias appear sedimentary.

Mineralization, Alteration, Metamorphism

Moderately to strongly weathered throughout, decreasing in intensity with depth. Even volcanic rock at base of core absorbs water and scratches easily, implying argillic alteration. Metamorphic grade is chlorite zone of greenschist. Au=20-45 ppb (company data). Pyrite is disseminated in nearly all rock types. Py as much as 25% occurs in graphitic zones, local marcasite balls. Qtz-feld-py veining.

Magnetic Susceptibility.

0.00-0.01

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MN UNIQUE NO. unknown 157-39-3 CACCB, Marshall Co. HOLE NAME G-1

Exxon, 3/74 0° / -60°

Relogged core 213-981' at DNR MGS TS and ASSAY @ 648'

LITHOLOGIC LOG<sup>1</sup>

- 0-213' "Overburden"
- 213-909' Pyroxene peridotite to gabbro; dark green, mg, local talc-serp alteration zones. Base of unit progressively fines to f.g. diorite with visible amphibole clots (talcose zone alteration is similar to Mentor L-series cores) TS indicates the rock is pyroxene-bearing peridotite.
- 909-981' Interbedded dacitic lithic tuff and cherty aphanitic tuff intruded by two thin f.g. metadiabase dikes that appear related to the gabbroic rock above. Entire unit and internal subunits are graded: finer up-core.

PRECAMBRIAN BEDROCK DATA III

Structure

Gabbro is weakly foliated, numerous zones of epidote-serpentine-talc-chlorite veining and shear dip 45° to CA, contacts between intrusive units dip similarly. Bedding, weak-moderate bed-parallel cleavage, and clast orientation in metasedimentary rocks dips 40-45° to CA, i.e. 65-80° S. Younging = up-core to S. Minor qtz veining (post-cleavage) dips 30-40° to CA in orientation that opposes bedding.

Mineralization, Alteration, Metamorphism

Sulfides locally abundant at contact zone in sedimentary rocks, otherwise are absent from both units. Serp-talc-chlor alteration occurs in peridotite. Assay at 648'= 2900 ppm Cr.

Magnetic Susceptibility

213-909'= 0.34-4.8

909-981'= 0.03

Density

2.86 @ 648'

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**MN UNIQUE NO. 244852 157-41-24 CADCBC, Marshall Co. HOLE NAME MPL-2-B2**

MGS test hole, 12/81 vertical

Relogged core 249-254' at DNR MGS TS @ 251', ASSAY MGS cutting #1778 by Clark, 1990

LITHOLOGIC LOG<sup>1,3</sup>

0-249' Drift

249-254' Amphibolitic metadiabase to metadiorite; homogeneous, equigranular, gray, and f.g.

PRECAMBRIAN BEDROCK DATA III

Structure

No obvious flow features, several thin ep-qtz veins dip 40°, chlor-lined joints dip 40-60°

Mineralization, Alteration, Metamorphism

Amphibole clearly metamorphic, chlor is retrogressive. Trace % py and po.

Magnetic Susceptibility

0.03 throughout

Density

2.95 @ 252'

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**MN UNIQUE NO. 219898 157-48-4 BCCCC, Marshall Co. HOLE NAME F-1**

USGS test hole vertical

USGS log, MGS cuttings #2348 interpreted by John Mossler, no core

LITHOLOGIC LOG<sup>3</sup>

0-237' Drift

237-260' Shale, lignite, pyrite; Cretaceous

260-282' Conglomeratic sandstone

282-304' Shale, red, "Hallock red beds" (Jurassic?)

304-340' Shale, greenish gray, Winnipeg Formation (Ordovician)

NO OTHER DATA

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**MN UNIQUE NO. unknown 157-51-34 D, North Dakota HOLE NAME RRVD-19**

Moore, 1979 vertical

Moore log only

LITHOLOGIC LOG<sup>3</sup>

0-324' Drift

324-637' Shale (all colors), sandstone, limestone interpreted all to be Jurassic in age

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**MN UNIQUE NO. unknown 158-40-15 DBBBBB, Marshall Co. HOLE NAME M-1**

Humble Oil, 1976 10° / -60°

Relogged core 336-1095' at DNR

LITHOLOGIC LOG<sup>1</sup>

0-336' "Overburden"

336-1095' Metabasalt to meta-andesite flows and flowtop breccias; locally pristine flow structures including amygdules, pillow structures, and pillow fragment breccias.

### PRECAMBRIAN BEDROCK DATA III

#### Structure

Vaguely flattened, local brittle brecciation, but no penetrative cleavage. Foliation defined by flow bands and contacts dips 30-45° to CA--vertical to 80° S. Stratigraphic younging is well defined by flow contacts that indicate it is down-hole to N. Many qtz-py-cpy-calcite veins.

#### Mineralization, Alteration, Metamorphism

Upper greenschist facies indicated by local garnet in mafic tuffaceous interflow sedimentary rocks. Pyrrhotite is disseminated, and occurs as semi-massive zones in some flowtop breccias (nearly sulfide facies iron-formation). Zones of magnetite and porphyroblasts occur, particularly below 741'.

#### Magnetic Susceptibility

extremely variable due in part to pyrrhotite content:

336-741' = 0.01-4.5, largest in semi-massive po zones giving 2.2-4.5

741-795' = 0.75-15.0, avg=2.5 in zone containing visible magnetite and po

795-1095' = 0.20-2.1 magnetite porphyroblasts not visible, even in po zones

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**MN UNIQUE NO. 22011      158-43-2 DABDBC, Marshall Co. HOLE NAME SC-1**

Newmont, 3/89      vertical

Relogged core 462-482' at DNR

#### LITHOLOGIC LOG<sup>1</sup>

0-360'      Drift

360-462'      Weathering residuum and broken rock

462-472'      Rock, no core

462-482'      Dunite/peridotite with zones of serpentinite (Strathcona pluton); most is fine-grained, but relict c.-v.c.g. texture defined by serpentinitized olivine crystals.

### PRECAMBRIAN BEDROCK DATA III

#### Structure

No penetrative foliation. One serpentinite zone dips 20°. Minor flow-aligned tabular crystals of relict olivine plunge nearly horizontally. Numerous magnetite veinlets and chlorite-serp veins dip 5-25°.

#### Mineralization, Alteration, Metamorphism

Serpentine alteration is abundant, distribution of magnetite in veins and as disseminated euhedra appears to be a magmatic product.

#### Magnetic Susceptibility

472-474' = 0.37-0.68

474-476' = 0.07-0.22 zone of multiple serp veins

476-482' = 0.32-1.5 largest at 480' in zone of magnetite veins

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**MN UNIQUE NO. 22012      158-43-5 CCDBBC, Marshall Co. HOLE NAME SC-2**

Newmont, 3/89      vertical

Relogged core 362-365.5' at DNR

#### LITHOLOGIC LOG<sup>1</sup>

0-332'      Drift

332-362'      Weathering residuum

362-365.5'      Plag-bio-pyroxene diorite to pyroxenite; flow banded, containing bands of c.g. px > bio and interstitial plag interlayered with bands of strongly foliated (nearly cleaved-looking) fine-grained mafic rock composed of bio > px. All minerals are fresh. Rock is lamproite.

### PRECAMBRIAN BEDROCK DATA III

#### Structure

Well-developed banding dips vertically to 75°.

Mineralization, Alteration, Metamorphism

Mineralogy is fresh, no significant alteration or metamorphic affects are apparent.

Magnetic Susceptibility

0.76-1.3, average 0.97

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**MN UNIQUE NO. 22013 158-43-9 BDBBBD, Marshall Co. HOLE NAME SC-3**

Newmont, 3/89 vertical

Relogged core 403-413' at DNR

LITHOLOGIC LOG<sup>1</sup>

0-350' Drift

350-403' Weathering residuum

403-413' Amphibolitic schist of basaltic protolith

**PRECAMBRIAN BEDROCK DATA III**

Structure

Moderately well developed cleavage dips 65-70°.

Mineralization, Alteration, Metamorphism

Local epidote-garnet-quartz alteration predates cleavage. Several qtz-feld-bio veins parallel to foliation contain trace % py. Some later, low-angle qtz veins occur.

Magnetic Susceptibility

0.02-0.13, average = 0.06

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**MN UNIQUE NO. 447052 158-43-10 CDCCCC, Marshall Co. HOLE NAME SC-4**

Newmont, 3/89 vertical

Relogged core 403-410.5' at DNR

LITHOLOGIC LOG<sup>1</sup>

0-365' Drift

365-395' Weathering residuum

395-403' Rock, no core

403-410.5' Biotite-pyroxene diorite to monzodiorite; mineralogically similar to SC-2, but differs in texture. Consists of subhedral px up to 5 mm, subhedral bio, and interstitial turbid feldspar that is locally poikilitic.

**PRECAMBRIAN BEDROCK DATA III**

Structure

Strongly lineated trachytic texture and irregular banding defined by bio+px vs. feld and dips 50-55°.

Mineralization, Alteration, Metamorphism

None, no evidence of metamorphic recrystallization

Magnetic Susceptibility

0.07-0.22, average = 0.17, most in the range of 0.12-0.19

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**MN UNIQUE NO. 244847 158-44-33 ABBBAB, Marshall Co. HOLE NAME MPL-1-B2**

MGS test hole 1981 vertical

MGS log, no core ASSAY by Clark, 1990 of MGS cuttings #1772

LITHOLOGIC LOG<sup>1,3</sup>

0-402' Drift

402-449' Weathering residuum

449-455' Feld-qtz-chlor-bio "granofels" of felsic tuff-graywacke protolith

PRECAMBRIAN BEDROCK DATA III

Structure--nd

Mineralization, Alteration, Metamorphism

Cuttings assay (Clark, 1990) at 400-405' reports Au=10ppb.

