Syenite-hosted gold mineralization in the Abitibi belt, Canada

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A work in progress

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Outline

- Introduction to the problem
- Focus on two deposits: Young-Davidson and Thunder Creek (Timmins West mine)
- Geology, alteration and mineralization
- Genetic constraints from pyrite chemistry and S isotopes
- Some new data
What is the relationship between ‘shear-hosted’ Au mineralization and intrusions? Is a single metamorphic fluid origin applicable?

Is the Au genetically related to the intrusion, or are intrusions good structural traps?
‘Syenite’-hosted one of several deposit types in the Abitibi

Thunder Creek
Indicated & Inferred
2.72 MT @ 4.6 g/t (TW 0.954 Moz)

Young-Davidson
Measured & Indicated 15.68 MT @ 2.97 g/t
(Proven & Probable 45.27 MT @ 2.63 g/t; 3.696 Moz)
Gold deposits are associated with:

- Regional-scale structures
- Felsic intrusive rocks (including alkalic suites)
- Timmiskaming (rift) sedimentary rocks
These two deposits are remarkably similar in appearance.
Geology of the Young-Davidson Deposit
Syenite as a Preferential Host
Veining system in the syenite – underground mapping

Structural map of the #9 ore crosscut
$V_1$ veins– Truncated by $D_1$ Thrusts

Boudinaged ankerite-quartz-pyrite, minor Gn, Cp, Mt, Mo, Au

Tartan Twinned K-feldspar; $T > 300^\circ C$
V$_2$ Veins (syn D$_2$)

- Shallow dipping, folded quartz-pyrite veinlets ± carbonate and chlorite rim
- Abundant hematite (Hem), magnetite and rutile (Rt) ± chalcopyrite inclusions in vein pyrite
- Au as inclusions and along fractures in pyrite
$V_3$ planar or en echelon veins syn to Pre-$D_2$

Qtz-Carb-Py-Au-Cp-Sch-Gn-Tour)

Much less deformed, Tartan twinned Ksp

$V_3$ veins are truncated by Late $D_2$ ductile shear zones
Formational Model

- Syenite emplacement after $D_0$
  - $V_1$ veins emplaced during $D_1$, NNE-SSW compression, regional $S_1$ foliation in volcanic and sedimentary rocks
  - $V_2$ veins emplaced during early $D_2$, NNW-SSE compression, penetrative E-W $S_2$ foliation
  - $V_3$ veins emplaced during late $D_2$, NNW-SSE compression, further development of E-W foliation
Schematic long section (looking north) through mineralization
Alteration (vein-free syenite)

Potassic (Kspar)-Hematite-Carbonate (ankerite) Associated with Au enrichment of Au, K$_2$O and Ba during alteration and $\delta^{18}$O lows

Yellow denotes mineralization
2 Styles of Mineralization

1) Strong association with potassic alteration and high S (pyrite) content (disseminated and V2 veins)
2) Free Au in quartz veins, poor association with wholerock K$_2$O or S
Oxygen Isotope Thermometry

- 43 mineral separates of quartz, hematite, potassium feldspar, tourmaline, biotite, chlorite, scheelite, calcite and ankerite.

- $V_1$ veins: $322 \pm 25^\circ C$ to $428 \pm 18^\circ C$
  $V_2$ veins: $408 \pm 28^\circ C$ to $431 \pm 30^\circ C$
  $V_3$ veins: $351 \pm 17^\circ C$ to $379 \pm 26^\circ C$. 
Summary

• There could be an early (pre-deformational) enrichment of Au, but most Au is early D2 deformation
• Multiple stages of Au (V1, V2, V3)
• Association with high temperature ~ 350-400°C alteration
• Overall strong association with pyrite
Initial study compared the Thunder Creek mine with the Hwy 144 prospect.
Thunder Creek Mine – Mineralization Style Similar to YD

(Cross section of 695m level syenite)
Thunder Creek Alteration is Different
little potassic or carbonate alteration

- 2 Feldspar alteration implies high temperature
- Disseminated pyrite implies pervasive fluids
Hwy 144 – Mineralization Style Similar to TC & YD

Hwy Alteration more similar to YD: Feldspathic & carb alteration

Figure 6.9: Hand sample photographs of Hwy-144 mineralization. A) Coarse grained disseminated pyrite. B) Medium to coarse-grained vein-hosted pyrite.

