Magmatic-Hydrothermal Gold Systems in the Archean of Northern Ontario, Canada: Examples of Syenite-Associated and Porphyry-Type Au-(Cu) Deposits

By

Dr. Daniel J. Kontak
Department of Earth Sciences
Laurentian University,
Sudbury, Ontario
Vein & disseminated
1-30 g/t Au
Underground & open pit
Magmatic origin or are the intrusions just good host rocks for mineralization?

**Syenite hosted** – vein and disseminated type mineralization; associated with mafic to felsic syenites; variable alteration (potassic, sodic, phyllic, hmt/mt, sulfide, carbonate, epidote, tourmaline); Au-Ag-Te-Cu-W-Mo-F, B association.

**Tonalite-diorite** – disseminated mineralization in a potassic altered (biot) breccia system (magmatic & hydrothermal).
Examine intrusion-related Au deposits in the 2750-2670 Ma Abitibi-(Swayze) Greenstone Belt of the Superior Province, Canada; historical production of about 150 M oz Au.
Deposits:

- Near large structural breaks (PDFZ, CLLFZ)
- Two deposit types: tonalite, syenite
- Syenite type in basins filled with terrestrial sediments and alkaline volcanics
Carbonate alteration

Quartz-carbonate (fuchsite) veins in Syenite (mafic-felsic)
Côté Lake, ~7 M oz

Young Davidson

Hoyle Pond

Fenn-Gibb

Black Fox

Upper Beaver, ~2 M oz

Kirkland Lake area

Canadian Malartic, 14 M oz

Dubé and Gosselin, 2007
Features of Syenite-Associated Gold Deposits:

- Syenites are late-stage in the evolution of the Abitibi Greenstone Belt (<2680 Ma) and oxidized mafic (pyx-amph) to felsic (qfp) intrusions;

- Host rocks are variable, but often hosted by the Porcupine or Timiskaming sedimentary (volcanic rocks);

- Mineralization styles (vein vs. disseminated), associated elements (Ag-Cu-Te-W-Bi-Mo-F-B) and alteration variable among deposits;

- Mineralization is structurally controlled and fluids are late-stage, thus these MUST be long lived magmatic systems.
Gold Deposits along the Porcupine-Destor Fault Zone

Côté Lake, ~7 M oz
Hoyle Pond
Fenn-Gibb
Black Fox
Timmins West
Kirkland Lake area
Young Davidson

Canadian Malartic, 12Moz

Dubé and Gosselin, 2007
LAKE SHORE GOLD: West Timmins and Thunder Creek Syenite-Associated Deposits

- Underground operations in syenite- and wallrock – hosted mineralization;
- Mineralization within shear zones (HSZ, RSZ) with hydrothermal overprint;
- Timmins West 4.2 Mt @ 5.4 g/t (0.83 M oz Au)
- Total reserves of several M oz
Deformed syenite overprinted by pyrite-carbonate-sericite and Au

Quartz-tourmaline fibre veins
GOLDCORP Hoyle Pond Deposit (≥2.5 M oz since 1985)

Legend:
- High-Mg tholeiitic basalt
- Fe-rich tholeiitic basalt
- Komatiite
- Basaltic-komatiite
- Sedimentary rocks
- Graphitic shear
- Quartz-carbonate vein
- Diabase
- Porphyry

Sericitic alteration (As, B)

Syenites (qfp)
Is there a spatial and temporal association with these deeper syenite/porphyry dykes?
LAKE SHORE GOLD: Fenn-Gibb Deposit:

- Mineralization is centred on syenite emplaced in a bend in the PDFZ.
- Ore as veinlets and disseminations in altered syenite.
- Resources (pit shell) of 65 Mt a@ 0.96 g/t (2.1 M oz).
- Indicates viability of low-grade, high-tonnage open pit operations.

