

Structural Controls on Gold Mineralization

**Auriferous intrusion-related sheeted veins and
orogenic veins in the Abitibi-Wawa subprovince**

Bruno Lafrance

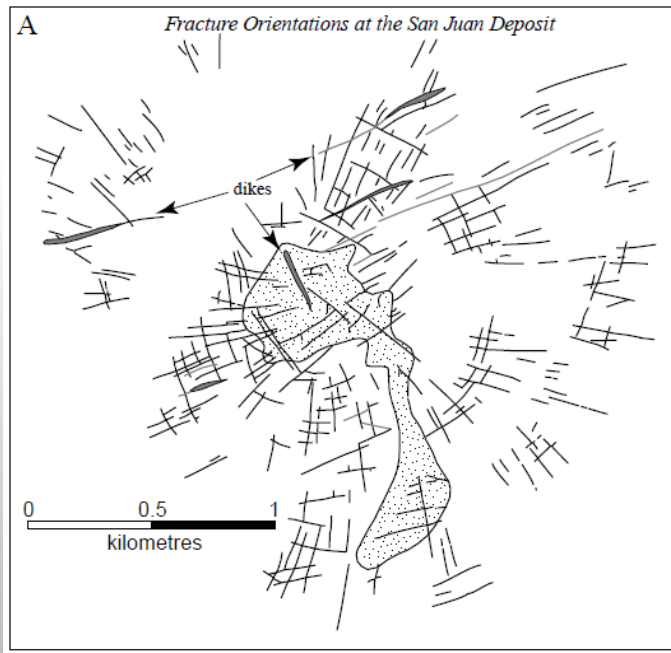
Mineral Exploration Research Centre

Harquail School of Earth Sciences

Laurentian University

What are intrusion-related sheeted veins?

Definition: They are sets of parallel quartz-sulfide veins spatially associated with intrusions and largely coeval with their emplacement.



Concentric and radial fracture patterns reflect magmatic processes and are more common above or in the upper parts of the stocks.

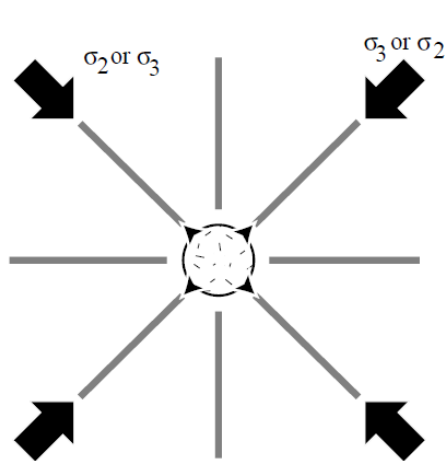
Concentric and radial mineralized fractures and veins developed at high levels in the San Juan mine area, Safford Mining District, Arizona.

Tosdal and Richards (2001)

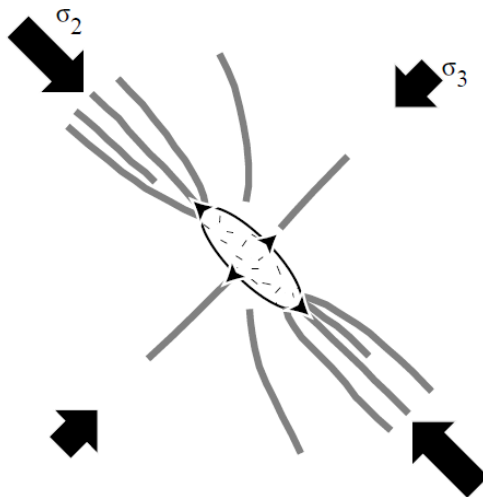
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Cross-sectional views of conduits of subvolcanic plutonic and dike complexes



Uniform or isotropic regional stress field



Differential horizontal or anisotropic stress field

More linear arrays of veins reflect tectonic influences and dominate at depth, forming as the system cools and the pluton solidifies. The resulting different vein arrays are therefore commonly vertically and temporally distributed in the porphyry system.

Tosdal and Richards (2001)

What are intrusion-related sheeted veins?

Definition: They are sets of parallel quartz-sulfide veins spatially associated with intrusions and largely coeval with their emplacement.

What is the problem?

Problem: For intrusions emplaced in large deformation zones, associated sheeted veins may be later sheared and mistaken for orogenic vein systems.

Examples: Renabie and Côté Gold deposits

Why are they mistaken for orogenic vein systems?

Answer: Sheeted veins and alteration halo acted as planar anisotropies that localized the formation of the shear zones and possible channelling of later pulses of orogenic hydrothermal fluids.

What structural tools can be used to interpret their origin as orogenic or intrusion-related veins?

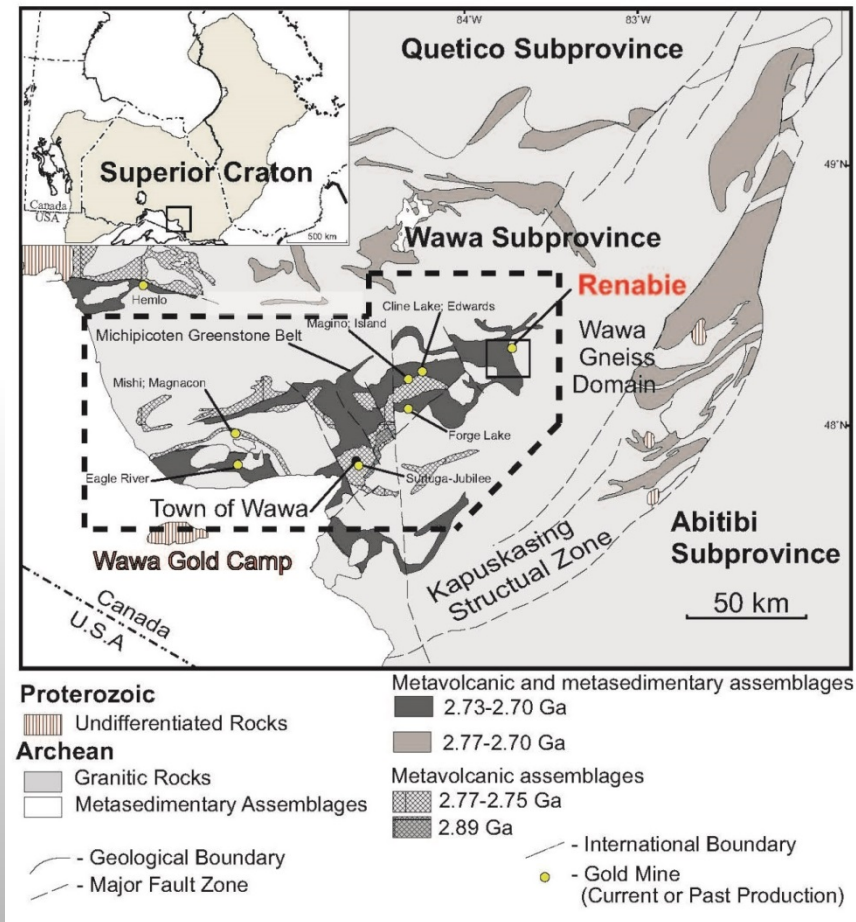
Renabie Gold Mine

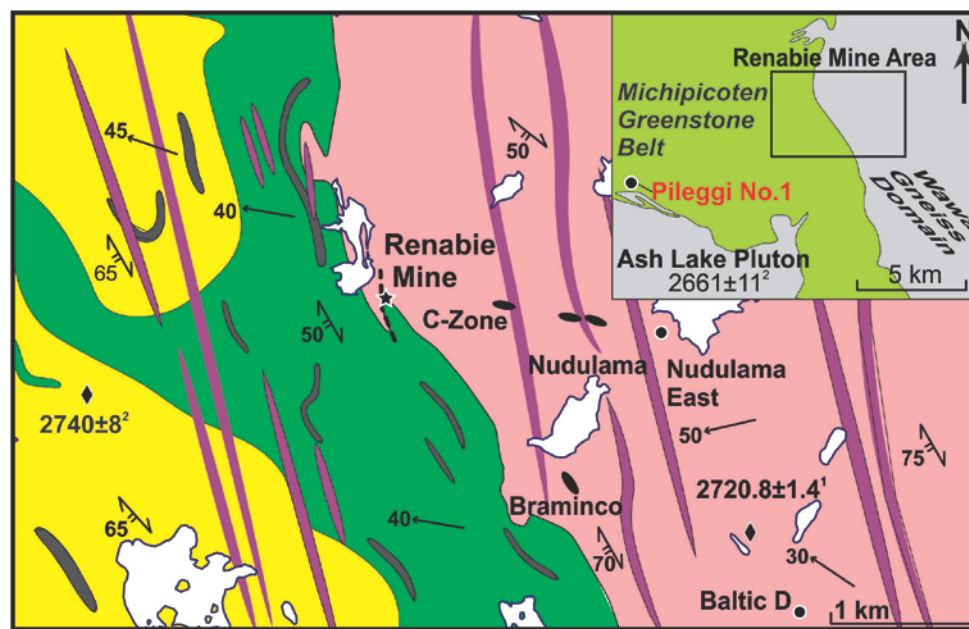
Wawa Subprovince

Laminated quartz-gold veins
within shear zones

Interpreted as an Orogenic Gold
Deposit because the veins hosted by
shear zones cut across the regional
foliation in the host tonalite pluton
and metavolcanic rocks

Jordan McDiVitt (MSc 2016 Laurentian)
McDivitt et al. 2017, 2018 Econ Geol





Proterozoic

■ Matachewan Mafic Dikes

Archean

■ Biotite-Bearing Tonalite
(Missinaibi Lake Batholith)

