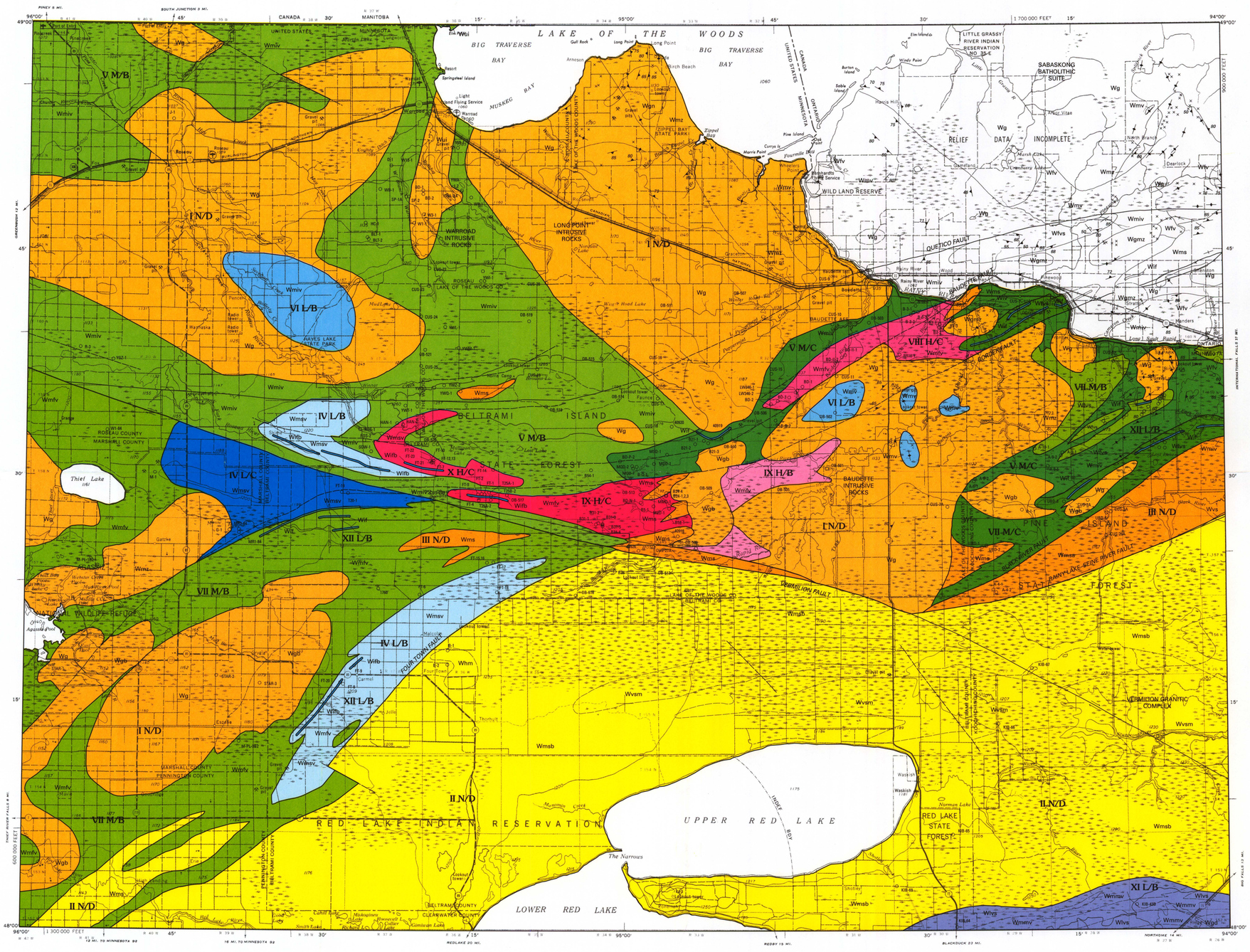
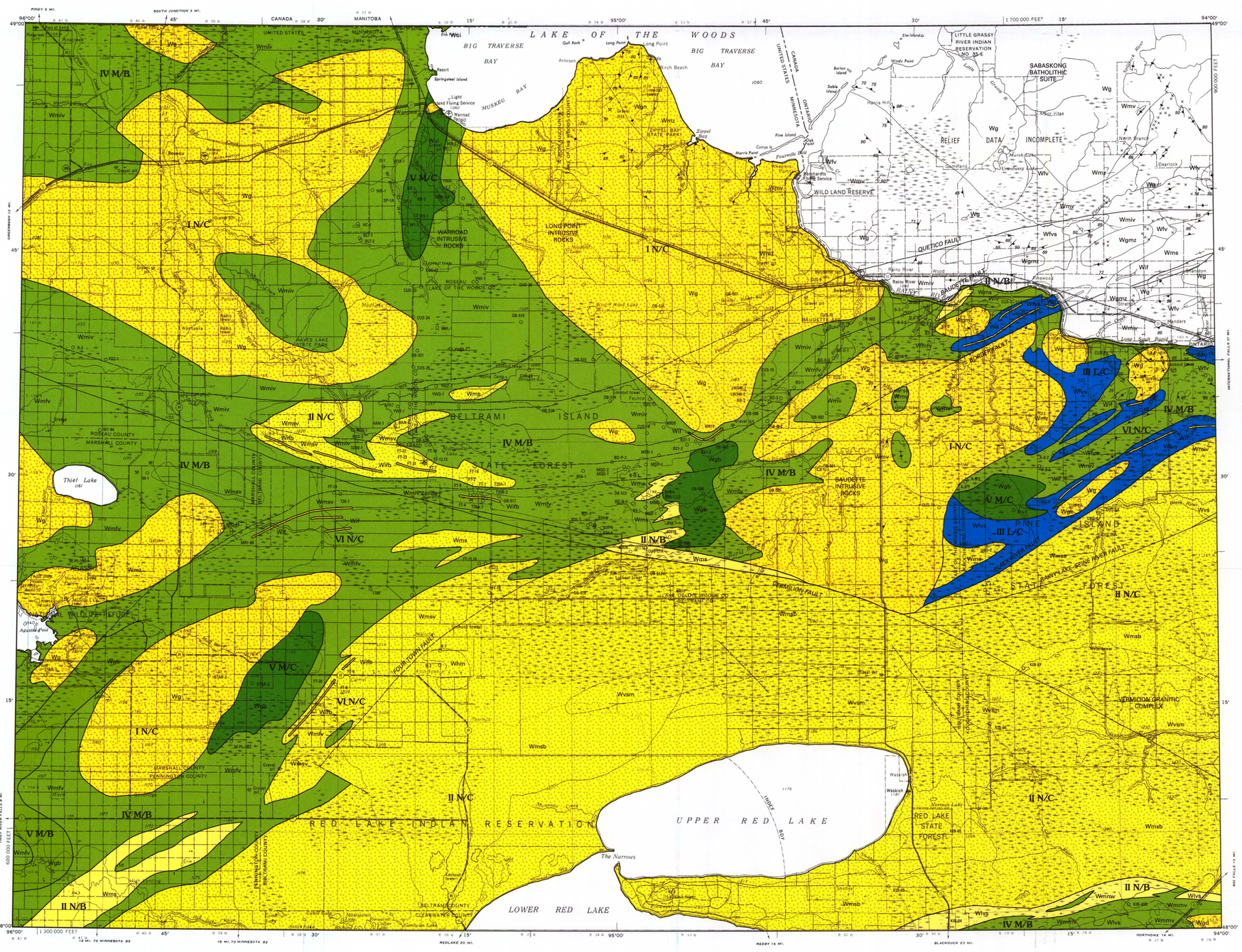
