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PRELIMINARY BEDROCK GEOLOGIC MAPS OF NORTHWESTERN MINNESOTA

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Minnesota Geological Survey
Open-File Report 93-1

by

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June 30, 1993

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Sheet 1-GEOLOGIC MAP OF PRECAMBRIAN BEDROCK, NORTHWESTERN MINNESOTA

by
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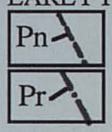
Minnesota Geological Survey
June 30, 1993

MAP UNITS

EARLY PROTEROZOIC DIKES



Diabasic and gabbroic dikes; the western-most part of the Kenora-Kabetogama swarm (Southwick and Day, 1983). The position of dikes is inferred from aeromagnetic maps and only rarely substantiated by the chance intersection in drill core. Their thickness is unknown; however, comparison of geophysical attributes with dikes of the same swarm exposed farther east indicate that they are 50-120m wide. Dikes inferred to have normal magnetic polarity (Pn) are shown by dashed line, reversely polarized ones (Pr) by dash-dot symbol. The inference of polarity is based solely on aeromagnetic expression.

LATE ARCHEAN INTRUSIONS

Agm

Granitoid intrusions that are variably magnetic; typically circular or oval shaped and commonly are concentrically magnetically zoned. Gravity expression is low, except for the more magnetic parts that have relatively higher gravity signature. Intersected in drill cores at several localities, the remainder are delineated from geophysical maps. Unit includes the small intrusion north of the Grygla pluton that is a magnetic, sheared, granodioritic porphyry. Geophysically similar to quartz-poor alkalic intrusions that post-date regional metamorphism and deformation and which occur in all belts farther east (for example, Jirsa, 1990, Jirsa, and others , 1991, and Day and others, 1990). Those better known plutons are composed of hornblende-, biotite- and pyroxene-bearing syenite, monzonite, and comagmatic dioritic phases, and coarse-grained granite.

Agp

Gabbro, peridotite, and pyroxenite; moderately to strongly magnetic, typically coarse to very coarse grained and locally oxide-rich. Commonly occurs as bulbous to elongate magnetic and gravity highs associated with quartz-poor alkalic intrusions (Agm), and with tonalitic (Adt-Grygla pluton) to anorthositic rocks (Aag-Mentor mafic intrusive complex). In the latter, Agp occurs as an irregular border phase to the largely anorthositic body. South of the Grygla pluton, Agp has a similar occurrence, but includes magmatic breccia and anorthositic phases (intruded by dikes of oxide gabbro). Lacks evidence in drill cores for significant tectonism or metamorphism. Igneous mineralogy is preserved and only deuteric alteration is evident. Emplacement is inferred to post-date tectonic fabric in enclosing supracrustal rocks.

Agg

Gabbroic plutons; mostly inferred from geophysical data. Typically small, irregular shaped to ovoid gravity and magnetic highs. Inferred from drill core and geophysical expression to be temporally late (post-deformation, syn-late granitoid plutonism).

Aag

Anorthosite, gabbroic anorthosite and anorthositic gabbro of the Mentor mafic intrusive complex. Dominant phase is saussuritized and locally magmatically brecciated anorthosite containing sub to euhedral, blocky to tabular and alteration-mottled relicts of plagioclase as large as 12 cm, in a mesostasis of finer grained relict plagioclase and chlorite. Mafic minerals include aggregate pseudomorphs of pyroxene now composed of serpentine, talc, and chlorite. Layering is not well developed. Intrusive relationships based on drill core and large samples at the Mentor propane storage facility (149-43-26 SW SW SW NE Polk Co.) indicate that Aag is intruded by, but approximately comagmatic with associated units of Agp.

Adt

to tonalite of the Grygla and Red Lake plutons. Medium grained, quartz-poor, and hornblende-, biotite-, and pyroxene-bearing. Foliation is weak and inferred to be magmatic. The Grygla pluton is bordered by units of gabbroic composition (Agp) that are inferred to be magmatically related.

Agu

Granitoid rocks, undifferentiated, completely inferred from map patterns of gravity and magnetic lows having no apparent internal "stratification". Because of this inference, the possibility exists that some areas mapped Agu may contain metasedimentary rocks in addition to, or instead of granite.

Agr

Granite and granodiorite, massive, locally coarse-grained to pegmatitic, and salmon red in drill core. Most units are inferred from geophysical expression that includes moderate to weak magnetic high, and low gravity signature.

Ahd

Hornblende diorite to granodiorite. Unit north of the Vermilion Fault is inferred to have had relatively uniform high aeromagnetic expression much like the central part of the Bemidji batholith (Agm) prior to dissection by horsetail splays of the fault which caused localized oxidation of primary magnetite and produced the linear map pattern. A compositionally similar unit occurs south of the Grygla pluton.

Agt

Foliated biotite granodiorite to tonalite; locally cut by pegmatitic dikes. Forms parts of large, elliptical to irregular-shaped batholitic complexes that locally have border or internal phases inferred to be Agr or Agu. Typically have low magnetic susceptibility, though locally are magnetically banded. Gravity expression is uniformly low. Differs from unit Agn in lacking gneissic banding, and paragneiss and schist enclaves.

Agn

Gneissic tonalitic rocks, compositionally heterogeneous assemblage of moderately deformed metaplutonic and minor metasedimentary rocks which are cut locally by post-metamorphic granitoid intrusions. Unit north of the Lancaster fault is characterized by sharp and narrow magnetic highs that produce a ptygmatic-looking aeromagnetic map pattern (shown by dashed lines). The precise source of narrow magnetic highs is unknown as none were intersected in drilling; however, mafic enclaves may in part be responsible. Gravity expression is variable, but noticeably higher overall than in the terrane to the south. Drill cores indicate that the dips of foliations are relatively shallow (40-60°). Rock types from drill cores typically are modally banded and include foliated (tectonically?) pyroxene-biotite diorite to monzodiorite, migmatite consisting of garnet-biotite schist and garnet-bearing monzogranite, biotite-hypersthene tonalite to granulite cut by garnet-bearing pegmatite, and foliated biotite tonalite cut by monzogranitic pegmatite and granite. A similar unit labeled Agn lies within the Snake River batholith. That unit has similar gravity expression, but is less magnetic.

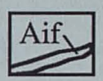
Ags — Gneiss composed of interbanded, migmatized biotite-quartz-plagioclase schist and paragneiss interpreted to be of intermediate tuff and tuffaceous graywacke protolith and orthogneiss of granodioritic composition. Characterized on geophysical maps by magnetic high and a variable low gravity expression.

Adp — Dacitic to latitic porphyry; typically small stocks and many dikes (the latter cannot be shown on map, but are common in drill core, particularly in cores from units Ads and Avs). Texturally and mineralogically identical with clasts in conglomerate in unit Ads.

LATE ARCHEAN SUPRACRUSTAL ROCKS

Ams — Metasedimentary rocks; no drill holes intersected this rock type within the map area; however, based on correlation of the distinctively low magnetic and gravity expression with areas just east of the map, the unit consists of quartz-, plagioclase-, biotite-, garnet-, and hornblende-bearing schists derived from graywacke and rare basaltic sills. Nearest outcrops lie east of Red Lakes (Jirsa and Boerboom, 1990; and Day and others, 1990).

Abs — Biotite-quartz-plagioclase schist similar to unit Ams, but that is inferred to grade into volcanogenic sedimentary rocks and flows of units Avs and Amv.



Narrow magnetic anomalies inferred to be magnetite-quartz iron-formation. May include numerous other associated volcanic and clastic rock types. Some magnetic anomalies labeled Aif may, in fact, be thin, magnetic metabasaltic or metadiabasic units.

Avs — Volcanic and volcaniclastic sedimentary rocks; diverse group composed of dacitic tuff, tuffaceous graywacke, argillite, magnetite-quartz and graphitic sulfidic iron-formation. Thin basaltic units are interbedded locally.

Ads — Dacitic conglomerate, tuff, and graywacke. Extremely diverse sequence dominated by clastic rocks of dacitic provenance including thickly bedded conglomerate containing cobble to pebble size and rounded clasts of aphanitic to coarse-grained and porphyritic dacite. Other clast compositions are basalt, chert, iron-formation, siliceous and graphitic argillite, graywacke, and dacitic tuff. Commonly interbedded and locally intergraded with the same rock types. Stratigraphic younging is consistently northward throughout the sequence. A northward progressive decrease in the thickness and abundance of interbedded metabasalt and a corresponding increase in dacitic clastic detritus occurs. The northernmost part of unit Ads is dominated by fine-grained dacitic tuff, tuffaceous graywacke, and argillite containing thin units of iron-formation.

Amv — Dominantly mafic to intermediate volcanic rocks; minor interflow sedimentary rocks including mafic breccia, mafic to felsic tuff, graywacke, and thin units of magnetite-quartz and graphitic argillaceous iron-formation. See Part 2 for description of alteration and metamorphic grade of supracrustal sequences.

MAP SYMBOLS

———— — — Inferred contact; *all contacts and faults are inferred from aeromagnetic and gravity anomaly data supplemented locally by drill hole information.* Thus, the symbology used reflects only the level of certainty based on the sharpness of anomaly boundaries, solid contact line; moderately sharp boundary, dashed contact; drawn to establish continuity of geologic units.

———— — — Geophysical discontinuity inferred to be a fault. Solid line implies the discontinuity is moderately sharp and well constrained by the geophysical data, dashed line indicates less clarity.

----- Trajectory of foliation inferred from second derivative map of aeromagnetic data. The map delineation of trajectories is restricted largely to supracrustal units and excludes those anomalies inferred to be related to the northwest-trending Proterozoic dikes.

Approximate limit of Paleozoic and Mesozoic strata which overlie the Precambrian bedrock; barb toward the covered area.

Location of drill hole that intersected Precambrian bedrock (see Drill Hole Database Map for hole number and attitude).

Approximate direction of stratigraphic younging interpreted from grading and contact relationships in drill core.

Approximate direction and angle of dip of the main foliation (bedding, cleavage and igneous layering). The short strike direction shown is approximate and is based on aeromagnetic anomalies and locally on electromagnetic conductors from geophysical surveys that were acquired by exploration companies and archived with the Department of Natural Resources Division of Minerals, Hibbing, Minnesota.

Approximate surface trace of steeply dipping fold axis; anticline, syncline

REFERENCES--*See end of Part 2*

Sheet 2-GEOLOGIC MAP OF PHANEROZOIC BEDROCK

by
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June 30, 1993

MAP UNITS

CRETACEOUS STRATA

K

The Cretaceous typically consists of a thin (<20 ft.) basal unit of sandstone or pebbly sandstone overlain by olive gray, gray and green silty claystone with lignite interbeds. Cretaceous outliers are composed of up to 249 feet of mostly fine- to coarse-grained, angular to subangular quartzose sandstone.

JURASSIC?-HALLOCK RED BEDS

Jh

A sequence of extremely heterolithic strata that locally lie above the Winnipeg Formation and below shaley strata of Cretaceous age. The Hallock is as much as 102 feet thick and consists of green, gray, brown and red shale; structureless to mottled white and tan micritic limestone and dolomite; calcareous shale; red, brown and white fine- to coarse-grained sandstone and siltstone; and nodules of chert and possibly gypsum.

ORDOVICIAN-RED RIVER AND WINNIPEG FORMATIONS

Orw

The Winnipeg Formation consists of a thin (<30 feet) basal unit of medium to coarse, rounded quartz sandstone overlain by as much as 150 feet of gray, green, and red shale with sandstone and limestone interbeds. The overlying Red River Formation is as much as 300 feet thick and consists mostly of partly dolomitized, bioclastic limestone to slightly dolomitic, micritic limestone. It is light gray, tan or yellow, and commonly has pink and orange mottles. Thin beds of red and green shale are common.

Sheet 3-DATABASE MAP

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June 30, 1993

MAP SYMBOLS

- • Exploration drill holes and scientific test holes
- ↗ Inclined exploration drill hole showing direction of inclination
- ⊙ Scientific test holes drilled as part of this project
- \+ Water wells

Five or six digit characters next to each of the above symbols are the unique number for each drill hole. Drill hole information can be referenced by this unique number and the location within each county, in the accompanying database.

Sheet 4-BEDROCK TOPOGRAPHY

by

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June 30, 1993

MAP SYMBOLS

- • Drill hole in which bedrock was intersected
- o Drill hole in which bedrock was not intersected; used to determine maximum bedrock elevation

700 — Contour lines connecting points of equal elevation on bedrock surface, contour interval; 50 feet

p300 — Contour lines connecting points of equal elevation on the Precambrian surface beneath Paleozoic and/or Mesozoic bedrock; contour interval, 50 feet

Approximate subsurface boundary between Precambrian rocks and Paleozoic or Mesozoic bedrock

CORRELATION OF MAP UNITS

K **Cretaceous**

Mesozoic

Jh **Jurassic**

Orw **Ordovician**

Paleozoic

Early Proterozoic Dikes

Pn | Pr

Late Archean Intrusive Rocks

Agm | Agp | Agg | Aag | Agt | Ags | Agn | Adp | Adt | Agu | Agr | Ahd

Late Archean Supracrustal Rocks

Quetico Subprovince

Ams

Wawa and Wabigoon Subprovinces

Abs | Aif | Ads | Avs | Amv

MGS OPEN-FILE REPORT 93-1
EXPLANATION-PART 2

BEDROCK GEOLOGY OF NORTHWESTERN MINNESOTA

by

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July 1993

The bedrock geology of the part of northwestern Minnesota shown on map sheets in this Open-File Report includes rocks of Late Archean and Early Proterozoic age, locally overlain by Paleozoic and Mesozoic strata (Figure 1), and by glacial deposits varying in thickness from 180 to 535 feet. Because no exposures of the bedrock exist within the map area, the geology depicted on map sheets and described below is based on the archived records of nearly 400 drill holes, on geophysical maps (for the Precambrian), and on extrapolation from better known and exposed terrane along strike.

PRECAMBRIAN ROCKS

Archean Rocks

The Archean geology of northwestern Minnesota includes parts of the Wabigoon, Quetico, and Wawa subprovinces of the Superior Province. The geology can be further subdivided into six lithotectonic blocks that are delineated on figure 1. The blocks have contrasting lithologic, structural, and metamorphic attributes, and are separated by major fault zones, all of which are described below.

Wabigoon subprovince

The internal part of the subprovince, blocks I, and II, below, is made up of large elliptical to irregular shaped, composite granitoid batholiths separated by subordinate cuspate wedges and septa of supracrustal rocks that are metamorphosed to the middle to upper greenschist facies. Long, sinuous fault zones are common within the segments of supracrustal rocks. The southern part of the subprovince, block III, 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. The 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 a later, largely dextral strike-slip offsets.

Block I. Amphibolite-granulite facies para and orthogneiss (Agn) cut by post-tectonic granitic pegmatite dikes and larger plutons (Agr, Agu, Agm). Orthogneiss is granodioritic to tonalitic in composition. Foliation locally is relatively shallow, on the order of 40-60°. Nearly ptygmatic distribution of narrow magnetic highs is attributed to folded gneissic banding and of 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.*

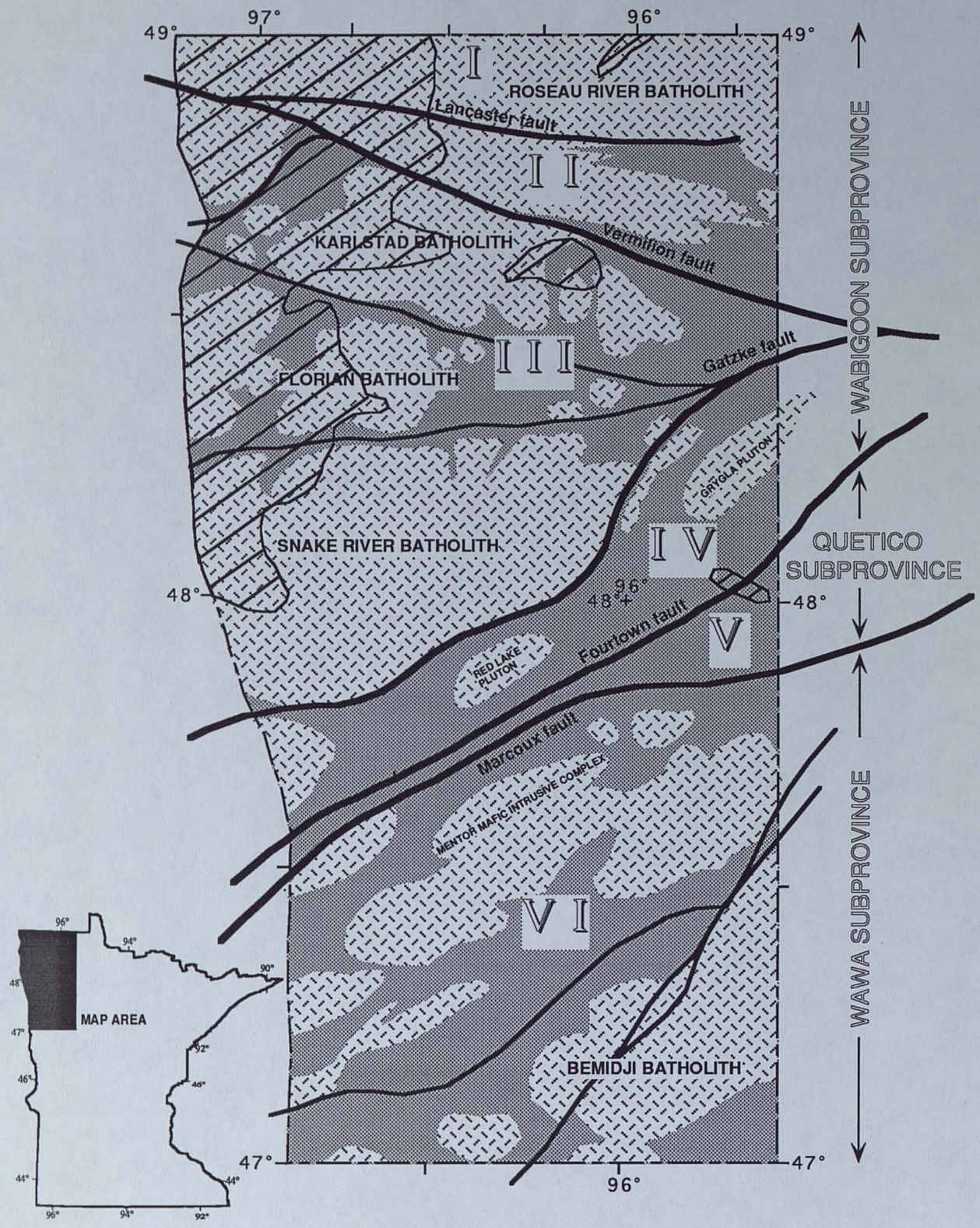

Figure 1. Generalized geologic map of northwestern Minnesota showing the subdivision of Archean subprovinces into lithotectonic blocks described in the text. Proterozoic dikes are omitted. Plutonic rocks are shown by the wisker pattern, supracrustal rocks are shaded. The Precambrian bedrock is overlain by Paleozoic and Mesozoic strata in the cross-hatchured areas..

Block II. Gneissic to strongly foliated and metamorphosed rocks which vary from mostly plutonic (Ags) to the west, to mostly supracrustal (Abs, Avs, Amv) to the east. Metamorphic grade is amphibolite, and schists 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 (inferred from scattered drill core, mostly east of the map area, to be stratigraphically down). Plutonic rocks are strongly but variably magnetic and show a decrease in expression adjacent to inferred fault structures that appear from map distribution to be splays of the Vermilion Fault. Alternatively, these 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_1 cleavage that is parallel to bedding and is cut by S_2 cleavage. 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 grade (chlorite zone) rocks to the south; therefore, presumably the fault had a strong dip-slip, north-side-up sense of displacement, though strike-slip offset 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 (Grygla and Red Lake plutons) occur within the zone. 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.

> ***Fourtown fault;*** *inferred to be the continuation of the Rainy Lake-Seine River fault mapped father to the east (Day et al, 1990), which is displaced about 40 km to the southeast along 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 dip-slip; however, significant right-lateral displacement is recorded from mapping along the correlative Rainy Lake-Seine River 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, those to the east indicate that the rocks are biotite schist of graywacke protolith containing thin interlayered amphibolitic schist. Gravity and magnetic expression are both low, though local banding can be discerned from derivative

aeromagnetic maps. This banding indicates that strata are truncated by the Fourtown fault and possibly also by the southern boundary of the subprovince, the Marcoux fault. Based on the geophysical expression, 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 the nearest drill holes to the southern boundary of the Quetico subprovince, 50 km east of this map sheet, contains biotite, garnet, hornblende, plagioclase, and quartz. The nearest to northern border lie 1-3km to the east of the map and contain approximately the same assemblage.

***Marcoux fault**; a geophysical discontinuity that separates the low gravity and magnetic Quetico subprovince 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 low 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 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 volcaniclastic rocks intruded by large composite granitoid batholiths, and mafic and ultramafic rocks 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 of the latter type of intrusion because it lacks evidence for metamorphism and deformation. The supracrustal rocks are composed of a northern sequence about which little is known: several drill holes intersect 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, to strata dominated by conglomerate of dacitic provenance. 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 intense to pristine. Much of the conglomeratic, central part of the sequence contains well preserved, delicate bedding features. Core samples from holes near large plutons, adjacent to "internal" fault zones, and along the northern edge of the subprovince are more intensely flattened and sheared.

Proterozoic Dikes

Diabasic to gabbroic dikes of the western part of the Kenora-Kabetogama swarm are delineated from detailed aeromagnetic maps, and groups of closely spaced dikes can be discerned from gravity anomaly maps locally. The distribution of dikes shown on the Precambrian geologic map is partly a function of the ability to differentiate them from other

magnetic features on aeromagnetic maps. Note for example that dike segments are more thoroughly delineated within the large plutonic and metasedimentary units having uniformly low magnetic expression. Presumably, many of the dike segments have far greater strike length than is shown. Dikes inferred to have reversed polarity have geophysical expressions that include a magnetic low central part, flanked by narrow highs. Commonly, the west side of the reversed dike has a slightly higher expression than the east. No polarity data have been acquired from dikes inferred to be reversely polarity, though work to that end is in progress. The reversely polarized dikes define an irregular zone in the west-central part of the map sheet. No evidence for reversed dikes exists on aeromagnetic maps of areas to the east, indicating that reversed dikes are relatively restricted to this zone. The scarcity of dikes in the extreme northern and northwestern parts of the map appears to represent a true decrease in the number of dikes in that part of the swarm.

