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# THE PALEOPROTEROZOIC LALOR VMS DEPOSIT, SNOW LAKE, MANITOBA: OBSERVATIONS ON THE NATURE AND ARCHITECTURE OF THE GOLD AND BASE METAL-RICH ORE ZONES AND ASSOCIATED ALTERATIONS


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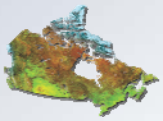


***GAC-MAC Winnipeg 2013***

***SS07 – Precious and Rare Metals in the Volcanogenic Massive Sulphide Environment***

*Geological Association of Canada – Mineralogical Association of Canada Joint Annual Meeting*

*Winnipeg Convention Center*

*May 22, 2013*




## Abstract


Lalor is a recently discovered Au-Zn-rich volcanogenic massive sulphide (VMS) deposit. It is located in the Paleoproterozoic Snow Lake arc assemblage, host to numerous past producing Cu-Zn and Zn-Cu VMS deposits.

Lalor is the largest deposit of the Snow Lake camp and also the richest in gold with reserves of 14.4 Mt grading 1.86 g/t Au, 24 g/t Ag, 0.6 wt.% Cu and 7 wt.% Zn and resources estimated at 12.6 Mt grading 3.85 g/t Au, 27.3 g/t Ag, 0.9 wt.% Cu and 2.3 wt.% Zn, for a total size of approximately 27 Mt and potentially containing 75 t Au. The deposit consists of distinct Zn-Cu-Pb±Au-Ag semi-massive to massive sulphide lenses and zones of disseminated Au-Ag-Pb-Cu sulphides. The ore zones are stratigraphically and/or structurally stacked in a complexly deformed and metamorphosed succession of intensely hydrothermally altered rocks of the Chisel mature arc sequence that hosts other Zn-rich VMS deposits.

Preliminary mapping and lithogeochemistry results indicate that the stratigraphic footwall is composed of at least three distinct but highly altered mafic to felsic volcanic (and perhaps sedimentary) units. The alteration of the footwall is both extensive and intense. At least 11 distinct alteration assemblages have been defined based on the distribution and relative abundance of specific metamorphic minerals such as amphiboles, chlorite, cordierite, biotite, muscovite, pyrite, staurolite, garnet, kyanite, sillimanite, diopside and epidote. The various alteration assemblages may be in part due to varying protolith compositions, together with the superposition of several hydrothermal events. The hanging wall does not show any extensive alteration and may be in structural contact with the deposit. Five ore types can be defined. They include Zn±Cu-rich massive sulphide lenses and three distinct ore types that contain significant gold: (1) Cu-rich massive sulphides; (2) low sulphide calc-silicate zones with high Ag-Pb-Cu±As-Se-Te and; (3) anthophyllite-rich alteration zones with trace of finely disseminated pyrrhotite.

The numerous alteration assemblages and the various ore styles result from a complex hydrothermal history and possible modifications during subsequent deformation and metamorphism. The gold endowment of the deposit, its size and its distinctive features compared to known anomalous and gold-rich VMS deposits make Lalor an ideal site to document and better understand gold enrichment processes in the VMS environment.

## Introduction

Herein, we present preliminary results from the Lalor research activity that is part of the VMS project of the Targeted Geoscience Initiative – Phase 4 program of the GSC. Our work at Lalor is part of a larger effort undertaken by the GSC and its collaborators from provincial surveys, academia and industry, to better understand the principal geologic processes that control precious metals enrichment in VMS deposits, contributing to improve exploration models.



## Introduction

The Lalor deposit, with about **27 Mt of mineralization**, is the largest VMS deposit of the Snow Lake camp. It may contain as much as **75 t Au** (2.66 Moz) and 684 t Ag, making it a precious metal-rich VMS deposit.

Some of the lenses of the Lalor deposit have atypical characteristics that contrast with those of other Au-rich VMS deposits.

Studying this deposit provides a unique opportunity to refine the genetic and exploration models for such deposits.

Here we present preliminary data on the nature and distribution of some of the main footwall units and briefly discuss the style and distribution of the alteration facies present at Lalor.

