Gold Mineralization Potential in a Wabigoon Subprovince Granite-Greenstone Terrane, International Falls Area, Minnesota
The State of Minnesota is located in the north-central portion of the United States, along the Canadian border. Most of Minnesota’s northern border is shared with Northwest Ontario.
The Archean Superior Province granite-greenstone terranes that host world-class gold mines and camps in Ontario extend along strike into Northern Minnesota.
The Superior Province, broadly speaking, consists of alternating belts of greenstone (green) and plutonic (tan) subprovinces. Two granite-greenstone provinces (Wawa and Wabigoon) are found in Northern Minnesota.
The Superior Province hosts many of the world’s richest mineral deposits. The Wabigoon and Wawa Subprovinces, in particular, are mineral rich, and these geologic terranes are found in Minnesota.
This simplified geologic map of Northern Minnesota and Northwestern Ontario shows the geologic continuity of granite greenstone belts along the U.S./Canadian border, and the proximity of Minnesota gold prospects and Canadian gold properties.
Gold Exploration in Minnesota?

This map was prepared by Brett Resources (see link) to show the proximity of the Hammond Reef gold project and two other major gold resources in Northwestern Ontario, Canada. Gold prospects on the Minnesota side of the U.S./Canadian border are also close to what Brett calls an “Emerging Gold Camp.”
There are currently six separate areas of active gold exploration in Northern Minnesota. The State offers mineral leases, including areas where gold prospects have been identified, either by historical mineral exploration, subsequent geologic mapping, and/or new gold in till sampling programs.
The granite-greenstone terrane in the International Falls area is part of the Wabigoon Subprovince of the Archean Superior Province.
International Falls, Minnesota is located within 50 kilometers of the Rainy River and Q-Gold (Mine Centre) Gold Properties just over the border in Northwestern Ontario. The Mine Centre Area is along strike.
International Falls, Minnesota is located within 50 kilometers of the Rainy River and Q-Gold (Mine Centre) Gold Properties just over the border in Northwestern Ontario. The Mine Centre Area is along strike.
Lands (in black) that are privately held, claimed, or unavailable for mineral exploration in Ontario.

Significant portions of the Wabigoon granite-greenstone terrane on the Canadian side of the border are stake claimed, excluded from exploration, or privately held. The amount of comparable State-held lands and mineral rights that are not leased but have been offered for lease in the past is noteworthy (white).
Significant portions of the Wabigoon granite-greenstone terrane on the Canadian side of the border are stake claimed, excluded from exploration, or privately held. The amount of comparable State-held lands and mineral rights that are not leased but have offered for lease in the past is noteworthy.
The Area Under Consideration for the April 28, 2011 Minnesota State Metallic Mineral Lease Sale is located just outside of the city, and just south of the U.S. – Canadian border. For specific areas offered, see http://files.dnr.state.mn.us/lands_minerals/leasesale/m_u_b_36-5_2011.pdf
The International Falls area is largely undeveloped wetlands and forested areas. There is excellent road access, and CN’s mainline track cuts straight through the Area Under Consideration for the 2011 State Mineral Lease Sale.
The State of Minnesota holds a dominant position of surface and mineral rights within the Area Under Consideration. There are two parcels that are actively leased for mineral exploration, separated by an area of historic mineral exploration.
A major thrust fault bisects the International Falls Area, separating Quetico Subprovince metasedimentary units to the South from Wabigoon Subprovince granite-greenstone that includes an Algoma-type iron formation and fault bound metavolcanics.
A major thrust fault bisects the International Falls Area, separating Quetico Subprovince metasedimentary units to the South from Wabigoon Subprovince granite-greenstone that includes an Algoma-type iron formation and fault bound metavolcanics.
The Active and Terminated State Mineral Leases in the International Falls Area are concentrated along the structural boundary between the Wabigoon and Quetico Subprovinces.
The International Falls Area has relatively low topographic relief. Bedrock outcrop exposures are limited to the northeastern portion of the area.
The areal distribution of bedrock outcrops is not lithologically controlled. Surface exposures of Wabigoon Subprovince metavolcanics and Quetico Subprovince metasediments are found in the northeastern part of the Area Under Consideration for the April 28, 2011 State Mineral Lease Sale.
In 1997, the US Geological Survey published a Mineral Resource Assessment for the U.S. Portion of the International Falls 1 x 2 Quadrangle. Their maps show areas with high potential for gold and volcanogenic massive sulfide deposits.
In 1997, the US Geological Survey published a Mineral Resource Assessment for the U.S. Portion of the International Falls 1 x 2 Quadrangle. Their maps show areas with high potential for gold and volcanogenic massive sulfide deposits.
A number of geophysical surveys were completed during historic exploration under terminated State mineral leases. The DNR also completed a geophysical survey in 1984. The results of these geophysical investigations are available for review in the MnDNR’s archive of lease documents and data in Hibbing.
Several drill holes were completed in the International Falls Area during a period of active exploration in the 1980’s and 1990’s. Assays from some of these drill holes returned high gold concentrations over core intervals of up to ten feet in length.
The MnDNR collected 110 new shallow soil samples in 2010. Most of the samples were collected on a 200m grid, and all samples were in areas with State-controlled surface and mineral rights. Samples were not collected where there were active mineral leases and/or wetlands.
Gold concentrations in the 110 A1 soil samples collected by the MnDNR in 2010 are comparable to those documented in a 1985 Mn DNR geochemical survey in the International Falls Area (Report 242).
New semi-quantitative X-ray fluorescence spectrometer data collected by the MnDNR on drill core from the International Falls Area. Gold mineralization is associated with Rb (potassium analog?), Cu, and Mn; along with quartz veining, sulfides, and local tourmaline in metamorphosed iron formation.
Gold association with local tourmaline