■ Intermediate to felsic volcaniclastic rocks

■ Massive to pillowed mafic volcanicrocks

★ Renabie Gold Mine

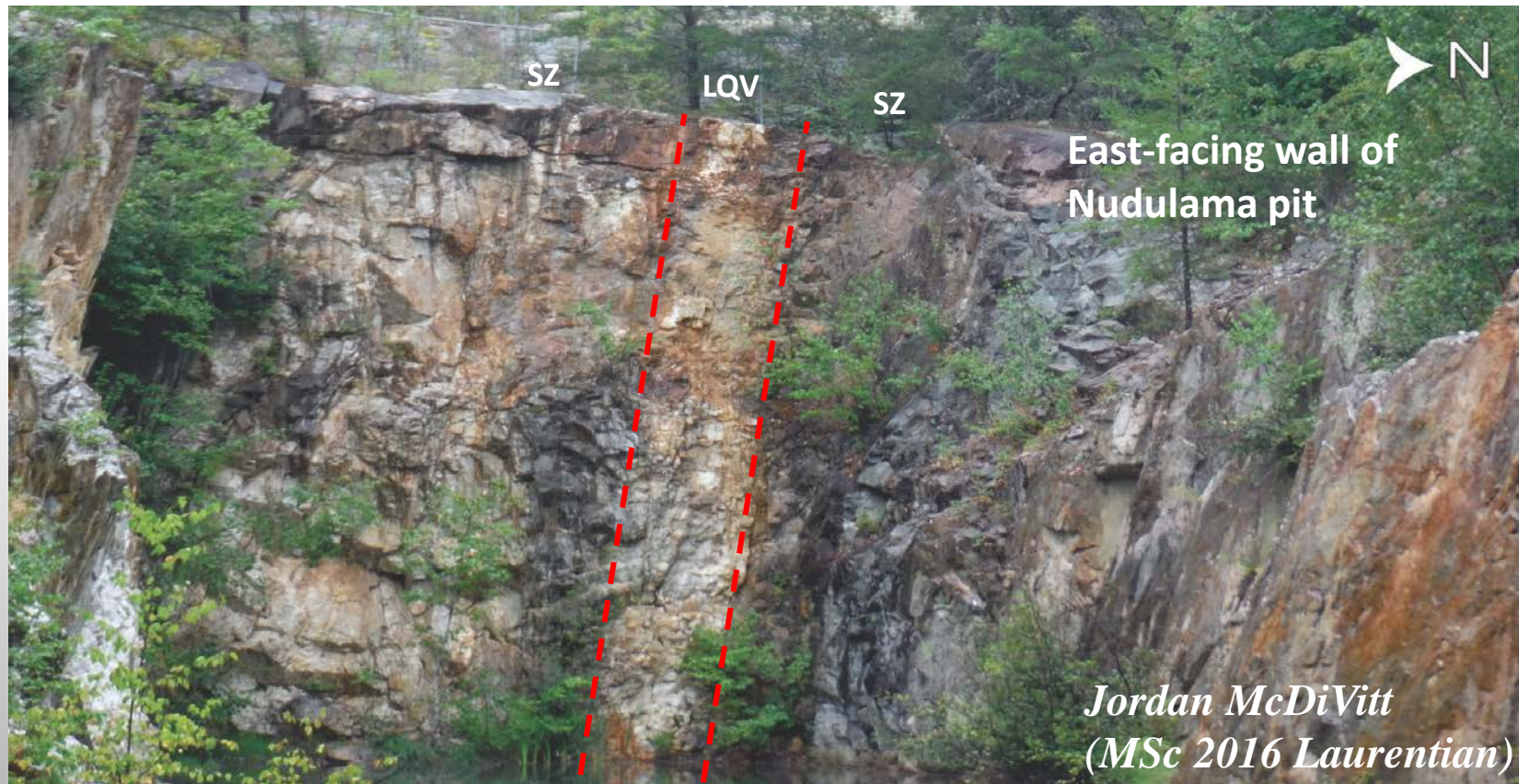
● Open Pit

● Mineralized Outcrop

--- Shaft Fault

*Jordan McDiVitt
(MSc 2016
Laurentian)
McDivitt et al. 2017,
2018 Econ Geol*

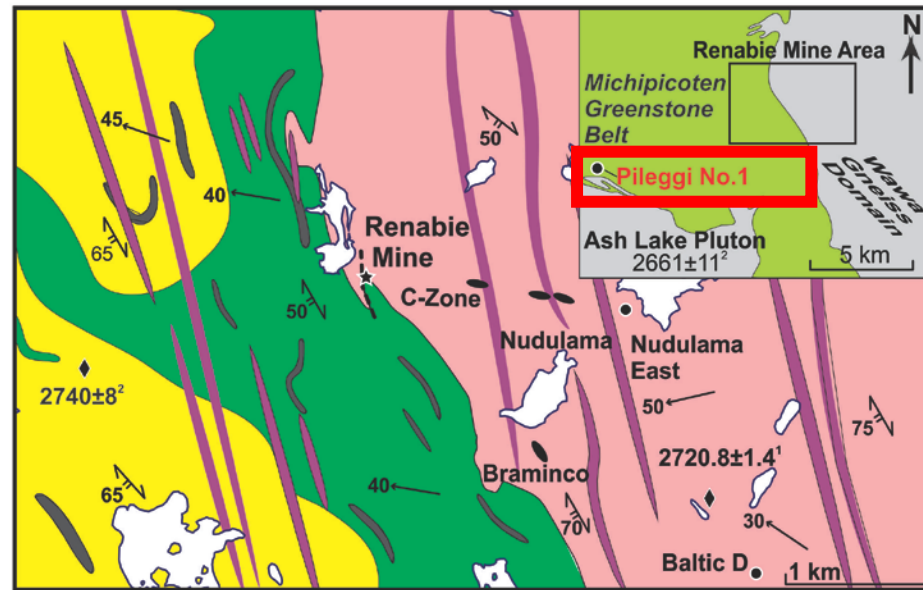
Laminated quartz vein (LQV) in shear zone (SZ) or quartz-sericite-pyrite schist



Laminated quartz vein with saccharoidal texture at Nudulama East



Jordan McDiVitt
(MSc 2016 Laurentian)



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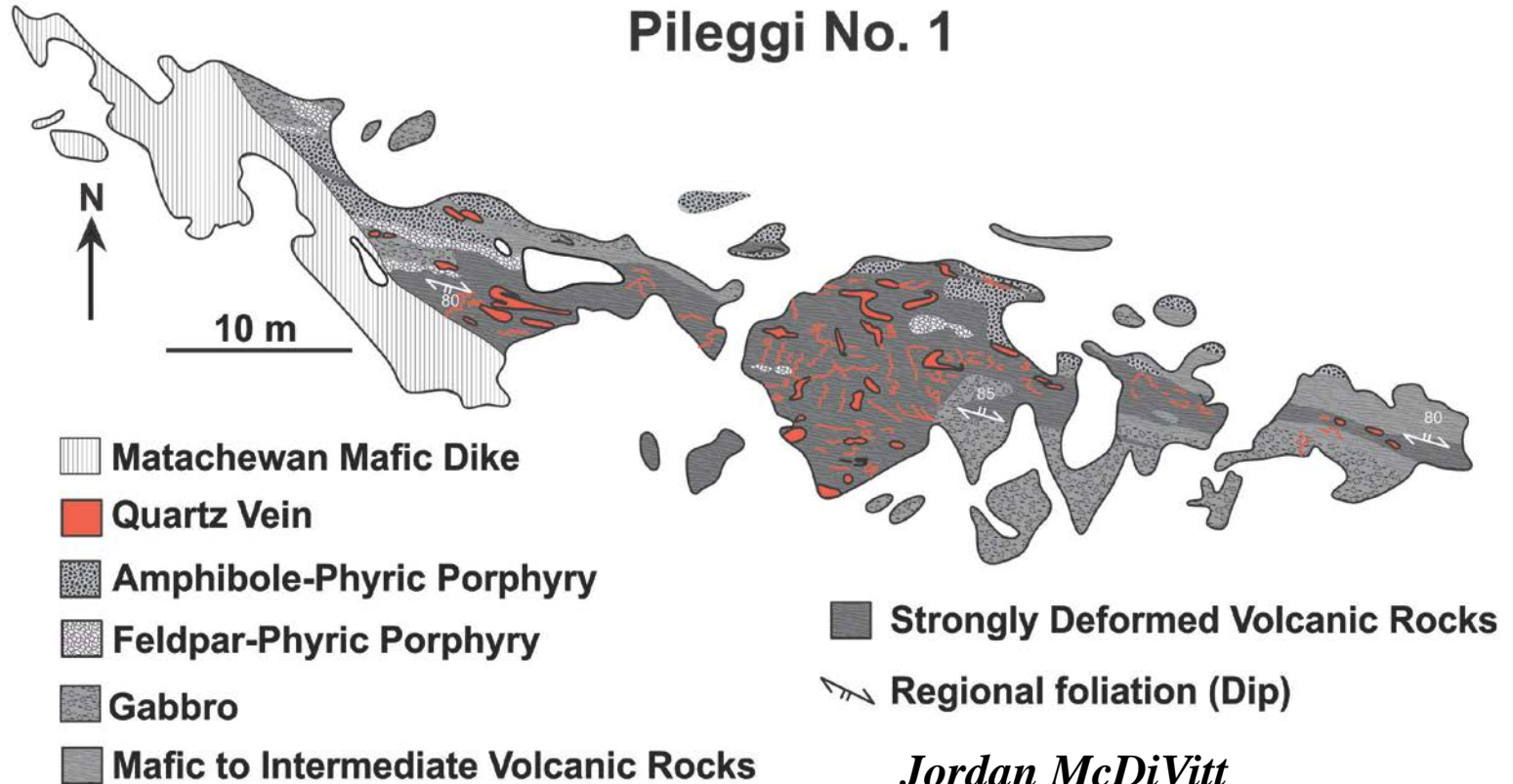
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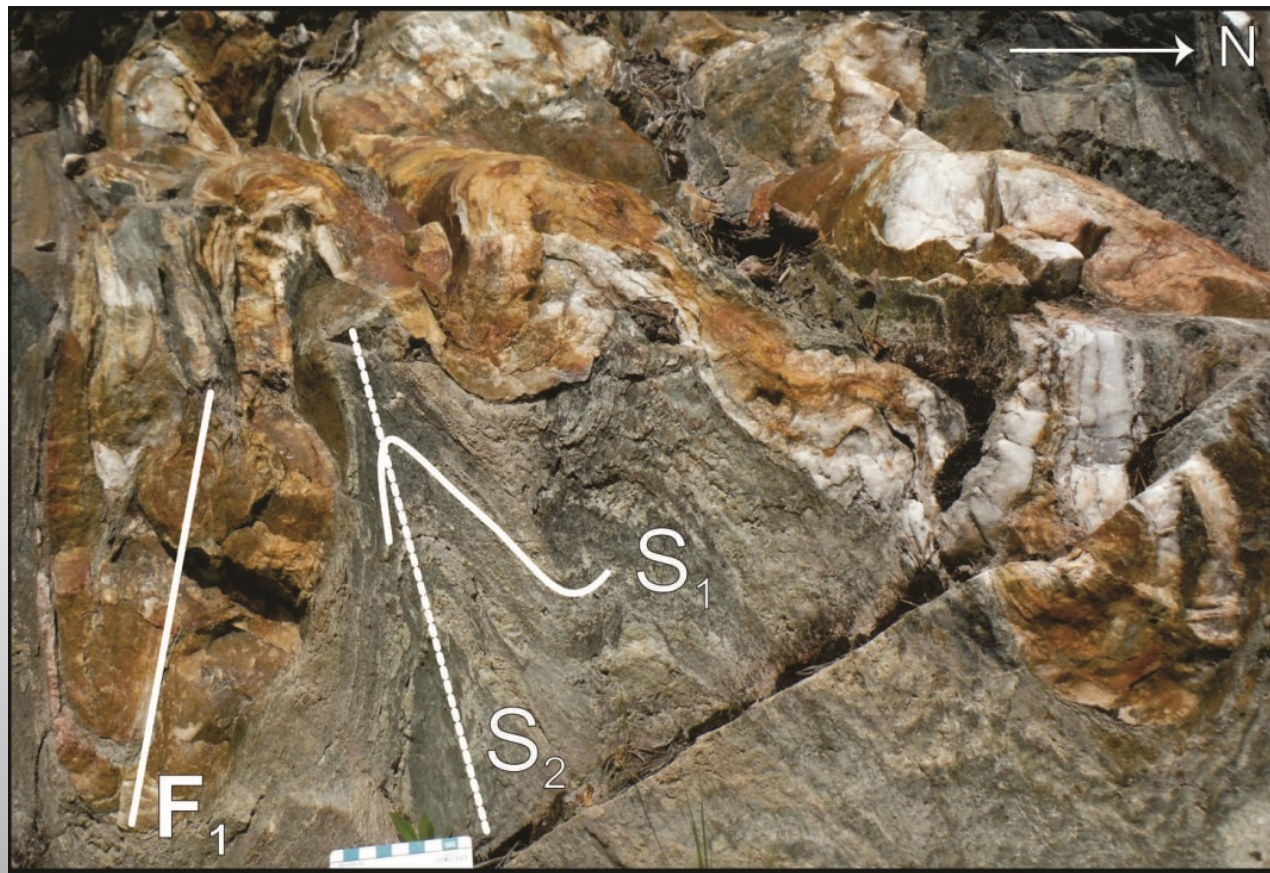
*McDivitt et al. 2017,
2018 Econ Geol*