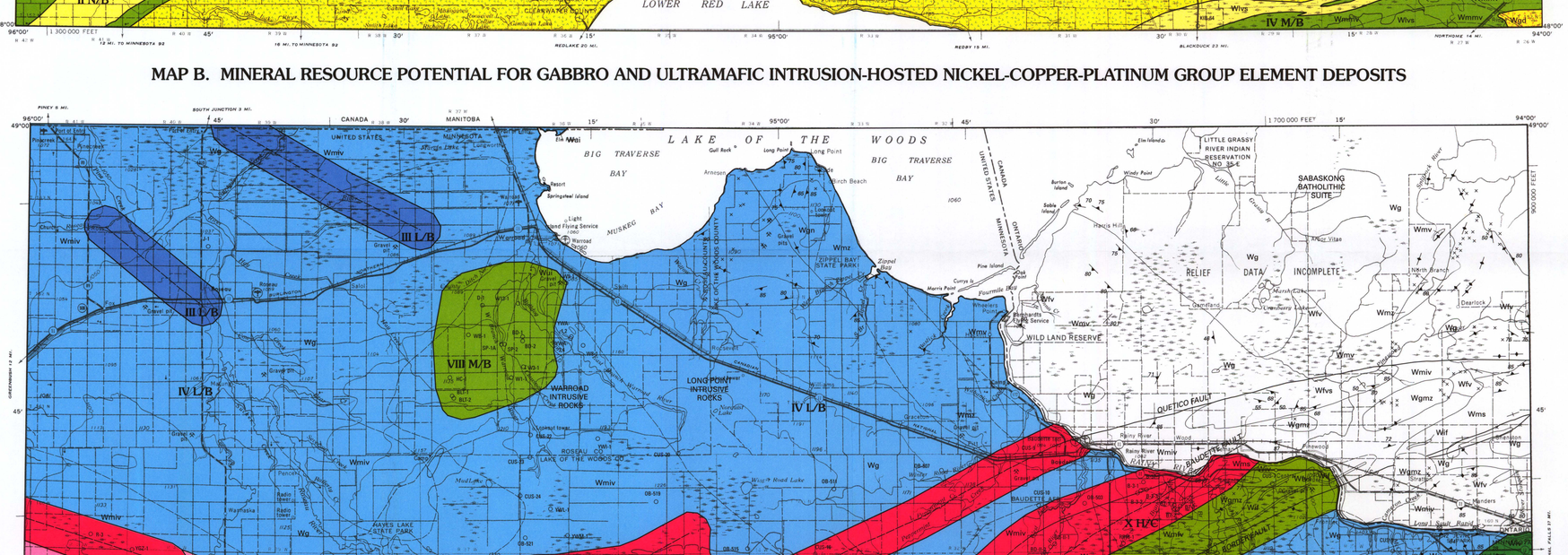