Magnetic Susceptibility--nd

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MN UNIQUE NO. 224273 158-47-23 CABBBB, Marshall Co. HOLE NAME RRVD-30

Moore, 1979 vertical

Relogged core 362-381' at MGS, TS @ 374', 378', and 383', ASSAY MGS cuttings #1490 by Clark, 1990

LITHOLOGIC LOG<sup>3</sup>

0-362' Drift

362-381' Granodioritic gneiss; m.-c.g., contains bio, hb, qtz and feld, trace % ep, sphene, apatite.

Cut by two deformed pegmatite dikes, one contains garnet, magnetite, and py.

PRECAMBRIAN BEDROCK DATA III

Structure

Thoroughly recrystallized and weakly banded, foliation dips 45-60°. Both pegmatite dikes are concordant and foliated.

Mineralization, Alteration, Metamorphism

Minor py is disseminated, py occurs in pegmatite at 383'. Bio locally chloritized.

Magnetic Susceptibility

0.00-0.17 variable, without apparent visible correlation with rock, except largest value (0.17)=pegmatite.

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MN UNIQUE NO. 219652 158-50-21 DAAAAD, Marshall Co. HOLE NAME Well B

MGS test well B, 1972 vertical

Log from Mossler, 1978, ASSAY MGS cuttings #887; Clark, 1990

LITHOLOGIC LOG<sup>3</sup>

0-190? Drift

190-320? Dolomitic limestone of Red River Formation (Ordovician)

NO OTHER DATA

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MN UNIQUE NO. 21041 159-41-36 ADCCBA, Roseau Co. HOLE NAME W1-84

Texasgulf, 2/84 204° / -45°

Relogged core 424-852' at DNR MGS TS and ASSAY @ 510'

LITHOLOGIC LOG<sup>1</sup>

0-424' "Overburden"

424-576' Felsic tuff, tuffaceous and graphitic argillite, and tuffaceous graywacke

576-852' Interbedded mafic to intermediate flows and thin tuffaceous sedimentary rocks.

PRECAMBRIAN BEDROCK DATA III

Structure

Fabric is defined by bedding, contacts, and weak cleavage (S<sub>1</sub>) dips 60-80° N. Local strong cleavage (S<sub>2</sub>?) crenulated S<sub>1</sub> and dips 70-80° S. Younging is up-core to the N; however, some large folds exist.

Mineralization, Alteration, Metamorphism

Sulfides (py mostly) as much as a few %, pyritic zones are deformed by S<sub>2</sub>. Possible spinifex texture at 601-604'. TS indicates cherty zone at 510' contains tourmaline and possible cpy.

Magnetic Susceptibility

Texasgulf data

424-576' = 0.00-0.1 667-760' = 1.5-4.5 avg 2.5

576-607' = 0.3-5.6 60-785' = 1.2-2.0 avg 1.5

607-667' = 0.7-1.5 785-852 = 0.2

Density

2.77 @ 510'

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**MN UNIQUE NO. unknown      159-51-2 C, North Dakota HOLE NAME RRVD-20**  
Moore, 1979      vertical  
Moore log  
LITHOLOGIC LOG<sup>3</sup>  
    0-247      Drift  
    247-380'      Limestone and dolomite--Red River Formation (Ordovician)  
NO OTHER DATA

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**MN UNIQUE NO. 20488      160-40-31 CDCCAA, Roseau Co. HOLE NAME YGZ-1**  
Houston Oil (Tenneco), 3/85      210° / -60°  
Relogged core 379-527' at DNR      MGS TS @ 407'  
LITHOLOGIC LOG<sup>1</sup>  
    0-379'      Drift  
    379-527'      Interlayered schist and granite; schist is varied from light colored and tonalitic in composition to darker and metabasaltic or metadioritic (the latter occurs below 518'), locally is porphyritic. Granite is medium-grained to pegmatitic and occurs in subparallel sill-like units of varying thickness throughout the core. No selvages or other evidence of partial melting.

**PRECAMBRIAN BEDROCK DATA II**

Structure

Contacts and mild cataclasis in granite dip 50-65° N. Foliation in tonalite is locally protomylonitic and most commonly dips 70-80° S, but varies from parallel to granite units, to sharply different in orientation. Fabric in country rock is more intensely developed than that in granite, and clearly pre-dates its emplacement.

Mineralization, Alteration, Metamorphism

Almost no mineralization and no conductive horizons--conductor may have been surficial, as the drift was much thicker than expected, according to the company log.

Magnetic Susceptibility

0.00-0.04

Density

2.58 @ 407' in granitic component

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**MN UNIQUE NO. 21265      160-41-34 AACBAB, Roseau Co. HOLE NAME R-1**  
Exxon, 1/84      180° / -50°  
Relogged core 375-782' at DNR 3/92      MGS ASSAY @ 743'  
LITHOLOGIC LOG<sup>1</sup>  
    0-350'      Drift  
    350-375'      Weathered rock, no core  
    375-567'      Interbedded amphibolitic and chloritic mafic tuff and fine-grained tuffaceous sedimentary rocks of less mafic affinity. Intruded by granitoid sill at 518-521'. Mafic units composed of chlorite, garnet, amphibole, and biotite.  
    567-782'      Interbedded mafic tuff and pyrrhotitic sulfide facies iron-formation; intruded by granitic, locally porphyritic dikes or sills at 579-580' and 741-743.5'.  
    782-1043'      Core not available at DNR

## PRECAMBRIAN BEDROCK DATA II

### Structure

Strong cleavage and banding dips 50-80° to CA; 60-75° N. Asymmetrical intrafolial folds indicate N-side up. Granitoid intrusions are moderately deformed and contain cataclasized feldspar crystals. Garnet, sulfides, dikes, and some qtz veins pre-date flattening; later, post-flattening qtz veins also occur.

### Mineralization, Alteration, Metamorphism

Pyrrhotite-rich bands are common below 567'. Local disseminated py, cpy and po occur at 567-579'. Strong shear fabric accompanied by ribbon qtz occurs in porphyries locally.

### Magnetic Susceptibility

375-567' = 0.00-0.05

580-660' = 0.05-0.07

567-579' = 0.18 (dissem. sulfide zone)

660-715' = 0.18-4.2 (semi-massive sulfide zone)

579-580' = 0.00 (dike)

715-782' = 0.05-0.07

### Density

2.75 @ 743' in sulfidic tuff

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**MN UNIQUE NO. 21569    160-41-34 AABADA, Roseau Co. HOLE NAME R-3**

Newmont, 7/86    178° / -60°

Company log

### LITHOLOGIC LOG<sup>2</sup>

0-350'    "Overburden"

350-1123'    Garnet-plag-chlor-biotite-amphibole schist of mafic tuff and flow origin. Local po-rich bands of sulfide iron-formation and rare dacitic dikes occur. Pillow rinds are discernible locally.

## PRECAMBRIAN BEDROCK DATA II

### Structure

Well-developed foliation dips 45-55° N. Flow contacts and apparent grading indicate N-younging.

### Mineralization, Alteration, Metamorphism

Garnet, amphibole and staurolite indicate amphibolite-facies metamorphism. Layered to disseminated po, py, and trace % cpy occur. Some zones contain as much as 50% sulfides.

### Magnetic Susceptibility--nd

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**MN UNIQUE NO. 224272    160-42-32 ABDACD, Roseau Co. HOLE NAME RRVD-29**

Moore, 1979    vertical

Relogged core 260-265' and 320-335' at MGS. TS @ 327' and 334', ASSAY cuttings #1489 by Clark, 1990

### LITHOLOGIC LOG<sup>3</sup>

0-248'    Drift

248-260'    Weathering residuum and broken rock

260-265'    Mylonite of possible granitic protolith, rock is variably clayey, qtz-feld-chlor-sericite schist.

265-320'    No core

320-335'    Variably broken and weathered mylonitic to cataclastic schist containing abundant quartz veins of pinch and swell type, and qtz ribbons. Protolith may be dacitic tuff or tuff-wacke.

## PRECAMBRIAN BEDROCK DATA II

### Structure

Strong anastomosing shear fabric surrounds grains and grain aggregates, and dips 75-80°. Ribbon qtz tends to be foliation-parallel, though perhaps is slightly later than the shear fabric.



Mineralization, Alteration, Metamorphism

Quartz flooding accompanied by epidote and pyrite most evident in lower part of core (py up to 10% in last foot). Salmon color may indicate feldspar introduction locally. Assay of cuttings (Clark, 1990): 285-300': Au=35 ppb, Ni to 196 ppm, Zn to 198 ppm, and Cr=165-479 ppm.

Magnetic Susceptibility

0.00 throughout

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MN UNIQUE NO. 21261 160-43-24 ABDDBA, Roseau Co. HOLE NAME GB-1

Exxon, 11/83 N / -55°

Relogged core 268-858' at DNR MGS TS @ 551', ASSAY @ 551' and 586'

LITHOLOGIC LOG<sup>1</sup>

- 0-268' Drift
- 268-340' Metabasalt to meta-andesite, strongly fractured, folded chert and iron oxide bands 322-330', qtz-feld pegmatite occur at 295-296', and in unit below at 372.5-372.7' and 373-374'. All are foliated and cut by veins and faults of later generation.
- 340-858' Sheared and altered tuffaceous sedimentary rocks; fine-grained and recrystallized. Graphitic and pyritic zone at 612-613'. TS indicates rock is muscovite-bio-chlor-qtz-feld schist.