Pileggi No. 1



Jordan McDiVitt
(MSc 2016 Laurentian)

Isoclinal F1-folded laminated quartz vein refolded by F2 folds at Pileggi No.1

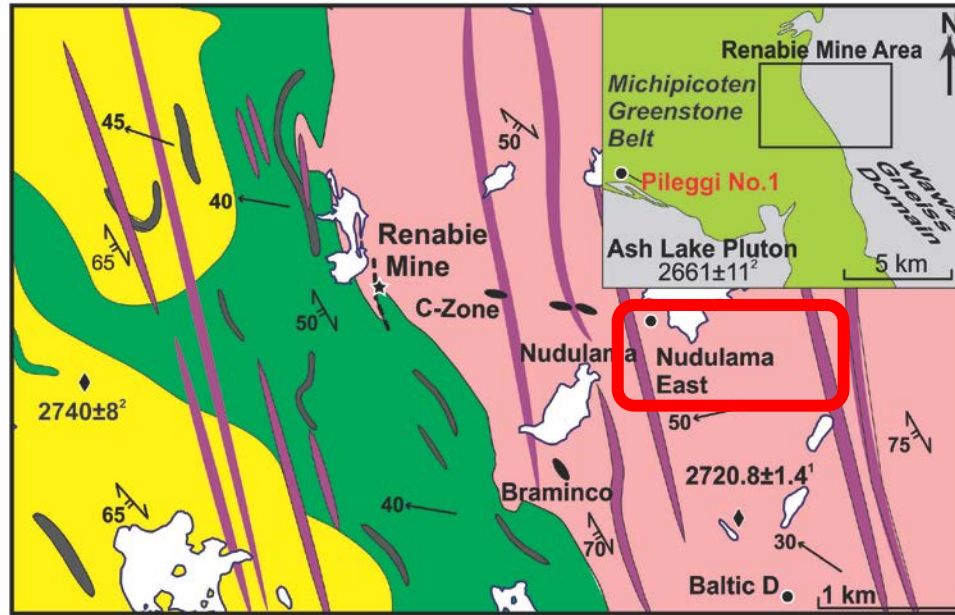


*Jordan
McDiVitt
(MSc 2016
Laurentian)*



**Laminated
quartz vein
transposed
parallel to S2
at Pileggi
No.1**

*Jordan
McDiVitt
(MSc 2016
Laurentian)*



Proterozoic

Matachewan Mafic Dikes

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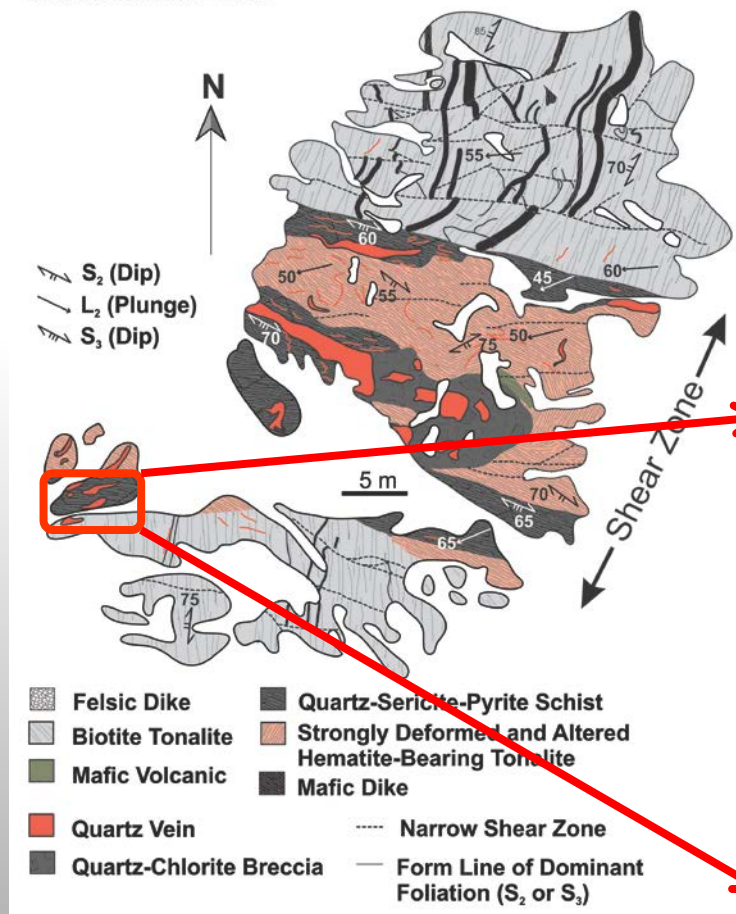
Jordan McDiVitt

(MSc 2016

Laurentian)