MAP A. MINERAL RESOURCE POTENTIAL FOR VOLCANOGENIC MASSIVE SULFIDE DEPOSITS



MAP B. MINERAL RESOURCE POTENTIAL FOR GABBRO AND ULTRAMAFIC INTRUSION-HOSTED NICKEL-COPPER-PLATINUM GROUP ELEMENT DEPOSITS



MAP C. MINERAL RESOURCE POTENTIAL FOR ARCHEAN LODE GOLD DEPOSITS

Base from U.S. Geological Survey, 1954 (U.S. area revised 1955)
100,000-foot grid based on Minnesota coordinate system, north zone
10,000-meter Universal Mercator grid zone 15
Transverse Mercator projection

Geology simplified from Day and others (1994)
Edited by Lorna M. Carter
Digital cartography by Alessandro J. Donatich
Manuscript approved for publication July 28, 1998

SCALE 1:250 000

CONTOUR INTERVAL 50 FEET
NATIONAL GEODETIC VERTICAL DATUM OF 1929

DESCRIPTION OF MAP UNITS FOR MAPS A–C

LATE ARCHEAN UNITS OF THE WABIGOON SUBPROVINCE

Post-tectonic intrusive rocks (younger than about 2,700 Ma)

- **Wgmz** — **Granodiorite, quartz monzonite, and granite**
- **Wmz** — **Hornblende monzonite**
- **Wgn** — **Granodiorite gneiss**

Pre- and syn-tectonic intrusive rocks (about 2,700–2,736 Ma)

- **Wg** — **Granitoid rocks**
- **Wgb** — **Mafic intrusive rock**
- **Wui** — **Ultramafic to mafic intrusive rocks**