Intersections of 1-2 g/t Au over 50-249 m

Is syenite genetically related or just a favourable host?
BRIGUS GOLD: BLACK Fox Complex

• Open pit (3g/t) and underground (6 g/t) producing 70,000 oz/yr.
• Mineralization in veined (Qtz-Carbonate) and altered syenite and host mafic volcanic rocks.
BRIGUS GOLD: Black Fox Contact-147 Zone Deposits

- Au coincident with carbonate - K+Na altered volcanic-sedimentary rocks near a syenitic intrusion.
- Vein and disseminated ore at deformed lithological boundaries related to PDFZ.
- Drill indicated resource 6.3 Mt @ 4g/t (e.g. 5.9 g/56.7 m, 26 g/15.5 m).
SEM-BSE images showing association of Au-W-Mo-LREE…. This is part of the syenite association in this and other areas. Also have locally abundant Hmt.
Gold Deposits along the Larder Lake-Cadillac Fault Zone

- Côté Lake, ~7 M oz
- Timmins West
- Hoyle Pond
- Black Fox
- Kirkland Lake area
- Young Davidson
- Canadian Malartic, 14 M oz

Key:
- Granitoid rock
- Proterozoic cover
- Mafic intrusion
- Sedimentary rock
- Volcanic rock
- Major fault
- World-class orogenic gold deposits
- World-class gold-rich volcanogenic massive-sulfides
- Other gold deposits
- LLCF: Larder Lake - Cadillac Fault Zone
- PDF: Pocumine - Destor Fault Zone

Scale: 100 km
Historical production (1934 -1957) of 0.97 M oz (9.7 Mt @ 3.3 g/t).
- Current reserves about 3.83 M oz (open at depth).
- Production to commence 2012/2013.
Syenite sheets intrude TM Group sedimentary rocks north of a suite of older volcanic rocks.

Ore zone (YD West and East) is a 30 m thick mineralized section of altered (K, Hmt) and veined (quartz) syenite.
V2 veins mineralized:
• Qtz-Carb-Py (Hmt-Mt-Cpy).
• Au as inclusions in pyrite.
• High T (400°C) magmatic-derived fluids.
• V1, V3 are barren stages!!!
KIRKLAND LAKE GOLD CAMP
(45 M oz historical production)

Mineralization occurs on several structures (Main, ’04 breaks, etc.)
• Au mineralization is along main or secondary structures.
• Au occurs within *Timiskaming sedimentary and volcanic rocks and rarely in the older volcanic package.*
• Deposits record post-mineralization deformation.
• Vein- and disseminated-type mineralization.
KIRKLAND LAKE GOLD Deposit(s) – >24 M oz Au

Series of syenites intrude TM sedimentary and volcanic rocks

‘04 Break

Main Break

SMC
Gold occurs in the syenites as:

- Quartz-(carbonate) veins in fault/shear zones (Main and ‘04 Breaks)
- Disseminations with pyrite-tellurides (South Mine Complex)
QUEENSTON MINING INC.: Upper Canada Deposit (6.8 Mt @ 3 g/t, 0.77 M oz); also Mc Bean and Anoki zones

- Mineralization as both veins and disseminations associated with extensive sodic (albite) altered zones.

Syenite

Ore zone

Gabbro

Timiskaming volcanics-seds.

Fresh & altered sediment  Fresh & altered syenite
QUEENSTON MINING INC.: Upper Canada Deposit

Historical vein workings (1.9 Mt @ 6.9 g/t AU)

Current open pit model: looking to bulk mine a low-grade reserve (6.8 Mt @ 3 g/t).

Alkaline volcanics

Sediments

Syenite

Queenston Mining Inc. Upper Canada Mine Property Larder Lakes Mining Division

Historic Upper Canada Resources

Queenston Mining Inc.

Fig. 23 - Longitudinal Section (Looking North)
QUEENSTON MINING INC.:
Mc Bean Deposit (1.9 Mt @ 4.7 g/t)

Syenite
Timiskaming volcanics-seds.