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## Working hypotheses

The Lalor deposit is:

- An auriferous VMS system;
- An evolving VMS system (shallow to deep or deep to shallow setting);
- A base metal VMS + « epithermal-style » overprint;
- A VMS + syn-deformation and/or metamorphic remobilization/overprint

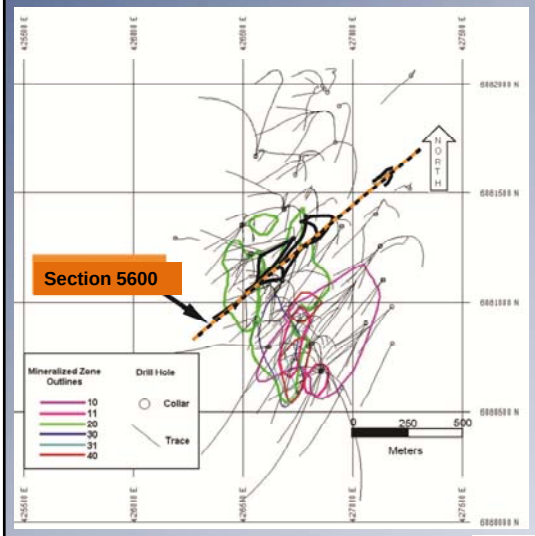
## Methods

As the deposit host succession has been intensely altered, deformed and metamorphosed, geological mapping is difficult.

We combine mapping / logging and lithogeochemistry to help trace units and alteration zones and determine the morphology of the deposit.

A number of representative cross-sections through the deposit various lenses have been selected and key drill holes along those sections have been studied and sampled in detail. This is supplemented by detailed underground mapping and logging of delineation / definition drill holes.

## Methods



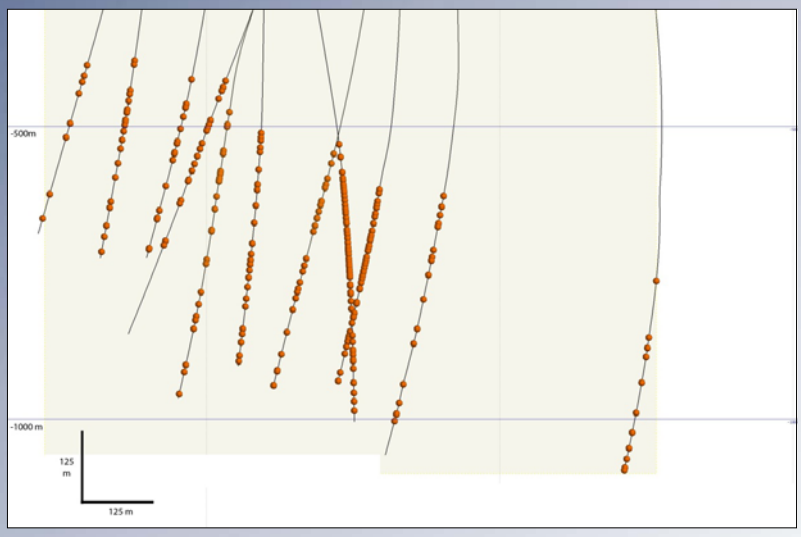

Composite plan view of the Lalor ore zones

From Caté et al. (2013)

- Section 5600 (shown here) has been completed, and 3 additional sections are currently being studied.
- 11 drillholes have been described and sampled from 50 m above the base of the hanging wall succession to the end of hole on section 5600.
- 363 samples were collected
  - 359 geochemical analyses on 68 elements
  - 355 thin sections



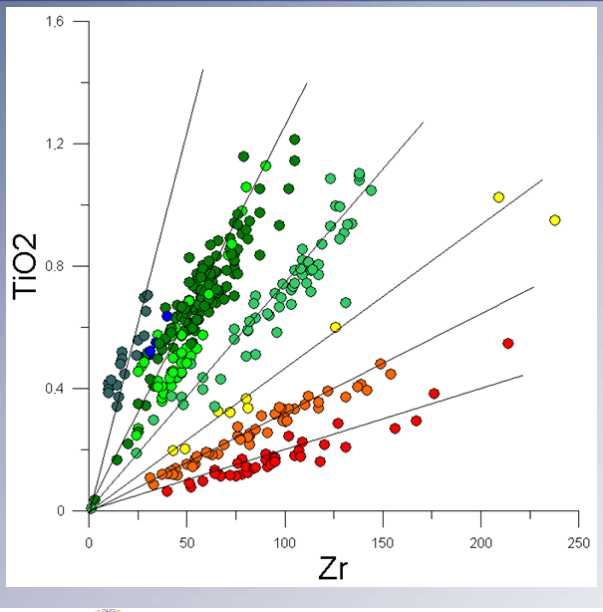
## Methods




5600 section – samples distribution

From Caté et al. (2013)