Supracrustal rocks

- **Wms** — **Metasedimentary rocks, undivided**
- **Wmsa** — **Metasedimentary rocks, amphibolite facies**
- **Wif** — **Iron-formation**
- **Wifb** — **Chert-rich iron-formation**
- **Wmsv** — **Metasedimentary and metavolcanic rocks**
- **Wfvs** — **Felsic metavolcanic and volcaniclastic metasedimentary rocks**
- **Wfv** — **Felsic metavolcanic rocks**
- **Wmfv** — **Mafic and felsic metavolcanic rocks**
- **Wiv** — **Intermediate metavolcanic rocks**
- **Wmiv** — **Mafic to intermediate metavolcanic rocks, undivided**
- **Wmv** — **Mafic metavolcanic rocks**
- **Wvs** — **Metavolcanic and metasedimentary rocks, undivided**

LATE ARCHEAN UNITS OF THE QUETICO SUBPROVINCE

Intrusive and migmatitic rocks

- **Whm** — **Hornblende monzonite**
- **Wvsm** — **Schist-rich migmatite**

Supracrustal rocks

- **Wmsb** — **Metasedimentary rocks, undivided**

LATE ARCHEAN UNITS OF THE WAWA SUBPROVINCE

Intrusive rocks

- **Wgd** — **Granodiorite, quartz diorite, and tonalite**

Supracrustal rocks

- **Wlvs** — **Layered volcanic-sedimentary rocks**
- **Wmmv** — **Metavolcanic rocks, undivided**

Approximate contact—Dashed where inferred

Fault—Dashed where inferred. Arrows show relative horizontal movement

Strike and dip of bedding

- 80 — **Inclined**
- **Vertical**
- 25 — **Overturned**

Strike and dip of schistosity

- 80 — **Inclined**
- **Vertical**

× **Location of outcrop**

A-9-1 ○ **Location of numbered drill hole**—See Klein and Day (1989) for geologic data and Klein and others (1987) and Klein (1988) for geochemical data for drill holes

EXPLANATION OF MINERAL RESOURCE POTENTIAL FOR MAP A

Mineral resource assessment tracts

- I N/D — **Tract I**—Granitoid, gabbro, and ultramafic plutonic rocks
- II N/D — **Tract II**—Graywacke-argillite-type metasedimentary rocks of the Quetico subprovince
- III N/D — **Tract III**—Graywacke-argillite-type metasedimentary rocks of the Wabigoon and Wawa subprovinces
- IV L/B, IV L/C — **Tract IV**—Metasedimentary rocks derived from volcanic sources
- V M/B, V M/C — **Tract V**—Mafic to intermediate metavolcanic rocks of the Wabigoon subprovince
- VI L/B — **Tract VI**—Roof pendants of mafic to intermediate volcanic rocks in granitoid rocks of the Wabigoon subprovince
- VII M/B, VII M/C — **Tract VII**—Felsic and bimodal metavolcanic rocks containing massive sulfide layers with low levels of base metals
- VIII H/C — **Tract VIII**—Highly deformed bimodal metavolcanic rocks in the central part of the Wabigoon subprovince containing base-metal-bearing massive sulfide layers
- IX H/B, IX H/C — **Tract IX**—Bimodal metavolcanic rocks in the central part of the Wabigoon subprovince containing base-metal-bearing massive sulfide layers
- X H/C — **Tract X**—Fine-grained metamorphosed layered tuffs, chert, and subordinate amounts of felsic volcaniclastic rocks containing a pyritic massive sulfide lens with generally low base-metal content
- XI L/B — **Tract XI**—Mafic metavolcanic rocks with minor amounts of felsic metavolcanic rocks of the Wawa subprovince
- XII L/B — **Tract XII**—Magnetic iron-formation

Table 2. *Diagnostic and permissive criteria for volcanogenic massive sulfide deposits*

Diagnostic criteria:

1. Presence of volcanic rocks.
   Geophysical indicators: irregular aeromagnetic patterns and relative gravity highs.
2. Proximity to felsic volcanic centers characterized by coarse felsic volcaniclastic breccias and fragmental rocks, subvolcanic intrusive rocks.
3. Evidence for hydrothermal fluids associated with massive sulfide deposits.
   a. Exhalite, volcanogenic chert-sulfide horizons, Algoma-type iron-formation, manganese-rich layers.
   b. Hydrothermal alteration such as Mg^{-}, Fe^{-}, and K-enrichment and Na-depletion.
   c. Base-metal and pathfinder-elemen t enrichment (Zn, Cu, ± Se, In, Sb, Sn, or B) as indicated by bedrock and B-horizon soil samples.
   d. Presence of barren, pyrite-rich massive sulfide horizons.
4. Presence of base-metal massive sulfide deposits as indicated by bedded sulfide mineral deposits or stockwork feeder zones, or bedrock electrical conductors.

Permissive criteria:

1. Presence of graphitic sediments.

Table 3. *Resource potential for volcanogenic massive sulfide deposits in the Roseau 1°x2° quadrangle*

Tract No. (map A)	Diagnostic criteria 1	2	3	4	Sum of tract scores	Resource potential	Confidence level
I	0	0	0	0	0	None	D
II	0	0	0	0	0	None	D
III	0	0	0	0	0	None	D
IV	1	0	1[a,b]	0	2	Low	B, C
V	1	0	1[a,b,c]	1	3	Moderate	B, C
VI	1	0	1[c]	0	2	Low	B
VII	1	1	1[a]	0	3	Moderate	B, C
VIII	1	1	1[a,b,c,d]	1	4	High	C
IX	1	1	1[a,b,c,d]	1	4	High	B, C
X	1	1	1[a,b,d]	1	4	High	C
XI	1	0	0	0	1	Low	B
XII	0	1	1[a,b,c,d]	0	2	Low	B

[a]Chert.
[b]Mg or Fe enrichment.
[c]Base-metal anomalies.
[d]Massive sulfide horizons present.

EXPLANATION OF MINERAL RESOURCE POTENTIAL FOR MAP B

Mineral resource assessment tracts

- I N/C — **Tract I**—Granitoid plutonic rocks of the Wabigoon subprovince
- II N/B, II N/C — **Tract II**—Granitoid and metasedimentary rocks of the Wabigoon, Wawa, and Quetico subprovinces
- III L/C — **Tract III**—Felsic metavolcanic and metavolcanic-sedimentary units of the Wabigoon subprovince
- IV M/B — **Tract IV**—Mafic metavolcanic units of the Wabigoon and Wawa subprovinces
- V M/B, V M/C — **Tract V**—Large metamorphosed gabbro or gabbro-peridotite bodies of the Wabigoon subprovince
- VI N/C — **Tract VI**—Magnetic iron-formation associated with mafic metavolcanic and metasedimentary rocks of the Wabigoon subprovince

Table 4. *Diagnostic criteria for nickel-copper-platinum group element deposits in gabbro and ultramafic rocks in the Roseau 1°x2° quadrangle*

1. Presence of layered gabbro, dunite, peridotite, pyroxenite, anorthosite, and norite intrusions or komatiitic volcanic rocks or subvolcanic sills.
2. Anomalously high concentrations of nickel, copper, ± cobalt, platinum group elements; presence of nickel and (or) copper sulfide or arsenide minerals.

Table 5. *Resource potential for gabbro- and ultramafic-intrusion-associated nickel-copper-platinum group element deposits and komatiite nickel-copper deposits in the Roseau 1°x2° quadrangle*

Tract No. (map B)	Diagnostic criteria 1	2	Sum of tract scores	Resource potential	Confidence level
I	-1	0	-1	None	C
II	-1	0	-1	None	B, C
III	0	0	0	Low	C
IV	1	1	2	Moderate	B
V	1	0	1	Moderate	B, C
VI	-1	0	-1	None	C