PRECAMBRIAN BEDROCK DATA II

Structure

Banding (likely a shear-modified bedding) dips 5-25° to CA: 60-85° N. Local isoclinal, intrafolial folds.

Mineralization, Alteration, Metamorphism

Rock appears to be strongly, but variably altered by silicification and/or feldspar introduction. Hydrothermal alteration is implied by odd accessory mineral assemblage including tourmaline and rutile.

Magnetic Susceptibility

- 276-593' = 0.03-0.07
- 593-610' = 0.18-0.39
- 610-735' = 0.00-0.43 variable, darker zones are greater
- 735-858' = 0.00 siliceous-looking schist

Density

2.69 @ 551 and 2.73 @ 586'

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MN UNIQUE NO. 219992 161-46-32 AAADBB, Kittson Co. HOLE NAME Lake Bronson 1

USGS test hole vertical

USGS log MGS cuttings #2486

LITHOLOGIC LOG<sup>3</sup>

- 0-375' Drift
- 375-415' Sandstone, shale and limestone of Winnipeg Formation (Ordovician)
- 415-419' Weathering residuum; white clay and quartz grains
- 419-421' Granite; gneissic and containing qtz, feld, mica and hb

NO OTHER DATA III

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MN UNIQUE NO. 224605 161-49-13 BCDDDC, Kittson Co. HOLE NAME Well A  
MGS test hole 1972 vertical

Mossler (1978) relogged scavenged intervals of core at DNR ASSAY MGS cuttings #888 @ 521'  
LITHOLOGIC LOG<sup>1,3</sup> ASSAY of cuttings by Clark, 1990

0-212' Drift  
212-255' Shale and sandstone--Cretaceous  
255-358' Shale, dolomitic shale, and gypsum--Jurassic ? (core 260-290')  
358-510' Sandstone and shale--Winnipeg Formation, Ordovician (core 377-382')  
510-529' Banded amphibolite of basaltic protolith (core 520-529')

PRECAMBRIAN BEDROCK DATA III

Structure

Well-developed schistosity, early veins of qtz and py are in-folded. Foliation dips 50-55°.

Mineralization, Alteration, Metamorphism

Foliation-parallel granular red qtz-py veins contain small % cpy. Late crossing veins of calcite, qtz and epidote. Assay at 521' (MGS) shows 390 ppm Cr. Assay of cuttings (Clark, 1990): 495-520' Cr=220 ppm.

Magnetic Susceptibility

0.02-0.04

Density

2.95 @ 521'

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MN UNIQUE NO. unknown 161-51-23 C, North Dakota HOLE NAME RRVD-21

Moore, 1979 vertical

Moore log, no core

LITHOLOGIC LOG<sup>3</sup>

0-210' Drift  
210'-? Limestone of Red River Formation?

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MN UNIQUE NO. 20464 162-44-33 DACBAA, Roseau Co. HOLE NAME YGH-1

Houston Oil, 2/84 0° / -60°

Company log--quick look shows rock is similar to that in YGH-2

LITHOLOGIC LOG<sup>2</sup>

0-250' Drift  
250-544' Banded qtz-biotite-feldspar gneiss of intermediate composition intruded by several pegmatitic to aplitic sills. No obvious EM source.

PRECAMBRIAN BEDROCK DATA II

Structure

Well-developed banding and foliation dips 25-40° to CA.

Mineralization, Alteration, Metamorphism--nd

Magnetic Susceptibility--nd

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MN UNIQUE NO. 20459 162-44-35 CBBCDD, Roseau Co. HOLE NAME YGH-2

Houston Oil, 2/84 S / -60°

Relogged core 240-595.5' at DNR Sampled dike at 390 and 466'

LITHOLOGIC LOG<sup>1</sup>

0-240' "Overburden"  
240-468' Gabbro and diabase; dk green, med. grained, equigranular. Grain size fines progressively 420-460', then becomes f.g. chilled diabase 465-468'. Inferred to be a Proterozoic diabasic dike.

468-595.5' Quartz-biotite-feldspar gneiss; modally banded and leucocratic, except for few narrow and concordant zones of bio-chlor-amphibole (?) schist in abrupt contact with gneiss. Gneiss has a recrystallized texture and no visible primary structures. Thin character and gradational contacts between modal bands, together with leucocratic composition, imply tuffaceous sediments are likely protolith.

**PRECAMBRIAN BEDROCK DATA II**

Structure

Modal banding dips 30-40° to CA, inferred to be vertical to 75° N. Contact between gneiss and gabbro is abrupt and dips 80° (40° to CA) subparallel to or slightly askew the trend of gneiss.

Mineralization, Alteration, Metamorphism

Sulfides typically absent from gneiss except for narrow zone immediately adjacent to gabbro. That contact is marked by a qtz vein at 468', and a zone from 468-489' in which feldspar in gneiss is salmon colored and oxidized, gneiss contains evidence for silicification, and py, cpy and possible molybdenite occur in small %. Alteration zone is inferred to be early and predates emplacement of the dike. Because sulfides occur within modal bands in the gneiss and appear deformed, this zone probably was a structural weakness along which the dike was emplaced.

Magnetic Susceptibility

240-420'=no readings	440-467'=1.3-2.0
420-436'=1.2-2.1	467-468'=0.04 in chill
436-440'=0.07-0.14	468-595.5=0.00-0.03, average=0.01

**MN UNIQUE NO. 219699 162-49-6 DDDDDDB, Kittson Co. HOLE NAME Florence 1**

Florence city well? vertical

MGS well record, no core

MGS cuttings #121 ASSAY by Clark, 1990

**LITHOLOGIC LOG<sup>3</sup>**

0-180'	Drift
180-415'	Limestone and shale
415-587'	Sandstone and shale
587-625'	Igneous rock containing biotite, qtz and feldspar; granitoid gneiss?

**PRECAMBRIAN BEDROCK DATA II**

Structure--nd

Mineralization, Alteration, Metamorphism

Assay shows Ba=1030 ppm at 570-575' (Clark, 1990)

Magnetic Susceptibility--nd

**MN UNIQUE NO. 21260 163-40-36 CDBACA, Roseau Co. HOLE NAME J-1**

Exxon, 10/83 240° / -55°

Relogged core 201-569' at DNR MGS TS @ 353'

**LITHOLOGIC LOG<sup>1</sup>**

0-168'	drift
168-201'	Weathered bedrock
201-903'	Interlayered lineated biotitic tonalite and coarse-grained quartz monzonite to monzogranite. Tonalite is strongly lineated and contains clots and individual crystals of biotite. It is modally banded by bio that varies from 30-50% to <10%. Monzogranite is locally c.g. enough to be called pegmatite. It contains K-spar, plag, biotite, interstitial qtz, and rare garnet.

**PRECAMBRIAN BEDROCK DATA I**

Structure

Most contacts between monzogranite and tonalite are sharp, irregular, and pegmatitic rock locally crosses the foliation in tonalite. Contacts dip 10-35° to CA (80° SW to vertical), internal lineation in

tonalite dips 35° to CA. Mixed zone at 493-503 implies the two components may be comagmatic, thus fabric may in part be of primary igneous origin.

Mineralization, Alteration, Metamorphism

Metamorphic fabric in tonalite is evidenced by elongate and recrystallized quartz. Trace to 2% py and po occurs in both rock types, commonly in more magnetic zones of tonalite and in mixed-looking zone at 493-503'.

Magnetic Susceptibility

0.00-0.04 except for:

346-360'=0.30-0.59 in tonalite

493-503'=0.80-2.5, average=1.4 in mixed zone. No data below 569'

Density

2.71 @ 353'

---

**MN UNIQUE NO. 244841 163-45-9 CCCCCC, Kittson Co. HOLE NAME KPL-1-B2**

MGS test hole, 12/81 vertical

Relogged core 396-401' at DNR MGS TS @ 398', ASSAY of cuttings #1766 by Clark, 1990

**LITHOLOGIC LOG<sup>1,3</sup>**

0-356'	Drift
356-377'	Weathering residuum; green clay
377-396'	Granodioritic; no core
396-401'	Biotite-hypersthene tonalite to granulite (having charnockitic affinities); gray, m.g.-c.g., banded. Thin concordant pegmatite sill at 400' contains large poikilitic garnet. Trace % magnetite visible in granulite.

**PRECAMBRIAN BEDROCK DATA I**

Structure

Modal banding dips 55-65°.

Mineralization, Alteration, Metamorphism

Low granulite facies metamorphism indicated by clean prograde assemblage bio-opx-qtz-plag. No visible sulfide minerals. Assay by Clark shows Ba=1050 ppm at 360-365'.