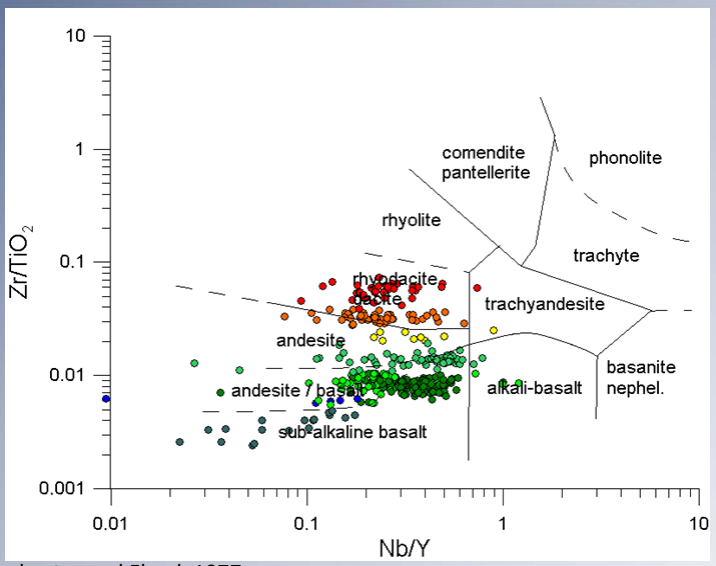
## Protolith signatures




From Caté et al. (2013)



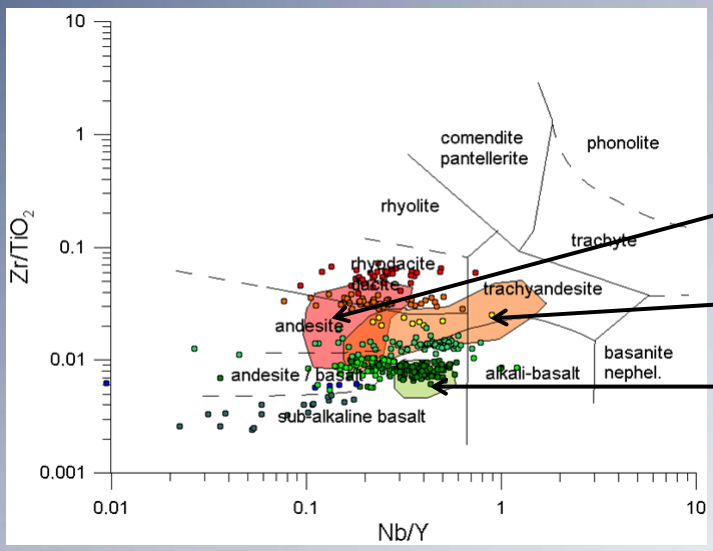
## Protolith signatures




Winchester and Floyd, 1977

From Caté et al. (2013)

## Determination of protoliths




**Shaded areas:**

Photo, Ghost & Chisel rhyolites

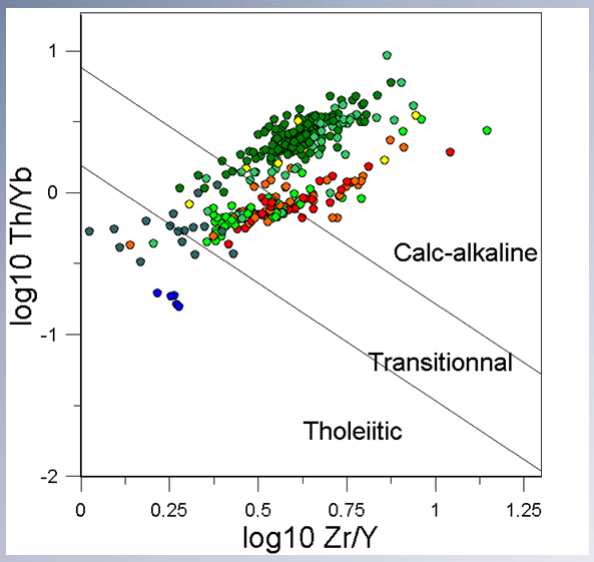
Powderhouse dacite

Moore basalt

Winchester and Floyd, 1977



## Protolith signatures




Ross and Bédard, 2009

**From Caté et al. (2013)**

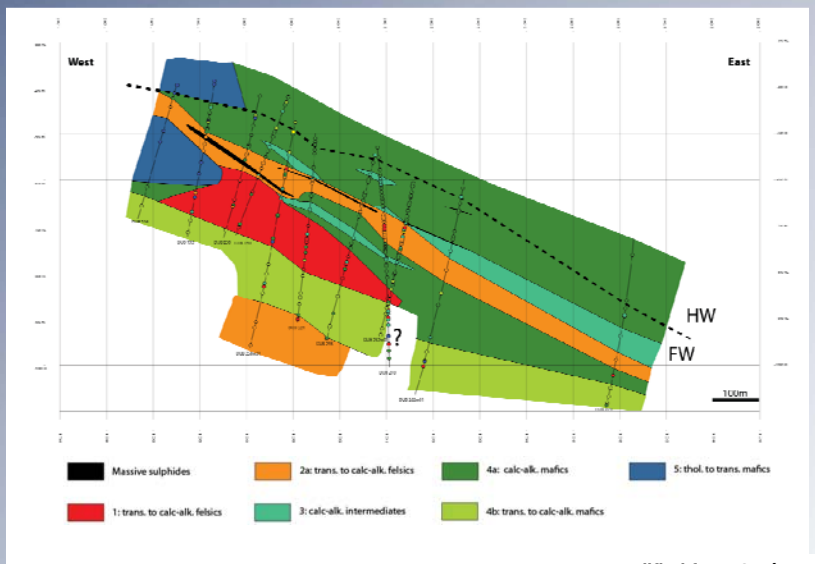
## Classification of protoliths – section 5600