Ore zone
50,000 oz open pit

Mc Bean

LEGEND
- 12: Deformation/Alteration Zone (Carbonate Trachyte)
- 61: Conglomerate - Greywacke
- 5T: Greywacke - Conglomerate
- 4T: Tachyte Tuff
- 3T: Tachyte Flow
- 7L: Gabbronorite
- 6L: Felsic Tuff (Gauthier Group)
- 2L: Mafic Flow
- 1L: Ultramafic Flow

KIRKLAND LAKE JOINT VENTURE
Queenston Mining - Newmont Mining
UPPER CANADA MINE PROPERTY
BEDROCK GEOLOGY

[Map showing Mc Bean Deposit with ore zones and geological features]
Green ore = Au mineralization

Carbonate alt. volcanics

Volcanics and sediments

Gabbro

Altered syenite porphyry

Green carbonate ore
Kirkland Lake Gold Camp, Ontario

100 years of production from 25 mines (40 M oz - 100 Mt @ 13 g/t)

Mc Bean green carbonate ore

Kerr Addison green carbonate ore
Kirkland Lake Gold Deposit(s) – What is the source of fluids and Au along this 40 km trend?

Kirkland Lake Batholith at depth (?)

Richards (2009)
OSISKO’S Canadian Malartic Deposit (425 Mt @ ~1 g/t, ~14 M oz):

- Near the Cadillac Fault Zone; historical workings as quartz-carbonate veins.
- New ore zones in Pontiac Group metasedimentary rocks cut by qf porphyry dykes with potassic alteration and disseminated pyrite.
- Production (Q1, 2012) at 50,000 t/day.

Porphyry dykes
Porphyry with disseminated pyrite and biotite alteration.
Upper Beaver Deposit
Historical: 0.77 Mt @ 7.7 g/t
Current: 6 Mt @ 7 g/t (1.5 M oz)
• Mineralization hosted by a multi-phase amphibole syenite (2680 Ma) that evolves to a quartz syenite

• Located off the Main break, thus unusual!
Deposit characterized by a magnetic anomaly due to pervasive Mt alteration, after early Hmt, related to remobilization of Fe from Fe-rich volcanic rocks.
Main Ore Zone: Steeply plunging (SE) series of vein/alteration packages at syenite-volcanic contact
Features of Mineralization:

• Dated (Re-Os) at 2685 Ma – thus overlaps syenite.

• Au-Cu-(Ag-Mo-Te-W-Bi-Hg) association (alkaline magmatism).

• Overlap of magmatic and hydrothermal breccias.

• Extensive alteration – epidote, actinolite, Mt-Hmt, sericite, tourmaline; **Au correlated with sericite alteration**

This is a oxidized, magmatic, syenite-associated Au-(Cu) deposit.
Côté Lake Au-Cu Deposit

Deposit hosted by 2740 Ma tonalite-diorite complex
**Stage 1: Leucotonalite**

Tonalite II  Tonalite I

**Stage 2: Diorite → Evolves to hydrothermal system**
Mineralization (1-2 g/t Au-Cu) in a 2740 Ma magmatic – hydrothermal breccia body with disseminated and stockwork pyrite (± cpy).
7 M oz defined by 66 km drilling (~150 ddh)

+ oz Au (?)
Cote Lake - Section 93+00 (Facing NE)
Distribution of Alteration

Biotite alteration

D. Beilhartz, 2012
What is Côté Lake:

Archean diorite-tonalite porphyry Au-Cu deposit with analogies to Phanerozoic equivalents – alteration, mineralization (e.g., Sillitoe, 2010)
**Summary:**

**Syenite Deposits:**

- Au mineralization spatially and temporally related to 2780 Ma syenitic intrusions.
- Nature of mineralization (vein vs. disseminated), Au grade, (1-30 g/t) and alteration are all variable.
- Mineralizing fluids derived from alkaline magmatic systems.

**Tonalite Deposit(s):**

- New deposit type for Canadian Archean.
- Porphyry type mineralization and offers potential for other tonalite-diorite settings in Canada and elsewhere.