PHANEROZOIC ROCKS

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.

Ordovician

Two Ordovician units, the Winnipeg and Red River Formations, can be distinguished in individual boreholes; however, they are mapped as a single unit in northwest Minnesota because there are not enough drill holes in the appropriate areas to accurately define the subcrop contact between the two units. The Winnipeg Formation unconformably overlies Precambrian rocks. It is as much as 178 feet thick in the extreme northwest corner of the map 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, rounded quartzose sandstone 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 is a partly dolomitized, bioclastic limestone to slightly dolomitic, micritic limestone containing thin beds of red and green shale. It is light gray, yellow, and tan, and commonly has pink and orange mottling. The Red River is nearly 300 feet thick in the extreme northwest part of the map area and it thins to the south and east. It apparently oversteps the Winnipeg Formation near its easternmost subcrop extent and locally may lie directly on Precambrian rocks.

Jurassic

A sequence of extremely heterolithic strata locally lie above the Winnipeg Formation and below shaley strata of Cretaceous age. These heterolithic 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 consists of green, gray, brown, and red shale; structureless to mottled, white to tan micritic limestone and dolomite; calcareous shale; red, brown, and white, fine- to coarse-grained sandstone and siltstone; and 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 south easternmost outlier of Jurassic age marginal marine deposits 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) on the basis 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 kaolinite-rich.

Two holes drilled for this study 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 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 equal to the Red River Formation in nearby drill holes. It has never been recognized directly overlying the Red River Formation. Additionally, although deep drill holes are sparse it appears that the northernmost Hallock strata in Minnesota are surrounded by the Red River Formation at equal or higher elevations. These relationships indicate that the Hallock may be the fill of an internally drained basin, the regolith of weathered Red River Formation, or both. If some of the Hallock is indeed a regolith, 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 in Jurassic and possibly Cretaceous time. As such, it likely includes in-situ weathered Red River Formation; fluvially 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 in this area is as much as 115 feet thick and typically consists 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 Hallock Test Well A (MGS unique no. 224605) indicated an age of Turonian or Conacian. 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.

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SUMMARY OF TEST DRILLING IN NORTHWESTERN MINNESOTA BY THE MINNESOTA GEOLOGICAL SURVEY: 1991-1992

by Mark A. Jirsa and Terrence J. Boerboom

This summary describes scientific test holes that were drilled in parts of Kittson, Marshall, Pennington, Red Lake, Polk, and Roseau Counties during 1991 and 1992 by the Minnesota Geological Survey (MGS). Drilling and subsequent study was funded by the State Legislature under the Mineral Diversification Program administered by the Minerals Coordinating Committee. The logs below describe primarily the bedrock, and are based on cores and locally on the interpretation of downhole geophysical data and cuttings sets. More detailed logs exist of the Quaternary sediment. A thorough description of the Quaternary materials and of bedrock, and the downhole geophysical logs and geochemical data will be published in August as an MGS Information Circular. Note that although the holes are listed in sequence from 1-27, no holes numbered 9, 13, 16, 17, and 18, were drilled. All holes are drilled in vertical orientation.

HOLE NO. NW-1 162-41-15 NE SE NE, Roseau Co. UNIQUE NO. - 247044

Thin sections made at 192.5, 198.7 and 201.5', whole-rock chemistry at 196-198' (Table 1).

LITHOLOGIC LOG

0-183' Quaternary deposits.

183-202' Dioritic to monzodioritic orthogneiss; pinkish-black, medium-grained, lineated, banded hornblende-pyroxene-biotite gneiss cut by weakly foliated, medium- to coarse-grained granite. Cored interval: 192-202'.

PRECAMBRIAN BEDROCK DATA

STRUCTURE

Foliation defined by lineation of hornblende and by banding dips 40° from horizontal (50° to CA).

MINERALIZATION, ALTERATION, METAMORPHISM

No pervasive alteration. Monzodiorite recrystallized to granoblastic texture, granite weakly foliated.

MAGNETIC SUSCEPTIBILITY(10^{-3} CGS)

0.07-0.28, extremely variable magnetite content.

DENSITY

192.5' depth, diorite, 2.84; 198.7' depth, monzodiorite, 2.9; 201.5 depth, granite, 2.63.

COMMENTS

Hole was drilled on the "nose" of fold-like pattern on aeromagnetic map, with the anticipation of supracrustal source rocks. The source of this magnetic high should have produced larger susceptibilities than those listed above. However, this hole, together with others in the terrane north of the Vermilion Fault indicate that even sharp magnetic signatures are to be expected in this plutonic rock-dominated area, and thus are not by themselves an indication of supracrustal rock types.

HOLE NO. NW-2 163-42-8 SE SE SE Roseau Co. UNIQUE NO. - 247041

Thin sections at 302.5' and 306'. No chemical analyses.

LITHOLOGIC LOG

0-185' Quaternary deposits.

185-204' Claystone, silty, gray, Cretaceous

204-252' Sandstone; coarse-grained, well-sorted, subangular, quartz arenite, Cretaceous

252-278' Weathering residuum; green, white, and brown clay, granitic protolith.

278306' Gneiss; medium- to coarse-grained, coarsely banded via alternating layers of garnet-bearing biotite schist restite and granitic bands. Bands are diffuse-bounded. Cored 296-306'.

PRECAMBRIAN BEDROCK DATA

STRUCTURE

Foliation dips 45°

MINERALIZATION, ALTERATION, METAMORPHISM

Pyrite occurs as both 1-2mm euhedra and as finer grained, tectonized-looking folia clots.

MAGNETIC SUSCEPTIBILITY(10^{-3} CGS)

0.00-0.01

DENSITY

302.5', granite, 2.63; 303', garnet-biotite schist, 2.79; 306', quartzo-feldspathic schist, 2.63.

COMMENTS

Hole was drilled to investigate large area of relatively low magnetic and gravity signature, to determine if sedimentary or plutonic rock lithology.

HOLE NO. NW-3 163-48-20 SW SW SW, Kittson Co. UNIQUE NO. - 247048

Thin sections at 542', 544.5' and 551.5'; whole rock geochemistry at 541.5 -542' interval (Table 1).

LITHOLOGIC LOG

0-181' Quaternary deposits.
181-209' Shale and lignite; Cretaceous.
209-350' Dolomitic limestone; yellowish-brown to light gray, fossiliferous, Red River Fm. Ordovician.
350-434' Sandstone and siltstone; yellowish-gray, fine to medium grained, Winnipeg Fm. Ordovician.
434-520' Shale and siltstone; light brown to grayish-green, Winnipeg Fm. Ordovician
520-528' Sandstone; lt. brownish-gray, medium to coarse-grained, Black Island Mbr. Winn. Fm, Ord.
528-536' Weathering residuum; gray clay with residual quartz grains.
536-556' Gneissic quartz syenite to granodiorite, banded pink and black, very coarse-grained, strongly foliated TS @ 542 is biotite granodiorite, TS @ 551.5' is K-rich granite to syenite with moderately recrystallized brittle deformation texture. Cored 540-556'.

PRECAMBRIAN BEDROCK DATA

STRUCTURE

Foliation defined by mineral lineation and modal and phase banding dips 45-70° (45-20° to CA).

MINERALIZATION, ALTERATION, METAMORPHISM

Minor silicification along zones of brittle deformation. Metamorphic fabric seems apparent in some zones, more equivocal in others.

MAGNETIC SUSCEPTIBILITY(10^{-3} CGS)

0.00-0.01

DENSITY

542', granodiorite, 2.7; 544.5', granite, 2.71; 551.5', quartz syenite, 2.64.

COMMENTS

Hole was drilled to investigate narrow, east-trending magnetic high, yet no magnetic material in core: either the source of mag high is very narrow and was therefore missed, or it is "buried" beneath a wedge of this plutonic rock. Latter scenario consistent with relatively shallow dip of foliation.

HOLE NO. NW-4A 161-45-6 SE SE SW,Kittson Co. UNIQUE NO. - 247046

LITHOLOGIC LOG

0-354' Quaternary deposits.
354-355' Clay, pink and sandy, with relict igneous texture.
355-359' Granite, determined from cuttings only, contains feldspar, quartz, and biotite. No core.

PRECAMBRIAN BEDROCK DATA

NO OTHER DATA

COMMENTS

Drilled to determine source of narrow, east-southeast - trending magnetic high along strike with supracrustal rocks to the east.

HOLE NO. NW-4B 161-45-9 SW SW SW, Kittson Co. UNIQUE NO. - 247049

Thin sections at 337.3' and 333.9', whole rock chemistry at 338' in fresh rock, assay at 333.9' in altered shear zone (Tables 1 and 2).

LITHOLOGIC LOG

0-314' Quaternary deposits.
314-324' Weathering residuum; green, white, locally red clay.
324-340' Hornblende granodiorite; grayish pink to light gray, medium- to coarse-grained, weakly banded and moderately well lineated. Contains small, local melanocratic phases. Cored 330 - 340'.

PRECAMBRIAN BEDROCK DATA

STRUCTURE

Foliation defined by melanocratic phases and by less obvious modal banding dips 50° (40° to CA).

MINERALIZATION, ALTERATION, METAMORPHISM

Feldspar is pervasively stained to red color, though some irregular patches are not. Epidote mineralization occurs in and adjacent to vein-like cataclastic zone 333-335.8'. In that zone, hornblende is altered to chlorite, and sphene to leucoxene.

MAGNETIC SUSCEPTIBILITY(10^{-3} CGS)

330-333' 0.19-0.23
333-335.8' 0.01-0.02 zone of alteration, oxidation and mild cataclasis
335.8-340' 0.17-0.21

DENSITY

337.3', granodiorite bordering on tonalite, 2.63.

NW-4B, continued

COMMENTS

Drilled to determine source of narrow, east-southeast - trending magnetic high along strike with supracrustal rocks to the east. Zone of cataclasis appears to be a product of relatively late deformation, and may in fact, be related to main Vermilion Fault which lies to the south. Reduction of magnetic susceptibility in the zone via oxidation(?) may explain numerous other linear magnetic lows in this gravity signature, i.e., it may be a magnetic pluton sliced by numerous faults which created conduits for oxidizing fluids.

HOLE NO. NW-5 161-47-30 NW SW SW, Kittson Co. UNIQUE NO. - 247047

LITHOLOGIC LOG

0-282' Quaternary deposits.
282-440' Shale and dolomitic siltstone; "Hallock Red Beds", Jurassic?
440-453' Siltstone and sandstone; Winnipeg Fm., Ordovician
453-459' Quartz-feldspar-biotite gneiss, fine - to medium-grained. Cuttings only, no core obtained.

PRECAMBRIAN BEDROCK DATA

NO OTHER DATA

COMMENTS

Hole drilled to investigate large area of low gravity and magnetic character.

HOLE NO. NW-6 160-44-6 NW NW Roseau Co. UNIQUE NO. - 247043

Thin sections at 359.9' and 360.3', whole rock chemistry at 359', assay at 360.3' (Tables 1 and 2).

LITHOLOGIC LOG

0-334' Quaternary deposits.
312-345' Weathering residuum; white and green clay.
345-366' Foliated diorite, dark gray, fine- to medium-grained, hornblende (?) altered to chlorite, cut by nebulous dikelets of late-phase pink diorite.

PRECAMBRIAN BEDROCK DATA

STRUCTURE

Foliation defined by mineral banding and lineation and dips 65° (25° to CA). Feldspathic dikelets are locally ptygmatically folded. Local zones are cataclastically deformed, as mortar texture at 360' indicates.

MINERALIZATION, ALTERATION, METAMORPHISM

Pyrite and a bluish-black sulfide occur in minor amounts.

MAGNETIC SUSCEPTIBILITY(10^{-3} CGS)

0.00 throughout.

DENSITY

359.9', diorite, 2.67; 360.3, diorite, 2.66.

COMMENTS

Target for hole was a gravity boundary within a narrow magnetic low; fault-like geophysical characteristics.

HOLE NO. NW-7 159-45-16 SW NE SW, Kittson Co. UNIQUE NO. - 247045

Thin section at 401.5' and 406.3', whole rock at 401.5' (Table 1)

LITHOLOGIC LOG

0-357' Quaternary deposits.
357-389' Weathering residuum; green and white clay.
389-395' Biotite granodiorite gneiss; banded gray to salmon-colored, medium grained, foliated; cut by dikes of pegmatitic to aplitic granite.

PRECAMBRIAN BEDROCK DATA

STRUCTURE

Foliation in granodiorite, defined by mineral fabric and minor modal banding, dips 40-70° (50-20° to core axis). Pegmatite and aplite dikes are mostly discordant to foliation in granodiorite. Minor brittle deformation affected dikes.

MINERALIZATION, ALTERATION, METAMORPHISM

Sulfide minerals are rare except along late, relatively flat-lying fractures accompanied by calcite and chlorite.

MAGNETIC SUSCEPTIBILITY(10^{-3} CGS)

0.00-0.01

DENSITY

401.5', biotite granodiorite, 2.7; 406.3', granite, 2.63.

HOLE NO. NW-8 161-40-12 SE SW SW, Roseau Co. UNIQUE NO. - 247042

Core taken of drift-weathering residuum contact 195-202.5', rotary drilled 202.5-218', bedrock core 218-228'. Thin sections at 223, 223.5, and 227.9'.

LITHOLOGIC LOG

0-202' Quaternary deposits.

202-216' Weathering residuum,

216-228' Biotite schist of probable graywacke protolith cut by deformed granitic and locally pegmatitic dikes. Contacts between granite and schist typically marked by selvage and some feldspathic pods of probable partial melt origin occur. Schist contains possible cordierite, minor garnet.

PRECAMBRIAN BEDROCK DATA

STRUCTURE

Schistosity dips 30-40° (60-50° to CA). Granitic dikes typically infolded into schistosity and locally are ptygmatically folded.

MINERALIZATION, ALTERATION, METAMORPHISM

Schist has a fresh prograde metamorphic texture.

MAGNETIC SUSCEPTIBILITY(10^{-3} CGS)

0.00-0.01, narrow zones in interval 222.5-224' of 0.02

DENSITY

223', schist, 2.72; 223.5, granite, 2.63; 227.9, schist, 2.77.

COMMENTS

Hole was drilled to investigate large area of low magnetic and gravity character that contains weak east-trending magnetic bands, principally to determine if source is sedimentary, as this core implies, or plutonic.

HOLE NO. NW-10 155-41-3 SW SE SE, Marshall Co. UNIQUE NO. - 247050

Thin section at 289', assay at 289' (Table 2).

LITHOLOGIC LOG

0-269' Quaternary deposits.

269-273' Weathered and broken bedrock, black to dark brown, clayey to gritty

273-274' Cuttings of black, fine-grained to aphanitic, cleaved rock; possibly amphibolite.

274-276' Cuttings of white to light green biotite- and plagioclase-bearing rock; possible tonalite.

276-281' Cuttings of fine-grained, magnetic, gray to green to pinkish rock; like core below

281-289.5' Sheared quartz-rich granodiorite; gray to pinkish gray, porphyrytic or porphyroclastic texture. Contains euhedral crystals up to 1mm, and crystal clusters of, plagioclase, very fine-grained dusty oxides in streaky bands which anastamose around feldspar crystals; 1-2mm elliptical clots of recrystallized quartz eyes, stilpnomelane, and garnet in a very fine-grained mortar-textured groundmass of quartz and feldspar. Also contains a small % of subhedral sphene now altered to leucoxene. Foliation-parallel, 1'-thick band of hornblende and chlorite occurs at 284'. Rock may be from a small sill in supracrustal rocks, or the sheared margin of a larger pluton.

PRECAMBRIAN ROCK DATA

STRUCTURE

Foliation and lineation of feldspar phenocrysts dips 80° from horizontal. Fabric appears to be shear-related, yet the possibility exists that it is the result of "magmatic shear".

MINERALIZATION, ALTERATION, METAMORPHISM

Disseminated magnetite, pyrite>> chalcopyrite

MAGNETIC SUSCEPTIBILITY(10^{-3} CGS)

1.8-3.9, Exceptions are oxidized joint at 282' (0.44), and melanocratic band at 284'-285' (0.04-0.45)

DENSITY

289', sheared granodiorite, 2.69.

COMMENTS

Target was narrow, NE-trending magnetic and gravity high adjacent to the non-magnetic Grygla pluton.

HOLE NO. NW-11 156-44-28 SE SE SE, Marshall Co. UNIQUE NO. - 247051

Thin section at 323', whole rock chemistry at 325' (Table 1).

LITHOLOGIC LOG

0-312' Quaternary deposits.

312-330' Multiphase hornblende--biotite monzodiorite to diorite; medium- to coarse-grained, slightly porphyritic, trachytic fabric defined by lineated hornblende. Multiple mesocratic, porphyritic to melanocratic phases.

NW-11, continued

PRECAMBRIAN ROCK DATA

STRUCTURE

Foliation defined by biotite folia and hb aggregates, dips 55-75° from horizontal, and is bent around larger feldspar crystals giving impression of tectonic fabric. However, at 324' this foliation is crossed by mafic phase having border-parallel fabric.

MINERALIZATION, ALTERATION, METAMORPHISM

Veins containing quartz and pyrite dip 45-80° from horizontal. Later veins of calcite-quartz-marcasite dip 5-15° from horizontal. No obvious alteration associated with either vein set. Rock is moderately weathered below 326'. Minor? metamorphism.

MAGNETIC SUSCEPTIBILITY(10^{-3} CGS)

0.01-0.03

DENSITY

323, hornblende tonalite, 2.78.

COMMENTS

Hole was drilled just south of the "Argyle geophysical break" (both gravity and magnetic) which separates metavolcanic rocks to the north from apparent plutonic rocks to the south.

HOLE NO. NW-12 157-44-24 NW SE NW, Marshall Co. UNIQUE NO. - 247052

Thin section at 485' (quartzofeldspathic unit), assay at 480-480.5' (Table 2)

LITHOLOGIC LOG

0-434' Quaternary deposits.

434-465' Weathering residuum (reworked saprolite); greenish clay

465-480' Weathering residuum composed of dk green and rare dk brown clay

480-490' Weathered metabasalt; a two-component rock: 70% is dk green clayey and strongly cleaved chloritic schist of basaltic protolith that locally contains altered epidotized feldspar and flattened epidote-filled amygdules. Cleavage is strongly wrapped around brecciated blocks of second component (30%) that is moderately hard, fine- to medium-grained dacitic sills/dikes.

PRECAMBRIAN ROCK DATA

STRUCTURE

Well-developed but bent cleavage in chloritic schist and the trend of dacitic units dips 65-90° from horizontal. Feldspathic zones lack cleavage as a result of competency contrast with schist. Feldspar zones do contain abundant, closely spaced brittle fractures dipping 45° that nearly everywhere show offset in the reverse sense. Asymmetry in schistosity around feldspathic blocks implies that faults are the brittle manifestation of the deformation that produced cleavage in the schist.

MINERALIZATION, ALTERATION, METAMORPHISM

Pyrite occurs in trace amounts to 2%, as disseminated, mostly oxidized 1-3mm cubes.

MAGNETIC SUSCEPTIBILITY(10^{-3} CGS)

0.01-0.05, average 0.03

DENSITY

485', dacite, 2.59; 437', chlorite schist, 2.74.

COMMENTS

Hole was drilled on broad gravity high inferred to be metavolcanic rocks, adjacent to NE-trending geophysical break inferred to be a fault structure. Both inferences appear to be appropriate.

HOLE NO. NW-14 159-49-22 SE SE SE, Kittson Co. UNIQUE NO. - 247053

Thin section at 437'. No geochemistry.

LITHOLOGIC LOG

0-183' Quaternary deposits.

183-248' Limestone, yellowish-gray, dense, slightly fossiliferous; Red River Formation, Ordovician.

248-261' Limestone, light olive-gray with minor thin shale beds; Red River Formation, Ordovician.

261-296' Shale, pale red to grayish-green, minor limestone; Winnipeg Formation, Ordovician.

296-416' Shale, greenish-gray, and sandstone, yellowish-gray, medium to coarse-grained, minor limestone; Winnipeg Formation, Ordovician

416-428' Weathering residuum; clayey to gritty

428-446' Quartzofeldspathic biotite schist of probable sedimentary protolith, dark gray to dark greenish-gray, strongly foliated, fine - to medium-grained; band of amphibolite. Banded due to variations in biotite and hornblende content, reflects primary bedding. Cored 436-446' interval.

NW-14, continued

PRECAMBRIAN ROCK DATA

STRUCTURE

Well-developed schistosity dips 80-85° from horizontal. Rock is thoroughly recrystallized and no primary textures are recognizable. Rare calcite-chlorite fractures dip 10-25°.

MINERALIZATION, ALTERATION, METAMORPHISM

Trace to 1% pyrite and rare chalcopyrite is disseminated and locally occurs in foliation-parallel, discontinuous bands.

MAGNETIC SUSCEPTIBILITY(10^{-3} CGS)

0.03-0.06

DENSITY

437', biotite schist, 2.74

HOLE NO. NW-15 156-50-35 NW NW NW, Marshall Co. UNIQUE NO. - 247054

Thin section at 496', assay at 496' and 501' (Table 2).

LITHOLOGIC LOG

0-298' Quaternary deposits.

298-319 Shale, black, lignitic to gray, silty, and sandstone (basal 9'), coarse-grained, pebbly; Cretaceous.

319-333' Limestone, yellowish-gray; brownish-red to white shale at base; Hallock Red Beds, Jurassic

333-470' Shale; grayish green to pale red, fossiliferous; Winnipeg Formation, Ordovician.

470-484' Shale, fine-grained and sandstone; Black Island Member, Winnipeg Formation, Ordovician.

484-488' Clay weathering residuum, white, and weathered schist, gray.