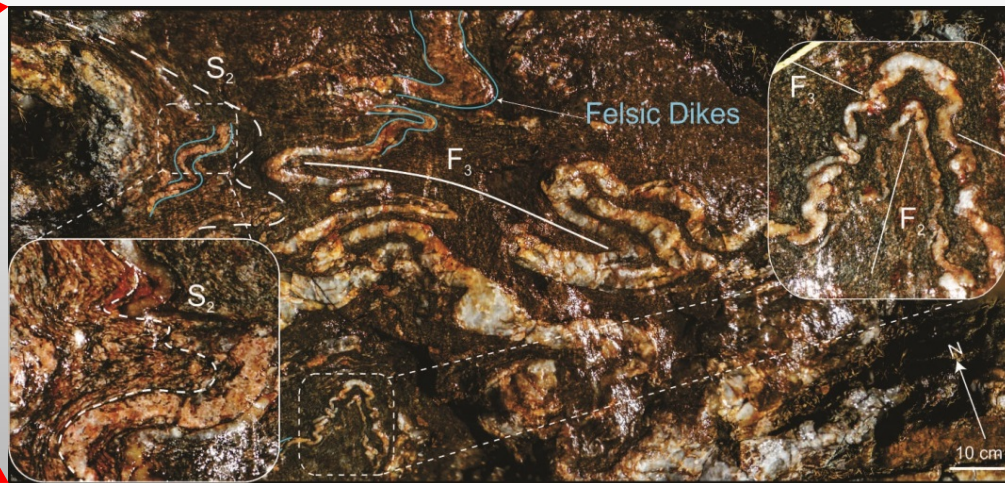
*McDivitt et al. 2017,
2018 Econ Geol*

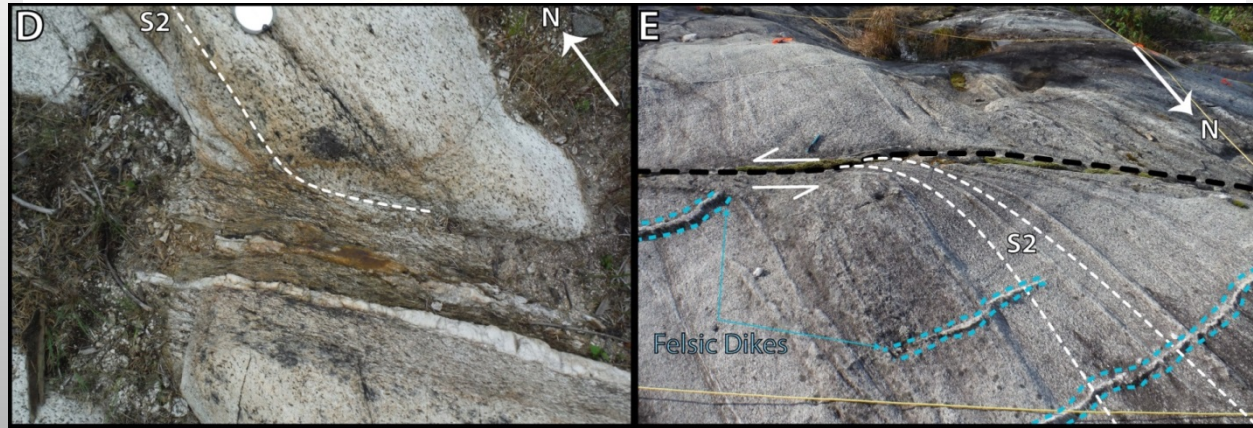
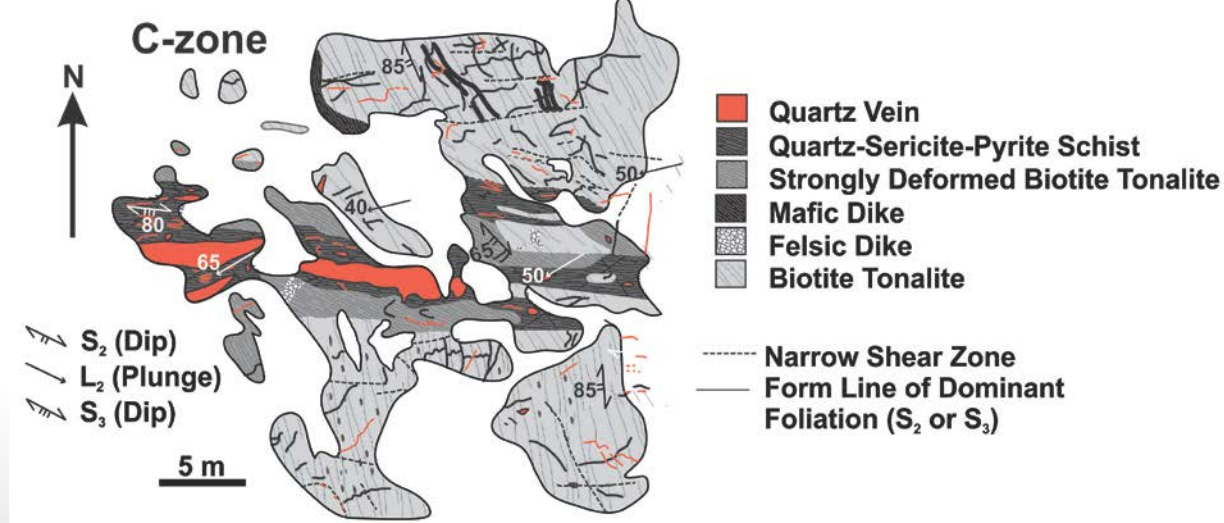
Nudulama East



Quartz veins are pre- foliation and shear zone.

They predate regional deformation of their host tonalite and metavolcanic rocks.





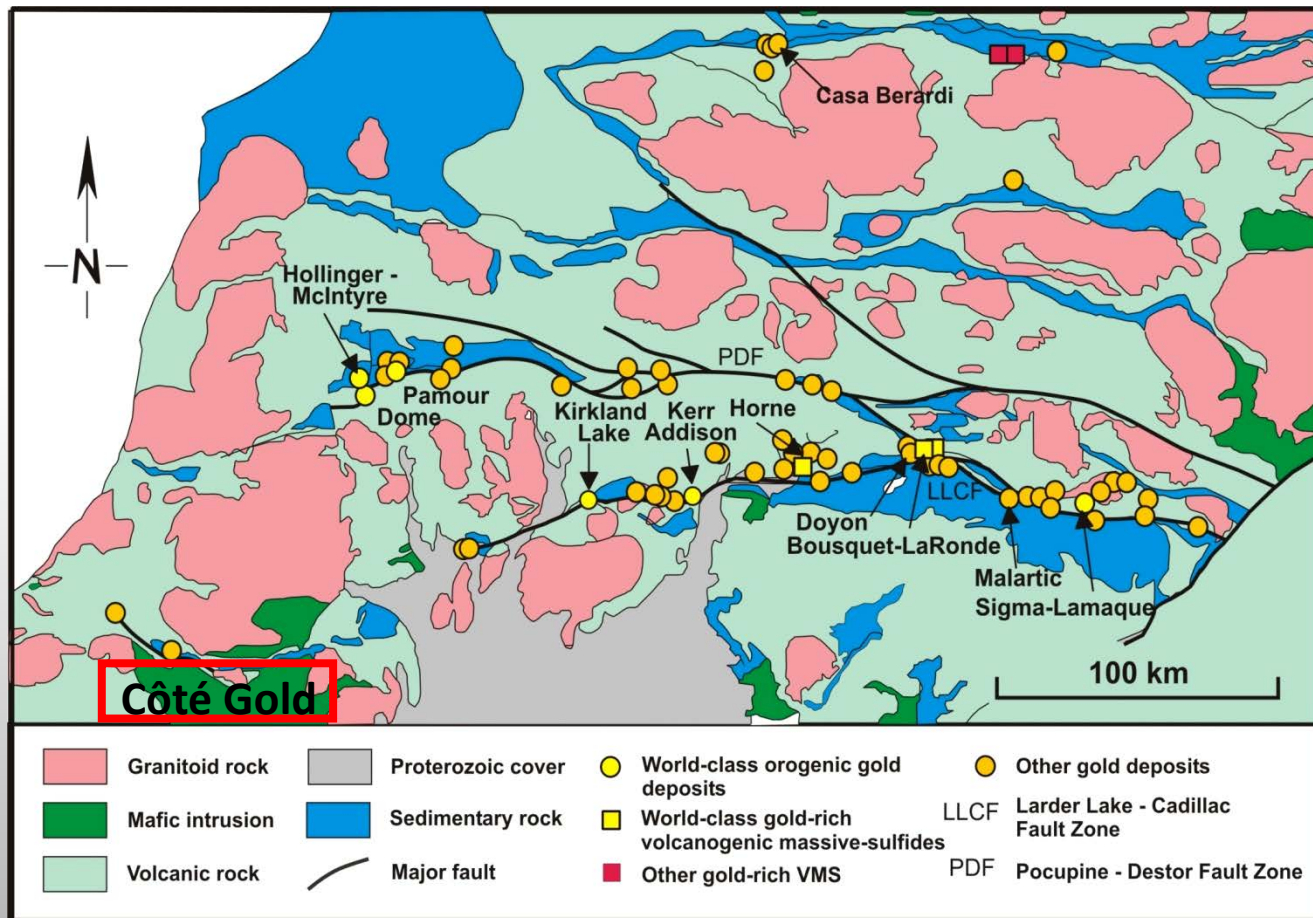
Summary

- Gold is associated with pre-orogenic laminated quartz veins with quartz-sericite-pyrite alteration halos
- Laminated quartz-gold veins predate the formation of regional cleavage and stretching lineation in the Wawa gold camp.

The veins and their weak alteration envelope acted as a planar anisotropy that localize the nucleation and propagation of the shear zones hosting them.