The volcanic rocks that host the Lalor deposit can be classified based on their composition and magmatic affinities:

- 1: trans. to calc-alk. felsics
- 2a: trans. to calc-alk. felsics
- 2b: calc-alk. felsics
- 3: calc-alk. intermediates
- 4a: calc-alk. mafics
- 4b: trans. to calc-alk. mafics
- 4c: thol. mafics
- 5: thol. to trans. mafics



## Classification of protoliths – section 5600




Modified from Caté et al. (2013)

## Characterization of the alteration assemblages

Characterization of the metamorphosed alteration assemblages in the footwall of the deposit:

•Detailed core logging and underground mapping in order to define the distribution of the alteration assemblages relative to ore, host units and major structural features;

•Bulk geochemistry to characterize the signature of the different alteration facies and define hydrothermal vectors in a deformed and metamorphosed environment (amphibolite facies – Lam et al., 2013).



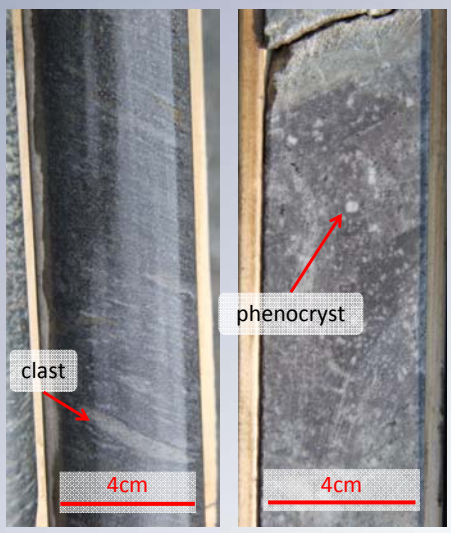
## Characterization of the alteration assemblages

**Quartz-plagioclase-biotite assemblage**

Quartz-plagioclase-biotite±muscovite-aluminosilicates-amphiboles

•Partially preserved volcanic textures

•Commonly overprinted by late Ca-rich alteration

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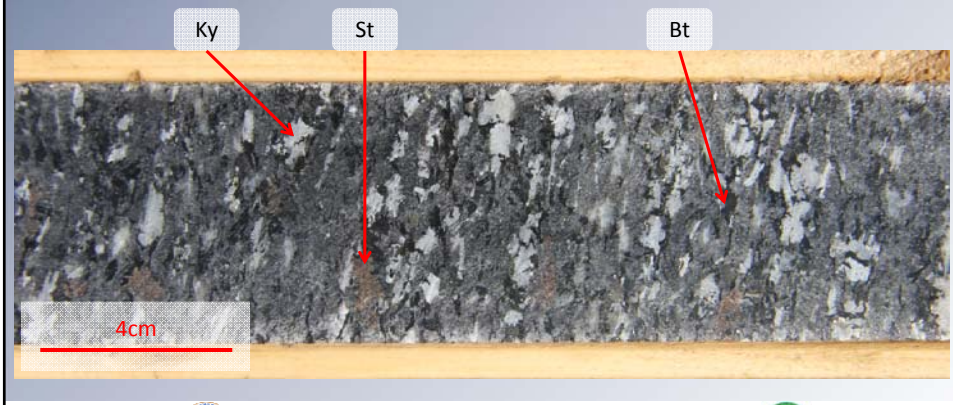
## Characterization of alteration the assemblages

**Biotite-aluminosilicates assemblage**
Quartz-biotite-aluminosilicates±pyrite-garnet-plagioclase assemblage
•Typical « gneissic texture »
•Pyrite abundance increases close to massive sulphides

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## Characterization of the alteration assemblages

**Muscovite assemblage**

Muscovite-quartz-biotite±felspar-aluminosilicates-garnet-pyrite and other sulphide assemblage

- Generally moderately to well foliated
- Up to 30% pyrite in areas close to massive sulphides