Magnetic Susceptibility

0.84-1.9, average 1.4

Density

2.78 @ 398'

---

**MN UNIQUE NO. 219702 163-50-23, SE SE SW, Kittson Co. HOLE NAME 219702**

Test hole vertical

Log from Allison (1932) ASSAY of MGS cuttings #01 by Clark, 1990

**LITHOLOGIC LOG<sup>3</sup>**

0-180'	Drift
180-400'	Dolomitic limestone
400-473'	Red limestone and shale
473-546'	Red-white sandstone
546-638'	Red, gray and green shale
638-644'	Cuttings of qtz, orthoclase and white feldspar, mica, and chlorite--infer granitic bedrock

**PRECAMBRIAN BEDROCK DATA I**

Structure--nd

Mineralization, Alteration, Metamorphism

Water chemistry reported in Allison (1932)

Magnetic Susceptibility--nd

---

MN UNIQUE NO. unknown 163-51-27 B, North Dakota HOLE NAME RRVD-22

Moore, 1979 vertical

Moore log

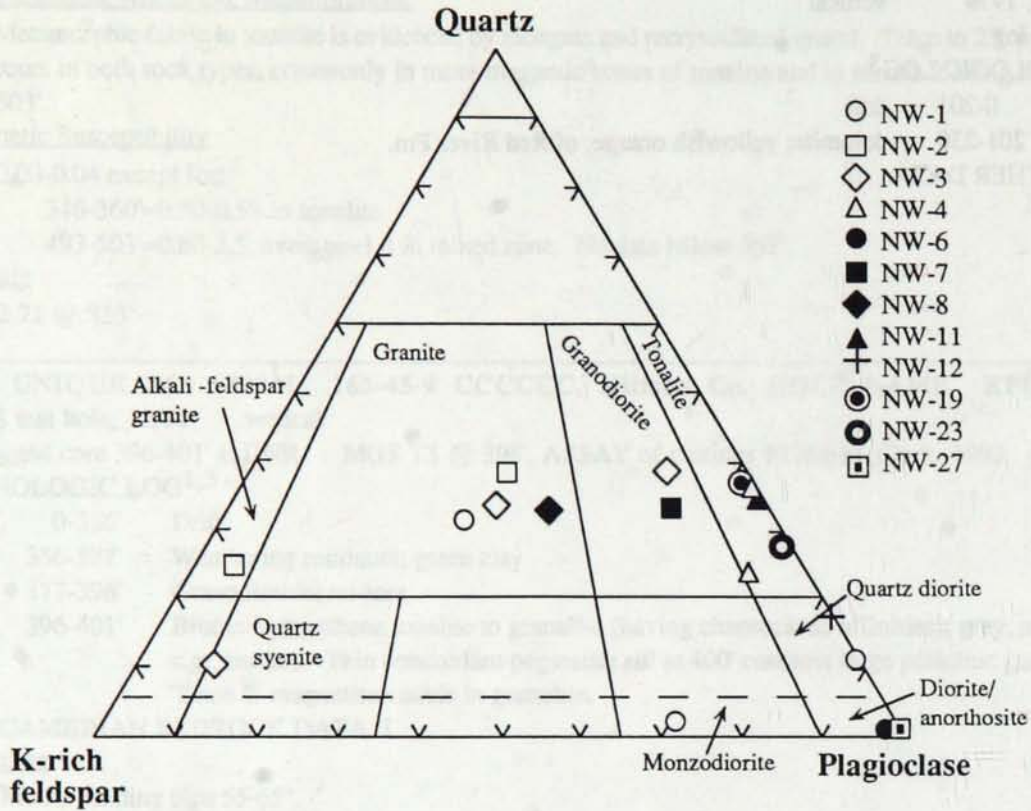
LITHOLOGIC LOG<sup>3</sup>

0-201 drift

201-230 dolomite; yellowish orange, of Red River Fm.

NO OTHER DATA

APPENDIX A. MODAL COMPOSITION OF PLUTONIC ROCKS



Middlesex University, London, W1P 3AP, UK

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0 54-1 3, average 1.4

1998

2.18 of 398

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0 54-1 3, average 1.4

1998

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0 54-1 3, average 1.4

1998

2.18 of 398

## APPENDIX B. MAJOR AND MINOR ELEMENT GEOCHEMICAL DATA

Sample	Rock Type	SiO <sub>2</sub>	Al <sub>2</sub> O <sub>3</sub>	CaO	MgO	FeO	Fe <sub>2</sub> O <sub>3t</sub>	Na <sub>2</sub> O	K <sub>2</sub> O	TiO <sub>2</sub>	MnO	P <sub>2</sub> O <sub>5</sub>	LOI	Sum wt. %	Fe <sub>2</sub> O <sub>3c</sub>								
NW-1-196	Hb. monzodiorite	59.8	15.8	5.17	4.07	2.7	5.70	4.27	2.53	0.834	0.11	0.50	1.00	100.1	2.70								
NW-3-542	Bio. granodiorite	68.7	16.3	2.11	0.61	0.9	1.40	4.26	4.62	0.172	0.02	0.10	0.90	99.5	0.40								
NW-4-338	Granodiorite	67.6	16.2	2.95	1.15	0.8	2.38	5.30	3.08	0.322	0.04	0.11	0.90	100.3	1.49								
NW-6-360	Diorite	58.5	19.0	0.23	4.69	3.6	5.03	9.01	0.20	0.518	0.10	0.15	2.65	100.1	1.03								
NW-7-401.5	Granodio. gneiss	71.0	15.0	1.84	0.88	1.0	1.91	5.16	3.11	0.296	0.06	0.10	0.45	100.0	0.80								
NW10-289	Sheared porphyry	72.1	11.3	0.91	0.32	2.1	5.78	5.37	2.70	0.433	0.08	0.03	0.90	100.1	3.45								
NW-11-325	Hb tonalite	60.2	14.8	5.49	4.58	4.0	7.03	4.16	1.60	0.614	0.14	0.14	1.50	100.3	2.58								
NW-20-522	Amygd. Basalt	47.3	11.0	10.60	8.72	10.9	16.20	2.03	0.14	1.730	0.25	0.17	2.25	100.5	4.09								
NW-25-360	Graywacke	64.2	15.0	1.87	3.02	4.0	6.18	3.64	2.25	0.623	0.10	0.16	2.75	99.9	1.73								
NOR-76-473	Dacite clast	64.2	15.9	4.75	1.59	1.7	4.44	6.37	1.07	0.617	0.12	0.25	1.00	100.5	2.55								
Sample	Rock Type	Au	Be	B	Sc	V	Cr	Co	Ni	Cu	Zn	Ge	As	Se	Br	Ba	Rb	Sr	Y	Zr	Nb	Mo	
NW-1-196	Hb. monzodiorite	<2	7	24	13.7	100	200	23.0	91	6.3	106	<10	1	<1	3.1	1260	140	916	11	171	20	<2	
NW-3-542	Bio. granodiorite	<2	4	39	2.18	24	8.5	4.3	8	9.4	16.5	<10	<1	<1	10.0	1030	110	757	11	890	18	<2	
NW-4-338	Granodiorite	<2	4	66	3.25	39	11.0	6.3	7	11.6	39.3	<10	<1	<1	4.7	1190	40	1110	<10	92	15	<2	
NW-6-360	Diorite	<2	3	29	7.47	70	29.0	17.0	44	2.8	99.7	<10	1	<1	10.0	73	<10	75	<10	120	13	<2	
NW-7-401.5	Granodio. gneiss	5	5	26	1.75	19	10.0	5.2	6	5.8	68.9	<10	<1	<1	2.9	981	230	425	<10	95	21	<2	
NW10-289	Sheared porphyry	<2	8	25	0.30	<2	19.0	1.8	3	30.9	416	10	<1	<1	2.0	506	20	70	136	848	108	<2	
NW-11-325	Hb tonalite	<2	5	39	15.2	96	140	24.0	120	52.5	112	10	1	<1	6.7	256	40	394	<10	97	27	<2	
NW-20-522	Chl. schist, dacite	<2	7	16	33.3	275	610	65.0	236	73.4	141	25	<1	<1	2.3	56	<10	347	12	108	<10	<2	
NW-25-360	Graywacke	<2	4	33	11.4	102	120	21.0	72	40.3	107	<10	3	<1	2.6	663	50	297	14	128	16	<2	
NOR-76-473	Dacite clast	<2	4	43	9.83	104	100	17.0	50	31	87.0	<10	3	<1	2.8	251	20	1070	<10	138	21	<2	
Sample	Rock Type	Ag	Cd	Sb	Cs	La	Ce	Nd	Sm	Eu	Tb	Yb	Lu	Hf	Ta	W	Ir	Pb	Th	U			
NW-1-196	Hb. monzodiorite	<0.1	<1	0.1	3.9	43.6	86	37	7.03	1.59	0.6	1.14	0.16	4.2	0.6	<1	<5	10	2.7	0.6			
NW-3-542	Bio. granodiorite	<0.1	<1	0.2	1.1	318	533	170	23.3	1.64	1.3	0.72	0.06	24.0	<0.5	<1	<5	26	130	4.2			
NW-4-338	Granodiorite	<0.1	<1	<1	0.5	7.8	17	9	1.96	0.57	0.2	0.35	0.05	2.9	<0.5	<1	<5	5	2.4	1.4			
NW-6-360	Diorite	<0.1	<1	<1	<0.5	13.9	27	11	2.03	0.44	<0.1	0.58	0.10	2.7	<0.5	<1	<5	<2	2.7	0.6			
NW-7-401.5	Granodio. gneiss	<0.1	<1	0.2	11.3	9.5	19	8	1.69	0.32	0.2	0.56	0.08	2.6	<0.5	<1	<5	9	1.7	3.5			
NW10-289	Sheared porphyry	<0.1	<1	0.1	0.5	76.6	166	87	19.5	4.02	3.1	9.12	1.32	19.0	5.2	<1	<5	2	7.2	2.8			
NW-11-325	Hb tonalite	<0.1	<1	0.1	1.7	24.7	52	24	5.10	1.10	0.6	1.38	0.20	2.9	0.9	<1	<5	6	6.4	1.4			
NW-20-522	Chl. schist, dacite	<0.1	<1	0.2	<0.5	12.0	29	17	4.56	1.43	0.8	1.73	0.25	2.8	0.5	<1	<5	<2	1.1	0.5			
NW-25-360	Graywacke	<0.1	<1	1.0	2.4	26.8	53	21	4.04	0.98	0.2	1.06	0.17	2.9	0.6	<1	<5	8	6.2	1.1			
NOR-76-473	Dacite clast	<0.1	<1	0.7	0.5	34.9	67	29	5.05	1.21	0.5	0.74	0.10	3.8	<0.5	<1	<5	12	6.3	2.3			