Drill core from the International Falls Area. Large tourmaline masses associated with deformed quartz-carbonate veins and segregations.
Gold association with local tourmaline

Section of tourmaline-quartz-carbonate drill core within its archived 10-foot core box. Drill core from the International Falls Area is available to the public in the MnDNR’s Drill Core Library in Hibbing, MN, a statewide repository that holds more than 3 million feet of core from more than 12,000 drill holes.
Spot gold concentrations (ppm) in drill core from a greenstone belt near International Falls, Minnesota. New semi-quantitative XRF analyses by MnDNR.

This is an example of the drill core accessible to the public as part of the Drill Core Library’s collection of archived materials. This specific section of core was submitted by an exploration company that was focused on a different interval of core.
U. S. Geological Survey: Criteria for Lode Gold Deposits

Diagnostic criteria

1. Presence of anomalous gold in bedrock or soils.
2. Proximity to shear zones (less than 2 km).
3. Evidence of appropriate hydrothermal alteration:
   - Vein and (or) ribbon quartz
   - Carbonate alteration minerals (ankerite, siderite, dolomite)
   - Potassic alteration (sericite)
   - Boron anomalies (tourmaline)
   - Metal pathfinder element anomalies (As, Se, Cu, Zn, Bi, Mo, Sb, etc.)
   - Disseminated or vein-filling arsenopyrite or pyrite

Permissive criteria

1. Presence of chemically favorable host rock, such as iron formation or iron-rich mafic rocks.
2. Presence of fuchsite or scheelite

Diagnostic criteria

1. Presence of anomalous gold in bedrock or soils.
2. Proximity to shear zones (less than 2 km).
3. Evidence of appropriate hydrothermal alteration:
   - Vein and (or) ribbon quartz
   - Carbonate alteration minerals (ankerite, siderite, dolomite)
   - Potassic alteration (sericite)
   - Boron anomalies (tourmaline)
   - Metal pathfinder element anomalies (As, Se, Cu, Zn, Bi, Mo, Sb, etc.)
   - Disseminated or vein-filling arsenopyrite or pyrite

Permissive criteria

1. Presence of chemically favorable host rock, such as iron formation or iron-rich mafic rocks.
2. Presence of fuchsite or scheelite

In this slide and those following, the USGS’s criteria for high potential for lode gold deposits is matched against the geology, mineralogy, and mineralization of the International Falls Area. The International Falls Area has all of the diagnostic criteria for lode gold deposits.
Diagnostic criteria

1. Presence of anomalous gold in bedrock or soils.
2. Proximity to shear zones (less than 2 km).
3. Evidence of appropriate hydrothermal alteration:
   - Vein and (or) ribbon quartz
   - Carbonate alteration minerals (ankerite, siderite, dolomite)
   - Potassic alteration (sericite)
   - Boron anomalies (tourmaline)
   - Metal pathfinder element anomalies (As, S, Zn, Bi, Mo, Sb, etc.)
   - Disseminated or vein-filling arsenopyrite or pyrite

Permissive criteria

1. Presence of chemically favorable host rock, such as iron formation or iron-rich mafic rocks.
2. Presence of fuchsite or scheelite
U. S. Geological Survey: Criteria for Lode Gold Deposits

**Diagnostic criteria**

- **1.** Presence of anomalous gold in bedrock or soils.
- **2.** Proximity to shear zones (less than 2 km).
- **3.** Evidence of appropriate hydrothermal alteration:
  - Vein and (or) ribbon quartz
  - Carbonate alteration minerals (ankerite, siderite, dolomite)
  - Potassic alteration (sericite)
  - Boron anomalies (tourmaline)
  - Metal pathfinder element anomalies (As, Se, Cu, Zn, Bi, Mo, Sb, etc.)
  - Disseminated or vein-filling arsenopyrite or pyrite

**Permissive criteria**

- **1.** Presence of chemically favorable host rock, such as iron formation or iron-rich mafic rocks.
- **2.** Presence of fuchsite or scheelite

Deformed quartz-carbonate-sulfide vein or segregation in a silicate-oxide-sulfide-chert(?) iron formation, with porphyroblastic garnet in chlorite-amphibole groundmass.