## Characterization of the alteration assemblages

**Anthophyllite assemblage**

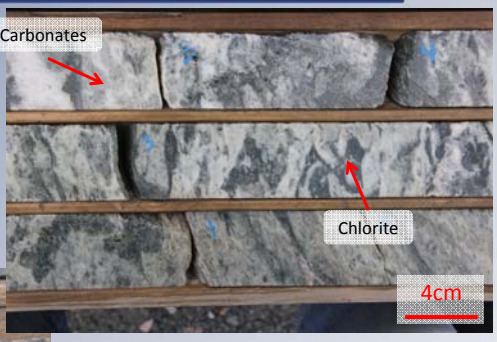
Anthophyllite-quartz±biotite-cordierite-garnet-staurolite-chlorite-plagioclase assemblage

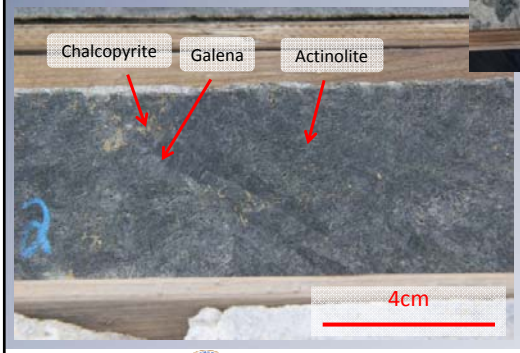
- Extensive alteration assemblage
- Host to disseminated to vein to semi-massive Cu-Au mineralization
- Associated chlorite-biotite rich bands
- Talc-rich assemblage close to massive sulphide lenses

## Characterization of the alteration assemblages

**Chlorite-carbonates assemblage**
- Host to (remobilized?) sulphides
- Situated close to massive sulphide lenses

**Chlorite-actinolite assemblage**
- Similar to the Chl-Cb ass.
- Less $CO_2$ and less mineralized than the chlorite-carbonates assemblage

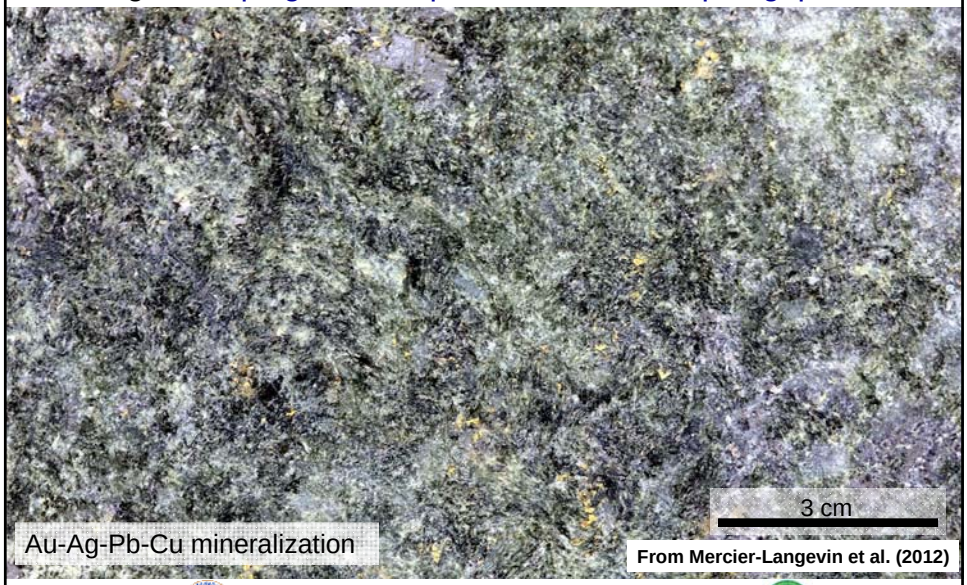



**Actinolite assemblage**
- Host to high-grade Au-Ag-Pb-Cu mineralization and (remobilized?) sulphides
- In association with Chl-Cb ass.



## Actinolite/tremolite-quartz: tremolite, actinolite, anthophyllite-cummingtonite, plagioclase, quartz, carbonates, phlogopite, biotite

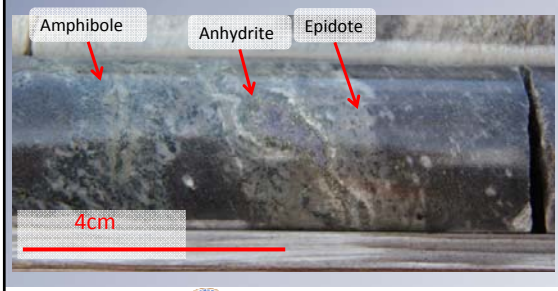


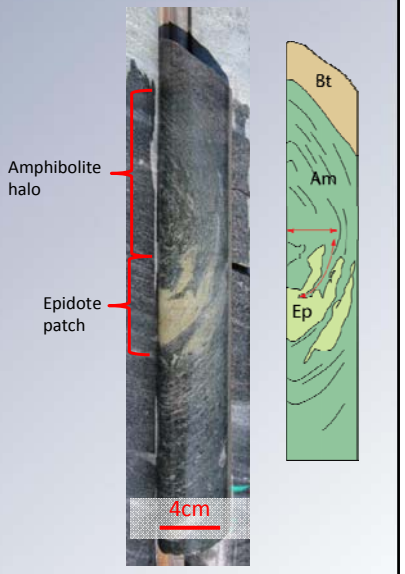

From Mercier-Langevin et al. (2012)