Major elements in wt. % oxides, minor elements in ppm, except Au (ppb). Fe<sub>2</sub>O<sub>3c</sub> = Fe<sub>2</sub>O<sub>3t</sub> - (FeO/0.8998). (X-Ray Assay Laboratories)

## Assay results (Activation Laboratories, Inc.)

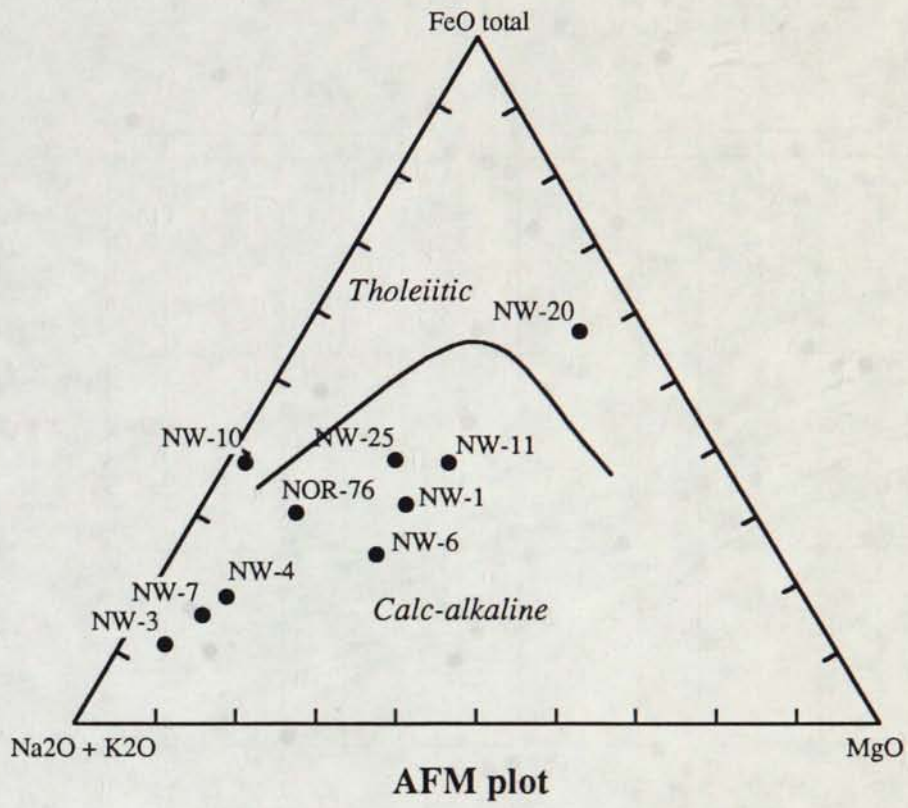
APPENDIX B, page 2

Sample	Rock Type	Au	Ag	As	Ba	Br	Ca	Co	Cr	Cs	Fe	Hf	Hg	Ir	Mo	Na	Ni	Zn	Rb
Units		ppb	ppm	ppm	ppm	ppm	%	ppm	ppm	ppm	%	ppm	ppm	ppb	ppm	ppm	ppm	ppm	ppm
Detection Limit		5	5	2	100	1	1	5	10	2	0.02	1	1	5	5	500	50	50	30
NW-10-289	Sheared porphyry	<5	<5	<2	410	<1	<1	<5	<10	<2	3.41	19	<1	<5	<5	30700	<50	280	<30
NW-12-480	Chl. schist, dacite	51	<5	4	510	<1	<1	14	10	<2	5.47	3	<1	<5	<5	4130	56	50	34
NW-15-496	Pyritic hb-bio schist	<5	<5	<2	180	<1	4	20	80	<2	4.57	3	<1	<5	<5	22500	120	100	37
NW-15-501	pink-altered schist	<5	<5	<2	280	3	4	13	81	<2	3.26	3	<1	<5	<5	26000	<50	64	33
NW-24-371	Chl. schist	7	<5	10	120	<1	6	36	82	<2	10.8	1	<1	<5	<5	5660	<50	104	<30
NW-25-360	Graywacke	13	<5	7	480	<1	2	23	180	3	5.1	4	<1	<5	<5	17800	<50	96	53
NW-26-436	Ank-py-qtz-ser schist	<5	<5	39	280	<1	2	21	160	<2	4.77	3	<1	<5	<5	11200	89	80	42
NW-27-413	Altered anorthosite	<5	<5	<2	140	<1	7	7	31	<2	1.52	<1	<1	<5	<5	14500	74	<50	<30
RRVD-28-386	Py-ser-ank-qtz schist	45	<5	27	560	<1	<1	12	78	<2	3.04	3	<1	<5	7	1290	<50	<50	64
Sample	Rock Type	Sb	Sc	Se	Sn	Sr	Ta	Th	U	W		La	Ce	Nd	Sm	Eu	Tb	Yb	Lu
Units		ppm	ppm	ppm	%	%	ppm	ppm	ppm	ppm		ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm
Detection Limit		0.2	0.1	5	0.01	0.05	1	0.5	0.5	4		1	3	5	0.1	0.2	0.5	0.05	0.05
NW-10-289	Sheared porphyry	<0.2	0.5	<5	0	<0.1	5	7.3	1.8	<4		83	180	88	18	4.9	3.5	13.2	1.9
NW-12-480	Chl. schist, dacite	0.2	6.3	<5	0	<0.1	<1	1.8	<0.5	<4		21	46	25	4	1.7	0.6	2.05	0.31
NW-15-496	Pyritic hb-bio schist	<0.2	11	<5	0	<0.1	<1	3.2	<0.5	<4		49	100	48	6.4	1.9	0.7	1.63	0.25
NW-15-501	pink-altered schist	<0.2	9.8	<5	0	0.07	<1	2.6	<0.5	<4		46	95	45	6.1	1.9	0.5	1.44	0.23
NW-24-371	Chl. schist	0.2	35	<5	0	<0.1	<1	<0.5	<0.5	<4		2	6	<5	1.4	0.7	<0.5	2.69	0.41
NW-25-360	Graywacke	1.6	14	<5	0	0.05	<1	7.3	<0.5	<4		20	41	16	2.8	1	0.6	1.55	0.25
NW-26-436	Ank-py-qtz-ser schist	<0.2	17	17	0	<0.1	<1	2.9	<0.5	4		12	26	13	2.2	0.9	<0.5	1.64	0.22
NW-27-413	Altered anorthosite	<0.2	4.5	<5	0	<0.1	<1	<0.5	<0.5	<4		<1	<3	<5	0.2	0.3	<0.5	0.29	<0.1
RRVD-28-386	Py-ser-ank-qtz schist	0.6	6.5	25	0	<0.1	<1	11	1.7	<4		45	81	25	3.7	1.2	<0.5	1.19	0.18