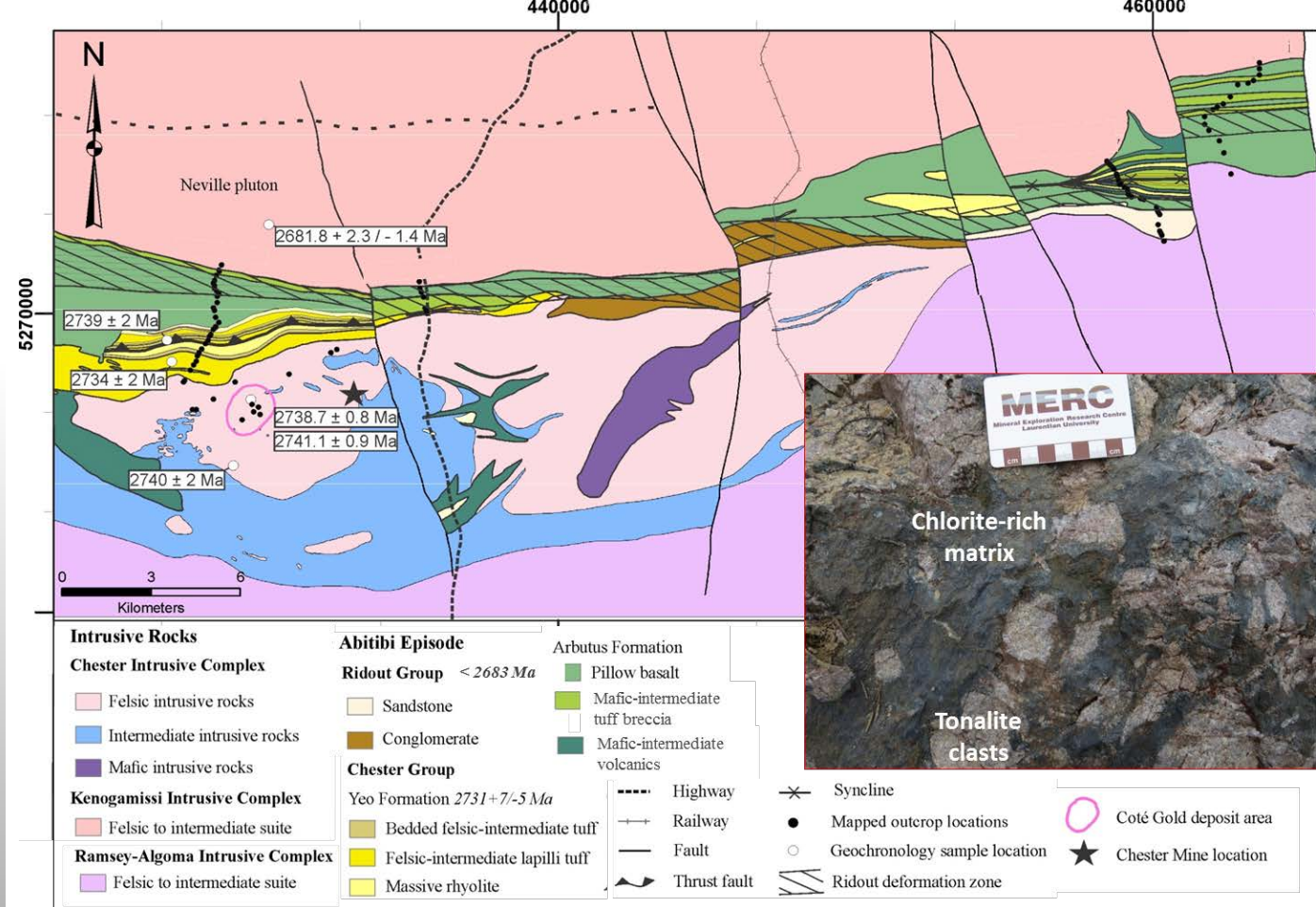
Example 2: Côté Gold deposit

*Poulsen et al.
(2000)*

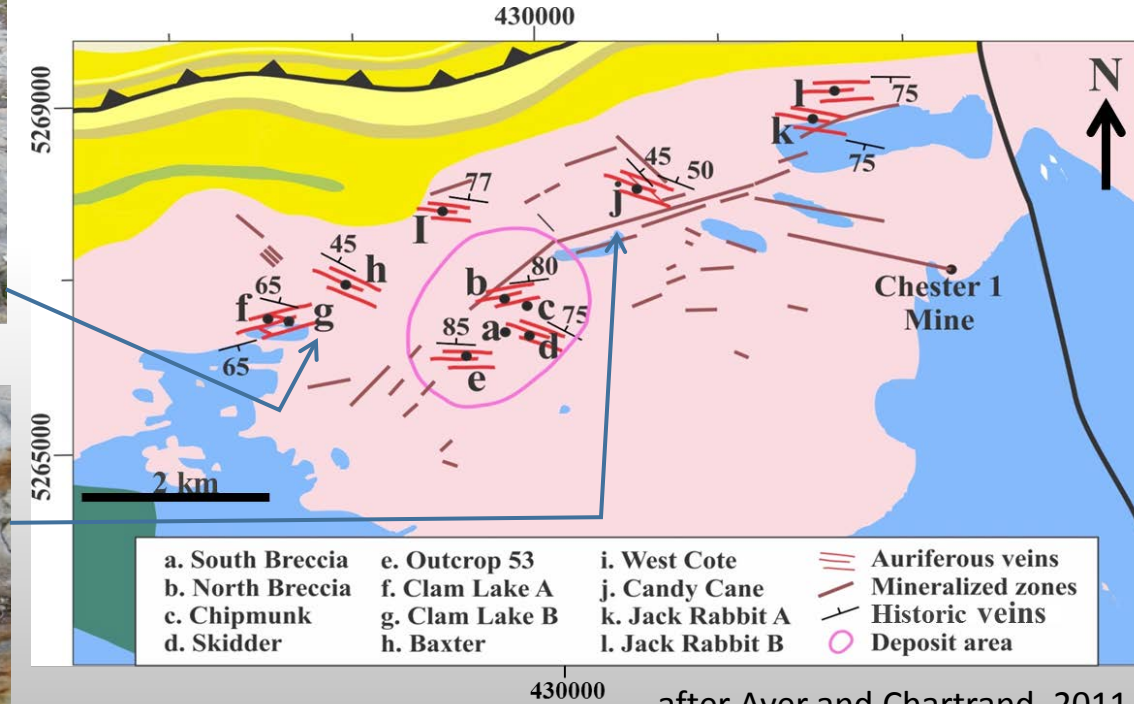


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After Ayer and
Chartrand, 2011
and Berger, 2011



Quartz-sulfide veins at Côté Gold deposit

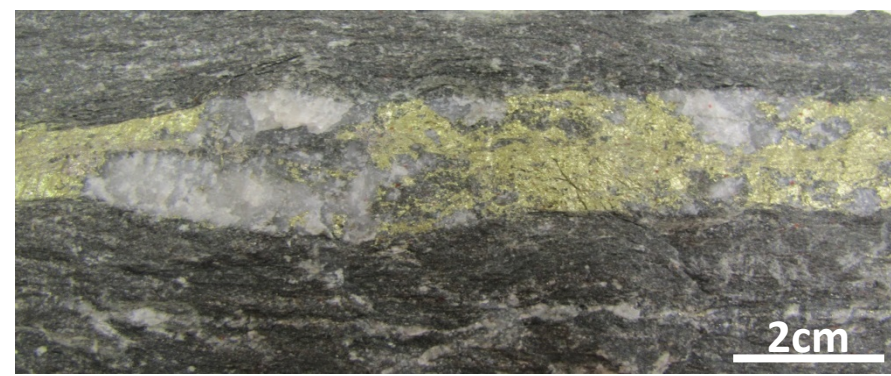


after Ayer and Chartrand, 2011

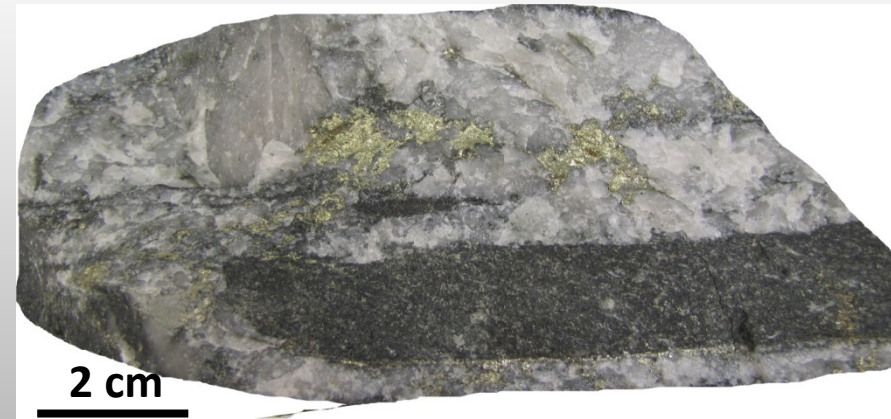
Joycelyn Smith (MSc 2016 Laurentian)

Chester Mine: An orogenic gold deposit?

Laminated
Vein with
sheared
foliated
wallrocks



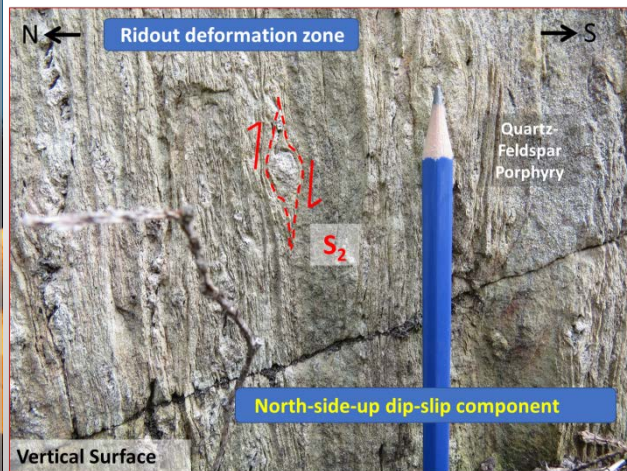
Boudinaged quartz vein with foliated
altered wallrocks



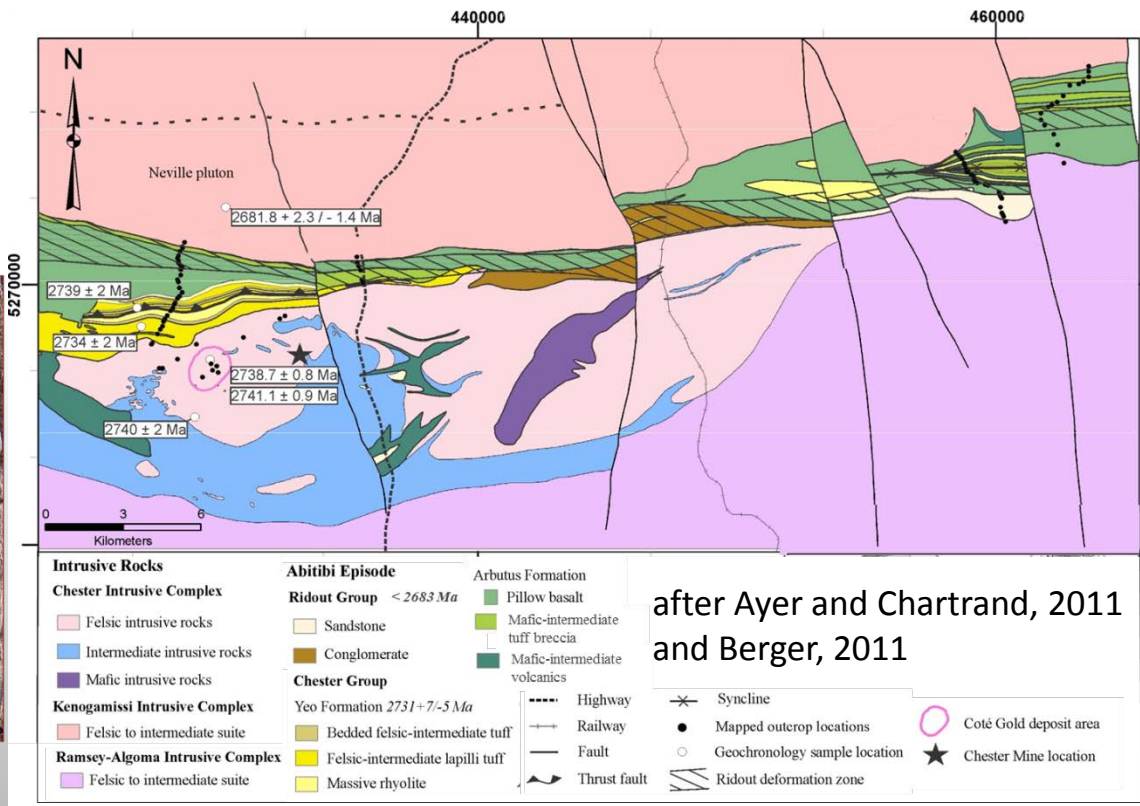
Quartz vein with undeformed wallrock
fragments