488-501' Partially recrystallized tuffaceous wacke (493-496') and darker fine grained tuffaceous argillite (496-501'). Pseudobedding defined by bands of variable hornblende, biotite, quartz and feldspar ratios. Wacke contains some relict feldspar grains and quartz eyes that give impression of a dacitic tuff composition, now mostly recrystallized.

PRECAMBRIAN ROCK DATA

STRUCTURE

Banding dips 60-65° (30-25° to CA). Bulk of fabric appears metamorphic, yet bedding-like structure exists, and grading (based on color more than grain size) implies stratigraphic top down-hole.

MINERALIZATION, ALTERATION, METAMORPHISM

Irregular alteration that produces chlorite from biotite and is darker in color than unaltered rock is folded into cleavage. Pyrite and lesser % chalcopyrite are disseminated . Interval 500-501' contains many brittle qtz veins that have epidotized and pink borders. Quartz veins locally contain pyrite and chalcopyrite. Native copper was reported by site geologist. Assay at 496 in most magnetic zone, that at 501 from altered base of core.

MAGNETIC SUSCEPTIBILITY(10^{-3} CGS)

0.89-4.1, most between 1.1 and 2.0

DENSITY

496', metagraywacke, 2.8.

COMMENTS

Target was narrow zone of moderately high gravity and magnetic signature inferred to be supracrustal rocks.

HOLE NO. NW-19 152-44-9 SE NE NE, Pennington Co. UNIQUE NO. - 247055

Thin section at 494'. No geochemical analyses.

LITHOLOGIC LOG

0-390' Quaternary deposits.

390-430' Weathering residuum; white and green clay.

430-470' Weathering residuum; bluish-gray gritty clay with gritty quartz veins.

470-502' Biotite tonalite; greenish-pink, medium- to coarse-grained, strongly foliated. Most is equigranular and relatively homogeneous, except for 497-500' which is leucocratic and sheared. Semi-brittle cataclasis has produced foliation, which anastamoses around undeformed pods.

PRECAMBRIAN ROCK DATA

STRUCTURE

Shear foliation dips 65-70°, locally abundant mesofractures dip more steeply than shear fabric.

MINERALIZATION, ALTERATION, METAMORPHISM

Irregular patches of alteration exist along the many brittle fault planes which dip more steeply than foliation. In these, feldspar is salmon colored and biotite is altered to chlorite. Very fine-grained pyrite is rare.

NW-19, continued

MAGNETIC SUSCEPTIBILITY(10^{-3} CGS)
0.00-0.01
DENSITY
494', biotite tonalite, 2.6.
COMMENTS
Hole explores large area of gravity and magnetic low.

HOLE NO. NW-20 153-42-15 NW NW NE, Pennington Co. UNIQUE NO. - 247056
Thin section at 527'. No geochemical analyses.
LITHOLOGIC LOG
0-512' Quaternary deposits.
512-529' Metabasalt; dark greenish-gray, amygdaloidal. Upper few feet are broken and slightly weathered, remainder is fresh metabasalt containing 1-3mm black amphibole pseudomorphs of pyroxene (?). Core intersects well developed flow contact composed of upper amygdaloidal part of flow overlain up-core by a flowtop breccia containing amygdaloidal and scoriaceous clasts in dark mafic tuff (now mostly chlorite) matrix.
PRECAMBRIAN ROCK DATA
STRUCTURE
Weak flow banding and flow contact dips 35-45° from horizontal. A flattening fabric preserved in the breccia-interflow and less obviously by elongation of amygdules dips more steeply, 85° from horizontal.
MINERALIZATION, ALTERATION, METAMORPHISM
Amygdules and one thin deformed vein contain calcite, quartz and a pink mineral (feldspar?). Pyrite is rare, locally oxidized, and appears to pre-date tectonic fabric.
MAGNETIC SUSCEPTIBILITY(10^{-3} CGS)
0.05-0.08
DENSITY
527', massive metabasalt, 2.91.

HOLE NO. NW-21 153-40-28 NE NW NW, Pennington Co. UNIQUE NO 247057
No core due to drilling difficulties- thick weathering residuum, crushed casing.
LITHOLOGIC LOG
0-265' Quaternary deposits; may contain siltstone in basal portion
265-305' Quartz sandstone, gray, medium- to coarse-grained. Lignite, shale top 4' of interval; Cretaceous.
305-514' Sandstone, fine- to coarse-grained, thin interbeds of shale; Cretaceous.
514-597' Weathering residuum; white and green clay with relict texture of schist.
597-601' Cuttings of chlorite-quartz-sericite schist; white to light green, very fine-grained.

PRECAMBRIAN ROCK DATA
NO OTHER DATA
COMMENTS
Target lies in narrow magnetic low that appears to mark the break between geophysical signatures typical of the Quetico subprovince metasedimentary rocks to the north, and Wabigoon subprovince volcanic and clastic rock to the south; i.e.., within the "Fourtown fault". Cuttings are compatible with shear zone interpretation.

HOLE NO. NW-22 152-43-13 SE, Pennington Co. UNIQUE NO. - 247058
No core due to shortage of drill rod.
LITHOLOGIC LOG
0-535' Quaternary deposits.
535-821' Weathering residuum of variably weathered chlorite-sericite schist; clayey, white to light green.
PRECAMBRIAN ROCK DATA
NO OTHER DATA
COMMENTS
Target was ovoid pattern of gravity and magnetic high inferred to be either basaltic or mafic intrusive in origin. This material, based on cuttings only, may be talcose and hence from an ultramafic rock, but talc has not been positively identified.

HOLE NO. NW-23 151-45-28 NW SE NE, Red Lake Co. UNIQUE NO. - 247059

Thin section at 537'. No geochemistry.

LITHOLOGIC LOG

0-364' Quaternary deposits.

364-520' Weathering residuum; interlayered brown and green clay with minor white clay.

520-529' Biotite- hornblende tonalite, pinkish- gray, medium- to coarse-grained, locally vaguely porphyritic via euhedral, zoned, saussuritized plagioclase surrounded by slightly smaller mesostasis of equant and subhedral plagioclase, biotite, K-spar and quartz.

PRECAMBRIAN ROCK DATA

STRUCTURE

Typically massive, although a weak, possible primary igneous lineation, plunges steeply at 70° from horizontal. Crushed, protomylonitic texture in thin section, with ribbony quartz. Cut by one 2cm dike of coarse-grained perthite and quartz that dips 55° from horizontal.

MINERALIZATION, ALTERATION, METAMORPHISM

Epidote alteration is pervasive but not intense. Py is very rare.

MAGNETIC SUSCEPTIBILITY(10^{-3} CGS)

0.01 - 0.03, average 0.01.

DENSITY

537', tonalite, 2.76.

COMMENTS

Hole investigates large ovoid of low magnetic and gravity expression.

HOLE NO. NW-24 150-47-12 center, Polk Co. UNIQUE NO. - 247060

Thin section at 371', assay at 371'.

LITHOLOGIC LOG

0-305' Quaternary deposits.

305-367' Weathering residuum, greenish-gray, olive-gray, and minor brown clay, harder near base.

367-380' Chloritic schist of basaltic protolith, dark green, fine-grained, strongly veined and altered by calcite. Contains large number of subrounded, darker colored clots of 1-3cm size that may be basaltic fragments and may indicate basaltic tuff-breccia origin, though shearing precludes positive determination.

PRECAMBRIAN ROCK DATA

STRUCTURE

Strong cleavage and shear-related fabric dips 65-70° from horizontal. Early calcite veins are flattened and sheared into parallelism with cleavage. Later calcite veins dip more gently at 25-50° from horizontal, but are moderately deformed.

MINERALIZATION, ALTERATION, METAMORPHISM

Pervasive calcite veining and spotty alteration locally accompanied by fine-grained pyrite and chalcopyrite. Abundance of chlorite implies low-greenschist facies metamorphism.

MAGNETIC SUSCEPTIBILITY(10^{-3} CGS)

0.03 - 0.07, average 0.03.

DENSITY

371', chlorite schist, 2.83.

COMMENTS

Target of banded magnetic character and generally high gravity, of assumed metavolcanic source.

HOLE NO. NW-25 149-45-28 SW SE SE, Polk Co. UNIQUE NO. - 247334

Thin section at 360', whole rock chemistry at 360' depth.

LITHOLOGIC LOG

0-260' Quaternary deposits.

260-340' Weathered bedrock, mostly green clay but with brown and white mottles.

340-360' Chloritic graywacke and argillite, medium greenish-gray with unit grains of quartz, feldspar, and hornblende, and clasts of felsic tuff, in actinolitic matrix. Probably a reworked crystal-lithic tuff of dacitic to andesitic composition.

PRECAMBRIAN ROCK DATA

STRUCTURE

Foliation defined by bedding-parallel cleavage dips 70° from horizontal. Grading is well preserved and indicates stratigraphic top is up-core. Minor foliation-parallel, pinch and swell quartz veins.

MINERALIZATION, ALTERATION, METAMORPHISM

Light green prismatic actinolite, and epidote after earlier mafics, indicate greenschist-facies metamorphism. Very fine grained pyrite is ubiquitous.

NW-25, continued

MAGNETIC SUSCEPTIBILITY(10^{-3} CGS)

0.01 - 0.03, average 0.02.

DENSITY

360', metagraywacke, 2.75.

COMMENTS

Hole was drilled as a companion to NW-26. See explanation below.

HOLE NO. NW-26 149-45-28 NW NW NW, Polk Co. UNIQUE NO. - 247335

Thin section at 437'.

LITHOLOGIC LOG

0-283' Quaternary deposits.

283-420' Weathered bedrock, green, red, gray, and white, with fresher rock in localized zones.

420-439' Pyrite-ankerite-sericite schist of probable volcanogenic graywacke protolith. Ankerite as oxidized brown clots 1-3mm is uniformly distributed throughout matrix of fine-grained quartz-sericite. Sericite has pale green color in thin section and is probably fuchsite.

PRECAMBRIAN ROCK DATA

STRUCTURE

Strong cleavage/shear fabric affects both carbonate and chlorite fractions, and dips 75° from horizontal. Cut by several foliation-parallel quartz-ankerite veins that both predate and post-date cleavage.

MINERALIZATION, ALTERATION, METAMORPHISM

Carbonate alteration is pervasive as ankerite clots, and large(up to 1.5cm), subhedral and oxidized pyrite is common. Micaceous minerals locally have fuchsitic green color. Very fine grained black mineral may be tourmaline?, but not seen in thin section. Metamorphism to low greenschist facies indicated by chlorite.

MAGNETIC SUSCEPTIBILITY(10^{-3} CGS)

0.00 - 0.01 throughout core.

DENSITY

437', pyrite-ankerite-sericite schist, 2.71

COMMENTS

Hole was drilled as a companion to NW-25 which lies south of the apparent geophysical boundary between a large gravity high inferred to be volcanic rocks of the Wawa subprovince to the south, and the relatively low geophysical signature of the Quetico subprovince to the north (location of hole NW-26). Both cores show evidence for mafic volcanic protolith or source, hole NW-26 differs from core at NW-25 by lacking discernible bedding features, and by being more intensely sheared and ankerite altered.

HOLE NO. NW-27 148-44-16 NE NW NE, Polk Co. UNIQUE NO. - 247336

Thin section at 410', assay at 413' (Table 2).

LITHOLOGIC LOG

0-397' Quaternary deposits.

397-402' Weathered bedrock, green and white clay.

402-418' Intensely altered, light greenish-white, very coarse grained gabbroic anorthosite nearly identical to that in cores L-2, 3, and 4, and samples from Mentor (149-43-26) Contains large (up to 4cm), white-altered cumulate plagioclase crystals of subhedral habit. Mafic minerals are completely altered to chlorite and talc, but appear to be intercumulus.

PRECAMBRIAN ROCK DATA

STRUCTURE

Fabric is generally massive, though difficult to determine due to relict very coarse grain size. Rock is cut by brittle-ductile shear zone dipping 80-85° from horizontal in lower 5' of core, weathering is more pronounced along shear.

MINERALIZATION, ALTERATION, METAMORPHISM

Intense deuteric? alteration of plagioclase to clinozoisite, mafic minerals to chlorite and talc - similar to Mentor body. No obvious regional metamorphic affects, however alteration may obscure any.

MAGNETIC SUSCEPTIBILITY(10^{-3} CGS)

0.00

DENSITY

410', altered anorthosite, 3.05

COMMENTS

Hole was targeted within area of moderate gravity signature and low magnetic character that lies several miles southwest along strike from the Mentor site.

1991-1992 NW MINNESOTA DRILLING
LOGISTICAL SUMMARY

PROJECT TOTALS	FEET	
Rotary drilling	9672.5'	
Core	197.5'	19 of 23 holes were cored (=82.6%)
Casing lost	932'	Casing loss as % of total depth=9.6%
Depth drilled	9870'	

Total number of holes	23	
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	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'

(Deepest holes are #22, #3, #21, #20, #5, #15. One of the shallowest drift holes is #14 which lies in the northwestern part of area. Deepest drift occurs SE of Thief River Falls.)

Thickness of weathering residuum	0-->286'(#22)	39.7'

NUMBER OF HOLES THAT INTERSECTED:		
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	(lacking residuum=#1, #4A, #5, #7, #8, #11, #20)
Precambrian rocks	23	

Assay results from Northwestern Minnesota Drilling Project, by Activation Laboratories, Inc.

Element	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	<5	<5	<2	410	<1	<1	<5	<10	<2	3.41	19	<1	<5	<5	30700	<50	280	<30	
NW-12-480	51	<5	4	510	<1	<1	14	10	<2	5.47	3	<1	<5	<5	4130	56	50	34	
NW-15-496	<5	<5	<2	180	<1	4	20	80	<2	4.57	3	<1	<5	<5	22500	120	100	37	
NW-15-501	<5	<5	<2	280	3	4	13	81	<2	3.26	3	<1	<5	<5	26000	<50	64	33	
NW-24-371	7	<5	10	120	<1	6	36	82	<2	10.8	1	<1	<5	<5	5660	<50	104	<30	
NW-25-360	13	<5	7	480	<1	2	23	180	3	5.1	4	<1	<5	<5	17800	<50	96	53	
NW-26-436	<5	<5	39	280	<1	2	21	160	<2	4.77	3	<1	<5	<5	11200	89	80	42	
NW-27-413	<5	<5	<2	140	<1	7	7	31	<2	1.52	<1	<1	<5	<5	14500	74	<50	<30	
HA-01.C	<5	<5	<2	510	2	2	21	270	3	5.3	5	<1	<5	<5	16100	70	117	80	
HA-05.A	<5	<5	52	<100	<1	13	<5	31	<2	8.05	1	<1	<5	<5	1460	<50	<50	<30	
C.284	<5	<5	<2	1200	3	<1	7	<10	<2	1.83	4	<1	<5	<5	38100	<50	<50	110	
RRVD-28-386	45	<5	27	560	<1	<1	12	78	<2	3.04	3	<1	<5	7	1290	<50	<50	64	
SD-5	8	<5	<2	<100	<1	5	84	38	<2	5.38	1	<1	<5	<5	8290	<50	73	<30	
Element	SB	SC	SE	SN	SR	TA	TH	U	W		LA	CE	ND	SM	EU	TB	YB	LU	Mass
Units	PPM	PPM	PPM	%	%	PPM	PPM	PPM	PPM		PPM	PPM	PPM	PPM	PPM	PPM	PPM	PPM	g
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	0
NW-10-289	<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	30.8
NW-12-480	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	33.9
NW-15-496	<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	34
NW-15-501	<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	34.1
NW-24-371	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	35.2
NW-25-360	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	27.8
NW-26-436	<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	27.3
NW-27-413	<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	31
HA-01.C	<0.2	16	<5	0	0.08	<1	9.1	2.2	<4		22	39	13	2.8	1	<0.5	1.72	0.27	35
HA-05.A	11	8	<5	0	0.31	<1	1.8	0.8	<4		18	30	13	1.9	0.9	<0.5	0.93	0.14	49.5
C.284	<0.2	3.1	<5	0	0.05	<1	8.5	2	<4		44	77	27	4.1	1.5	<0.5	1.62	0.26	29.3
RRVD-28-386	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	31.6
SD-5	<0.2	13	5	0	0.05	<1	<0.5	<0.5	<4		3	8	5	1.3	0.4	<0.5	1.6	0.28	28.5

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Major and minor-element geochemistry from Northwestern Minnesota Drilling Project, X-Ray Assay Laboratories, Inc.

Sample	SiO2	Al2O3	CaO	MgO	FeO	Fe2O3t	Na2O	K2O	TiO2	MnO	P2O5	LOI	Sum wt. %	Fe2O3calc.									
NW-1-196	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	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	67.6	16.2	2.95	1.15	0.1	2.38	5.30	3.08	0.322	0.04	0.11	0.90	100.3	1.49									
NW-6-360	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	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	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	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	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-25-359	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-76-374	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	Au	Be	B	Sc	V	Cr	Co	Ni	Cu	Zn	Ge	As	Se	Br	Ba	Rb	Sr	Y	Zr	Nb	Mo	Ag	Cd
NW-1-196	<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	<.1	<1
NW-3-542	<2	4	39	2.2	24	8.5	4.3	8	9.4	16.5	<10	<1	<1	10.0	1030	110	757	11	890	18	<2	<.1	<1
NW-4-338	<2	4	66	3.3	39	11.0	6.3	7	11.6	39.3	<10	<1	<1	4.7	1190	40	1110	<10	92	15	<2	<.1	<1
NW-6-360	<2	3	29	7.5	70	29.0	17.0	44	2.8	99.7	<10	1	<1	10.0	72	<10	75	<10	120	13	<2	<.1	<1
NW-7-401.5	5	5	26	1.8	19	10.0	5.2	6	5.8	68.9	<10	<1	<1	2.9	981	230	425	<10	95	21	<2	<.1	<1
NW10-289	<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	<.1	<1
NW-11-325	<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	<.1	<1
NW-20-522	<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	<.1	<1
NW-25-359	<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	<.1	<1
NOR-76-374	<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	<.1	<1
Sample	Sb	Cs		La	Ce	Nd	Sm	Eu	Tb	Yb	Lu		Hf	Ta	W	Ir	Pb	Th	U				
NW-1-196	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	0.2	1.1		318	533	170	23.3	1.64	1.3	0.72	0.06		24.0	<.5	<1	<5	26	130	4.2				
NW-4-338	<.1	0.5		7.8	17	9	1.96	0.57	0.2	0.35	0.05		2.9	<.5	<1	<5	5	2.4	1.4				
NW-6-360	<.1	<.5		13.9	27	11	2.03	0.44	<.1	0.58	0.10		2.7	<.5	<1	<5	<2	2.7	0.6				
NW-7-401.5	0.2	11.3		9.5	19	8	1.69	0.32	0.2	0.56	0.08		2.6	<.5	<1	<5	9	1.7	3.5				
NW10-289	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	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	0.2	<.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-25-359	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-76-374	0.7	0.5		34.9	67	29	5.05	1.21	0.5	0.74	0.10		3.8	<.5	<1	<5	12	6.3	2.3				

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DIGITAL DRILL HOLE DATABASE EXPLANATION

Anthony C. Runkel and Mark A. Jirsa

June 30, 1993

All of the drill holes used to create the maps for this project are herein listed by county and location. Each well is assigned one of three kinds of unique numbers. Six digit unique numbers are from records filed to the Minnesota Department of Health by drillers, or are a unique number assigned by the MGS to a drill hole for which no formal record was filed but a drilling record is archived at MGS. Five digit unique numbers are from abandonment reports submitted to the Minnesota Department of Health and to which a six digit unique number was not assigned. Unique numbers prefixed with a "D" are from a DNR database of exploratory drill holes having no other unique number assignment.

The location of each hole is given in township, range, section, and subsection. The alphabetical listing for subdivision of sections is described in MGS information circulars on scientific drilling. Most wells were located on a 7.5' or 15' quadrangle in the field by an MGS or exploration geologist. The location of drill holes denoted with an asterisk in the subsection column have not been field verified.

Additional information regarding the drill holes used in this database is available from several sources. Water well drill hole records are archived at the Minnesota Geological Survey: most are, or soon will be, incorporated into the County Waterwell Index (CWI) system. Exploration drill hole data are filed with the Minnesota Department of Natural Resources-Minerals Division in Hibbing, Minnesota. More detailed information regarding the holes drilled as part of this project will be published as a Minnesota Geological Survey Information Circular in August, 1993. Scientific test holes with unique numbers from 224269 to 224273 are described in detail in a report by Moore (1979). Several holes from the Moore report which lie in adjacent North Dakota near the Minnesota border were used in compiling the maps, but are not shown on the database map nor included in the digital database. All other scientific test hole data are archived at MGS.

This database is also available on disk in two d-base files that can be related by a relateid number:
-**NWDHI.DBF** lists the drill hole location and describes the type of available information Holes are sorted in ascending order by township, range, section, subsection
-**NWDINFO.DBF** contains the date drilled, drilling inclination, depth and stratigraphy for each hole. Holes are in ascending numerical order by the relateid number
-

Codes and abbreviations used in database:

Unno=unique number
Co=county
- 14=CLAY
- 35=KITTSON
- 45=MARSHALL
- 54=NORMAN
- 57=PENNINGTON

60=POLK
63=RED LAKE
Type=type of drill hole
SI =SCIENTIFIC INVESTIGATION
EX =EXPORATION
WW=WATER WELL
Name=name of well
Twp=township
Sec=section
Sub=subsection
Quad=quadrangle number (MGS numbering system)
Elev. =elevation
Datacomp= agency that compiled data
Dataprog=project for which data was compiled
Core=core available at DNR or MGS=Y, N=not available
Cuttings = cuttings available at DNR or MGS=Y, N=not available
Bhg=borehole geophysics
Handsmpl=hand sample
Geochem=geochemistry
Geophys=geophysical properties
Quattext=Quaternary textures
Quatgcnt=Quaternary grain count
Geolintrp= initials of geologist that made stratigraphic interpretations
Cwi_wl= stratigraphic information available in MGS county well index =Y, N=not available
Cwi_wc= water chemisty available in MGS county well index= Y, N=not available.
Fieldloc= method used to locate drill hole.
Geocoord= location of drill hole in latitudinal and longitudinal coordinates
Utme= Universal transverse mercator easting coordinate
Utmn= Universal transverse mercator northing coordinate
Utmsone= Universal transverse mercator zone
Relateid=county number and unique number
D2bdrk=depth in feet to bedrock
Frstbdrk=first bedrock type. Stratigraphic codes are those used by the Minnesota Geological Survey (Wahl and Tipping, 1991) (see attached list)
D2pcmb=depth to Precambrian bedrock
Pcrocktype=Precambrian rock types. Lithologic codes are those used by the Minnesota Geological Survey (see attached list) and one code created for this project: PUNK= unknown Precambrian rock;

REFERENCES

Moore, W.L., 1979, A preliminary report on the uranium geology of the Red River Valley drilling project, eastern North Dakota and northwestern Minnesota: U.S. Department of Energy report, Grand Jucntion, Colorado, 292p.