**DDH SS-7, 265.8 -266.2ft**
Deformed quartz-carbonate-sulfide vein or segregation in a silicate-oxide-sulfide-chert iron formation, with porphyroblastic garnet in chlorite-amphibole groundmass.

DDH SS-7, 265.8 - 266.2 ft

U. S. Geological Survey: Criteria for Lode Gold Deposits

*Diagnostic criteria*

- 1. Presence of anomalous gold in bedrock or soils.
- 2. Proximity to shear zones (less than 2 km).
- 3. Evidence of appropriate hydrothermal alteration:
  - Vein and (or) ribbon quartz
  - Carbonate alteration minerals (ankerite, siderite, dolomite)
  - Potassic alteration (sericite)
  - Boron anomalies (tourmaline)
  - Metal pathfinder element anomalies (As, Se, Cu, Zn, Bi, Mo, Sb, etc.)
  - Disseminated or vein-filling arsenopyrite or pyrite

*Permissive criteria*

- 1. Presence of chemically favorable host rock, such as iron formation or iron-rich mafic rocks.
- 2. Presence of fuchsite, scheelite, sphalerite, tourmaline in quartz vein with carbonate

DDH ND-3 @ 340’ Sphalerite lamina/vein in siliceous lapilli tuff with an exhalative component
Deformed quartz-carbonate-sulfide vein or segregation in a silicate-oxide-sulfide-chert (?) iron formation, with porphyroblastic garnet in chlorite-amphibole groundmass. DDH SS-7, 265.8 - 266.2 ft

Sphalerite

Tourmaline in quartz vein with carbonate

DDH ND-1 @ 84.5'

CM Scale

Sphalerite lamina/vein in siliceous lapilli tuff (?) with an exhalative component

U. S. Geological Survey: Criteria for Lode Gold Deposits

**Diagnostic criteria**

1. Presence of anomalous gold in bedrock or soils.
2. Proximity to shear zones (less than 2 km).
3. Evidence of appropriate hydrothermal alteration:
   - Vein and (or) ribbon quartz
   - Carbonate alteration minerals (ankerite, siderite, dolomite)
   - Potassic alteration (sericite)
   - Boron anomalies (tourmaline)
   - Metal pathfinder element anomalies (As, Se, Cu, Zn, Bi, Mo, Sb, etc.)
   - Disseminated or vein-filling arsenopyrite

**Permissive criteria**

1. Presence of chemically favorable host rock, such as iron formation or iron-rich mafic rocks.
2. Presence of fuchsite or scheelite

DDH ND-3 @ 340’ Sphalerite lamina/vein in siliceous lapilli tuff (?) with an exhalative component
Deformed quartz-carbonate-sulfide vein or segregation in a silicate-oxide-sulfide-chert (?) iron formation, with porphyroblastic garnet in chlorite-amphibole groundmass. DDH SS-7, 265.8 – 266.2 ft.

Sphalerite
Tourmaline in quartz vein with carbonate DDH ND-3 @ 340'. Sphalerite lamina/vein in siliceous lapilli tuff (?) with an exhalative component CM Scale U. S. Geological Survey: Criteria for Lode Gold Deposits

Diagnostic criteria
1. Presence of anomalous gold in bedrock or soils.
2. Proximity to shear zones (less than 2 km).
3. Evidence of appropriate hydrothermal alteration:
   - Vein and (or) ribbon quartz
   - Carbonate alteration minerals (ankerite, siderite, dolomite)
   - Potassic alteration (sericite)
   - Boron anomalies (tourmaline)
   - Metal pathfinder element anomalies (As, Se, Cu, Zn, Bi, Mo, Sb, etc.)
   - Disseminated or vein-filling arsenopyrite or pyrite

Permissive criteria
1. Presence of chemically favorable host rock, such as iron formation or iron-rich mafic rocks.
2. Presence of fuchsite or scheelite

DDH SS-9 @ 222.1’ Deformed chert-silicate-oxide-sulfide iron formation with garnet porphyroblasts that have calcite and sulfide strain shadows.
Deformed quartz-carbonate-sulfide vein or segregation in a silicate-oxide-sulfide-chert(?), iron formation, with porphyroblastic garnet in chlorite-amphibole groundmass.