## Characterization of the alteration assemblages

**Ca-rich alteration**

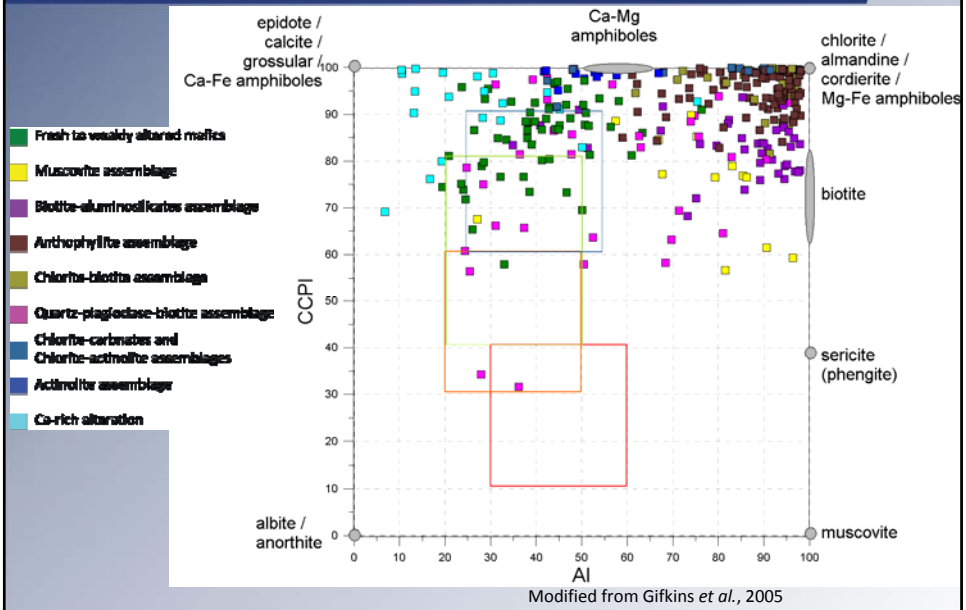
- Epidote and/or grossular and/or calcite and/or anhydrite and/or quartz veins
- Epidote-quartz patches to haloes
- Pervasive calcic amphibole haloes
- Affects FW and HW
- Overprints the other alteration types
- Not related to mineralization