Wahl, T.E., and Tipping, R.G., 1991, Ground-water data management: the county well index: Minnesota Geological Survey handbook.

NORTHWEST DRILLING PROJECT: DRILL HOLE INDEX. 6/30/93

Unno	Co	Type	Name	Twp	Range	Sec	Sub	Quad	Elev	Datacomp	Dataprog	Core	Cuttings	Bhg	Geochem	Geophys	Handsmpl	Quattext	Quatgcnt	Geolintrp	Cwi_wl	Cwi_wc	Fieldloc	Geocoord	Utme	Utmn	Utmzone	Relateid
21735	14	EX	239108/2	141	48	2	DDB	285C	889			Y													0	0	0	1421735
232327	14	EX	SL-1	142	44	29	ADBCBC	284D	1132			Y													0	0	0	14232327
21709	54	EX	239-60/2	143	44	18	ABACDB	284A	1052			Y	Y	Y											0	0	0	5421079
D12734	54	EX	HL-1	143	44	34	ACBDAC	283B	1130			Y													0	0	0	54D12734
21254	54	EX	W-1	143	45	5	BBADDC	284B	930			Y													0	0	0	5421254
23597	54	EX	BCH91-1	143	45	14	BDBCCC	284A	1024			Y													0	0	0	5423597
D12736	54	EX	RK-1	143	45	20	ABCCCB	284B	928			Y													0	0	0	54D12736
23599	54	EX	BE91-1	143	45	29	ACACDD	284B	930			Y													0	0	0	5423599
21257	54	EX	W-1	143	46	12	DDABCD	284B	921			Y													0	0	0	5421257
235774	54	WW		143	46	21	DDCDAB	285A	903																0	0	0	54235774
23600	54	EX	BW91-1	143	46	23	ACBDDC	284B	911			Y													0	0	0	5423600
188575	54	WW		143	47	8	DCDCCA	285B	887																0	0	0	54188575
239253	54	WW		143	47	17	CDADCD	285B	882																0	0	0	54239253
221998	54	WW		143	47	21	CDACDA	285B	886																0	0	0	54221998
219047	54	WW		143	47	31	BBABBC	285B	883																0	0	0	54219047
147204	54	WW		143	48	25	ADADAC	285B	875																0	0	0	54147204
21264	54	EX	E-2	144	44	9	AACCAC	308D	1063			Y													0	0	0	5421264
21259	54	EX	E-1	144	44	9	ADACCC	308D	1060			Y													0	0	0	5421259
107263	54	WW		144	44	11	BAABDD	307C	1095																0	0	0	54107263
107262	54	WW		144	44	11	BABAAB	307C	1095																0	0	0	54107262
107264	54	WW		144	44	11	BBBAAA	307C	1070																0	0	0	54107264
429355	54	WW		144	44	27	CBBABC	308D	1094																0	0	0	54429355
107275	54	WW		144	45	12	CADDAD	308D	997																0	0	0	54107275

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Unno	Co	Type	Name	Twp	Range	Sec	Sub	Quad	Elev	Datacomp	Dataprog	Core	Cuttings	Bhg	Geochem	Geophys	Handsmpl	Quattext	Quatgcnt	Geolintrp	Cwi_wl	Cwi_wc	Fieldloc	Geocoord	Utme	Utmn	Utmzone	Relateid
166507	54	WW		144	45	25	CBAACD	308D	997																0	0	0	54166507
21253	54	EX	K-1	144	46	1	CDCBAB	308C	918			Y													0	0	0	5421253
220489	54	WW		144	46	7	CDDACD	309D	892																0	0	0	54220489
220500	54	WW		144	46	9	CBABAB	309D	903																0	0	0	54220500
220458	54	WW		144	46	16	DAADCB	309D	900																0	0	0	54220458
220487	54	WW		144	46	17	CBBCAB	309D	896																0	0	0	54220487
222030	54	WW		144	46	31	CCDCBC	285A	893																0	0	0	54222030
117138	54	WW		144	47	7	AAAACA	309C	887																0	0	0	54117138
247555	54	WW		144	47	10	DDD*	309D	886																0	0	0	54247555
220502	54	WW		144	47	15	ABDBAA	309D	886																0	0	0	54220502
220485	54	WW		144	47	15	BABABC	309D	886																0	0	0	54220485
166205	54	WW		144	48	7	CBCDAA	310D	867																0	0	0	54166205
166202	54	WW		144	48	16	ACABDA	310D	873																0	0	0	54166202
168259	54	WW		144	48	18	BCBADA	310D	862																0	0	0	54168259
511082	54	WW		144	48	19	DDDAAC	310D	866																0	0	0	54511082
130591	54	WW		144	48	22	ADAAAD	309C	878																0	0	0	54130591
247554	54	WW		144	48	22	CBC*	310D	870																0	0	0	54247554
147208	54	WW		144	48	30	BADBDA	310D	870																0	0	0	54147208
220494	54	WW		144	48	34	BACDDC	285B	869																0	0	0	54220494
220491	54	WW		144	48	34	BADDAB	285B	871																0	0	0	54220491
D12741	54	EX	GD-1	145	43	7	CB*	307B	1142			Y													0	0	0	54D12741
23656	54	EX	NOR-76	145	43	10	CABCDC	307B	1192			Y													0	0	0	5423656
221961	54	WW		145	43	33	DAADAB	307C	1152																0	0	0	54221961

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Unno	Co	Type	Name	Twp	Range	Sec	Sub	Quad	Elev	Datacomp	Dataprog	Core	Cuttings	Bhg	Geochem	Geophys	Handsmpl	Quattext	Quatgcnt	Geolintrp	Cwi_wl	Cwi_wc	Fieldloc	Geocoord	Utme	Utmn	Utmzone	Relateid
23651	54	EX	SP91-1	145	44	13	ABCAAC	307B	1134			Y													0	0	0	5423651
236564	54	EX	ST-2	145	44	15	ACDACB	307B	1106			Y													0	0	0	54236564
236565	54	EX	ST-3	145	44	15	ADDCDD	307B	1112			Y													0	0	0	54236565
236563	54	EX	ST-1	145	44	15	DBBBBD	307B	1101			Y													0	0	0	54236563
23655	54	EX	NOR-58	145	44	18	BCDCBA	308A	1050			Y													0	0	0	5423655
236567	54	EX	GM-1	145	45	8	DACAAB	308B	944			Y													0	0	0	54236567
236568	54	EX	FL-1	145	45	14	BDBADB	308A	1001			Y													0	0	0	54236568
23652	54	EX	JO91-1	145	45	20	ACCBCD	308C	935			Y													0	0	0	5423652
224270	54	EX	RRVD 26	145	47	15	CBBDBA	309C	881			Y	Y	Y											0	0	0	54224270
457601	54	WW		145	47	33	BAABCB	309C	876																0	0	0	54457601
457595	54	WW		145	48	11	DADBBC	309B	870																0	0	0	54457595
221943	54	WW		145	48	19	BDDCAD	310D	860																0	0	0	54221943
221941	54	WW		145	48	33	DDCCAC	310D	873																0	0	0	54221941
23813	54	EX	SH91-1	146	44	32	ABBDCC	308A	1110			Y													0	0	0	5423813
22001	54	EX	GA-2	146	44	36	DCBCBB	307B	1150			Y													0	0	0	5422001
236566	54	EX	GA-1	146	44	36	DDBAAB	307B	1160			Y													0	0	0	54236566
236552	54	WW		146	45	32	ADCDDB	308B	951																0	0	0	54236552
220440	54	WW		146	46	6	DDDCAB	309A	891																0	0	0	54220440
221969	54	WW		146	47	8	CCCDDC	309B	879																0	0	0	54221969
220446	54	WW		146	48	18	DCABBD	310A	865																0	0	0	54220446
478182	54	WW		146	48	33	C*	310A	865																0	0	0	54478182
221037	60	WW		147	40	4	DBDABB	333D	1291																0	0	0	60221037
101770	60	WW		147	42	20	CBACCB	334D	1226																0	0	0	60101770

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Unno	Co	Type	Name	Twp	Range	Sec	Sub	Quad	Elev	Datacomp	Dataprog	Core	Cuttings	Bhg	Geochem	Geophys	Handsmpl	Quattext	Quatgent	Geolintrp	Cwi_wl	Cwi_wc	Fieldloc	Geocoord	Utme	Utmn	Utmzone	Relateid
221582	60	WW		147	44	22	CBDDBA	335D	1063																0	0	0	60221582
221595	60	WW		147	44	29	ADAADB	335D	1083																0	0	0	60221595
221620	60	WW		147	46	16	BCACCC	336D	899																0	0	0	60221620
139839	60	WW		147	46	16	CCDCDA	336D	901																0	0	0	60139839
102635	60	WW		147	46	16	CDDACA	336D	903																0	0	0	60102635
247547	60	WW		147	46	19	D*	336D	900																0	0	0	60247547
215387	60	WW		147	46	21	BBACCB	336D	902																0	0	0	60215387
247546	60	WW		147	46	31	A*	336D	894																0	0	0	60247546
215390	60	WW		147	47	3	BCCBAB	336C	877																0	0	0	60215390
221617	60	WW		147	47	28	DDDAAC	336C	875																0	0	0	60221617
423509	60	WW		147	48	15	DCDABB	337D	864																0	0	0	60423509
221027	60	WW		148	41	16	ACBABA	333B	1235																0	0	0	60221027
221572	60	WW		148	43	36	DBBBBD	334D	1242																0	0	0	60221572
247336	60	SI	NW-27	148	44	16	ABAABB	335A	1149			Y	Y	Y											0	0	0	60247336
D12784	60	EX	P4-B	148	45	19	DB*	335C	937			Y													0	0	0	60D12784
107911	60	WW		148	46	10	BDDCAC	336A	899																0	0	0	60107911
130577	60	WW		148	47	35	BCDDCA	336D	881																0	0	0	60130577
468901	60	WW		148	48	27	AAB*	337D	867																0	0	0	60468901
101787	60	WW		149	39	12	ADCDAA	332A	1132																0	0	0	60101787
247549	60	WW		149	41	33	C*	333B	1200																0	0	0	60247549
D12785	60	EX	L-2	149	43	26	DABBAB	334A	1170			Y													0	0	0	60D12785
D12786	60	EX	L-3	149	43	26	DABBAB	334A	1170			Y													0	0	0	60D12786
D12787	60	EX	L-4	149	43	26	DABBAB	334A	1170			Y													0	0	0	60D12787

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247335	60	SI	NW-26	149	45	28	BBBBBB	335B	949			Y	Y	Y											0	0	0	60247335
247334	60	SI	NW-25	149	45	28	DDCCDD	335B	980			Y	Y	Y											0	0	0	60247334
215385	60	WW		149	46	6	ADDAAB	366D	886																0	0	0	60215385
215382	60	WW		149	46	6	BDADC	366D	883																0	0	0	60215382
107942	60	WW		149	46	7	AAAACD	336A	886																0	0	0	60107942
138859	60	WW		149	46	14	CBBCCA	336A	903																0	0	0	60138859
181708	60	WW		149	46	22	ADDADB	336A	900																0	0	0	60181708
215406	60	WW		149	46	35	BAAACA	336A	903																0	0	0	60215406
221634	60	WW		149	47	1	BAABD	366D	880																0	0	0	60221634
221637	60	WW		149	47	1	CCBABD	336B	874																0	0	0	60221637
221635	60	WW		149	47	1	CCBDDD	336B	876																0	0	0	60221635
166245	60	WW		149	47	4	DDA*	336B	865																0	0	0	60166245
247543	60	WW		149	47	10	D*	336C	870																0	0	0	60247543
221639	60	WW		149	47	11	ADDDAC	336B	875																0	0	0	60221639
244664	60	WW		149	47	13	BCBBBB	336B	872																0	0	0	60244664
215405	60	WW		149	47	14	DDCDAD	336B	870																0	0	0	60215405
107288	60	WW		149	48	24	BBABAD	337A	855																0	0	0	60107288
224271	63	SI	RRVD#28	150	44	10	CCDBD	365D	1051			Y	Y	Y											0	0	0	63224271
158512	63	WW		150	44	14	AAAACD	364C	1068																0	0	0	63158512
125775	60	WW		150	45	5	BDC*	365C	945																0	0	0	60125775
215411	60	WW		150	45	10	CCCDAC	365C	953																0	0	0	60215411
215409	60	WW		150	45	10	CCDCBC	365C	953																0	0	0	60215409
101808	60	WW		150	46	6	CCCDA	366D	895																0	0	0	60101808

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221048	60	WW		150	46	9	ADACAB	366D	937																0	0	0	60221048
215395	60	WW		150	46	18	ACAABB	366D	892																0	0	0	60215395
138889	60	WW		150	46	26	ACCABD	366D	906																0	0	0	60138889
130563	60	WW		150	46	33	AAABAC	366D	899																0	0	0	60130563
102602	60	WW		150	46	34	AACACA	366D	885																0	0	0	60102602
221641	60	WW		150	46	34	ADDCAD	366D	900																0	0	0	60221641
247541	60	WW		150	47	4	C*	366C	875																0	0	0	60247541
247060	60	SI	NW-24	150	47	12	DBCAAD	366D	885			Y	Y	Y											0	0	0	60247060
101829	60	WW		150	47	28	CCDDBC	366C	865																0	0	0	60101829
247542	60	WW		150	47	34	A*	366C	865																0	0	0	60247542
221058	60	WW		150	47	35	DADDC	366C	878																0	0	0	60221058
130571	60	WW		150	48	6	AABDCB	367D	840																0	0	0	60130571
419770	60	WW		150	48	14	DCCACD	367D	856																0	0	0	6019770
247540	60	WW		150	48	22	B*	367D	850																0	0	0	60247540
247539	60	WW		150	48	27	B*	367D	850																0	0	0	60247539
247553	60	WW		150	49	27	DDB*	367C	843																0	0	0	60247553
247550	60	WW		151	39	28	B*	362C	1160																0	0	0	60247550
247523	63	WW		151	40	8	DBD*	363A	1163																0	0	0	63247523
449140	63	WW		151	42	27	DBBABC	364D	1132																0	0	0	63449140
150675	63	WW		151	43	6	DCDDCA	364B	1071																0	0	0	63150675
103102	63	WW		151	44	2	DDDCAB	364B	1054																0	0	0	63103102
125736	63	WW		151	44	7	BBBCAC	365A	1022																0	0	0	63125736
471562	63	WW		151	44	14	CCB*	365A	1030																0	0	0	63471562

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221008	63	WW		151	44	21	BAAADD	365A	1025																0	0	0	63221008
181358	63	WW		151	44	27	DBABCA	365D	1043																0	0	0	63181358
247059	63	SI	NW-23	151	45	28	ADBABB	365C	962			Y	Y	Y											0	0	0	63247059
107290	60	WW		151	46	13	ACCCCC	365B	948																0	0	0	60107290
107289	60	WW		151	46	14	BCDDDD	366A	938																0	0	0	60107289
419760	60	WW		151	46	28	DCDDBD	366D	935																0	0	0	60419760
423520	60	WW		151	49	13	BCCDBD	367B	836																0	0	0	60423520
421631	57	WW		152	43	7	AABAAB	394C	1087																0	0	0	57421631
247058	57	SI	NW-22	152	43	13	DADDDD	364A	1110			Y	Y	Y											0	0	0	57247058
247055	57	SI	NW-19	152	44	9	AADDAA	395D	1090			Y	Y	Y											0	0	0	57247055
247552	63	WW		152	44	32	NO SUB*	365A	1030																0	0	0	63247552
107924	63	WW		152	45	33	ABAABB	365B	994																0	0	0	63107924
103101	63	WW		152	45	34	AABBDC	365B	1001																0	0	0	63103101
125739	60	WW		152	46	11	BCCCCC	396C	955																0	0	0	60125739
247548	60	WW		152	46	12	B*	396D	980																0	0	0	60247548
247545	60	WW		152	46	17	E1/2*	366A	925																0	0	0	60247545
101703	60	WW		152	46	21	CBCCBA	366A	927																0	0	0	60101703
107922	60	WW		152	47	8	DCCCDB	366B	866																0	0	0	60107922
220354	60	WW		152	47	23	ADCADD	366B	891																0	0	0	60220354
101830	60	WW		152	47	35	BABACC	366B	852																0	0	0	60101830
247537	60	WW		152	49	5	A*	397C	830																0	0	0	06247537
224269	60	SI	RRVD-27	152	49	11	DCDAAD	367B	831			Y	Y	Y											0	0	0	60224269
247538	60	WW		152	49	28	E1/2*	367B	833																0	0	0	60247538

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132772	57	WW		153	39	29	DAAABB	392C	1166																0	0	0	57132772
247519	57	WW		153	40	8	DDA*	393D	1167																0	0	0	57247519
247057	57	SI	NW-21	153	40	28	BBABAB	393D	1154			Y	Y	Y											0	0	0	57247057
247056	57	SI	NW-20	153	42	15	ABBABB	394D	1132			Y	Y	Y											0	0	0	57247056
139823	57	WW		153	42	20	ABCABC	394D	1132																0	0	0	57139823
247520	57	ww		153	44	8	DCCC	395d	1107																0	0	0	68247520
463917	57	WW		153	44	11	CCCACB	395D	1129																0	0	0	57463917
158510	57	WW		153	44	23	DDDBAA	395D	1101																0	0	0	57158510
128436	57	WW		153	45	12	CBCDBC	395C	1058																0	0	0	57128436
219602	57	WW		153	45	31	DABADC	395C	1000																0	0	0	57219602
247522	60	WW		153	47	8	BDB*	396C	860																0	0	0	60247522
215377	60	WW		153	47	21	CBBCCC	396C	867																0	0	0	60215377
107928	60	WW		153	47	24	CDCCCA	396C	892																0	0	0	60107928
247544	60	WW		153	47	27	N1/2*	396C	875																0	0	0	60247544
105633	57	WW		154	42	27	BACADC	394A	1147																0	0	0	57105633
158514	57	WW		154	43	31	BAADAB	394C	1127																0	0	0	57158514
247521	57	WW		154	43	34	BBB*	394C	1130																0	0	0	5747521
105671	57	WW		154	44	27	BACADC	395A	1140																0	0	0	57105671
181712	57	WW		154	45	14	DAAACC	395B	1170																0	0	0	57181712
219926	45	SI	J3	154	46	2	BBAACB	396A	955				Y	Y											0	0	0	45219926
162389	45	WW		154	47	9	ABBABD	396B	883																0	0	0	45162389
439551	60	WW		154	47	29	AAABDD	396B	867																0	0	0	60439551
409814	60	WW		154	47	30	CDD*	397D	856																0	0	0	60409814

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Unno	Co	Type	Name	Twp	Range	Sec	Sub	Quad	Elev	Datacomp	Dataprog	Core	Cuttings	Bhg	Geochem	Geophys	Handsmpl	Quattext	Quatgcnt	Geolintrp	Cwi_wl	Cwi_wc	Fieldloc	Geocoord	Utme	Utmn	Utmzone	Relateid
502807	60	WW		154	47	36	BACAAA	396C	903																0	0	0	60502807
219996	45	SI	W-1	154	48	1	BBBCCB	397A	851				Y	Y											0	0	0	45219996
D12496	45	EX	STAR-3	155	39	1	CDDDAD	413D	1182			Y													0	0	0	45D12496
D12497	45	EX	STAR-2	155	39	4	BBBBBD	413C	1172			Y													0	0	0	45D12497
247502	45	WW		155	39	28	BBD*	392B	1172																0	0	0	45247502
244858	45	SI	MPL3-B-2	155	39	34	AAAAAC	392B	1173			Y	Y												0	0	0	45244858
419778	45	WW		155	40	20	DAA*	393A	1157																0	0	0	45419778
247050	45	SI	NW-10	155	41	3	DDCCDD	414C	1149			Y	Y	Y											0	0	0	45247050
D12498	45	EX	STAR-1	155	41	5	BAACAD	414C	1142			Y													0	0	0	45D12498
219615	45	WW		155	41	34	DDADCD	393B	1157																0	0	0	45219615
219930	45	SI	J6A	155	44	20	DAAACD	395A	1123				Y	Y											0	0	0	45219930
174747	45	WW		155	44	34	DDADCD	395A	1135																0	0	0	45174747
219921	45	SI	H4A	155	45	2	CCCACC	416C	1070				Y	Y											0	0	0	45219921
181745	45	WW		155	46	10	BDD*	417D	955																0	0	0	45181745
219927	45	WW		155	46	31	CDAABB	396A	916																0	0	0	45219927
219332	45	SI	H2	155	47	11	AAAABA	417C	904				Y	Y											0	0	0	45219332
236526	45	WW		155	47	19	AAADBD	396B	872																0	0	0	45236526
219929	45	SI	J6	155	47	34	CDDDBB	396B	888				Y	Y											0	0	0	45219929
247504	45	WW		155	48	2	BDC*	418D	847																0	0	0	45247504
21737	45	EX	238105/2RI	155	48	10	BCABDA	418D	840			Y													0	0	0	4521737
247503	45	WW		155	48	34	CDA*	397A	840																0	0	0	45247503
247551	45	WW		155	48	36	NO SUB	397A	855																0	0	0	45247551
247505	45	WW		155	49	31	DD*	398A	811																0	0	0	45247505