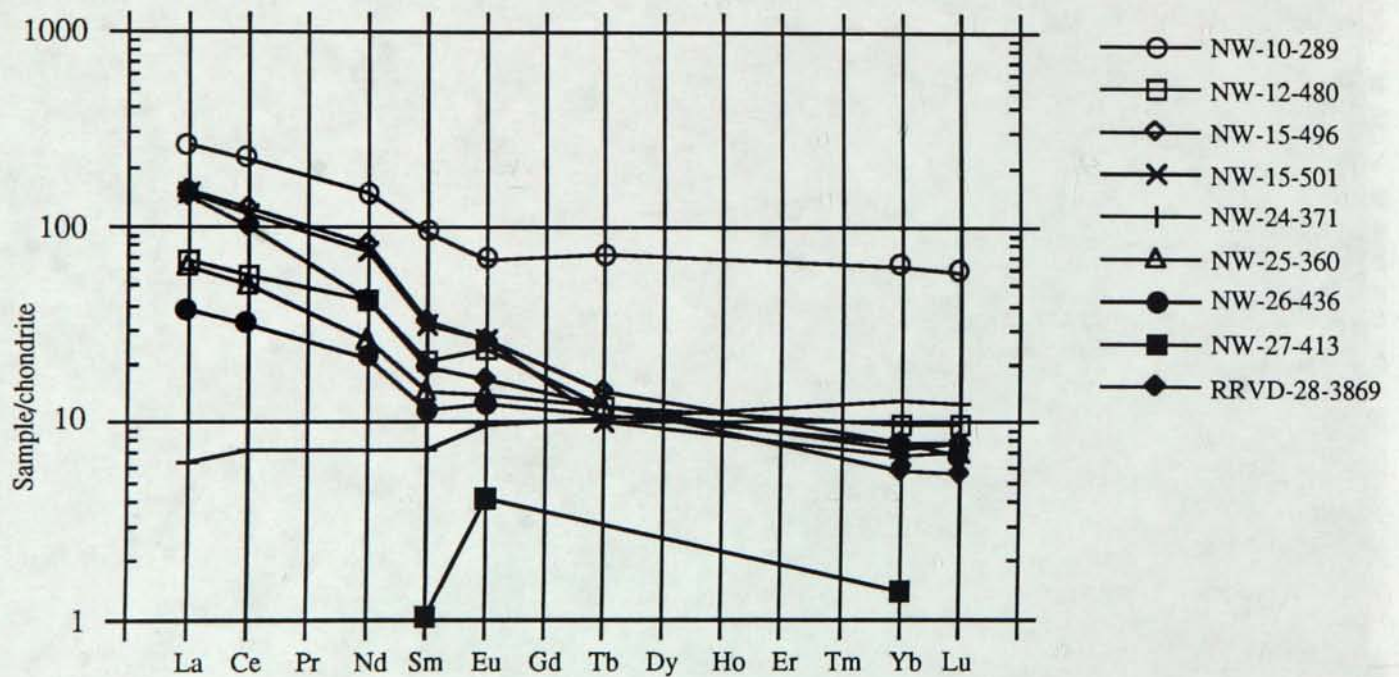
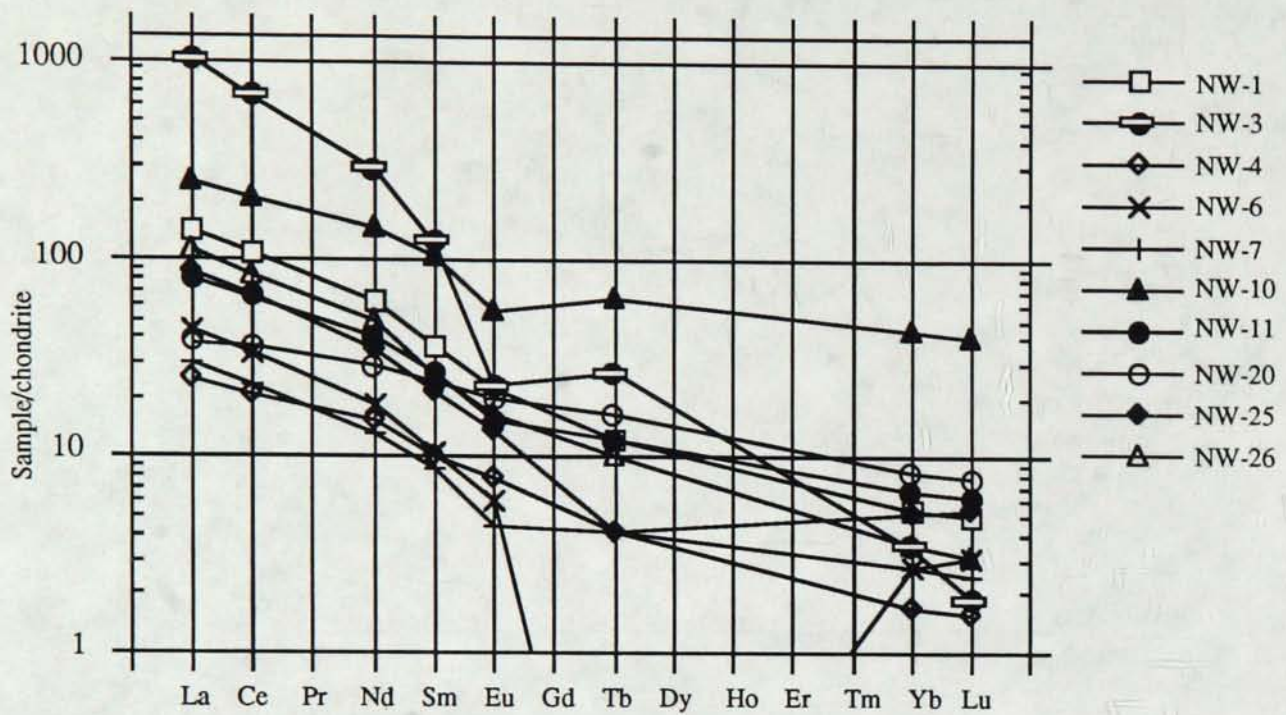
86

Note: Sample RRVD-28 from drill hole in T.150 N., R.44 W., sec. 10 is described in Archived Drill Hole section of this report.

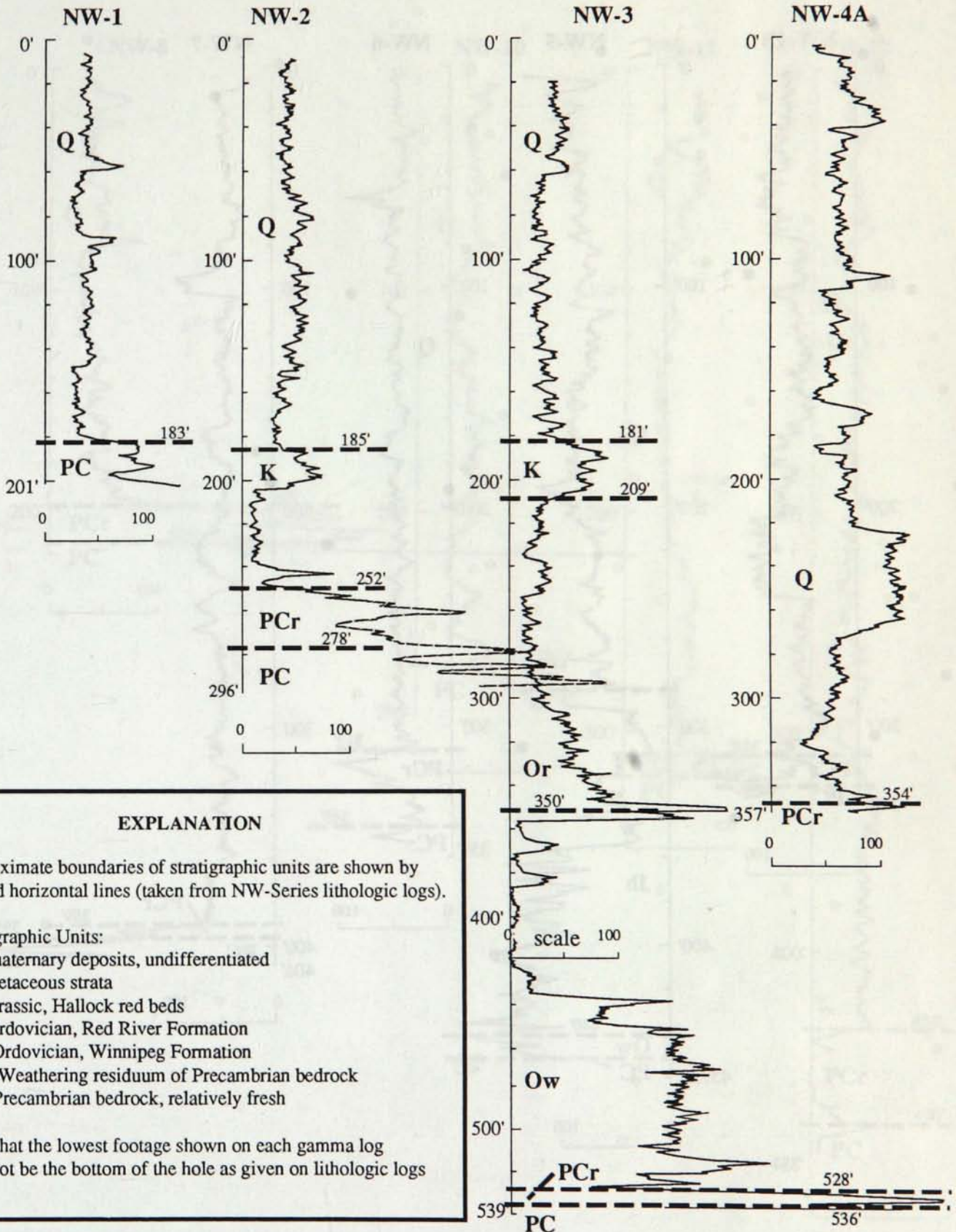




Chondrite-normalized REE plots



APPENDIX C. DOWNHOLE GAMMA LOGS OF NW-SERIES DRILL HOLES.



