Mineral Exploration Concepts & Targets

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Although a Junior Exploration Company, the Duluth Metals/Twin Metals geologic team has advanced the understanding of mineralization within the Duluth Complex well beyond the norm.

This fundamental understanding is the result of several factors:

- Detailed geological mapping within the Duluth Complex,
- Comprehensive compilation of historic drill hole assay data,
- Extensive drilling (>1,000,000 Ft.) within the region,
- Fundamental research in similar magmatic systems (Antarctica),
- Integration of these data into exploration models, and most importantly,
- Questioning geologic thought & ore deposit models.
Understanding the Big Picture

The Duluth Metals approach to exploration attempts to understand ore deposits as final expressions of multi-scale Earth systems that focus mass and transfer energy to ultimately form ore deposits.

This approach to mineral exploration leads to systematic, scale-dependent targeting models and allows for the recognition of the largest-scale footprints of ore-forming systems.

We’re searching for giant World-Class ore deposits
The Lake Superior Mining District

Midcontinent Rift Legend
- Green: Volcanic Rocks
- Purple: Intrusive Rocks
- Yellow: Sedimentary Rocks
- Black dashed line: Major Fault
- Gray dashed line: Minor Fault

Ore Deposits
- Fe
- Fe-Mn
- Cu
- Cu-Zn-Pb
- Au
- Ni-Cu-PGE

Duluth Complex
- Cu-Ni-PGE
- TiO₂
- Ni-Cu-PGE (rift associated)

Duluth Complex Cu-Ni-PGE deposits will add an another 100+ years of production into perhaps the most important mining district on the North American Continent.
Bedrock Geology, NE Minnesota

Modified from Miller et al., 2001
The two gravity anomalies (+50 & +70 milligals) imply intrusive roots more than 13 km deep (Allen and others, 1997)
Duluth Complex Mineral Resources

On the cusp of developing one of the world’s most important new mining districts.

**Nokomis**
550 Million Tonnes Indicated
- 0.639% Cu, 0.200% Ni
- 0.660 ppm Pt + Pd + Au

274 Million Tonnes Inferred
- 0.632% Cu, 0.207% Ni
- 0.685 ppm Pt + Pd + Au

**Maturi**
- 120 Million Tonnes
- 0.67% Cu, 0.25% Ni
- 380 ppb Pt + Pd + Au

**Spruce Road**
- 529 Million Tonnes
- 0.43% Cu, 0.15% Ni

**Nickel Lake**
- Cu-Ni-PGE

**Birch Lake**
- 169 Million Tonnes
- 0.56% Cu, 0.17% Ni
- 932 ppb Pt + Pd + Au

**South Fillson Creek**
- Cu-Ni-PGE

**Dunka Pit**
- Cu-Ni-PGE

**NorthMet**
- 910 Million Tonnes
- 0.27% Cu, 0.08% Ni
- 400 ppb Pt + Pd + Au

**Mesaba**
- ~1 Billion Tons
- 0.43% Cu, 0.09% Ni
- plus Pt + Pd + Au

**Serpentine**
- 257 Million Tons
- 0.42% Cu, 0.14% Ni

**Wetlegs**
- 38 Million Tons (surface)
- 0.57% Cu equivalent
- 16 Million Tons (underground)
- 0.94% Cu equivalent

**Wyman Creek**
- Cu-Ni-PGE

**Titanium Resources**
- ~220 Million Tons
- ~10% TiO₂
100% Duluth Metals lands within this area include:

1) The junction of the Nickel Lake Macrodike and the South Kawishiwi Intrusion;

2) The Eastern basal contact zone of the South Kawishiwi Intrusion;

3) Within the Bald Eagle Intrusion.
DM’s New Bedrock Geology Map

Target Types

Ni-rich Massive Sulfide

Pt-Pd Reefs w/ Cr

Disseminated Cu-Ni-PGE

Have other companies spent the time and energy creating their own internal geologic maps??
Regional Magmatic Flow Model

1. Magma ascends through a mantle feeder dike
2. Sulfide saturation occurs while magma incorporates sedimentary rocks (Virginia Fm sulfidic argillites)
3. Rift-parallel faulting opens a sub-horizontal space (NLM) that magma traverses to the SW along
4. Subhorizontal sill intersects an active transform fault and magma sills out (to NNW) to form the Spruce Road Deposit
5. Continued flow lifts the hangingwall Anorthosite as sill-like magma fingers traverse to the WSW
6. Much Later – The Bald Eagle Intrusion intrudes in a “Trap Door” fashion structurally higher than the SKI
The volume of the South Kawishiwi Intrusion was >2,000 km$^3$
Pending Federal Prospecting Permits on these two properties gives Duluth Metals exploration rights on the magma conduit that formed all of the South Kawishiwi Intrusion Cu-Ni-PGE mineralization.

The Nor’East property is the best exploration target I’ve personally ever known (~25 years).
• An understanding of common features of magmatic Ni-Cu-PGE deposits is required in order to get a grasp on the potential significance of the SKI & NLM.

• Massive sulfide may accumulate at the base of intrusions in areas where the velocity of the magma lessens.

• Such accumulations form a hot disordered mass which cools to form Ni-Fe sulfides and a Cu-PGE rich sulfide liquid.

• Sulfides in the SKI are highly enriched compared to typical magmatic sulfide deposits; in fact they are similar to in metal tenor footwall veins in Sudbury.

• Are the disseminated sulfides in the SKI simply the Cu-PGE rich fractionated liquid that evolved out of an extremely large Ni rich massive sulfide body?

Recalculated to 100% sulfide, Nokomis mineralization averages about 23% Cu, 6% Ni, and nearly 1 oz/ton TPM.
So Where’s the Nickel?

There appears to be only two answers to this question.

- It’s not there and never was, but ....
  - Not supported by data

- We haven’t found it yet, but what about ....
  - The base of the Nickel Lake Macrodike
  - The junction of the Macrodike and South Kawishiwi Intrusion
  - At great depth in some unknown place
Nickel Lake Macrodike: The Facts

• Has Cu-Ni-PGE along the northern margin.
• Contains large exotic xenoliths (e.g., BIF).
• The junction with the SKI is marked by a “logjam” of wall rock xenoliths.
• The logjam is interpreted to have formed due to a drop in the velocity of the magma.
• New AMS data has shown that the NLM magmas flowed horizontally to the Southwest.
The Bald Eagle Intrusion is the MOST MAFIC intrusion within the Duluth Complex. As such, the intrusion has potential to host Platinum-rich Reef type deposits associated with layers of Chromite.
Stratiform PGE Mineralization

A broad definition
- 1 - 10 meter thick horizons
- laterally continuous (up to 100’s of km)
- 1 - 20+ ppm PGM
- association with chromitite horizons and/or sulfides (0.5 - 5 wt.%)

World class examples
- Merensky reef (Bushveld)
- UG2 chromitite (Bushveld)
- J-M reef (Stillwater Complex)
- Platinova (Skaergaard)
- MSZ (Great Dyke)
The Land O’ Dixie Property
Searching for stratiform mineralization within the Bald Eagle Intrusion

Intrusion anatomy
• Dunite, troctolite and gabbro
• Foliated and modally layered
• Presence of stratiform VTEM anomalies

Strong similarities with other reefs
• Plume influenced continental rift-related
• Upper gabbro present
• Magmatic unconformities present

Subcrop of BEI melatroctolite along Dunka River Rd; photo by G. Sweet (2010)
New Drill Core Facility, Ely Minnesota