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Unno	Co	Type	Name	Twp	Range	Sec	Sub	Quad	Elev	Datacomp	Dataprog	Core	Cuttings	Bhg	Geochem	Geophys	Handsmpl	Quattext	Quatgcnt	Geolintrp	Cwi_wl	Cwi_wc	Fieldloc	Geocoord	Utme	Utmn	Utmzone	Relateid
219924	45	SI	J1	155	49	36	CCDDAC	397B	824				Y	Y											0	0	0	45219924
125714	45	WW		156	40	11	BCDDDC	414D	1163																0	0	0	45125714
400235	45	WW		156	40	35	BAC*	414D	1162																0	0	0	45400235
D12566	45	EX	GS-1	156	42	31	ACAAAA	415D	1182			Y													0	0	0	45D12566
219912	45	SI	G5	156	43	4	DCCCDB	415C	1141				Y	Y											0	0	0	45219912
219913	45	SI	G6	156	43	11	ADADBA	415C	1148				Y	Y											0	0	0	45219913
242963	45	SI	H3	156	43	28	CCCDBD	415C	1149				Y	Y											0	0	0	45242963
21736	45	EX	238109/2RT	156	43	35	DDBABB	415C	1140			Y													0	0	0	4521736
219914	45	SI	G7	156	44	1	DDCDAD	415C	1129				Y	Y											0	0	0	45219914
247506	45	WW		156	44	5	DDA*	416D	1097																0	0	0	45247506
105683	45	WW		156	44	5	DDCDD	416D	1096																0	0	0	45105683
247051	45	SI	NW-11	156	44	28	DDDADD	416D	1119			Y	Y	Y											0	0	0	45247051
219922	45	SI	H5	156	44	32	ACBCBA	416C	1102				Y	Y											0	0	0	45219922
438049	45	WW		156	44	35	CCCCBA	416D	1126																0	0	0	45438049
219911	45	SI	G4	156	45	1	DDCCDA	416D	1084				Y	Y											0	0	0	45219911
219910	45	SI	G3	156	45	4	CDCCBC	416C	1056				Y	Y											0	0	0	45219910
247508	45	WW		156	45	13	AAC*	416D	1082																0	0	0	45247508
247507	45	WW		156	45	22	DDB*	416C	1062																0	0	0	45247507
219936	45	SI	G8	156	46	2	CDCCBD	417D	1011				Y	Y											0	0	0	45219936
219908	45	SI	G1	156	47	8	CDDCDA	417C	873				Y	Y											0	0	0	45219908
219915	45	SI	G9	156	47	13	BBBDBA	417C	913				Y	Y											0	0	0	45219915
215373	45	WW		156	47	31	CBBDBC	418D	871																0	0	0	45215373
219909	45	SI	G2	156	48	15	AABAAB	418D	848				Y	Y											0	0	0	45219909

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Unno	Co	Type	Name	Twp	Range	Sec	Sub	Quad	Elev	Datacomp	Dataprog	Core	Cuttings	Bhg	Geochem	Geophys	Handsmpl	Quattext	Quatgcnt	Geolintrp	Cwi_wl	Cwi_wc	Fieldloc	Geocoord	Utme	Utmn	Utmzone	Relateid
247509	45	WW		156	48	22	CAA*	418D	847																0	0	0	45247509
244718	45	WW		156	49	4	BCBDDA	418C	808																0	0	0	45244718
247054	45	SI	NW-15	156	50	35	BBBBAB	419D	800			Y	Y	Y											0	0	0	45247054
21040	45	EX	MR2-84	157	39	2	CB*	413B	1180			Y													0	0	0	4521040
21039	45	EX	MR1-84	157	39	2	CCB*	413B	1180			Y													0	0	0	4521039
D12585	45	EX	G1	157	39	3	CACCBD	413B	1177			Y													0	0	0	45D12585
128419	45	WW		157	39	19	CADDBA	413B	1177																0	0	0	45128419
247510	45	WW		157	40	5	CDB*	414A	1177																0	0	0	45247510
132735	45	WW		157	40	10	CCCBAA	414A	1177																0	0	0	45132735
244852	45		MPL-2	157	41	24	CADCBC	414A	1147			Y	Y												0	0	0	45244852
219904	45	SI	F7	157	44	11	BAABBC	416A	1135				Y	Y											0	0	0	45219904
247052	45	SI	NW-12	157	44	24	BDBC	416A	1144			Y	Y	Y											0	0	0	45247052
219902	45	SI	F5	157	45	4	DDADAA	416B	1071				Y	Y											0	0	0	45219902
455443	45	WW		157	45	30	CCA*	417A	1030																0	0	0	45455443
101657	45	WW		157	47	35	CCCBC	417C	890																0	0	0	45101657
219898	45	SI	F1	157	48	4	BCCCCC	418A	832				Y	Y											0	0	0	45219898
247511	45	WW		157	48	24	ACA*	418A	852																0	0	0	45247511
244721	45	WW		157	48	27	BDCCCD	418A	844																0	0	0	45244721
247513	45	WW		157	50	3	AAC*	419A	792																0	0	0	45247513
247512	45	WW		157	50	12	DBB*	419A	797																0	0	0	45247512
D12599	45	EX	M1	158	40	15	DBBBBB	433D	1195			Y													0	0	0	45D12599
219641	45	WW		158	41	20	DDACAA	433C	1167																0	0	0	45219641
101785	45	WW		158	41	34	DCB*	414B	1170																0	0	0	45101785

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Unno	Co	Type	Name	Twp	Range	Sec	Sub	Quad	Elev	Datacomp	Dataprog	Core	Cuttings	Bhg	Geochem	Geophys	Handsmpl	Quattext	Quatgcnt	Geolintrp	Cwi_wl	Cwi_wc	Fieldloc	Geocoord	Utme	Utmn	Utmzone	Relateid
128413	45	WW		158	42	25	DAABDD	414B	1183																0	0	0	45128413
22011	45	EX	SC-1	158	43	2	DABDBC	434C	1130			Y													0	0	0	4522011
22012	45	EX	SC-2	158	43	5	CCDBBC	434C	1120			Y													0	0	0	4522012
22013	45	EX	SC-3	158	43	9	BDBBBD	434C	1130			Y													0	0	0	4522013
447052	45	EX	SC-4	158	43	10	CDCCCC	434C	1130			Y													0	0	0	45447052
244847	45	SI	MPL-1-B-2	158	44	33	ABBBAB	416A	1099				Y												0	0	0	45244847
215363	45	WW		158	45	22	BDDAD	416B	1055																0	0	0	45215363
247518	45	WW		158	47	6	CADA*	437D	862																0	0	0	45247518
224273	45	SI	RRVD#30	158	47	23	CABBBB	417B	906			Y	Y	Y											0	0	0	45224273
247517	45	WW		158	47	31	ADB*	418A	857																0	0	0	45247517
247516	45	WW		158	47	32	CBD*	418A	862																0	0	0	45247516
247515	45	WW		158	49	32	BDD*	419A	802																0	0	0	45247515
219652	45	SI	WELL B	158	50	21	DAAAAD	419A	790			Y	Y	Y											0	0	0	45219652
247514	45	WW		158	50	27	DBB*	419A	797																0	0	0	45247514
147726	68	WW		159	39	4	BACCAC	432C	1133																0	0	0	68147726
219716	68	WW		159	39	20	DADDBA	432C	1162																0	0	0	68219716
21041	68	EX	W1-84	159	41	36	ADCCBA	433D	1175			Y													0	0	0	6821041
181810	68	WW		159	43	6	AAAACC	434B	1067																0	0	0	68181810
219889	68	SI	E5	159	43	29	BBDBCA	434C	1103				Y	Y											0	0	0	68219889
185204	68	WW		159	44	4	BCCCDB	435D	1027																0	0	0	68185204
132151	68	WW		159	44	12	ABCDD	435D	1072																0	0	0	68132151
247524	68	WW		159	44	14	AAC*	435D	1082																0	0	0	68247524
247525	68	WW		159	44	17	BDD*	435D	1072																0	0	0	68247525

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Unno	Co	Type	Name	Twp	Range	Sec	Sub	Quad	Elev	Datacomp	Dataprog	Core	Cuttings	Bhg	Geochem	Geophys	Handsmpl	Quattext	Quatgcnt	Geolintrp	Cwi_wl	Cwi_wc	Fieldloc	Geocoord	Utme	Utmn	Utmzone	Relateid
219890	68	SI	E6	159	44	20	CAAAAA	435D	1077				Y	Y											0	0	0	68219890
219888	68	SI	E4A	159	44	23	DBCACB	435D	1091				Y	Y											0	0	0	68219888
132157	68	WW		159	44	32	BCCBD	435D	1081																0	0	0	68132157
138900	35	WW		159	45	8	CBDCB	435C	1047																0	0	0	35138900
247045	35	SI	NW-7	159	45	16	CACBCC	435C	1055			Y	Y	Y											0	0	0	35247045
502805	35	WW		159	45	18	BABCBD	436C	1040																0	0	0	35502805
219891	35	SI	E7	159	45	23	CDDCDD	435C	1059				Y	Y											0	0	0	35219891
215221	35	WW		159	46	24	DCDABA	436D	1047																0	0	0	35215221
215219	35	WW		159	46	26	BABAC	436D	1013																0	0	0	35215219
219892	35	SI	E8	159	46	30	ABBBBC	436C	970				Y	Y											0	0	0	35219892
219659	35	WW		159	47	8	BBADAB	437D	883																0	0	0	35219659
219886	35	SI	E2	159	47	27	AAAAAA	436C	914				Y	Y											0	0	0	35219886
219885	35	SI	E1	159	48	21	CCDDCC	437D	835				Y	Y											0	0	0	35219885
219896	35	SI	E13	159	48	25	DDADAA	437D	865				Y	Y											0	0	0	35219896
247053	35	SI	NW-14	159	49	22	DDDD	437C	814			Y	Y	Y											0	0	0	35247053
247499	35	WW	-	159	50	10	CCA*	438D	800																0	0	0	35247499
219729	68	WW		160	39	2	BDDAAC	432B	1100																0	0	0	68219729
247526	68	WW		160	39	7	CCD*	432B	1097																0	0	0	68247526
147708	68	WW		160	39	16	AABBDA	432B	1107																0	0	0	68147708
247527	68	WW		160	39	18	ADB*	432B	1097																0	0	0	68247527
111813	68	WW		160	40	1	CAABBD	432B	1088																0	0	0	68111813
418288	68	WW		160	40	22	BBB*	433A	1131																0	0	0	68418288
20488	68	EX	YGZ-1	160	40	31	CDCCAA	433B	1150			Y													0	0	0	6820488

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Unno	Co	Type	Name	Twp	Range	Sec	Sub	Quad	Elev	Datacomp	Dataprog	Core	Cuttings	Bhg	Geochem	Geophys	Handsmpl	Quattext	Quatgcnt	Geolintrp	Cwi_wl	Cwi_wc	Fieldloc	Geocoord	Utme	Utmn	Utmzone	Relateid
247528	68	WW		160	41	6	DDBBBB	433B	1102																0	0	0	68247528
21569	68	EX	R-3	160	41	34	AABADA	433B	1138			Y													0	0	0	6821569
21265	68	EX	R-1	160	41	34	AACBAB	433B	1138			Y													0	0	0	6821265
215183	68	WW		160	42	22	ADADAD	434A	1104																0	0	0	68215183
224272	68	SI	RRVD#29	160	42	32	ABDACD	434A	1112			Y	Y	Y											0	0	0	68224272
219833	68	SI	C9	160	43	1	BBBBBA	434B	1070				Y	Y											0	0	0	68219833
215203	68	WW		160	43	10	CADDDB	434B	1058																0	0	0	68215203
467904	68	WW		160	43	15	CBB*	434B	1070																0	0	0	68467904
21261	68	EX	GB-1	160	43	24	ABDDBA	434B	1071			Y													0	0	0	6821261
219859	68	SI	D5	160	43	33	DCDDCD	434B	1076				Y	Y											0	0	0	68219859
430983	68	WW		160	44	4	BCBCDB	435A	1030																0	0	0	68430983
247043	68	SI	NW-6	160	44	6	BBABBC	435B	1025			Y	Y	Y											0	0	0	68247043
219860	68	SI	D6	160	44	34	BBBBBA	435A	1051				Y	Y											0	0	0	68219860
219857	35	SI	D3	160	45	28	CADADB	435B	1037				Y	Y											0	0	0	35219857
219863	35	SI	D8	160	45	36	AABDBC	435B	1055				Y	Y											0	0	0	35219863
219834	35	SI	C10	160	46	2	BABBAA	436A	1008				Y	Y											0	0	0	35219834
153716	35	WW		160	46	14	ACCDAA	436D	1013																0	0	0	35153716
219869	35	SI	D14	160	46	21	CCDDCC	436A	999				Y	Y											0	0	0	35219869
219858	35	SI	D4	160	46	25	BBCCAC	436A	1010				Y	Y											0	0	0	35219858
215214	35	WW		160	47	22	CCCAD	436C	922																0	0	0	35215214
219856	35	SI	D2	160	47	32	BAAAB	436B	892				Y	Y											0	0	0	35219856
219864	35	SI	D9	160	48	28	DCDCDA	437A	841				Y	Y											0	0	0	35219864
219855	35	SI	D1	160	48	30	CCDCDD	437B	826				Y	Y											0	0	0	35219855

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Unno	Co	Type	Name	Twp	Range	Sec	Sub	Quad	Elev	Datacomp	Dataprog	Core	Cuttings	Bhg	Geochem	Geophys	Handsmpl	Quattext	Quatgcnt	Geolintrp	Cwi_wl	Cwi_wc	Fieldloc	Geocoord	Utme	Utmn	Utmzone	Relateid
219828	35	SI	C4	160	49	2	DAADDB	437B	819				Y	Y											0	0	0	35219828
247501	35	WW	-	160	50	11	ABD*	438A	792																0	0	0	3247501
220018	68	WW		161	39	1	AAAABC	443D	1099																0	0	0	68220018
220019	68	WW		161	39	1	AAAABC	443D	1099																0	0	0	68220019
220045	68	WW		161	39	27	AACBDA	432B	1085																0	0	0	68220045
247042	68	SI	NW-8	161	40	12	CCDDCC	444D	1060			Y	Y	Y											0	0	0	68247042
181785	68	WW		161	40	22	BAD*	444D	1082																0	0	0	68181785
147706	68	WW		161	41	36	BCCBDC	433B	1117																0	0	0	68147706
219832	68	SI	C8	161	43	33	BABAAC	434B	1037				Y	Y											0	0	0	68219832
219830	68	SI	C6	161	44	30	CBCCCB	435B	1015				Y	Y											0	0	0	68219830
247046	35	SI	NW-4A	161	45	6	CDDAD	447D	1009			Y	Y	Y											0	0	0	35247046
247049	35	SI	NW-4B	161	45	9	CCCCCB	446C	1008			Y	Y	Y											0	0	0	35247049
219835	35	SI	C11	161	45	31	DDCCDD	436A	1013				Y	Y											0	0	0	35219835
219829	35	SI	C5	161	45	33	DDDDDD	435B	1019				Y	Y											0	0	0	35219829
219668	35	WW		161	46	24	BACCDD	447D	1007				Y												0	0	0	35219668
219992	35	SI	LAKE BRONSON #1	161	46	32	AAADBB	436A	983				Y	Y											0	0	0	35219992
219825	35	SI	C1	161	47	26	DCCDCA	436B	937				Y	Y											0	0	0	35219825
247047	35	SI	NW-5	161	47	30	CCBBBB	437A	872			Y	Y	Y											0	0	0	35247047
219826	35	SI	C2	161	47	33	BBAABA	437A	909				Y	Y											0	0	0	35219826
219827	35	SI	C3	161	48	36	BBBCBB	437A	864				Y	Y											0	0	0	35219827
219999	35	SI		161	49	13	AAAADB	448C	810																0	0	0	35219999
224605	35	SI	WELL A	161	49	13	BCDDDC	448C	805			Y	Y	Y											0	0	0	35224605
220188	68	WW		162	39	23	DDDDCC	443C	1069																0	0	0	68220188

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Unno	Co	Type	Name	Twp	Range	Sec	Sub	Quad	Elev	Datacomp	Dataprog	Core	Cuttings	Bhg	Geochem	Geophys	Handsmpl	Quattext	Quatgcnt	Geolintrp	Cwi_wl	Cwi_wc	Fieldloc	Geocoord	Utme	Utmn	Utmzone	Relateid
220195	68	WW		162	39	27	CABCDD	443C	1062																0	0	0	68220195
247530	68	WW		162	40	1	BBD*	444A	1037																0	0	0	68247530
247529	68	WW		162	40	6	CCAAAA	444A	1035																0	0	0	68247529
221433	68	WW		162	40	13	CAAC	444D	1046																0	0	0	68221433
220233	68	WW		162	40	20	BAAAAC	444D	1082																0	0	0	68220233
220237	68	WW		162	40	22	ADAABA	444D	1048																0	0	0	68220237
220244	68	WW		162	40	24	BBBBAC	444D	1048																0	0	0	68220244
247531	68	WW		162	40	33	ACDA*	444D	1062																0	0	0	68247531
185484	68	WW		162	41	3	BCC*	444B	1039																0	0	0	68185484
247044	68	SI	NW-1	162	41	15	ADAAAB	444C	1057			Y	Y	Y											0	0	0	68247044
247532	68	WW		162	42	18	BBA*	445C	1032																0	0	0	68247532
173379	68	WW		162	43	3	BCDABD	445B	1024																0	0	0	68173379
219931	68	SI	B6	162	43	28	CCDACA	445C	1023				Y	Y											0	0	0	68219931
219818	68	SI	B7	162	43	36	BBBBBB	445C	1033				Y	Y											0	0	0	68219818
219821	68	SI	B10	162	44	15	DDDDAA	446D	1019				Y	Y											0	0	0	68219821
20464	68	EX	YGH-1	162	44	33	DACBAA	446D	1015			Y													0	0	0	6820464
20459	68	EX	YGH-2	162	44	35	CBBCDD	446D	1020			Y													0	0	0	6820459
219810	35	SI	A9	162	45	4	ADAAAB	446B	1024				Y	Y											0	0	0	35219810
219811	35	SI	A10	162	45	12	DDBACB	446C	1026				Y	Y											0	0	0	35219811
220000	35	SI	LANCASTER #1	162	46	6	BBBBBA	447B	970				Y												0	0	0	35220000
219815	35	SI	B3	162	46	23	DDCBAD	447D	997				Y	Y											0	0	0	35219815
219816	35	SI	B4	162	46	29	BAAABC	447C	982				Y	Y											0	0	0	35219816
215212	35	WW		162	47	9	ABDBBB	447C	941																0	0	0	35215212

NORTHWEST DRILLING PROJECT: DRILL HOLE INDEX. 6/30/93

Unno	Co	Type	Name	Twp	Range	Sec	Sub	Quad	Elev	Datacomp	Dataprog	Core	Cuttings	Bhg	Geochem	Geophys	Handsmpl	Quattext	Quatgcnt	Geolintrp	Cwi_wl	Cwi_wc	Fieldloc	Geocoord	Utme	Utmn	Utmzone	Relateid
219819	35	SI	B8	162	47	18	CCCCCC	448D	908				Y	Y											0	0	0	35219819
215258	35	WW		162	47	19	BBADBB	448D	908																0	0	0	35215258
219820	35	SI	B9	162	47	22	CDDDCC	447C	942				Y	Y											0	0	0	35219820
219691	35	WW		162	47	23	CDDCAA	447C	953																0	0	0	35219691
219694	35	WW		162	48	13	ADBBDA	448D	908																0	0	0	35219694
219813	35	SI	B1	162	48	16	DDDDDC	448D	862				Y	Y											0	0	0	35219813
219814	35	SI	B2	162	48	18	CCADBC	448C	825				Y	Y											0	0	0	35219814
219699	35	SI	FLORENCE #1	162	49	6	DDDDDB	449A	801				Y												0	0	0	35219699
219817	35	SI	B5	162	49	15	DDCCDD	448C	804				Y	Y											0	0	0	35219817
247533	68	WW		163	40	24	CBDC*	444A	1037																0	0	0	68247533
247534	68	WW		163	40	35	BBBA*	444A	1032																0	0	0	68247534
21260	68	EX	J1	163	40	36	CDBACA	444A	1038			Y													0	0	0	6821260
220346	68	WW		163	41	27	DDDACD	444B	1033																0	0	0	68220346
247535	68	WW		163	41	34	AAA*	444B	1032																0	0	0	68247535
247041	68	SI	NW-2	163	42	8	DDDADD	445A	1034			Y	Y	Y											0	0	0	68247041
244841	35	SI	KPL-1-B2	163	45	9	CCCCCC	446B	1015			Y	Y												0	0	0	35244941
219804	35	SI	A4	163	46	26	BBBACC	447A	1000				Y	Y											0	0	0	35219804
219803	35	SI	A3	163	46	30	BABACB	447B	983				Y	Y											0	0	0	35219803
153709	35	WW		163	46	31	CAACCA	447A	978																0	0	0	35153709
219802	35	SI	A2	163	47	28	ACAACB	447B	957				Y	Y											0	0	0	35219802
219809	35	SI	A8	163	48	15	BABABB	448A	917				Y	Y											0	0	0	35219809
247048	35	SI	NW-3	163	48	20	CCCCBC	448B	855			Y	Y	Y											0	0	0	35247048
219801	35	SI	A1	163	48	24	AADDAC	448A	947				Y	Y											0	0	0	35219801

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Unno	Co	Type	Name	Twp	Range	Sec	Sub	Quad	Elev	Datacomp	Dataprog	Core	Cuttings	Bhg	Geochem	Geophys	Handsmpl	Quattext	Quatgcnt	Geolintrp	Cwi_wl	Cwi_wc	Fieldloc	Geocoord	Utme	Utmn	Utmzone	Relateid
219806	35	SI	A6	163	49	16	CDDDCC	449A	798				Y	Y											0	0	0	35219806
219702	35	WW		163	50	23	CDDCDA	449B	794																0	0	0	35219702