Photographs courtesy of Dr. Dan Kontak

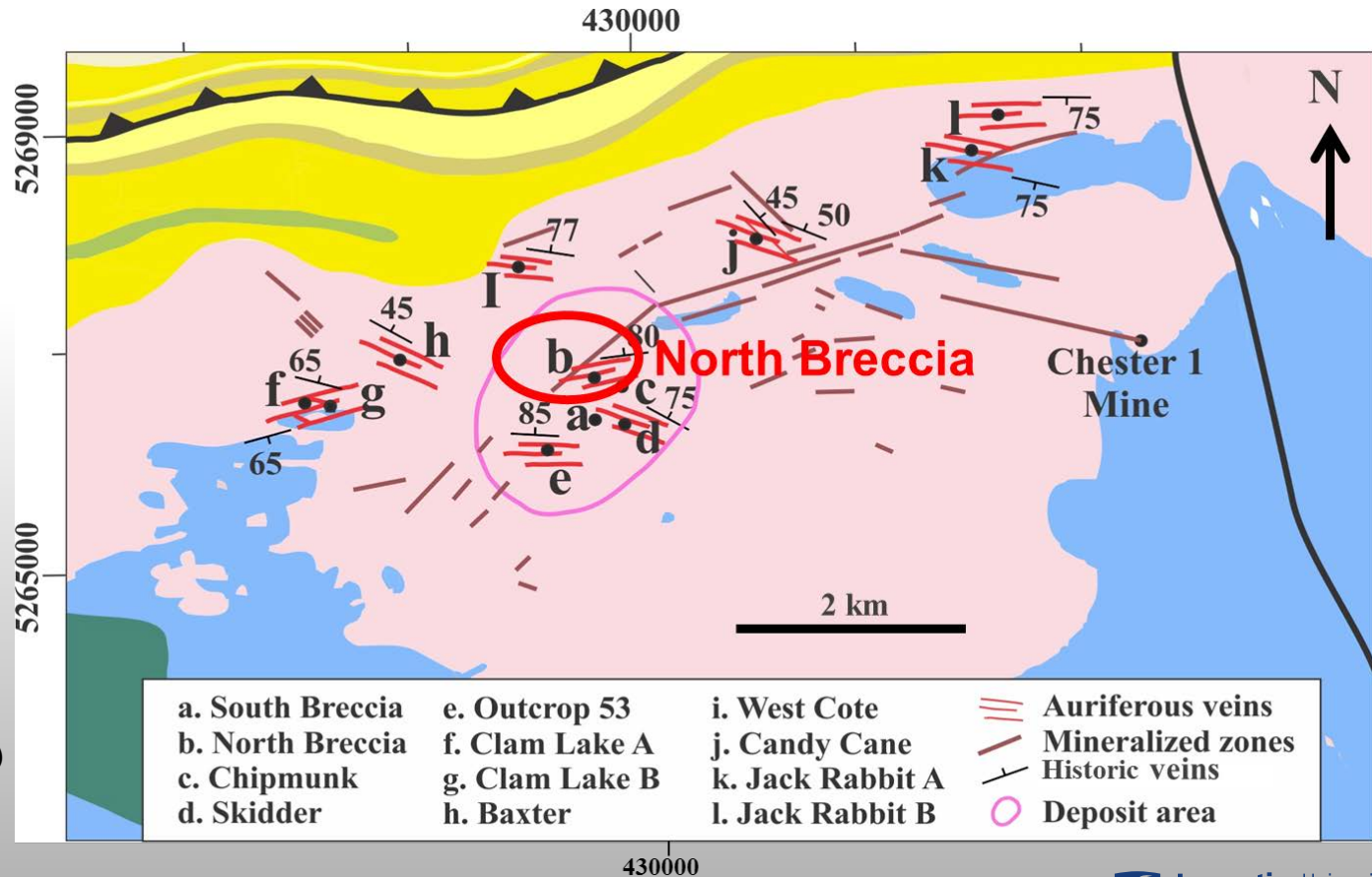
Ridout Deformation Zone



Joycelyn Smith (MSc
2016 Laurentian)



Quartz-sulfide veins at Côté Gold deposit

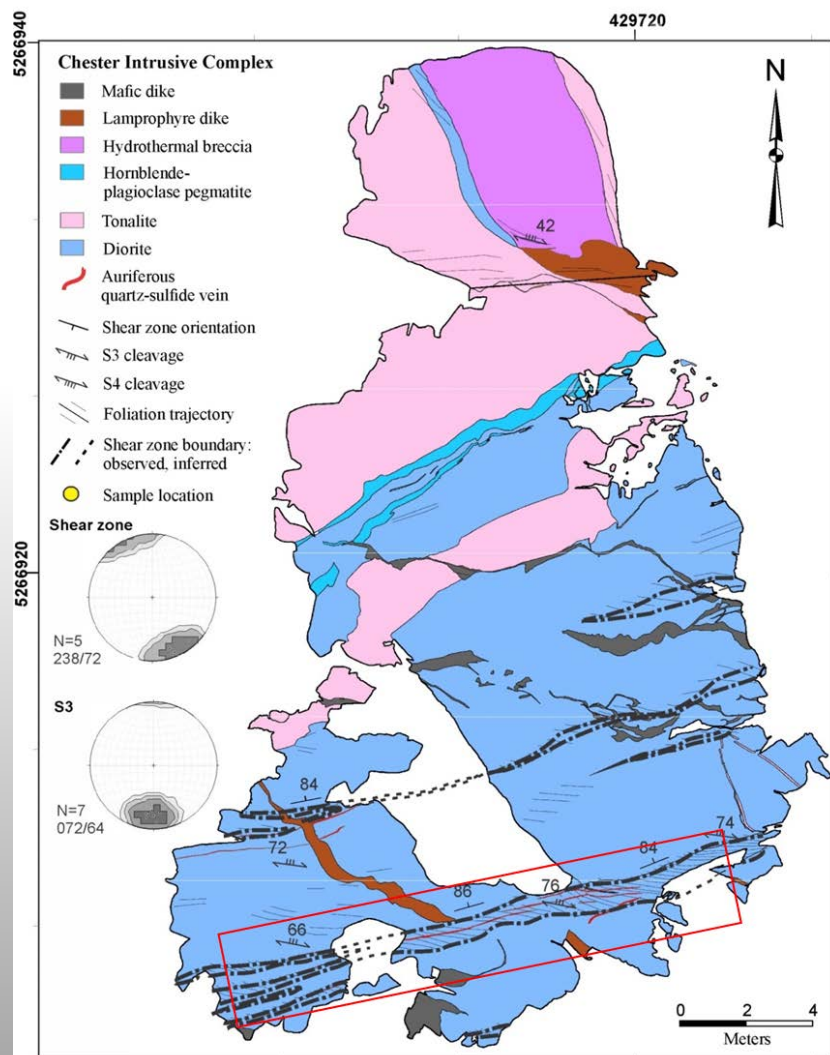


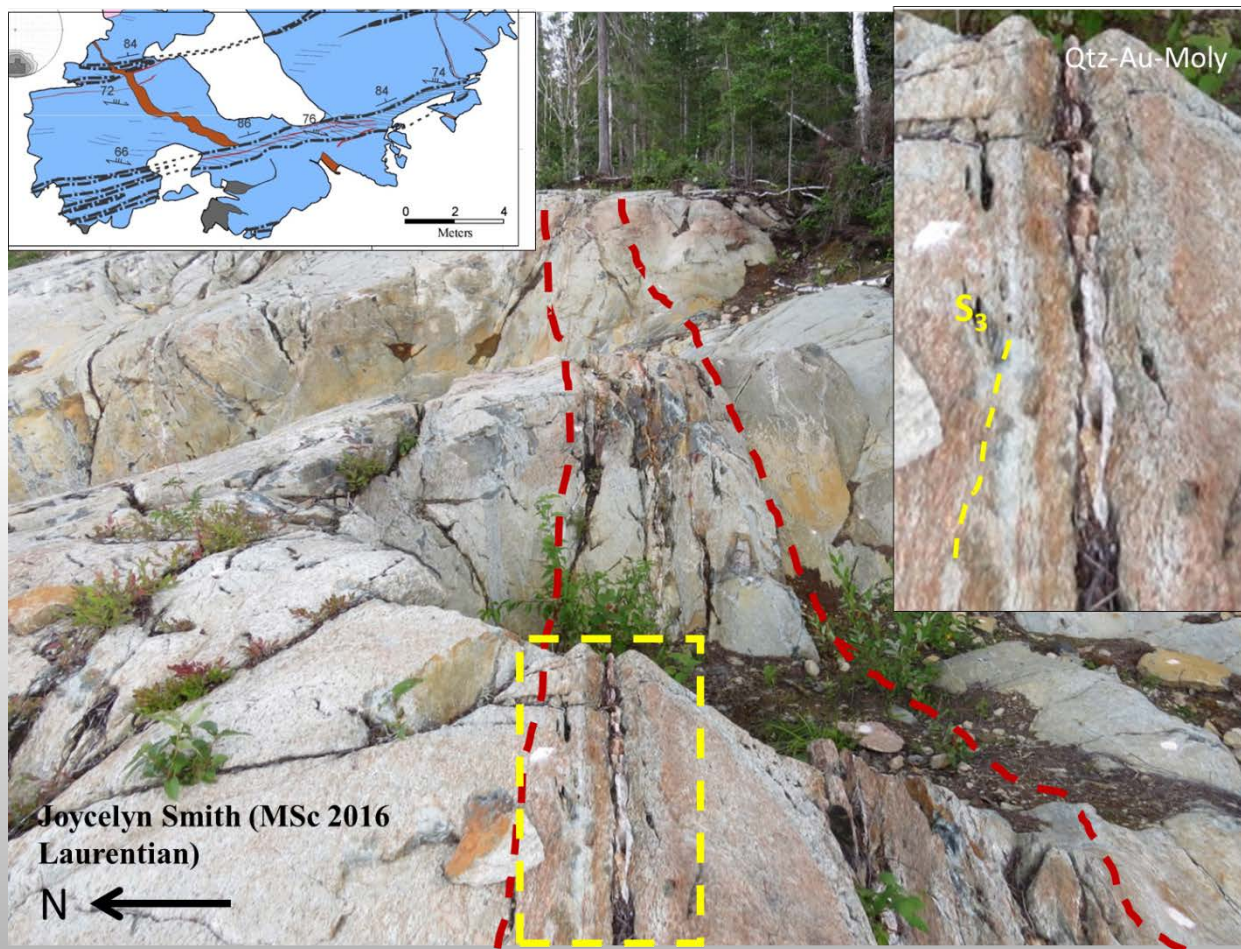
After Ayer
and
Chartrand,
2011

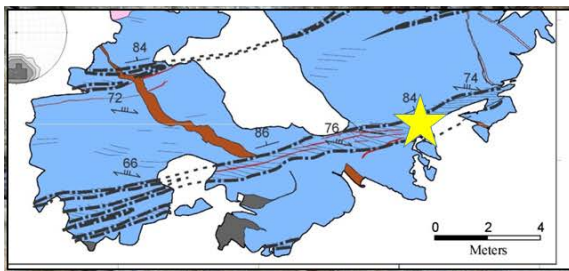
J. Smith
(MSc 2016
Laurentian)