EXPLANATION OF MINERAL RESOURCE POTENTIAL FOR MAP C

Mineral resource assessment tracts

- I L/B — **Tract I**—Metasedimentary rocks of the Quetico subprovince located more than 2 km from known or inferred shear zones
- II L/B — **Tract II**—Plutonic and supracrustal rocks of the Wawa subprovince located more than 2 km from known or inferred shear zones
- III L/B — **Tract III**—Metasedimentary rocks of the Quetico subprovince located within 2 km of known or inferred shear zones
- IV L/B — **Tract IV**—Granitoid and supracrustal rocks of the Wabigoon subprovince located more than 2 km from known or inferred shear zones
- V L/B — **Tract V**—Rocks within 2 km of known or inferred shear zones of the Wabigoon subprovince that do not have positive diagnostic criteria other than proximity to shear zones
- VI L/B — **Tract VI**—Large granitoid plutons and some mafic and felsic volcanic rocks characterized by tellurium anomalies in overlying soils
- VII M/B — **Tract VII**—Rocks of the Quetico and Wabigoon subprovinces located within 2 km of the Four Town and Border faults and overlain by soils containing geochemical anomalies possibly related to gold deposits
- VIII M/B, VIII M/C — **Tract VIII**—Metavolcanic rocks and granitoid rocks of the Wabigoon subprovince that contain low-level gold and base-metal anomalies in small shear zones near Birchdale, Minn. (VIII M/C), and southwest of Warroad, Minn. (VIII M/B)
- IX M/B — **Tract IX**—Bimodal (mafic-felsic) metavolcanic rocks between the Border fault and the Vermilion fault that show evidence of hydrothermal alteration possibly related to gold deposits
- X H/B, X H/C — **Tract X**—Highly deformed metavolcanic rocks of the Wabigoon subprovince that contain low-level gold anomalies and quartz-calcite veins

Table 6. *Diagnostic and permissive criteria for Archean low-sulfide gold-quartz vein deposits in the Roseau 1°x2° quadrangle*

Diagnostic criteria:

1. Presence of anomalous gold and silver concentrations in drill core or B-horizon soil samples.
2. Proximity to shear zones (<2 km), or presence of structural "breaks," dilatant zones, or highly sheared rock.
3. Evidence of appropriate hydrothermal alteration.
   a. Vein and (or) ribbon quartz.
   b. Carbonate alteration minerals.
   c. Potassic alteration (sericite).
   d. Anomalous boron (exclusive of high abundances typical of sedimentary rocks and massive sulfide deposits).
   e. Anomalous concentrations of As, Se, W, Hg, Sb, Te, Mo, Bi, Zn, and (or) Cu in soil or rock samples.
   f. Disseminated or vein-filling arsenopyrite or pyrite.

Permissive criteria:

1. Presence of chemically favorable host rock, such as iron-formation and iron-rich tholeiitic basalt.
2. Presence of fuchsite or scheelite.

Table 7. *Resource potential for Archean low-sulfide gold-quartz vein deposits in the Roseau 1°x2° quadrangle*

[Superscript letters indicate which type of hydrothermal alteration is present in a given tract. Criterion 3f, presence of disseminated or vein-filling arsenopyrite or pyrite, was not recognized in the present study]

Tract No. (map C)	Diagnostic criteria 1	2	3	Sum of tract scores	Resource potential	Confidence level
I	0	0	0	0	Low	B
II	0	0	0	0	Low	B
III	0	1	0	1	Low	B
IV	0	0	1[d,e]	1	Low	B
V	0	1	0	1	Low	B
VI	0	0	1[e]	1	Low	B
VII	0	1	1[a,b,e]	2	Moderate	B
VIII	0	1	1[a,b,c,d]	2	Moderate	B, C
IX	0*	1	1[d,e]	2	Moderate	B
X	1	1	1[a,b,c,d,e]	3	High	B, C

*Gold present in this tract is related to massive sulfide deposits.
[a]Vein and (or) ribbon quartz.
[b]Carbonate alteration minerals.
[c]Potassic alteration (sericite).
[d]Anomalous boron (exclusive of high abundances typical of sedimentary rocks and massive sulfide deposits).
[e]Anomalous concentrations of As, Se, W, Hg, Sb, Te, Mo, Bi, Zn, and (or) Cu in soil or rock samples.

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1999

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