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Relateid	Datedrlld	Depthdrlld	Azimuth	Plunge	D2bdrk	Frstbdrk	D2pcmb	Pcrocktype
1421735	1/10/90	316	0	0	197	PAUD	197	GBRO
14232327	7/2/81	1003	143	50	410	PAUD	410	VOLU;MSED;BSLT
35138900	10/77	397	0	0	392	UREG	392	REGO
35153709	09/78	360	0	0	>360			
35153716	09/78	405	0	0	>405			
35215212	04/72	341	0	0	302	ORRV		
35215214	04/72	210	0	0	208	KRET		
35215219	05/73	372	0	0	372	ORRV		
35215221	08/62	414	0	0	413	UREG	413	REGO
35215258	/ /	331	0	0	>331			
35219659	01/72	314	0	0	294	OWIN		
35219668	08/76	328	0	0	311	UREG	311	REGO
35219691	04/72	266	0	0	259	KRET		
35219694	/ /	300	0	0	240	KRET		
35219699	11/64	625	0	0	180	ORRV	588	GNIS?
35219702	1984	644	0	0	180	ORRV	638	GRAN
35219801	07/14/55	374	0	0	367	ORRV		
35219802	07/16/55	356	0	0	351	ORRV		
35219803	07/19/55	336	0	0	331	ORRV		
35219804	07/20/55	332	0	0	322	ORRV		
35219806	07/21/55	176	0	0	174	ORRV		
35219809	07/23/55	324	0	0	321	ORRV		
35219810	09/17/55	366	0	0	358.5	UREG	359	REGO
35219811	09/22/55	298	0	0	>298			
35219813	07/12/55	250	0	0	245	ORRV		
35219814	07/12/55	212	0	0	203	ORRV		
35219815	07/13/55	372	0	0	361	OWIN		

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Relateid	Datedrlld	Depthdrlld	Azimuth	Plunge	D2bdrk	Frstbdrk	D2pcmb	Pcrocktype
35219816	07/16/55	342	0	0	334	KRET		
35219817	07/20/55	190	0	0	183	ORRV		
35219819	09/15/55	300	0	0	291.5	ORRV		
35219820	09/17/55	347	0	0	337	KRET		
35219825	07/07/55	354	0	0	339	ORRV		
35219826	07/07/55	330	0	0	316	ORRV		
35219827	07/08/55	294	0	0	288	JURA		
35219828	07/09/55	225	0	0	217	JURA		
35219829	07/23/55	344	0	0	>344			
35219834	09/28/55	375	0	0	>374.5			
35219835	/ /	420	0	0	414	UREG	414	REGO
35219855	06/30/55	235	0	0	220	JURA		
35219856	07/05/55	268	0	0	262	KRET		
35219857	08/01/55	336	0	0	273	KRET		
35219858	08/08/55	325	0	0	322	KRET		
35219863	09/20/55	377	0	0	>377			
35219864	09/27/55	265	0	0	259	JURA		
35219869	/ /	332	0	0	329	KRET		
35219885	06/29/55	206	0	0	204	ORRV		
35219886	07/05/55	317	0	0	242	KRET		
35219891	09/10/55	394	0	0	392	KRET		
35219892	09/10/55	380	0	0	379	ORRV		
35219896	10/04/55	229	0	0	228.5	ORRV		
35219992	/ /	421	0	0	375	ORRV	415	REGO;GRAN
35219999	/ /	495	0	0	200	KRET	472	REGO;SHST?
35220000	/ /	440	0	0	335	OWIN	432	GRAN?
35224605	8/1/72	529	0	0	212	KRET	510	REGO;AMPH

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Relateid	Datedrlld	Depthdrlld	Azimuth	Plunge	D2bdrk	Frstbdrk	D2pcmb	Pcrocktype
35244841	12/03/81	402	0	0	356	UREG	356	REGO;TONT;GNLT
35247045	10/19/91	407	0	0	357	UREG	357	REGO;GNIS;PEGM
35247046	10/21/91	359	0	0	354	PAUD	354	PEGM;GNIS
35247047	10/25/91	459	0	0	282	JURA	453	SHST
35247048	11/17/91	556	0	0	181	ORRV	528	REGO;SYEN;GRAN
35247049	11/21/91	340	0	0	314	UREG	314	REGO;GNDI
35247053	06/25/92	446	0	0	183	ORRV	416	REGO;SHST
35247499	/ /	?	0	0	100	ORRV		
35247501	/ /	200	0	0	155	ORRV		
35502805	9/88	400	0	0	>400			
45101657	08/75	303	0	0	>303			
45101785	11/15/76	320	0	0	>320			
45105683	09/76	396	0	0	390	UREG	390	REGO
45125714	05/76	220	0	0	>220			
45128413	/ /	312	0	0	312	PAUD	312	PUNK
45128419	05/77	225	0	0	>225			
45132735	07/78	212	0	0	>212			
45162389	05/81	303	0	0	303	PAUD	303	PUNK
45174747	06/81	480	0	0	460	UREG	460	REGO
45181745	09/29/83	358	0	0	>358			
4521039	02/02/84	583	330	45	303	PAUD	303	GRSN;TUFF;MSED
4521040	02/08/84	883	150	45	310	PAUD	310	MSED;ANDS
45215363	05/72	443	0	0	427	UREG	427	REGO
45215373	12/72	302	0	0	>302			
4521736	01/24/90	380	0	0	345	UREG	345	DIOR
4521737	01/18/90	405	0	0	272	ORRV	343	REGO;MSED
45219332	06/26/55	302	0	0	262	KRET		

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Relateid	Datedrlld	Depthdrlld	Azimuth	Plunge	D2bdrk	Frstbdrk	D2pcmb	Pcrocktype
45219615	06/04	280	0	0	>280			
45219641	01/54	320	0	0	>320			
45219652	08/72	323	0	0	195	ORRV		
45219898	06/28/55	340	0	0	237	KRET		
45219902	08/10/55	363	0	0	363	PAUD	363	PUNK
45219904	09/06/55	459	0	0	455	UREG	455	REGO
45219908	06/27/55	286	0	0	250	KRET		
45219909	06/28/55	272	0	0	262	ORRV		
45219910	08/11/55	323	0	0	322.5	PAUD	323	PUNK
45219911	08/12/55	277	0	0	>277			
45219912	08/12/55	337	0	0	332	PAUD	332	GRAN?
45219913	08/13/55	313	0	0	312.5	PAUD	313	PUNK
45219914	08/29/55	350	0	0	>350			
45219915	09/02/55	283	0	0	282	ORRV		
45219921	08/26/55	435	0	0	433.5	PAUD	434	GRSN
45219922	08/26/55	320	0	0	316	UREG	316	PUNK
45219924	06/23/55	179	0	0	177	KRET		
45219926	08/17/55	295	0	0	>295			
45219927	08/18/55	361	0	0	>361			
45219929	08/20/55	307	0	0	300.5	UREG	301	REGO
45219930	08/02/55	407	0	0	399	PAUD	399	GRAN
45219936	08/31/55	366	0	0	365	PAUD	365	GRSN
45219996	/ /	280	0	0	259	UREG	259	REGO;GRAN
4522011	03/12/89	482	0	0	360	UREG	360	REGO;PRDT
4522012	03/16/89	365	0	0	332	UREG	332	REGO;DIOR;PYRX
4522013	03/22/89	413	0	0	350	UREG	350	REGO;SHST;DIOR
45224273	09/04/77	381	0	0	362	PAUD	362	GNIS

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Relateid	Datedrlld	Depthdrlld	Azimuth	Plunge	D2bdrk	Frstbdrk	D2pcmb	Pcrocktype
45236526	10/71	305	0	0	298	UREG	298	REGO;PUNK
45242963	08/13/55	406	0	0	>406			
45244718	07/53	496	0	0	190	KRET	489	PUNK
45244721	07/62	177	0	0	122	KRET		
45244847	12/17/81	455	0	0	402	KRET	449	TUFF;MSED
45244852	12/09/81	254	0	0	249	PAUD	249	DIAB;DIOR
45244858	12/07/81	176	0	0	167	PAUD	167	GNDI;TONT
45247050	06/11/92	291	0	0	269	PAUD	269	GNDI
45247051	06/13/92	330	0	0	312	PAUD	312	DIOR;TONT
45247052	06/16/92	490	0	0	434	UREG	434	REGO;SHST;DACT
45247054	06/29/92	501	0	0	298	KRET	484	REGO;SHST
45247502	/ /	?	0	0	270	UREG	270	REGO
45247503	/ /	285	0	0	<285	OWIN	?	GNDI
45247504	/ /	?	0	0	<290	KRET	290	PUNK
45247505	/ /	197	0	0	175.5	ORRV		
45247506	/ /	?	0	0	350	UREG	350	REGO
45247507	/ /	?	0	0	358	UREG	358	REGO
45247508	/ /	?	0	0	270	UREG	270	REGO
45247509	/ /	?	0	0	<285	KRET	285	PUNK
45247510	/ /	?	0	0	225	PAUD	225	PUNK
45247511	/ /	385	0	0	<260	KRET	260	REGO
45247512	/ /	?	0	0	<385	KRET	385	PUNK
45247513	/ /	?	0	0	149	KRET		
45247514	/ /	?	0	0	176	KRET		
45247515	/ /	?	0	0	140	KRET		
45247516	/ /	?	0	0	330	PAUD	330	PUNK
45247517	/ /	263	0	0	<263	KRET		

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Relateid	Datedrlld	Depthdrlld	Azimuth	Plunge	D2bdrk	Frstbdrk	D2pcmb	Pcrocktype
45247518	/ /	?	0	0	310	PAUD	310	PUNK
45247551	/ /	?	0	0	300	UREG	300	REGO
45400235	10/02/84	275	0	0	>275			
45419778	07/24/87	284	0	0	>284			
45438049	10/88	405	0	0	>405			
45447052	03/31/89	410	0	0	365	UREG	365	REGO;DIOR
45455443	12/20/88	335	0	0	>335			
45D12496	07/21/77	495	0	0	235	PAUD	235	GBRO
45D12497	07/14/77	357	0	0	250	PAUD	250	DIOR
45D12498	06/12/77	615	0	0	406	UREG	406	REGO;DIOR;SYEN
45D12566	10/17/79	919	0	60	415	UREG	415	REGO;MSED;TUFF;DACT
45D12585	03/18/74	985	0	60	213	PAUD	213	PRDT;GBRO;TUFF
45D12599	/ /	1095	10	60	336	PAUD	336	BSLT;ANDS
54107262	07/75	323	0	0	328	PAUD	328	PUNK
54107263	08/75	330	0	0	322	PAUD	322	PUNK
54107264	08/75	335	0	0	355	PAUD	355	PUNK
54107275	02/76	292	0	0	285	UREG	285	REGO
54117138	07/77	299	0	0	>299			
54130591	07/77	314	0	0	305	UREG	305	REGO;GRAN
54147204	03/78	258	0	0	>258			
54147208	07/78	307	0	0	>307			
54166202	07/81	317	0	0	312	UREG	312	REGO
54166205	09/81	300	0	0	278	UREG	278	REGO
54166507	06/79	333	0	0	>333			
54168259	05/79	250	0	0	219	UREG	219	REGO
54188575	10/70	324	0	0	>324			
5421253	08/04/82	1004	270	60	402	UREG	402	REGO;GNDI

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Relateid	Datedrlld	Depthdrlld	Azimuth	Plunge	D2bdrk	Frstbdrk	D2pcmb	Pcrocktype
5421254	08/30/82	1724	113	55	418	UREG	418	MSED;BSLT
5421257	07/20/82	1213	293	55	200	UREG	200	REGO;TUFF;MSED
5421259	09/08/82	864	347	55	368	UREG	368	REGO;TUFF;MSED
5421264	12/05/83	843	125	55	364	UREG	364	REGO;TUFF;MSED
5421709	10/14/86	309	0	0	299	PAUD	299	GBRO;DIOR;ANDS
54219047	05/73	302	0	0	>302			
5422001	12/23/88	982	350	60	480	PAUD	480	ANDS;DACT;DIOR
54220440	07/41	309	0	0	306	PAUD	306	PUNK
54220446	1920	309	0	0	307	UREG	307	REGO;PUNK
54220458	04/58	350	0	0	214	UREG	214	REGO;PUNK
54220485	09/68	270	0	0	268	PAUD	268	PUNK
54220487	12/70	320	0	0	318	PAUD	318	PUNK
54220489	07/73	215	0	0	210	UREG	210	REGO
54220491	08/63	338	0	0	337	UREG	337	REGO
54220494	/ /	321	0	0	261	UREG	261	REGO
54220500	04/59	311	0	0	262	UREG	262	REGO
54220502	/ /	240	0	0	150	UREG	150	REGO;PUNK
54221941	10/60	310	0	0	302	UREG	302	REGO
54221943	11/61	349	0	0	280	UREG	280	REGO;PUNK
54221961	07/46	223	0	0	>223			
54221969	08/72	377	0	0	362	UREG	362	REGO;PUNK
54221998	09/67	279	0	0	>279			
54222030	05/71	204	0	0	204	UREG	204	REGO
54224270	09/12/77	394	0	0	309	UREG	309	REGO;GNDI;QZMZ
54235774	/ /	192	0	0	163	UREG	163	REGO
5423597	02/04/91	818	360	55	338	UREG	338	REGO;VOLU;TUFF
5423599	02/13/91	800	342	55	160	UREG	160	REGO;VOLU;DIAB

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Relateid	Datedrlld	Depthdrlld	Azimuth	Plunge	D2bdrk	Frstbdrk	D2pcmb	Pcrocktype
5423600	02/21/91	798	360	55	260	UREG	260	MSED
5423651	02/26/91	672	325	55	452	PAUD	452	MSED
5423652	03/06/91	914	335	55	320	UREG	320	REGO;MSED;DACT;DIOR
5423655	11/24/91	705	348	60	370	UREG	370	REGO;MGRB;DTAB
54236552	09/84	332	0	0	327	UREG	327	REGO
5423656	11/20/91	896	325	67	390	UREG	390	REGO;GRSN;MSED
54236563	09/18/79	1010	0	61	405	UREG	405	REGO;MSED;TUFF
54236564	10/07/79	1523	0	56	425	UREG	425	REGO;TUFF;BSLT
54236565	11/05/80	1295	0	55	465	PCUU	465	TUFF;MSED;DIAB
54236566	12/20/79	1143	348	56	500	PAUD	500	UMFU;SYEN;VOLU
54236567	03/23/79	789	180	55	300	UREG	300	REGO;VOLU;TUFF;MSED
54236568	01/07/80	390	330	56	364	UREG	364	REGO;BSLT;MSED
5423813	03/14/91	1197	180	45	685	PAUD	685	DACT;ANDS;MSED
54239253	12/72	282	0	0	272	UREG	272	REGO
54247554	/ /	347	0	0	344	UREG	344	REGO
54247555	04/24/65	243	0	0	241	UREG	241	REGO;GRAN
54429355	01/86	310	0	0	305	UREG	305	REGO
54457595	09/89	338	0	0	>338			
54457601	11/89	370	0	0	>370			
54478182	05/14/91	323	0	0	273	UREG	273	REGO;PUNK
54511082	07/89	262	0	0	260	UREG	260	REGO
54D12734	12/18/81	1003	320	55	350	UREG	350	REGO;VOLU;MSED
54D12736	04/01/79	854	163	56	251	UREG	251	REGO;MSED;ANDS
54D12741	12/11/80	1165	0	50	495	PAUD	495	MSED
57105633	09/77	409	0	0	>409			
57105671	10/76	454	0	0	452	PAUD	452	PUNK
57128436	06/77	380	0	0	>380			

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NORTHWEST DRILLING PROJECT: DRILL HOLE INFORMATION. 6/30/93

Relateid	Datedrlld	Depthdrlld	Azimuth	Plunge	D2bdrk	Frstbdrk	D2pcmb	Pcrocktype
57132772	06/77	350	0	0	>350			
57139823	11/80	497	0	0	>497			
57158510	04/79	440	0	0	>440			
57158514	05/79	530	0	0	>530			
57181712	11/81	450	0	0	446	UREG	446	REGO
57219602	09/65	334	0	0	328	PAUD	328	PUNK
57247055	07/08/92	502	0	0	390	UREG	390	REGO;TONT
57247056	07/08/92	529	0	0	512	PAUD	512	BSLT
57247057	07/15/92	601	0	0	514	UREG	514	REGO;SHST
57247058	07/28/92	821	0	0	535	UREG	535	REGO;SHST?
57247519	/ /	?	0	0	400	PAUD	400	PUNK
57247520	/ /	455	0	0	400	PAUD	400	PUNK
57247521	/ /	490	0	0	462	PAUD	462	PUNK
57421631	9/85	410	0	0	>410			
57463917	09/90	412	0	0	>412			
60101703	05/75	281	0	0	>281			
60101770	07/76	320	0	0	>320			
60101787	11/76	285	0	0	>285			
60101808	09/77	287	0	0	>287			
60101829	08/78	299	0	0	>299			
60101830	08/78	264	0	0	>264			
60102602	05/76	302	0	0	295	UREG	295	REGO
60102635	06/76	350	0	0	348	UREG	348	REGO
60107288	03/76	377	0	0	322	UREG	322	REGO
60107289	03/76	290	0	0	276	UREG	276	REGO
60107290	03/76	277	0	0	265	UREG	265	REGO
60107911	09/75	198	0	0	>198			

NORTHWEST DRILLING PROJECT: DRILL HOLE INFORMATION. 6/30/93

Relateid	Datedrlld	Depthdrlld	Azimuth	Plunge	D2bdrk	Frstbdrk	D2pcmb	Pcrocktype
60107922	06/76	265	0	0	>265			
60107928	09/76	286	0	0	>286			
60107942	08/76	236	0	0	236	PAUD	236	PUNK
60125739	07/76	324	0	0	>324			
60125775	11/11/79	410	0	0	>410			
60130563	09/76	257	0	0	255	UREG	255	REGO
60130571	06/76	327	0	0	311	UREG	311	REGO
60130577	03/77	422	0	0	412	UREG	412	REGO
60138859	08/77	297	0	0	282	UREG	282	REGO
60138889	08/77	227	0	0	220	UREG	220	REGO
60139839	04/81	360	0	0	358	UREG	358	REGO
60166245	05/25/82	309	0	0	>309			
60181708	09/81	271	0	0	>271			
60215377	06/71	302	0	0	271	UREG	271	REGO
60215382	02/70	300	0	0	287	UREG	287	REGO
60215385	10/71	312	0	0	307	UREG	307	REGO
60215387	11/74	336	0	0	335	UREG	335	REGO
60215390	03/77	402	0	0	394	UREG	394	REGO
60215395	06/67	292	0	0	>292			
60215405	11/74	230	0	0	220	UREG	220	REGO;PUNK
60215406	12/69	256	0	0	>256			
60215409	08/70	327	0	0	322	UREG	322	REGO
60215411	08/70	327	0	0	321	UREG	321	REGO
60220354	08/40	250	0	0	>250			
60221027	08/75	412	0	0	382	UREG	387	REGO
60221037	/ /	385	0	0	>385			
60221048	04/73	292	0	0	>292			

NORTHWEST DRILLING PROJECT: DRILL HOLE INFORMATION. 6/30/93

Relateid	Datedrlld	Depthdrlld	Azimuth	Plunge	D2bdrk	Frstbdrk	D2pcmb	Pcrocktype
60221058	07/52	218	0	0	213	PAUD	213	PUNK
60221572	12/74	352	0	0	351	PAUD	351	PUNK
60221582	11/60	328	0	0	>328			
60221595	04/53	394	0	0	387	UREG	387	REGO;PUNK
60221617	02/74	347	0	0	317	UREG	317	REGO
60221620	05/67	318	0	0	316	UREG	316	REGO
60221634	1950	183	0	0	>183			
60221635	11/62	216	0	0	215	PAUD	215	PUNK
60221637	1963	221	0	0	220	PAUD	220	PUNK
60221639	09/76	207	0	0	205	UREG	205	REGO
60221641	07/75	302	0	0	285	UREG	285	REGO
60224269	09/15/77	321	0	0	279	OWIN	299	GNIS
60244664	09/86	215	0	0	214	UREG	214	REGO
60247060	08/09/92	380	0	0	305	UREG	305	REGO;SHST
60247334	08/19/92	360	0	0	252	UREG	252	REGO;MSED
60247335	08/22/92	439	0	0	283	UREG	283	REGO;SHST
60247336	08/12/92	418	0	0	395	UREG	395	REGO;PEGM
60247522	/ /	?	0	0	257	UREG	257	REGO
60247537	/ /	370	0	0	270	OWIN		
60247538	/ /	?	0	0	240	ORRV		
60247539	/ /	?	0	0	275	KRET		
60247540	/ /	?	0	0	280	KRET		
60247541	/ /	?	0	0	260	PAUD	260	PUNK
60247542	/ /	237	0	0	230	PAUD	230	PUNK
60247543	/ /	?	0	0	235	PAUD	235	PUNK
60247544	/ /	?	0	0	310	UREG	310	REGO
60247545	/ /	?	0	0	245	KRET		

NORTHWEST DRILLING PROJECT: DRILL HOLE INFORMATION. 6/30/93

Relateid	Datedrlld	Depthdrlld	Azimuth	Plunge	D2bdrk	Frstbdrk	D2pcmb	Pcrocktype
60247546	/ /	?	0	0	330	PAUD	330	PUNK
60247547	/ /	?	0	0	330	PAUD	330	PUNK
60247548	/ /	?	0	0	330	PAUD	330	PUNK
60247549	/ /	?	0	0	340	UREG	340	REGO
60247550	/ /	220	0	0	>220			
60247553	/ /	265	0	0	261	UREG	261	REGO
60409814	10/15/84	308	0	0	>308			
60419760	10/86	291	0	0	>291			
60419770	06/87	309	0	0	>309			
60423509	03/85	397	0	0	>397			
60423520	09/85	260	0	0	>260			
60439551	06/88	366	0	0	>366			
60468901	07/90	326	0	0	>326			
60502807	09/88	300	0	0	>300			
60D12784	10/15/74	592	0	55	298	PAUD	298	BSLT;ANDS;MAFU
60D12785	/ /	599	0	0	496	PAUD	496	ANOR
60D12786	/ /	593	0	0	491	UREG	491	REGOANOR
60D12787	/ /	594	0	0	476	UREG	476	REGO:ANOR
63103101	12/74	436	0	0	>436			
63103102	12/74	337	0	0	330	UREG	330	REGO
63107924	07/76	417	0	0	>417			
63125736	07/76	350	0	0	338	UREG	338	REGO
63150675	09/78	346	0	0	341	UREG	341	REGO
63158512	05/79	340	0	0	>340			
63181358	06/82	374	0	0	>374			
63221008	08/67	339	0	0	324	UREG	324	REGO
63224271	09/06/77	395	0	0	378	PAUD	378	SHST