DDH SS-7, 265.8 - 266.2 ft

Sphalerite

Tourmaline in quartz vein with carbonate

DDH ND-3 @ 340'
Sphalerite lamina/vein in siliceous lapilli tuff(?) with an exhalative component

CM Scale

U. S. Geological Survey: Criteria for Lode Gold Deposits

Diagnostic criteria
1. Presence of anomalous gold in bedrock or soils.
2. Proximity to shear zones (less than 2 km).
3. Evidence of appropriate hydrothermal alteration:
   - Vein and (or) ribbon quartz
   - Carbonate alteration minerals (ankerite, siderite, dolomite)
   - Potassic alteration (sericite)
   - Boron anomalies (tourmaline)
   - Metal pathfinder element anomalies (As, Se, Cu, Zn, Bi, Mo, Sb, etc.)
   - Disseminated or vein-filling arsenopyrite or pyrite

Permissive criteria
1. Presence of chemically favorable host rock, such as iron formation or iron-rich mafic rocks.
2. Presence of fuchsite or scheelite

DDH SS-9 @ 222.1' Deformed chert-silicate-oxide-sulfide iron formation with garnet porphyroblasts that have calcite and sulfide strain shadows.
U. S. Geological Survey:
Criteria for Lode Gold Deposits

**Diagnostic criteria**

1. Presence of anomalous gold in bedrock or soils.
2. Proximity to shear zones (less than 2 km).
3. Evidence of appropriate hydrothermal alteration:
   - Vein and (or) ribbon quartz
   - Carbonate alteration minerals (ankerite, siderite, dolomite)
   - Potassic alteration (sericite)
   - Boron anomalies (tourmaline)
   - Metal pathfinder element anomalies (As, Se, Cu, Zn, Bi, Mo, Sb, etc.)
   - Disseminated or vein-filling arsenopyrite or pyrite

**Permissive criteria**

1. Presence of chemically favorable host rock, such as iron formation or iron-rich mafic rocks.
2. Presence of fuchsite or scheelite

DDH SS-9 @ 222.1’ Deformed chert-silicate-oxide-sulfide iron formation with garnet porphyroblasts that have calcite and sulfide strain shadows.

Fuchsite in drill core
SS-9 @ 191’
TC36-1 @ 354’
ND-2 @ 496-499’
S-2 @ 66’and 189’
Deformed quartz-carbonate-sulfide vein or segregation in a silicate-oxide-sulfide-chert (?) iron formation, with porphyroblastic garnet in chlorite-amphibole groundmass. DDH SS-7, 265.8 - 266.2 ft

Sphalerite in quartz vein with carbonate.

Sphalerite lamina/vein in siliceous lapilli tuff (?) with an exhalative component.

**U. S. Geological Survey: Criteria for Lode Gold Deposits**

- **Diagnostic criteria**
  - Presence of anomalous gold in bedrock or soils.
  - Proximity to shear zones (less than 2 km).
  - Evidence of appropriate hydrothermal alteration:
    - Vein and (or) ribbon quartz
    - Carbonate alteration minerals (ankerite, siderite, dolomite)
    - Potassic alteration (sericite)
    - Boron anomalies (tourmaline)
    - Metal pathfinder element anomalies (As, Se, Cu, Zn, Bi, Mo, Sb, etc.)
    - Disseminated or vein-filling arsenopyrite or pyrite

- **Permissive criteria**
  - Presence of chemically favorable host rock, such as iron formation or iron-rich mafic rocks.
  - Presence of fuchsite or scheelite

This map shows the locations of the drill cores identified in the previous slides as having geological and mineralogical conditions that meet the USGS’s criteria for high potential for lode gold deposits.

Drill hole locations for core samples photographed in previous slides

DDH SS-9 @ 222.1’ Deformed chert-silicate-oxide-sulfide iron formation with garnet porphyroblasts that have calcite and sulfide strain shadows.
International Falls Area

April 28, 2011

http://www.dnr.state.mn.us/lands_minerals/leasesale/index.html
For More Information:

Gold Mineralization and Geology of Northern Minnesota

Don Elsenheimer, Minnesota DNR
donald.elsenheimer@state.mn.us
(651) 259-5433

Barry Frey, Minnesota DNR
barry.frey@state.mn.us
(218) 231-8484

State of Minnesota Metallic Mineral Lease Sale

Aaron Vande Linde, Minnesota DNR
aaron.vande-linde@state.mn.us
(651) 259-5955