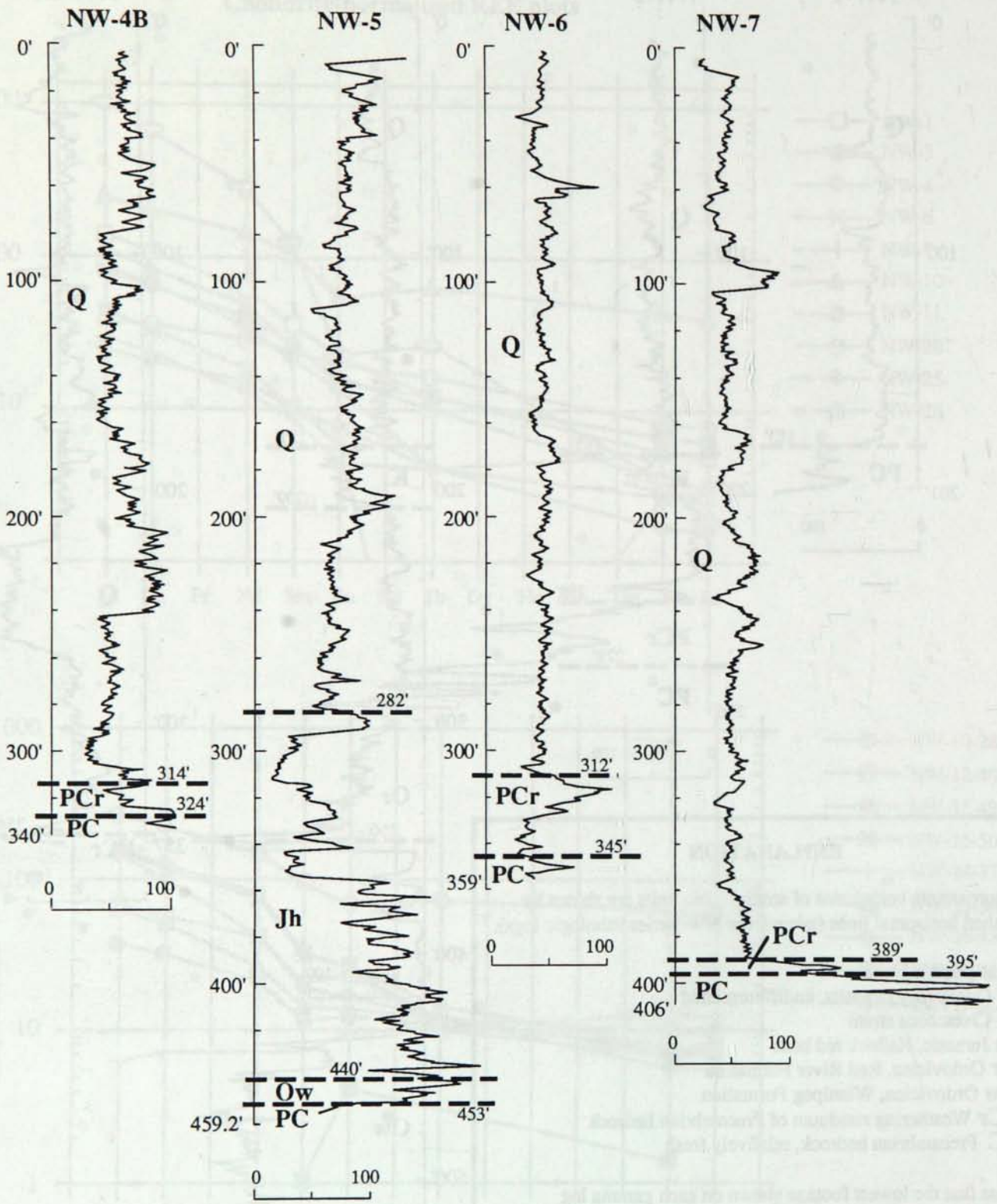
**EXPLANATION**

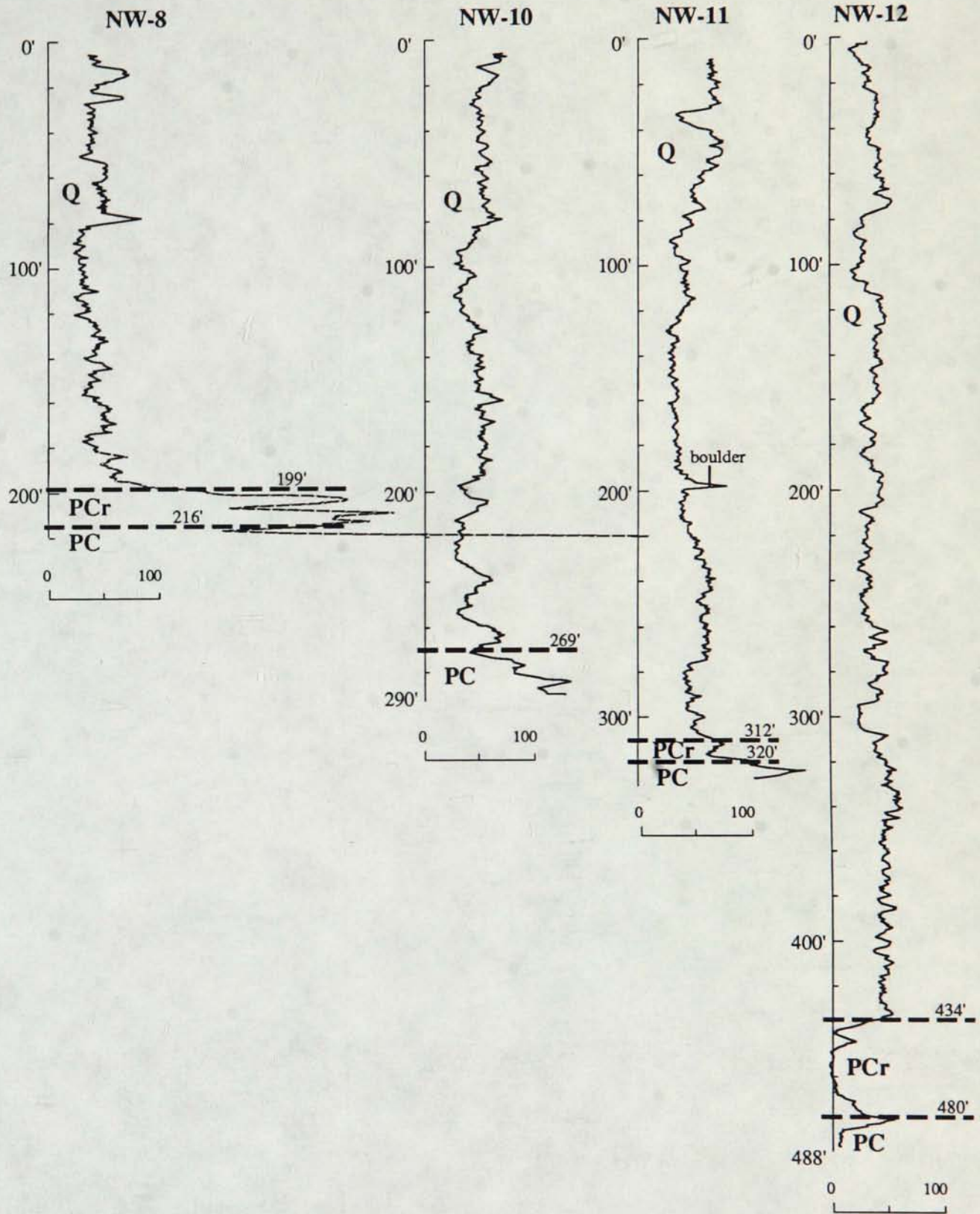
Approximate boundaries of stratigraphic units are shown by dashed horizontal lines (taken from NW-Series lithologic logs).

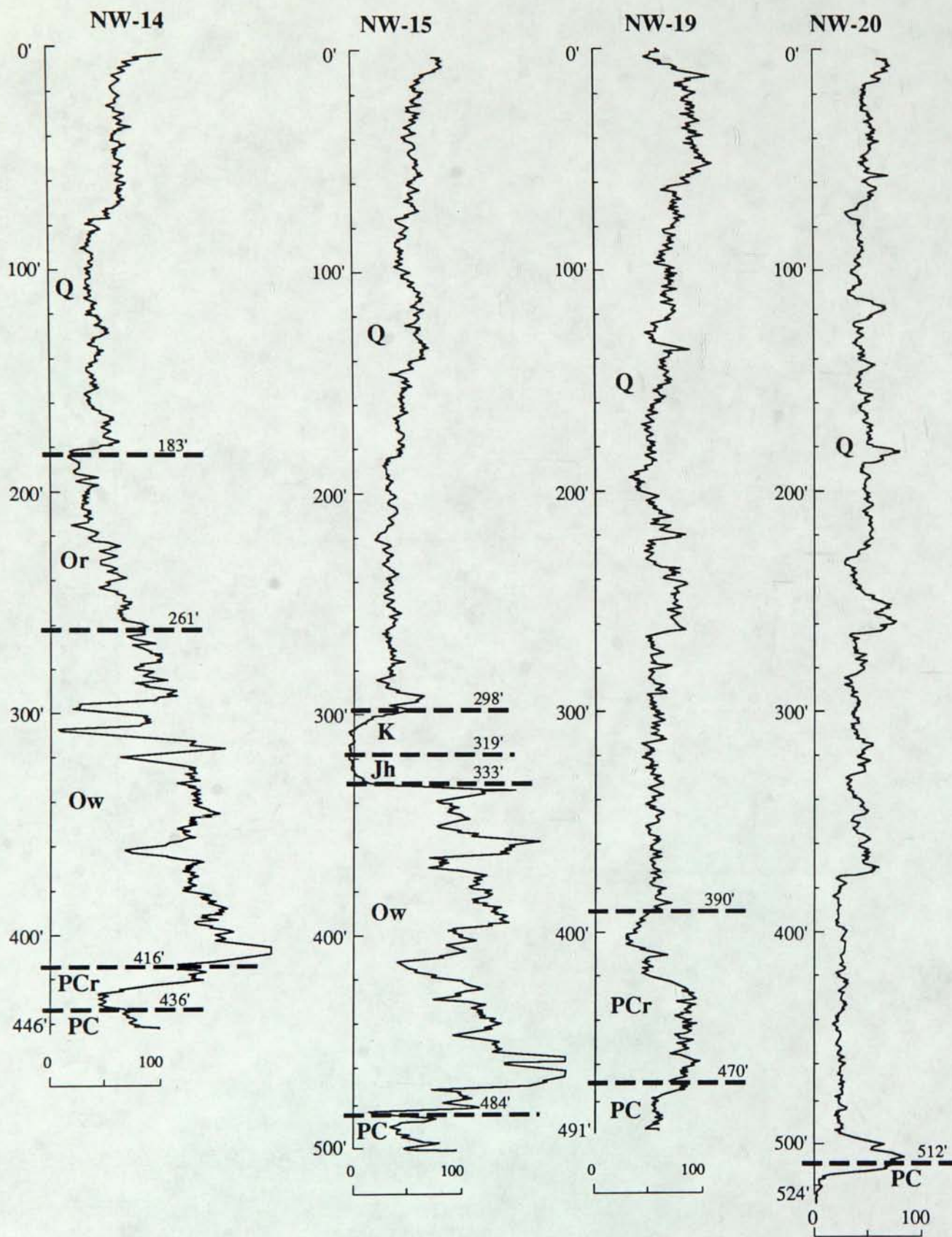
Stratigraphic Units:

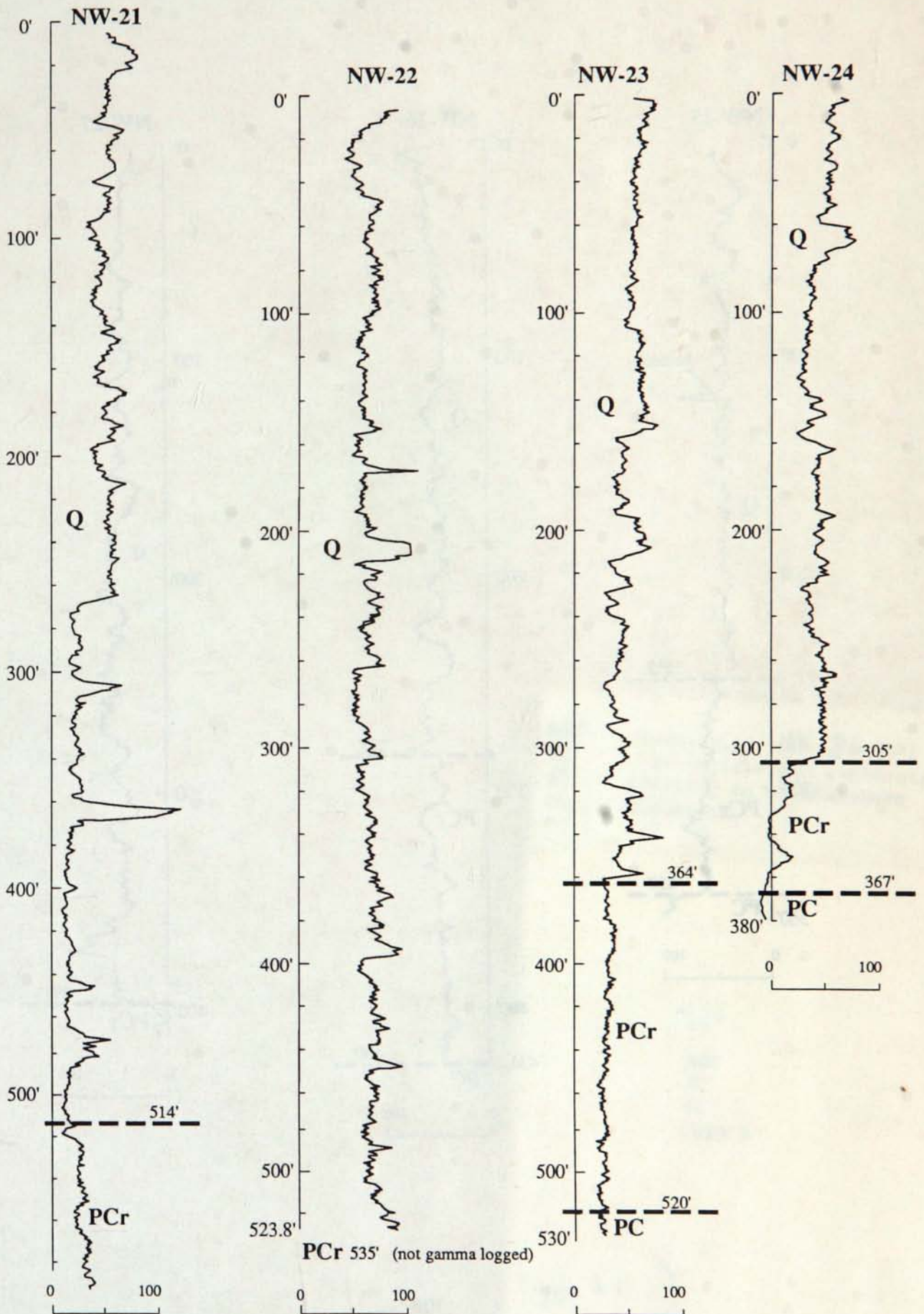
- Q** Quaternary deposits, undifferentiated
- K** Cretaceous strata
- Jh** Jurassic, Hallock red beds
- Or** Ordovician, Red River Formation
- Ow** Ordovician, Winnipeg Formation
- PCr** Weathering residuum of Precambrian bedrock
- PC** Precambrian bedrock, relatively fresh

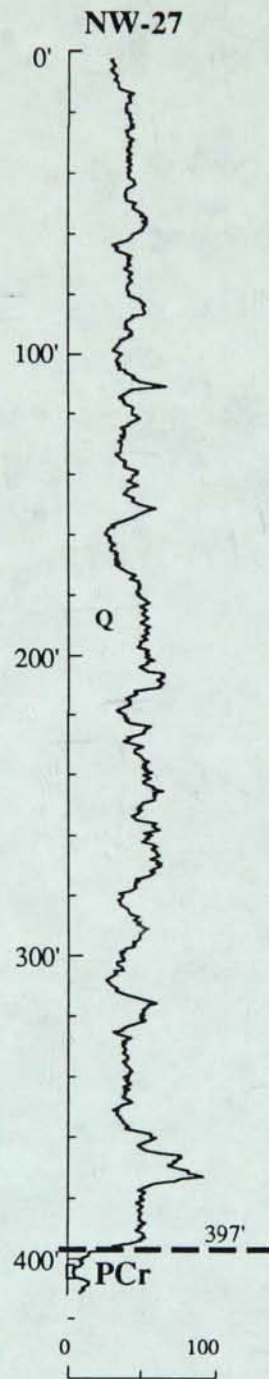
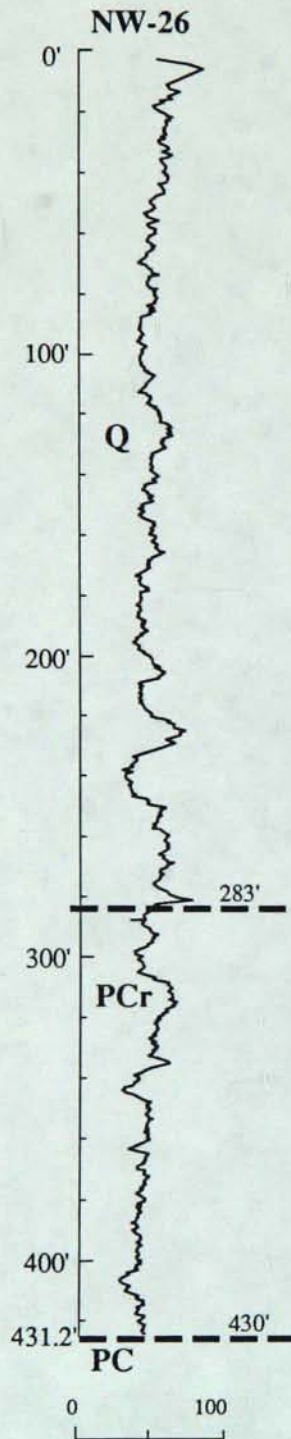
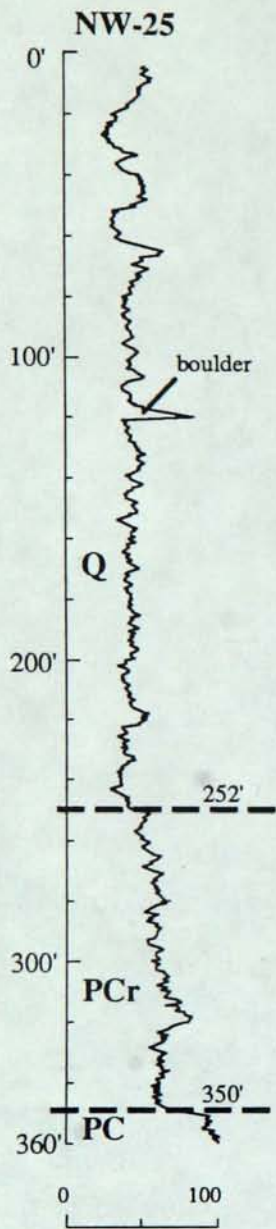
Note that the lowest footage shown on each gamma log may not be the bottom of the hole as given on lithologic logs













MGS Jirsa, M.A. JAN 20 1944  
IC Scientific and exploration  
40 drilling in northwestern  
Copy 3 Minnesota.

MGS  
IC  
40  
Copy 3

JAN 20 1944