NORTHWEST DRILLING PROJECT: DRILL HOLE INFORMATION. 6/30/93

Relateid	Datedrlld	Depthdrlld	Azimuth	Plunge	D2bdrk	Frstbdrk	D2pcmb	Pcrocktype
63247059	08/07/92	539	0	0	364	UREG	364	REGO;TONT
63247523	/ /	?	0	0	365	UREG	365	REGO
63247552	/ /	?	0	0	345	KRET		
63449140	10/88	423	0	0	>423			
63471562	10/04/91	430	0	0	>430			
68111813	07/76	215	0	0	>215			
68132151	04/77	195	0	0	>195			
68132157	04/77	355	0	0	>355			
68147706	07/78	270	0	0	>270			
68147708	07/78	235	0	0	>235			
68147726	11/78	215	0	0	215	PAUD	215	PUNK
68173379	05/81	240	0	0	>240			
68181785	12/07/81	210	0	0	>210			
68181810	07/83	195	0	0	>195			
68185204	08/82	276	0	0	>276			
68185484	06/11/84	200	0	0	>200			
6820459	02/08/84	596	180	60	240	PCUU	240	GBRO;DIAB;GNIS
6820464	02/02/84	544	0	60	250	PAUD	250	GNIS
6820488	03/06/85	527	210	60	379	PAUD	379	SHST;GRAN
6821041	02/14/84	857	204	45	424	PAUD	424	TUFF;MSED;VOLU
6821260	10/24/83	903	240	55	168	UREG	168	REGO;TONT;MNZT
6821261	11/18/83	858	0	55	268	PAUD	268	BSLT;ANDS;MSED
6821265	01/08/84	1043	180	50	350	UREG	350	REGO;TUFF;IRFM
68215183	12/74	269	0	0	>269			
68215203	/ /	252	0	0	248	UREG	248	REGO
6821569	03/24/86	1123	178	60	350	UREG	350	REGO;SHST;TUFF;VOLU
68219716	11/68	160	0	0	>160			

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NORTHWEST DRILLING PROJECT: DRILL HOLE INFORMATION. 6/30/93

Relateid	Datedrlld	Depthdrlld	Azimuth	Plunge	D2bdrk	Frstbdrk	D2pcmb	Pcrocktype
68219729	09/73	203	0	0	>203			
68219818	08/11/55	238	0	0	230	UREG	230	REGO
68219821	09/23/55	234	0	0	>233.5			
68219830	07/27/55	313	0	0	307	UREG	307	REGO
68219832	07/29/55	250	0	0	245	UREG	245	REGO
68219833	09/20/55	258	0	0	255	UREG	255	REGO
68219859	08/03/55	215	0	0	>215			
68219860	08/04/55	306	0	0	299	KRET		
68219888	08/06/55	291	0	0	290.5	KRET		
68219889	08/06/55	280	0	0	277	KRET		
68219890	08/08/55	297	0	0	>296.5			
68219931	07/30/55	178	0	0	171	PAUD	171	GRAN?
68220018	/ /	150	0	0	140	UREG	140	REGO;PUNK
68220019	/ /	117	0	0	101	UREG	101	REGO;PUNK
68220045	11/65	220	0	0	>220			
68220188	08/69	127	0	0	>127			
68220195	/ /	160	0	0	>160			
68220233	04/62	221	0	0	>221			
68220237	10/61	155	0	0	>155			
68220244	/ /	137	0	0	>137			
68220346	09/50	152	0	0	>152			
68221433	/ /	127	0	0	96	PAUD	96	PUNK
68224272	09/03/77	335	0	0	248	PAUD	248	MYLN;SHST
68247041	10/91	306	0	0	204	KRET	252	REGO;DIOR;GRAN;SHST
68247042	10/09/91	228	0	0	195	UREG	195	REGO;SHST;PEGM
68247043	10/16/91	366	0	0	334	UREG	334	REGO;DIOR
68247044	10/09/91	202	0	0	183	PAUD	183	DIOR;GNIS;GRAN

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NORTHWEST DRILLING PROJECT: DRILL HOLE INFORMATION. 6/30/93

Relateid	Datedrlld	Depthdrlld	Azimuth	Plunge	D2bdrk	Frstbdrk	D2pcmb	Pcrocktype
68247524	/ /	?	0	0	175	KRET		
68247525	/ /	210	0	0	<210			
68247526	/ /	264	0	0	190	UREG	190	REGO
68247527	/ /	?	0	0	165	KRET		
68247528	/ /	?	0	0	220	UREG	220	REGO
68247529	/ /	?	0	0	182	PAUD	182	PUNK
68247530	/ /	?	0	0	119	PAUD	119	PUNK
68247531	/ /	?	0	0	193	UREG	193	REGO
68247532	/ /	?	0	0	225	UREG	225	REGO
68247533	/ /	?	0	0	90	PAUD	90	PUNK
68247534	/ /	?	0	0	137	PAUD	137	PUNK
68247535	/ /	?	0	0	130	UREG	130	REGO;PUNK
68418288	11/25/86	272	0	0	265	UREG	265	REGO
68430983	07/87	280	0	0	>280			
68467904	06/01/90	280	0	0	>280			

Appendix C.2
Stratigraphic (and aquifer) codes

Ages for stratigraphic units are abbreviated in CWI as follows: *UNK* - unknown; *REC* - Quaternary-Recent (Holocene); *QUA* - Quaternary-Pleistocene; *CRE* - Cretaceous; *JUR* - Jurassic; *DEV* - Devonian; *ORD* - Ordovician; *D-O* - Devonian/Ordovician; *CAM* - Cambrian; *O-C* - Ordovician/Cambrian; *C-P* - Cambrian/Precambrian; *PRC* - pre-Croixan; *PZC* - Paleozoic; *PC* - Precambrian; *PCM* - Middle Proterozoic; *PCE* - Early Proterozoic; *PCP* - Proterozoic; *PCA* - Archean.

Note that stratigraphy is not a static science and changes are to be expected over time. Some of the units listed below, particularly some Precambrian igneous and metamorphic rocks, are no longer accepted by geologists working in that area of study. They are included here as an aid in deciphering older data and are not used in assigning codes to newly interpreted data. Note also that the "stratigraphic units" for the Quaternary are descriptive rather than interpretive in nature; there is not an established system of identifiable named units for these deposits in Minnesota.

Paleozoic (pre-Cretaceous) of southeastern Minnesota

DEVO	DEVONIAN, UNDIFFERENTIATED	DEV
DCVA	CEDAR VALLEY	DEV
DCOM	CEDAR VALLEY-MAQUOKETA	D-O
DCOG	CEDAR VALLEY-GALENA	D-O
DWAP	WAPSIPINICON FORMATION	DEV
DSPL	SPILLVILLE FORMATION	DEV
DSOM	SPILLVILLE-MAQUOKETA	D-O
DSOG	SPILLVILLE-GALENA	D-O
OMAQ	MAQUOKETA	ORD
OMQD	MAQUOKETA-DUBUQUE	ORD
OMQG	MAQUOKETA-GALENA	ORD
ODUB	DUBUQUE	ORD
ODGL	DUBUQUE-GALENA	ORD
OGAL	GALENA	ORD
OGSV	GALENA/STEWARTVILLE MBR	ORD
OGPR	GALENA/PROSSER MBR	ORD
OGCM	GALENA/CUMMINGSVILLE MBR	ORD
OGDC	GALENA-DECORAH	ORD
ODCR	DECORAH	ORD
ODPL	DECORAH-PLATTEVILLE	ORD
OGDP	GALENA-DECORAH-PLATTEVILLE	ORD
OPVL	PLATTEVILLE	ORD
OPVC	PLATTEVILLE/CARIMONA MBR	ORD
OPVM	PLATTEVILLE/MAGNOLIA MBR	ORD
OPVH	PLATTEVILLE/HIDDEN FALLS MBR	ORD
OPVF	PLATTEVILLE/MIFFLIN MBR	ORD
OPVP	PLATTEVILLE/PECATONICA MBR	ORD
OPGW	PLATTEVILLE-GLENWOOD	ORD
OGWD	GLENWOOD	ORD
OPSP	PLATTEVILLE-ST.PETER	ORD
OGSP	GLENWOOD-ST.PETER	ORD
OSTP	ST.PETER	ORD
OSPC	ST.PETER-PRAIRIE DU CHIEN	ORD
OPDC	PRAIRIE DU CHIEN GROUP	ORD
OPSH	SHAKOPEE FM(PRAIRIE DU CHIEN)	ORD
OPWR	SHAKOPEE/WILLOW RIVER MBR	ORD
OPNR	SHAKOPEE/NEW RICHMOND MBR	ORD
OPOD	ONEOTA FM(PRAIRIE DU CHIEN)	ORD
OPCJ	PRAIRIE DU CHIEN-JORDAN	O-C
ORDO	ORDOVICIAN, UNDIFFERENTIATED	ORD
CJDN	JORDAN	CAM
CJSL	JORDAN-ST.LAWRENCE	CAM
CSTL	ST.LAWRENCE	CAM
CSLF	ST.LAWRENCE-FRANCONIA	CAM
CFRN	FRANCONIA	CAM
CFIG	FRANCONIA-IRONTON-GALESVILLE	CAM
CFRA	FRANCONIAN STAGE	CAM
CIRN	IRONTON	CAM
CIGL	IRONTON-GALESVILLE	CAM
CIGE	IRONTON-GALESVILLE-EAU CLAIRE	CAM
CGSL	GALESVILLE	CAM
CGEC	GALESVILLE-EAU CLAIRE	CAM
CDRE	DRESBACHIAN STAGE	CAM
CECR	EAU CLAIRE	CAM
CEMS	EAU CLAIRE-MT.SIMON	CAM
CMTS	MT.SIMON	CAM
CAMB	CAMBRIAN, UNDIFFERENTIATED	CAM
CMSH	MT.SIMON-HINCKLEY	C-P
PUDF	PALEOZOIC, UNDIFFERENTIATED	PZC
PCRG	PRE-CROIXAN REGOLITH	PRC

Cretaceous units; Paleozoic of western Minnesota

KRET	CRETACEOUS, UNDIFFERENTIATED	CRE
KCLR	COLERAINE	CRE
KWND	WINDROW	CRE
KWOS	WINDROW/OSTRANDER MBR	CRE
KWIH	WINDROW/IRON HILL MBR	CRE
KREG	CRETACEOUS REGOLITH	CRE
KPRR	PIERRE SHALE	CRE
KNBR	NIOBRARA	CRE
KCRL	CARLILE SHALE	CRE
KCBH	CARLILE/BLUE HILL MBR	CRE
KCFP	CARLILE/FAIRPORT MBR	CRE
KCCD	CARLILE/CODELL SANDSTONE MBR	CRE
KGRN	GREENHORN	CRE

KGRS	GRANEROS SHALE	CRE
KDKT	DAKOTA	CRE
KDNB	DAKOTA/NISHNABOTNA MBR	CRE
KDWB	DAKOTA/WOODBURY MBR	CRE
KSRC	SPLIT ROCK CREEK	CRE
JURA	JURASSIC-HALLOCK REDBEDS	JUR
OSTW	STONEWALL	ORD
OSTM	STONEY MOUNTAIN	ORD
ORRV	RED RIVER	ORD
ORWN	RED RIVER-WINNIPEG	ORD
OWIN	WINNEPEG	ORD

Quaternary/Pleistocene deposits

QUUU	PLEISTOCENE UNDIFF.	QUA
QPUU	CLAY + SAND + SILT - PEBBLY	QUA

In general Pleistocene deposit codes have the form **Qxyz** *or* **Wxyz** *where* **Q** *indicates Pleistocene and* **W**, *more specifically, Wisconsinan deposits.* **x**, **y**, *and* **z** *may have any of the following designations:*

x

- =B boulder or boulders
- =C clay
- =F sand
- =G gravel
  - rock + gravel
  - gravel + rock
  - gravel + stones or cobbles
  - gravel + boulders
- =I silt
- =H sand + gravel
  - sand + rocks or cobbles
  - sand + stones
  - sand + boulders
- =L clay + sand
  - sandy clay
  - clayey sand
- =W clay + sand + silt - pebble free
- =P clay + sand + silt - pebbly
  - clay + cobbles or pebbles
  - clay + gravel *or* gravelly clay
  - gravel + clay *or* clayey gravel
- =N silt + sand and/or gravel (no clay)
  - silty sand
  - dirty sand *or* muddy sand
- =R sand + gravel + broken limerock, sandrock, dolomite, or rubble
- =S peat, muck, organic-rich material
- =U deposit type unknown or undifferentiated

y

- =C contains predominantly calcareous pebbles
- =P contains predominantly Precambrian pebbles
- =S contains predominantly shale pebbles
- =U materials undifferentiated or sorting unknown
- =N unsorted
- =O poorly sorted
- =D moderately sorted
- =W well sorted

z

- =B brown
- =G gray or blue
- =K black
- =R red
- =L green
- =U color unknown or unspecified
- =W white
- =Y yellow

For example, QPUB, *is used for a brown pebbly deposit of clay with some sand and/or silt of unknown material composition or sorting. Note that "pebbly" as used above indicates larger than sand-size grains and could include gravel, pebbles, cobbles, and/or boulders.*

Quaternary/Recent (Holocene) deposits

RMMF	MAN-MADE FILL	REC
RUUU	RECENT DEPOSIT	REC

In general Holocene deposit codes have the form **Rxyz** *where* **R** *denotes Recent or Holocene deposits and* **x**, **y**, *and* **z** *may have any of the codes specified for Pleistocene deposits.*

Precambrian

PCUU	PRECAMBRIAN, UNDIFFERENTIATED	PC
PCCR	PRECAMBRIAN CRYSTALLINE ROCKS	PC

Precambrian (Archean)

[equivalent to old PW– codes]

PAAU	ALGOMAN GRANITES UNDIVIDED	PCA
PAAR	ARGO GNEISS	PCA
PABL	BELLINGHAM GRANITE	PCA
PABR	BURNTSIDE GNEISS	PCA
PADL	DEER LAKE COMPLEX	PCA
PAES	SOUDAN IRON-FORMATION	PCA
PAEY	ELY GREENSTONE	PCA
PAFR	FORT RIDGLEY GRANITE	PCA
PAGR	GIANTS RANGE GRANITE UNDIVIDED	PCA
PAGF	GRANITE FALLS GNEISS	PCA
PAKG	KNIFE LAKE GROUP	PCA
PALL	LAC LACROIX GRANITE	PCA

PALV	LAKE VERMILION FORMATION	PCA
PAMC	MCGRATH GNEISS	PCA
PAMV	MONTEVIDEO GNEISS	PCA
PAMR	MORTON GNEISS	PCA
PANL	NEWTON LAKE FORMATION	PCA
PAOD	ODESSA GRANITE	PCA
PAOR	ORTONVILLE GRANITE	PCA
PARG	RICHMOND GNEISS	PCA
PASW	ST.WENDEL METAGABBRO	PCA
PASH	SACRED HEART GRANITE	PCA
PASG	SAGANAGA TONALITE	PCA
PASR	SAUK RAPIDS META. COMPLEX	PCA
PAST	SARTELL GNEISS	PCA
PASF	SEAFORTH GNEISS	PCA
PAUD	ARCHEAN ROCKS UNDIVIDED	PCA
PAVC	VERMILION GRANITIC COMPLEX	PCA
PAWT	WATAB AMPHIBOLITE	PCA
PAGU	ARCHEAN GRANITE PLUTON	PCA

Precambrian (Early Proterozoic)

[equivalent to old PX– codes]

PEAG	ANIMIKIE GROUP	PCE
PEBI	BIWABIK IRON-FORMATION	PCE
PEBC	BRADBURY CREEK GRANODIORTE	PCE
PECM	CEDAR MOUNTAIN COMPLEX	PCE
PEDN	DENHAM FORMATION	PCE
PEFH	FREEDHEM GRANODIORITE	PCE
PEGT	GLEN TOWNSHIP FORMATION	PCE
PEGI	GUNFLINT IRON-FORMATION	PCE
PEHL	HILLMAN MIGMATITE	PCE
PEIL	ISLE GRANITE	PCE
PELF	LITTLE FALLS FORMATION	PCE
PEMN	MAHNOMEN FORMATION	PCE
PEML	MILLE LACS GROUP	PCE
PEPZ	PIERZ GRANITE	PCE
PEPK	POKEGAMA QUARTZITE	PCE
PERB	RABBIT LAKE FORMATION	PCE
PERL	RABBIT LK.FM-LOWER MEMBER	PCE
PERE	RABBIT LK.FM-EMILY MEMBER	PCE
PERU	RABBIT LK.FM-UPPER MEMBER	PCE
PERF	REFORMATORY GRANITE	PCE
PERK	ROCKVILLE GRANITE	PCE
PERD	RANDALL FORMATION	PCE
PERV	ROVE FORMATION	PCE
PESC	ST.CLOUD GRANITE	PCE
PEST	STEARNS GRANITIC COMPLEX	PCE
PETM	THOMSON FORMATION	PCE
PETR	TROMMALD FORMATION	PCE
PETL	TROUT LAKE FORMATION	PCE
PEUD	EARLY PROTEROZOIC ROCKS UND.	PCE
PEVR	VIRGINIA FORMATION	PCE
PEWR	WARMAN GRANITE	PCE
PEGU	E.PROTEROZOIC GRANITE PLUTON	PCE
PEYV	PROTEROZOIC BASALT DIKES	PCP

Precambrian (Middle Proterozoic)

[equivalent to old PY– codes]

PMBB	BEAVER BAY COMPLEX	PCM
PMCV	CHENGWATANA VOLCANIC GROUP	PCM
PMDC	DULUTH COMPLEX	PCM
PMDA	DULUTH CPLX-ANORTH.SERIES	PCM
PMDF	DULUTH CPLX-FELSIC SERIES	PCM
PMDT	DULUTH CPLX-TROCT.SERIES	PCM
PMFL	FOND DU LAC FORMATION	PCM
PMHF	HINCKLEY-FOND DU LAC	PCM
PMHN	HINCKLEY SANDSTONE	PCM
PMLG	LOGAN INTRUSIONS	PCM
PMNP	NOPEMING SANDSTONE	PCM
PMNS	NORTH SHORE VOLCANIC GROUP	PCM
PMPK	PUCKWUNGE FORMATION	PCM
PMRC	RED CLASTIC SERIES	PCM
PMSX	SIOUX QUARTZITE	PCM
PMSC	SOLOR CHURCH FORMATION	PCM
PMPR	PIGEON RIVER INTRUSIONS	PCM
PMUD	MIDDLE PROTEROZOIC ROCKS UND.	PCM
PMVU	KEWEENAWAN VOLCANICS UND.	PCM
PMSU	MID.PROTEROZOIC SEDIMENTARY	PCM

Miscellaneous codes

QBAA	QUAT. BURIED ARTES. AQUIFER	QUA
QBPA	QUAT. BURIED PERCHED AQUIFER	QUA
QBUA	QUAT. BURIED UNCONF. AQU.IFER	QUA
QTTA	QUAT. AQUITARD	QUA
QWPA	QUAT. PERCHED AQUIFER	QUA
QWTA	QUAT. WATER TABLE AQUIFER	QUA
UREG	WEATHERING RESIDUUM	UNK

BSMT	BASEMENT
MTPL	MULTIPLE AQUIFER
NA	NOT APPLICABLE
NRCD	NO RECORD
PITT	PIT
PVMT	PAVEMENT

Appendix C.3
Lithologic codes

ACTN	ACTINOLITE
ADAM	ADAMELLITE
AGLM	AGGLOMERATE
ALKB	ALKALI BASALT
ALKG	ALKALI GRANITE
ALKR	ALKALI RHYOLITE
ALKS	ALKALI SYENITE
ALKT	ALKALI TRACHYTE
ALQS	ALKALI QUARTZ SYENITE
ALQT	ALKALI QUARTZ TRACHYTE
ALSK	ALASKITE
ALUV	ALLUVIUM
AMPH	AMPHIBOLITE
ANDL	ANDALUSITE
ANDS	ANDESITE
ANGB	ANORTHOSITIC GABBRO
ANNR	ANORTHOSITIC NORITE
ANOG	ANORTHOSITIC OLIVINE GABBRO
ANOR	ANORTHOSITE
ANPT	ANORTH. PYROXENE TROCTOLITE
ANTR	ANORTHOSITIC TROCTOLITE
APLT	APLITE
AREN	ARENITE
ARGI	ARGILLITE
ARKS	ARKOSE
BDRK	BEDROCK
BENT	BENTONITE
BIOS	BIOTITE SCHIST
BLDR	BOULDER
BRNZ	BRONZITE
BSLT	BASALT
BSMT	BASEMENT (BUILDING)
BXSD	BRECCIA, SEDIMENTARY
BXTT	BRECCIA, TECTONIC
CARB	CARBONATE
CATA	CATACLASTITE
CHAL	CHALCEDONY
CHAR	CHARNOCKITE
CHLK	CHALK
CHLR	CHLORITE, CHLORITIC
CHRT	CHERT
CLAY	CLAY
CLPX	CLINOPYROXENITE
CLSN	CLAYSTONE
CNGL	CONGLOMERATE
COAL	COAL
COBL	COBBLE
COLV	COLLUVIUM
CORD	CORDIERITE
CPRT	CHALCOPYRITE
CRBT	CARBONITITE
CRVC	CREVICE
CVRN	CAVERN
DACT	DACITE
DIAB	DIABASE
DIOP	DIOPSIDE
DIOR	DIORITE
DLMT	DOLOMITE
DOLE	DOLERITE
DRFT	DRIFT
DUNT	DUNITE
DURI	DURICRUST
ECLO	ECLOGITE
ENST	ENSTATITE
EPID	EPIDOTE
FCLP	FELDSPATHIC CLINOPYROXENITE
FDUN	FELDSPATHIC DUNITE
FELD	FELDSPAR
FELS	FELSITE
FGRD	FERROGRANODIORITE
FILL	FILL
FLNT	FLINT
FOCL	FLDSPTHC OLIV. CLNPYROXENITE
FOPY	FLDSPTHC OLIVINE PYROXENITE
FORP	FLDSPTHC ORTHOPYROXENITE
FPRH	FLDSPTHC PERID. (HARZBURGITE)
FPRW	FLDSPTHC PERID. (WEHRLITE)
FRDI	FERRODIORITE
FRGB	FERROGABBRO
GARN	GARNET
GBAN	GABBROIC ANORTHOSITE
GBRO	GABBRO
GLAU	GLAUCONITE
GNDI	GRANODIORITE
GNIS	GNEISS
GNLT	GRANULITE
GOSS	GOSSAN
GOUG	GOUGE
GRAN	GRANITE
GRPH	GRANOPHYRE
GRSC	GREENSCHIST
GRSN	GREENSTONE
GRST	GRAINSTONE
GRVL	GRAVEL
GRWK	GRAYWACKE
GYPS	GYPSUM
HARZ	HARZBURGITE
HDPN	HARDPAN
HEMA	HEMATITE
HNBT	HORNBLENDITE