Quartz-sulfide veins at North Breccia outcrop

*Joycelyn Smith (MSc 2016
Laurentian)*







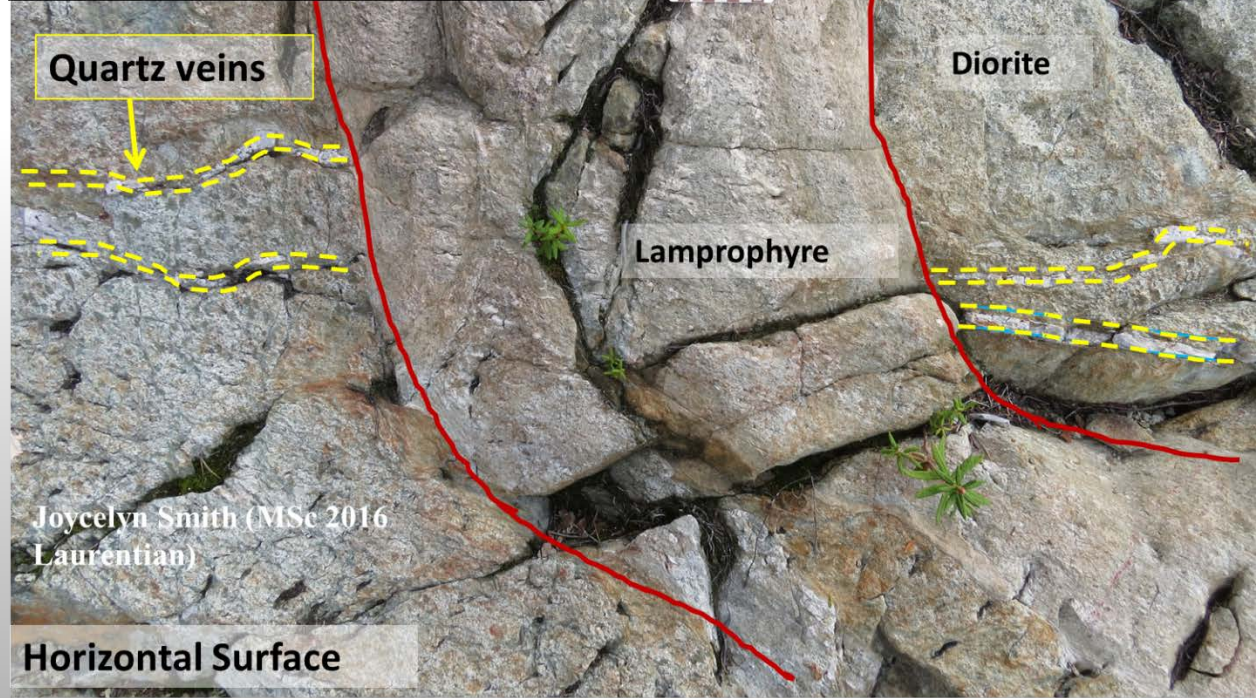
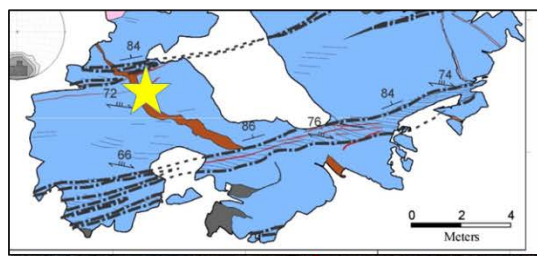
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Diorite