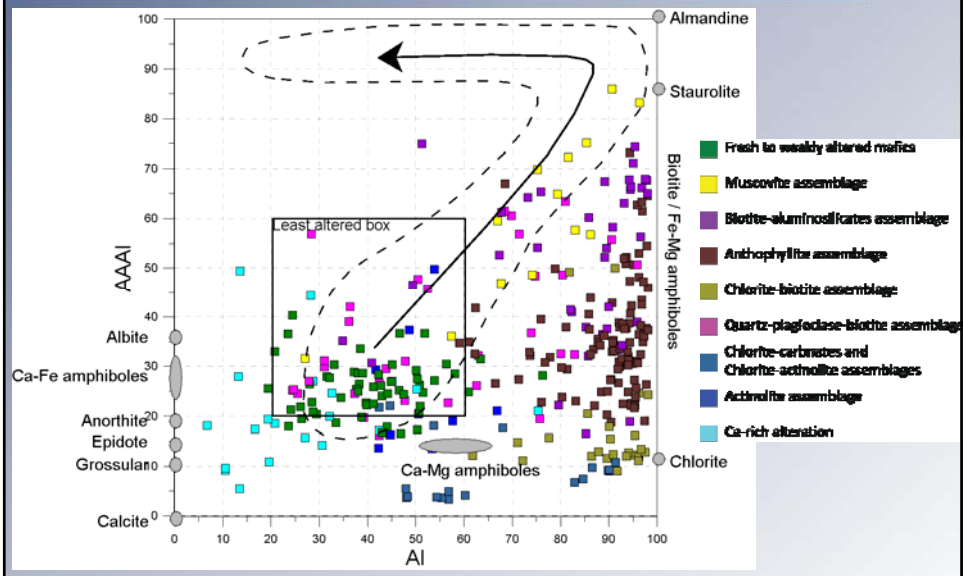



## Characterization of the alteration assemblages




Modified from Gifkins *et al.*, 2005

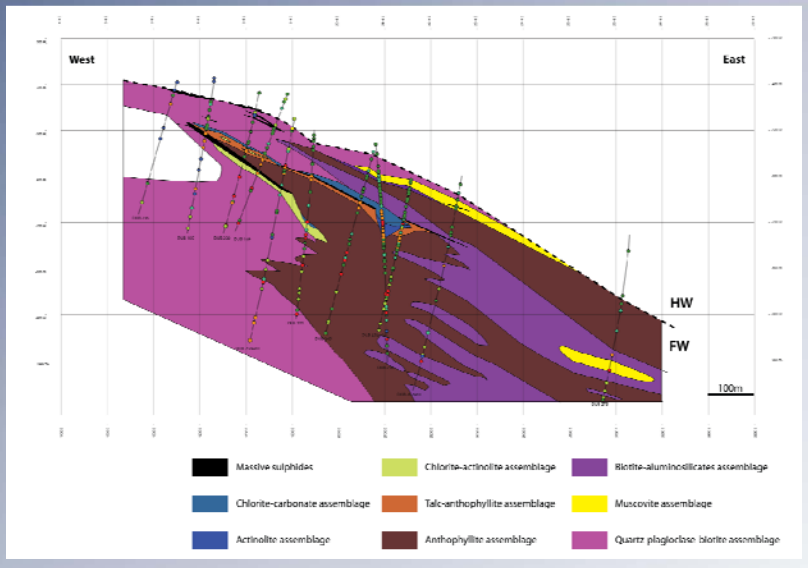
## Characterization of the alteration assemblages




Modified from Williams and Davidson, 2004



## Distribution of the alteration assemblages – section 5600



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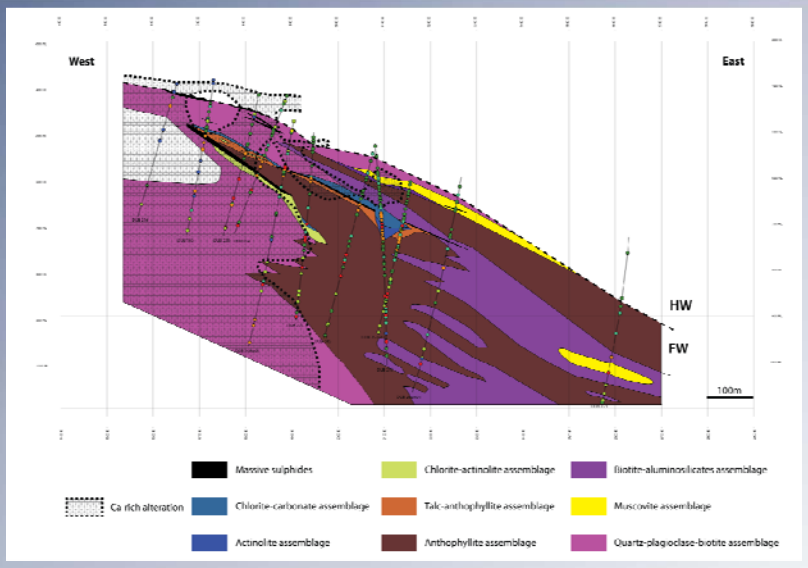
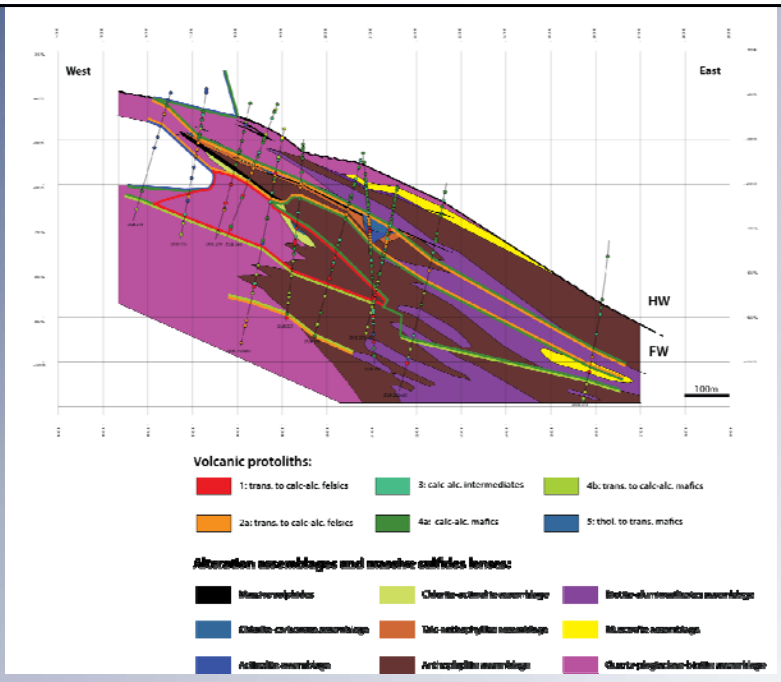