HNFL	HORNFELS
HRNB	HORNBLEND
HYPS	HYPERSTHENE
INSU	INTERFLOW SEDIMENTS, UNDIF.
IRFM	IRON FORMATION
IRON	IRON ORE
JASP	JASPER
KAOL	KAOLINITE, KAOLINITIC
KERA	KERATOPHYRE
KIMB	KIMBERLITE
KOMA	KOMATIITE
KYAN	KYANITE
LAMP	LAMPROPHYRE
LATI	LATITE
LATR	LATERITE
LGNT	LIGNITE
LHRZ	LHERZOLITE
LMNT	LIMONITE; LIMONITE/GOETHITE
LMSN	LIMESTONE
LOAM	LOAM
LOES	LOESS
MAFU	MAFIC, UNDIF.
MARB	MARBLE
MARL	MARL
MDSN	MUDSTONE
MELI	MELILITITE
MGBR	MELAGABBRO
MGMT	MIGMATITE
MGNT	MAGNETITE
MICA	MICA
MICR	MICRITE
MMUO	MAN-MADE UGRND OBSTRUCTION
MMUV	MAN-MADE UNDERGROUND VOID
MNOR	MELANORITE
MNZT	MONZONITE
MSED	METASEDIMENTARY ROCK, UNDIF.
MUCK	MUCK
MUDD	MUD
MUSC	MUSCOVITE
MXTA	MIXED TROCTOLITE/ANORTHSTE
MYLN	MYLONITE
NEPH	NEPHELINITE
NOAN	NORITIC ANORTHOSITE
NORT	NORITE
NRCD	NO RECORD
OBSD	OBSIDIAN
OBTR	OLIVINE-BEARING TROCTOLITE
OLCL	OLIVINE CLINOPYROXENITE
OLGB	OLIVINE GABBRO
OLMG	OLIVINE MELAGABBRO
OLPX	OLIVINE PYROXENITE
OLVN	OLIVINE
OOLT	OOLITE
OPHI	OPHIOLITE
ORGD	ORGANIC DEPOSITS
ORGN	ORTHOGNEISS
ORPX	ORTHOPYROXENITE
ORQZ	ORTHOQUARTZITE
ORTH	ORTHOCLASE
OVBD	OVERBURDEN
PEAT	PEAT
PEBL	PEBBLES
PEGM	PEGMATITE
PELT	PELITE
PHON	PHONOLITE
PHOS	PHOSPHATIC
PHYL	PHYLLITE
PICR	PICRITE
PITT	PIT
PORY	PORPHYRY
PRDH	PERIDOTITE (HARZBURGITE)
PRDT	PERIDOTITE
PRDW	PERIDOTITE (WEHRLITE)
PUMC	PUMICE
PVMT	PAVEMENT (MAN-MADE)
PYPC	PYROXENE PICRITE
PYRT	PYRITE, PYRITIC
PYRX	PYROXENITE
PYTR	PYROXENE TROCTOLITE
QRTZ	QUARTZITE
QUTZ	QUARTZ, QUARTZOSE
QZAN	QUARTZ ANDESITE
QZAR	QUARTZ ARENITE
QZDI	QUARTZ DIORITE
QZLA	QUARTZ LATITE
QZMD	QUARTZ MONZODIORITE
QZMZ	QUARTZ MONZONITE
QZPY	QUARTZ PORPHYRY
QZSY	QUARTZ SYENITE
QZTR	QUARTZ TRACHYTE
REGO	REGOLITH
RHYD	RHYODACITE
RHYL	RHYOLITE
SAND	SAND
SAPR	SAPROLITE
SERP	SERPENTINITE
SHLE	SHALE
SHST	SCHIST
SIDR	SIDERITE, SIDERITIC
SILC	SILICA
SILT	SILT
SINT	SINTER
SKRN	SKARN
SLSN	SILTSTONE
SLTE	SLATE
SNDS	SANDSTONE
SOIL	SOIL
SPAR	SPARITE

STAU	STAUROLITE
SYEN	SYENITE
TACT	TACONITE
THOL	THOLEIITE
TILL	TILL,TILLITE
TONT	TONALITE
TRAN	TROCTOLITIC ANORTHOSITE
TRAV	TRAVERTINE
TRAY	TRACHYTE
TRDJ	TRONDHJEMITE
TREM	TREMOLITE
TRGB	TROCTOLITIC GABBRO
TROC	TROCTOLITE
TUFA	TUFA
TUFF	TUFF
UMFU	ULTRAMAFICS, UNDIF.
VOLU	VOLCANICS, UNDIF.
WATR	WATER
WOOD	WOOD
ZEOL	ZEOLITE, ZEOLITIC

PRELIMINARY GEOLOGIC MAP OF PRECAMBRIAN BEDROCK, NORTHWESTERN MINNESOTA

University of Minnesota
Minnesota Geological Survey
Priscilla C. Grew, Director

by,

Mark A. Jirsa and Val W. Chandler

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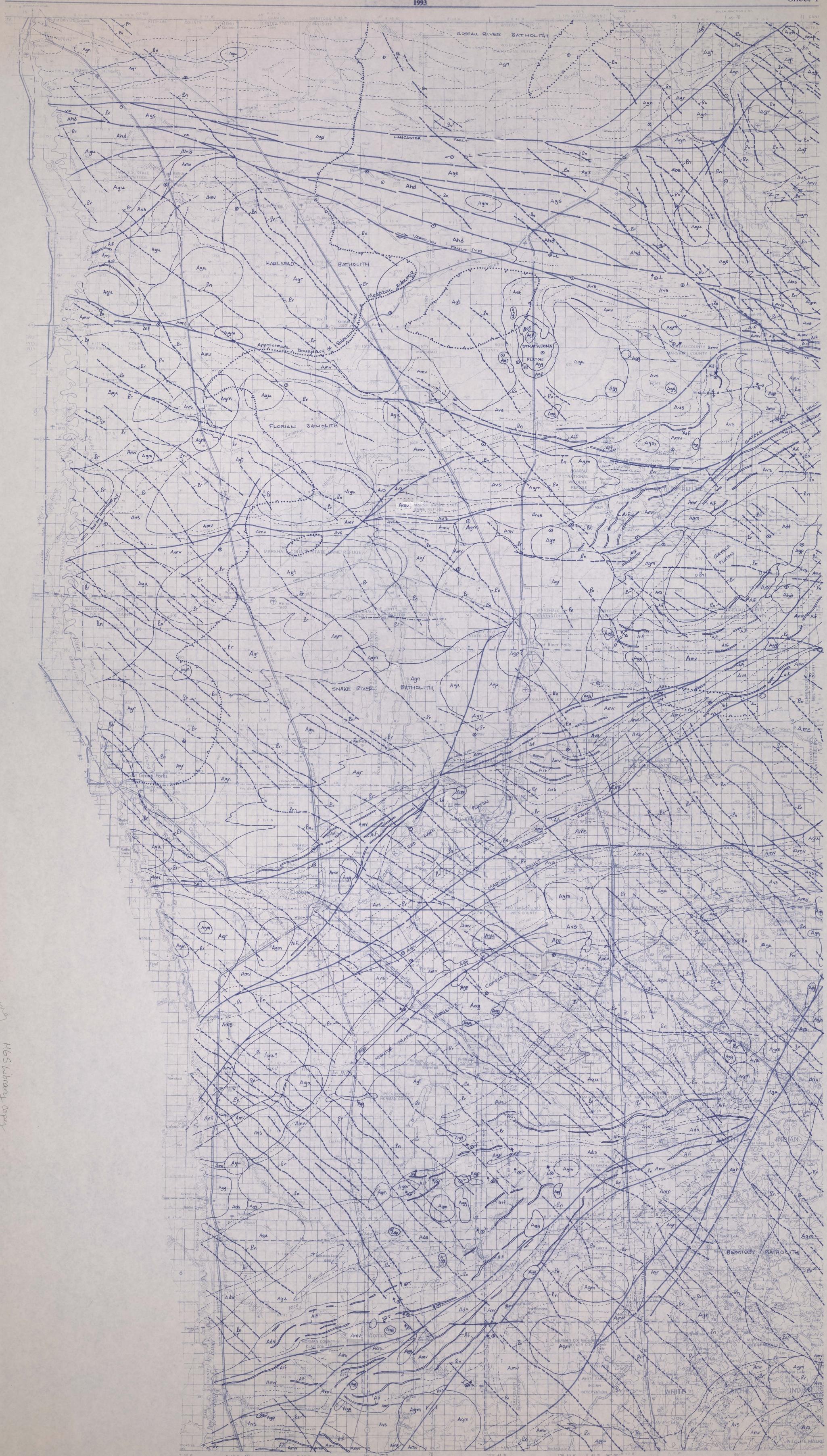

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SCALE 1:250,000

5 0 5 10 15 20 25 miles

5 0 5 10 15 20 25 30 kilometers

PRELIMINARY GEOLOGIC MAP OF PHANEROZOIC BEDROCK, NORTHWESTERN MINNESOTA

by,

Anthony C. Runkel

1993

University of Minnesota
Minnesota Geological Survey
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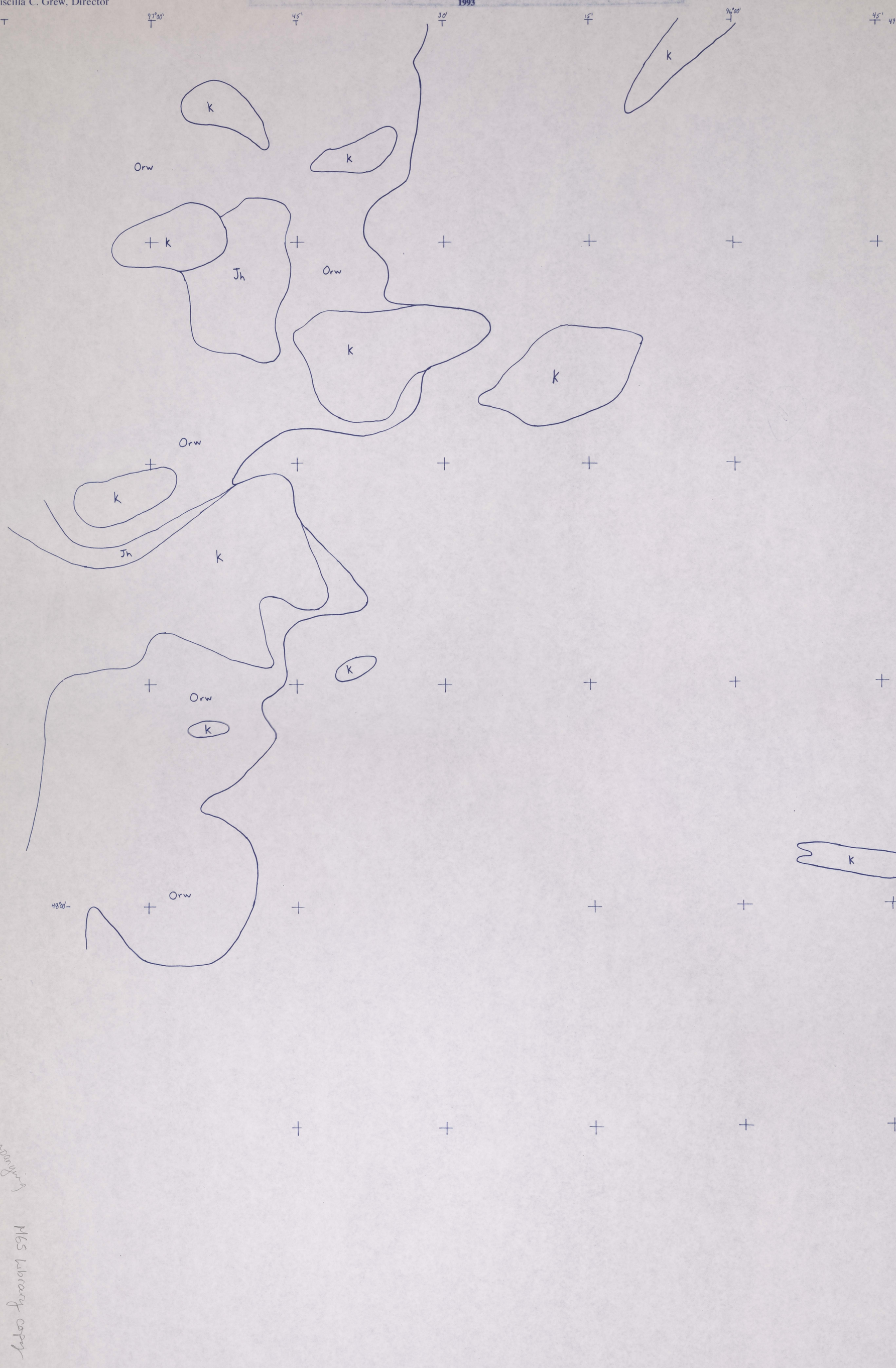

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PRELIMINARY DATABASE MAP, NORTHWESTERN MINNESOTA

by,

Anthony C. Runkel and Mark A. Jirsa

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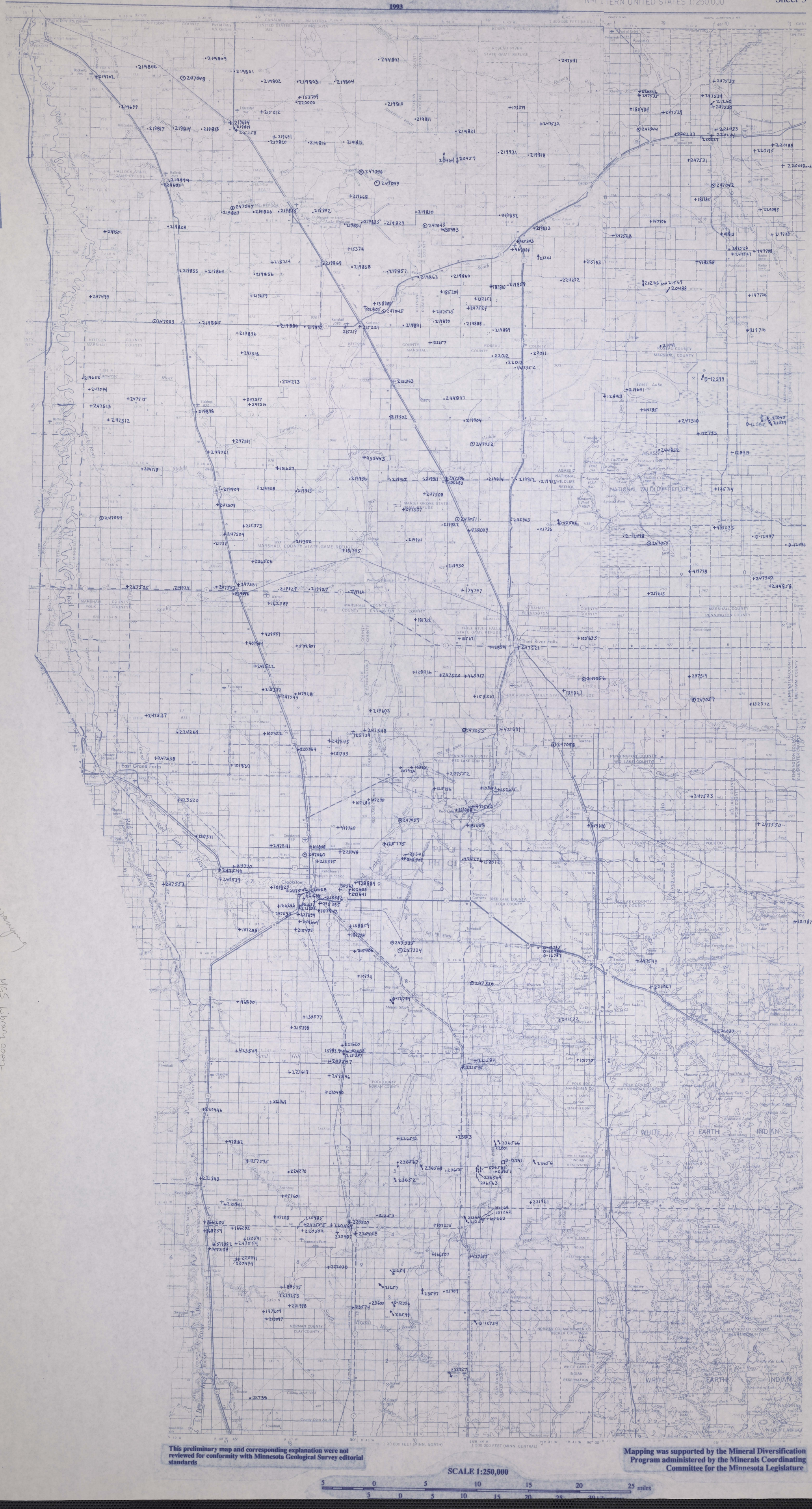

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5 0 5 10 15 20 25 miles

1 300 000 FEET (MINN.) 1 30 000 FEET (MINN. NORTH) 1 500 000 FEET (MINN. CENTRAL)

PRELIMINARY BEDROCK TOPOGRAPHIC MAP, NORTHWESTERN MINNESOTA

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Anthony C. Runkel

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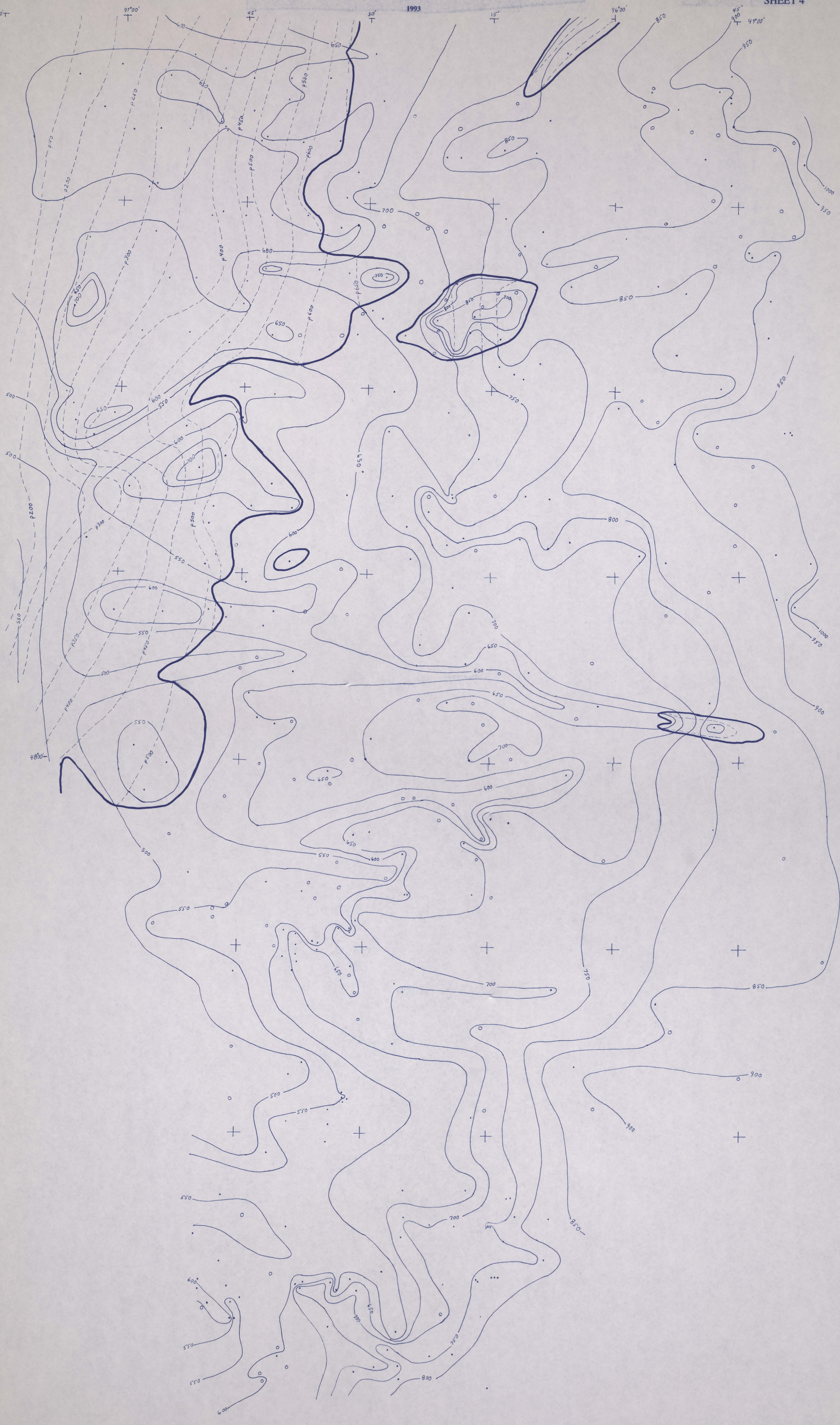

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5 0 5 10 15 20 25 30 kilometers