Graph: Hwy 11-13

- Weight Percent (%)
- Drill Hole Depth (m)

Lines represent:
- K2O (red)
- Na2O (blue)
- CaO (orange)
Strongest Association of Gold is with Pyrite
Summary: Similar to Young-Davidson

• most Au is early D2 deformation
• Multiple stages of Au (V1, V2, V3)
• Likely association with high temperature alteration (geothermometry lacking)
• Overall strong association with quartz veins and pyrite
Mineralization and Pyrite Chemistry & Textures

Young-Davidson: 2 Types of Pyrite
Pyrite

Type 1 Pyrite: Inclusion-rich

Corroded grain boundaries and abundant oxide inclusions (hem, mt, rt)
Found as disseminated pyrite and $V_1$, $V_2$ vein pyrite
Dominant gold hosting pyrite
Pyrite

Type 2 Pyrite:

Euuhedral, minor inclusions
(gangue, ccp, gn, ± rt ± hem)

Minor proportion of disseminated pyrite, mostly $V_3$ vein pyrite

Associated with free gold and $V_3$ veins
Similar for both textural types

Ni: ~100 to 2600 ppm
Co: 600 ppm to 15000 ppm
As: 700 ppm to 4300 ppm

Type 2 pyrite is typically late
Thus the similarity of compositions suggests repetitive fluids
Sulphur Isotopes
Note:
- Au nearly absent
- Strong zoning
- Corrosion and secondary porosity
Ni contents range from 30 to 2760 ppm

Co zoning overlaps with Ni 10 to 1375 ppm

Low As contents <40 to 640 ppm
In Situ Analysis of Pyrite: 
*Sulphur Isotopes: SIMS*

-4.4 to 4.1‰ variation
In Situ Analysis of Pyrite: 
Trace elements: LA-ICP-MS (spot analyses)

Au ranges from <1 to 22.6 ppm
Overall Au Correlates with
- $\delta^{34}S$ values of near zero
- low Ni-Co contents
- no correlation with As
Au-As Contents in YD Pyrite

Au saturation line from Reich et al. (2005)
Conclusions About Young-Davidson

- Au associated with repetitive stages of pyrite growth and corrosion

- Near-saturation Au contents of pyrite are indicative of a fertile Au hydrothermal system

- Fluid mixing likely very important, and possibly controlled Au deposition
2 Pyrite Types at both TC & Hwy144

Corroded

Euohedral
## Sulphur Isotopes (SIMS)
### Thunder Creek & Hwy 144

<table>
<thead>
<tr>
<th>Location</th>
<th>Generation</th>
<th>$\delta^{34}\text{S}$ Range</th>
<th>Avg. $\delta^{34}\text{S}$</th>
<th>n</th>
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<tbody>
<tr>
<td>Thunder Creek</td>
<td>Disseminated</td>
<td>-3.0 to -6.1</td>
<td>-4.7</td>
<td>8</td>
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<tr>
<td>Thunder Creek</td>
<td>Vein-Hosted</td>
<td>-3 to -5.3</td>
<td>-4.3</td>
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<tr>
<td>Hwy-144</td>
<td>Disseminated</td>
<td>-1.8 to -3</td>
<td>-2.4</td>
<td>2</td>
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<tr>
<td>Hwy-144</td>
<td>Vein-Hosted</td>
<td>-0.1 to -3.3</td>
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<td>8</td>
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<tr>
<td>Hwy-144</td>
<td>Fracture Filling</td>
<td>-1.4 to -6.9</td>
<td>-3.7</td>
<td>9</td>
</tr>
</tbody>
</table>
Thunder Creek Pyrite

- Poorly zoned and low concentrations of Ni-Co
- Abundant micro-nanonuggets of Au
- ‘Background’ Au
Thunder Creek Pyrite
Thunder Creek Pyrite

Au saturation line from Reich et al. (2005)
Hwy 144 Pyrite
Hwy 144 Pyrite

![Graph showing Au saturation line from Reich et al. (2005)](image)
Conclusions About Thunder Creek and Hwy 144

- Thunder Creek and Hwy 144 appear to be different systems
- Pyrite chemistry can be applied to recognizing systems
- Au contents of pyrite can possibly be used to assess the fertility of Au hydrothermal systems
Syenite-hosted gold mineralization in the Abitibi Sub-Province of Ontario: Orogenic or Orthomagmatic?

Mineralization is syn-deformational **BUT**
- Fluids are too hot to be metamorphic (regional greenschist facies)
- Oscillatory zoning suggests supersaturation via fluid mixing
- Fluid mixing may also be supported by S isotopes (but redox changes can’t be discounted)
- Au contents of pyrite have potential to indicate the fertility of systems
What’s Next?
More Petrography-Pyrite Mapping

At Least 2 Stages of Au
Au inclusions in pyrite, or free Au – possibly early

Au with galena in pyrite in mineralized syenite
Mineralized Syenite
- Co-Ni zoning
- Ga-Au inclusions

Au-Pb seems to be synchronous with primary pyrite zoning
Disseminated Pyrite in Mineralized Syenite Porphyry
Mafic volcanic-strong ankerite alteration (1.65 ppm Au)
Late fracture assemblage Au-celestine-barite-ankerite-Kfeldspar-albite. Disseminated Py in syenite.
CaREE fluorcarbonate (pt 1-Synchisite/Parisite?) associated with Fe oxide (pt 2) and zircon (pt 3). Weakly mineralized syenite (0.7 ppm Au)
Au association with oxidation
Sulphate Distribution

- celestine, barite, anhydrite
Late Au is Associated with oxidized, F-rich, REE-rich fluids

Is this a magmatic signature?
Acknowledgements

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