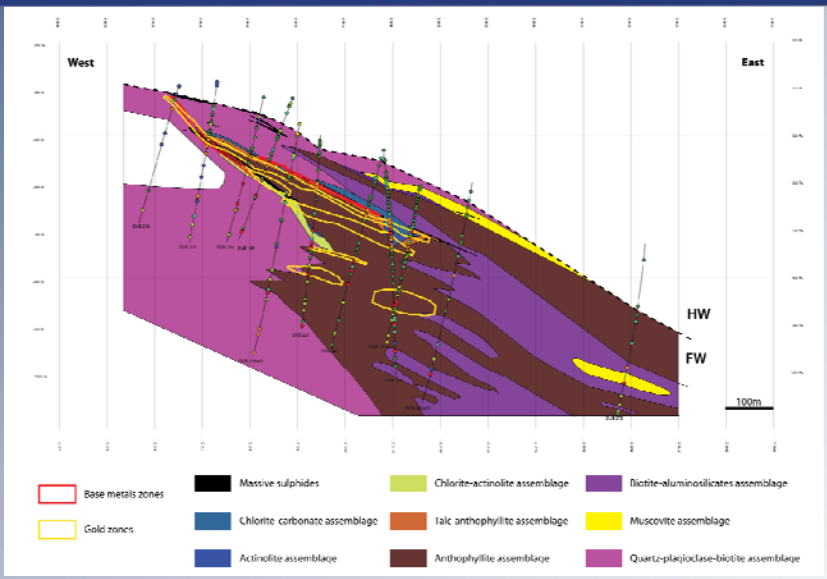

Ca-rich alteration envelope






Superposition of volcanic protoliths and alteration assemblages

## Distribution of the alteration assemblages – section 5600




Superposition of alteration assemblages and ore zones



## Conclusions

**Summary:**

•The Lalor auriferous VMS deposit is hosted by a complex volcanic stratigraphy including units of contrasting magmatic affinities and numerous intrusive units (dykes).

•The deposit and its footwall are affected by an extensive, intense, polyphased? alteration that obliterates most of the primary volcanic and intrusive textures.

•Gold is hosted in base metal-rich massive sulphide lenses, in Mg-Ca-rich alteration assemblages (Chl-Cb ass. and Act ass.) close to massive sulphide lenses and in disseminated to vein to semi-massive chalcopyrite-pyrrhotite mineralization in the anthophyllite assemblage at depth.

•Based on preliminary lithogeochemistry, the Powderhouse dacite may not be present, or only locally present, in the Lalor deposit footwall succession; however more work is necessary to confirm this.

•The geometry of the deposit is largely controlled by structural features and possible synvolcanic faults, and current work focuses on these controls.

## Conclusions

The Lalor auriferous deposit shares some characteristics with other gold-rich VMS deposits including:

- Complex architecture
- Complex ore and alteration mineralogy/paragenesis
- Association with an evolved/mature arc sequence
- Gold is associated with base metals and is also present in base metal-poor zones
- Primary textures are obscured by major deformation and mineralization, in its current state, is at least partially structurally controlled

Major differences from other well-studied Au-rich VMS deposits include:

- Lacks of an advanced argillic alteration style present in some Au-rich VMS deposits;
- Some gold-rich zones are associated with Ca- and Mg-rich alteration;
- A strong Au-Cu-Pb-Ag association



## Conclusions

**On-going and future work includes:**

- Description and sampling of several more core intervals to better understand and illustrate the distribution and geometry of volcanic and intrusive units and metamorphosed alteration assemblages
- Continue the characterization of the metamorphosed hydrothermal alterations (including mass-balance calculations)
- Continue the structural study of the deposit
- Study the relationships between primary volcanic stratigraphy, hydrothermal alteration characteristics and distribution and geometry of base and precious metal mineralization
- Integrate our work in a constrained 3D environment in collaboration with the current GSC's TGI-4 passive and active seismic surveys project and downhole multiparameter geophysics (Schetselaar, Bellefleur et al.)
- U-Pb geochronology (McNicoll, Mercier-Langevin et al.)
- Mapping of paleo-hydrothermal upflow zones using oxygen isotopes
- In depth characterization of the ore mineralogy, mineral chemistry and isotopic signature (Duff, Hannington et al.)

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- GSC
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  - J. Peter
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  - V. Bécu
- Laurentian University
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  - H. Gibson
  - B. Lafrance
  - J. Lam
  - M. Engelbert
- Mount Royal University
  - M. DeWolfe
  - V. Frie


**Refer to Hudbay's website for any information about the Lalor Project R&R, technical data and development status.**



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