Mylonitic
fabric

Shortening Direction

Horizontal Surface



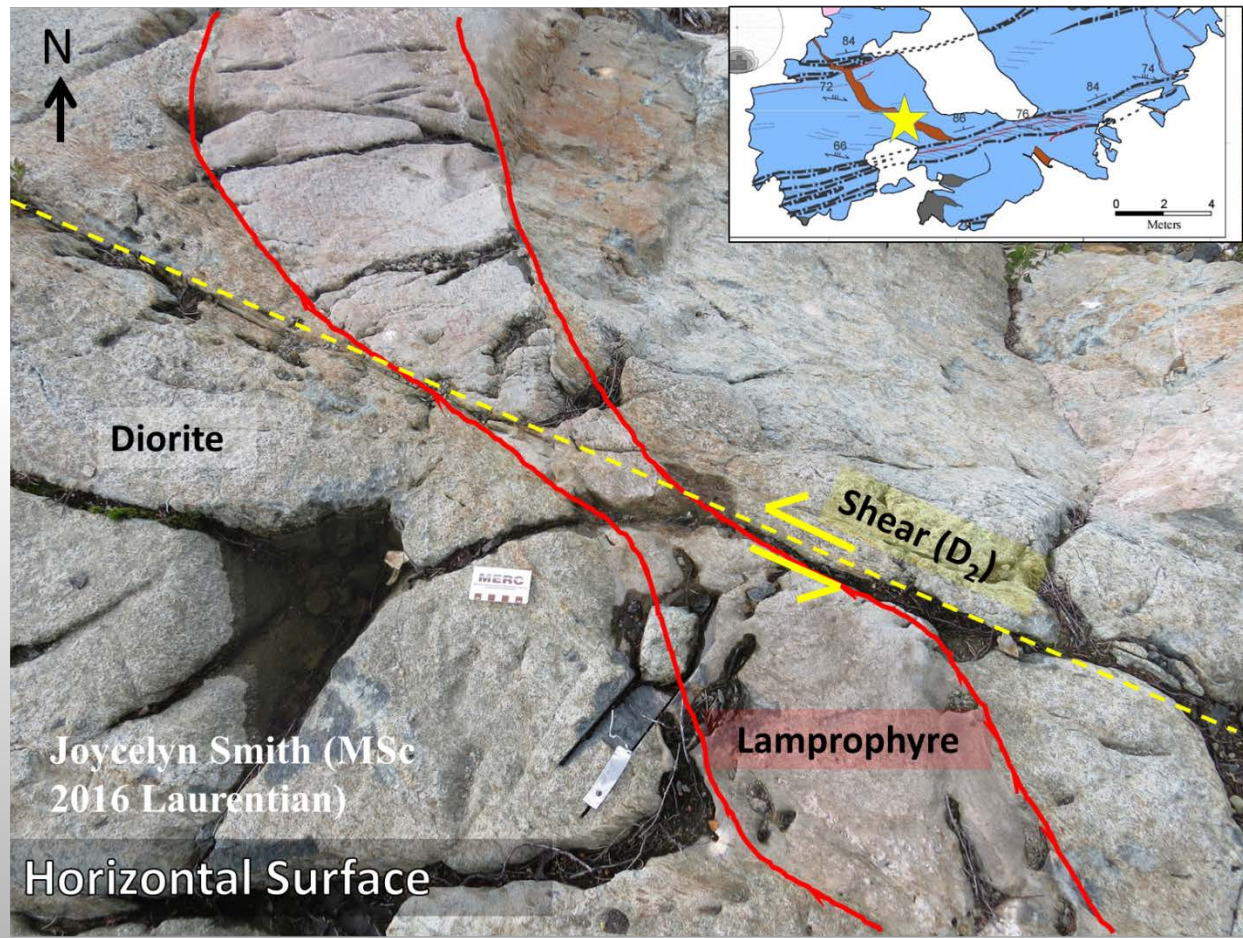
Quartz veins

Diorite

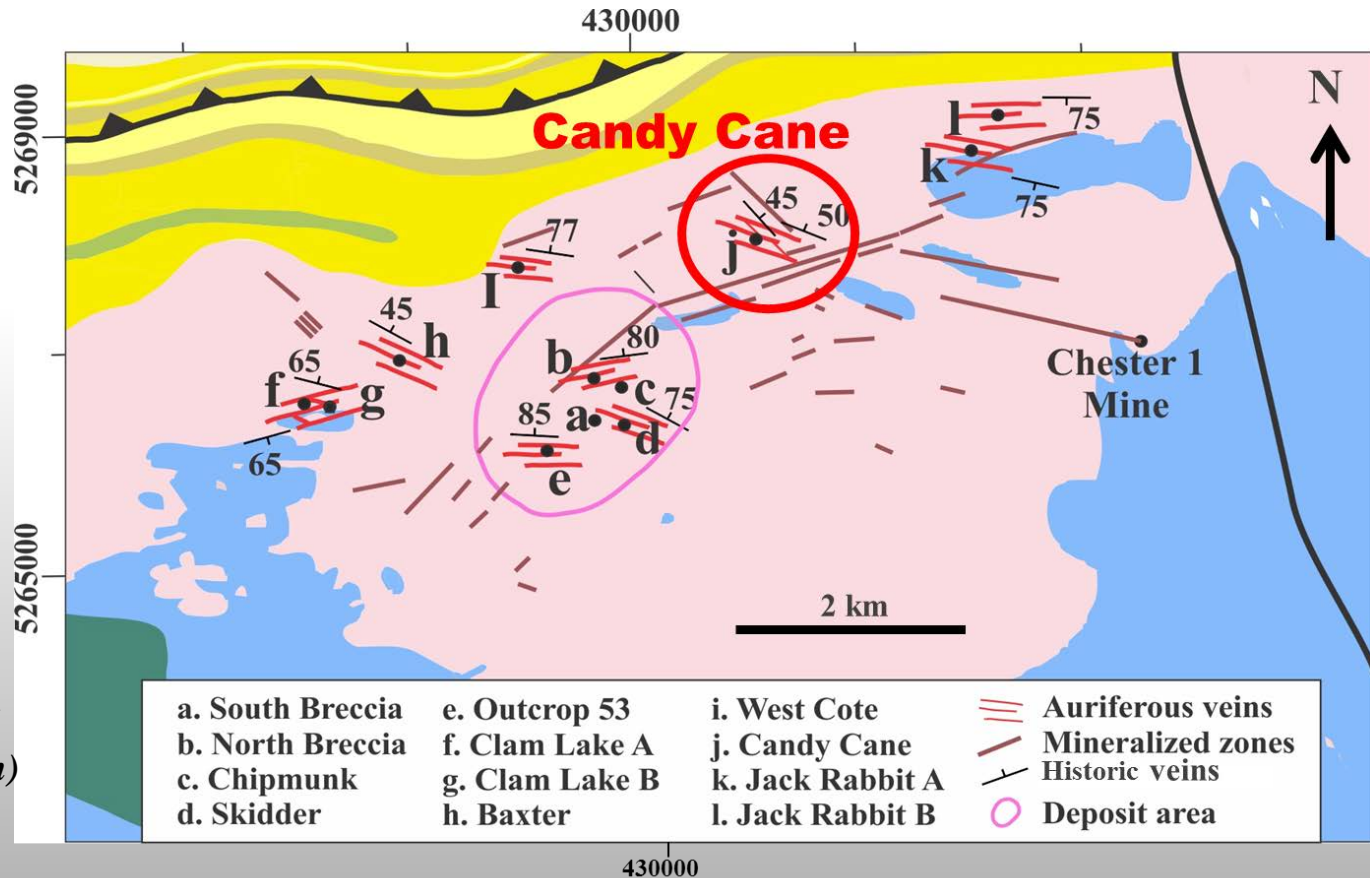
Lamprophyre

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Horizontal Surface

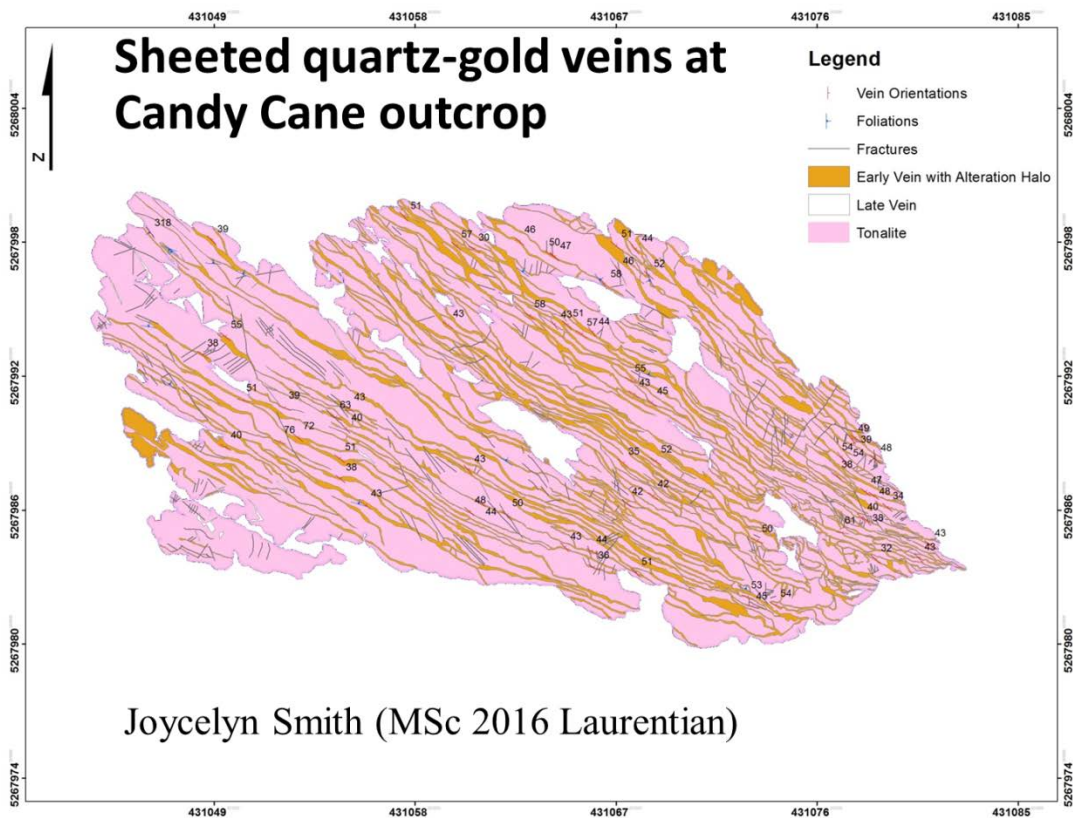


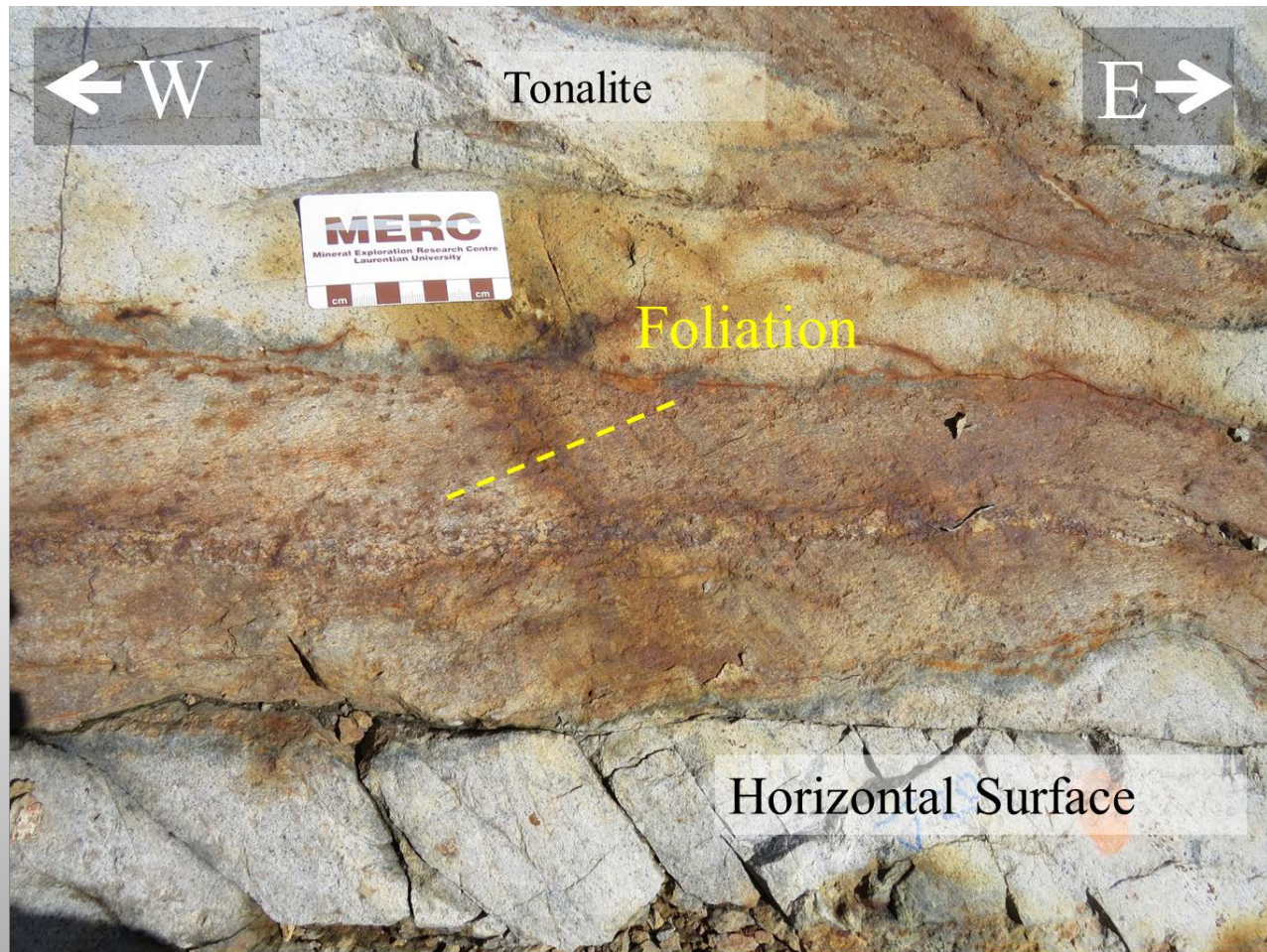
Quartz-sulfide veins at Côté Gold deposit



*J. Smith
(MSc 2016
Laurentian)*

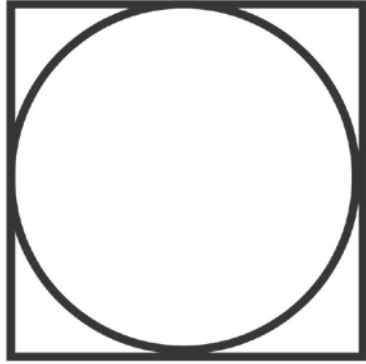
After Ayer
and
Chartrand,
2011



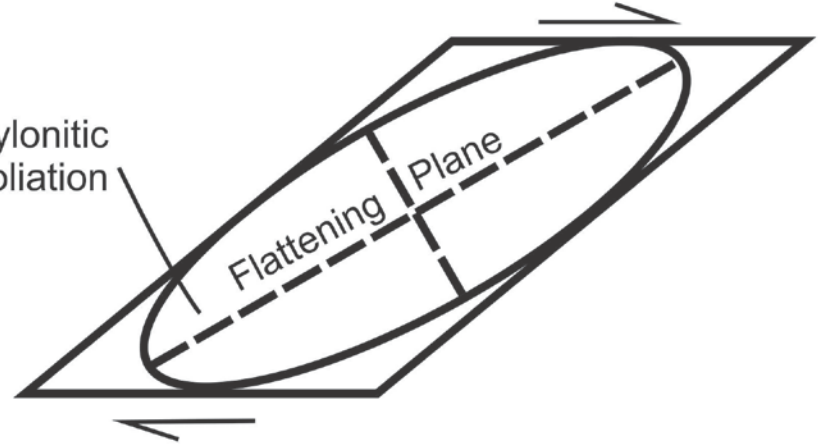


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Undeformed square & circle



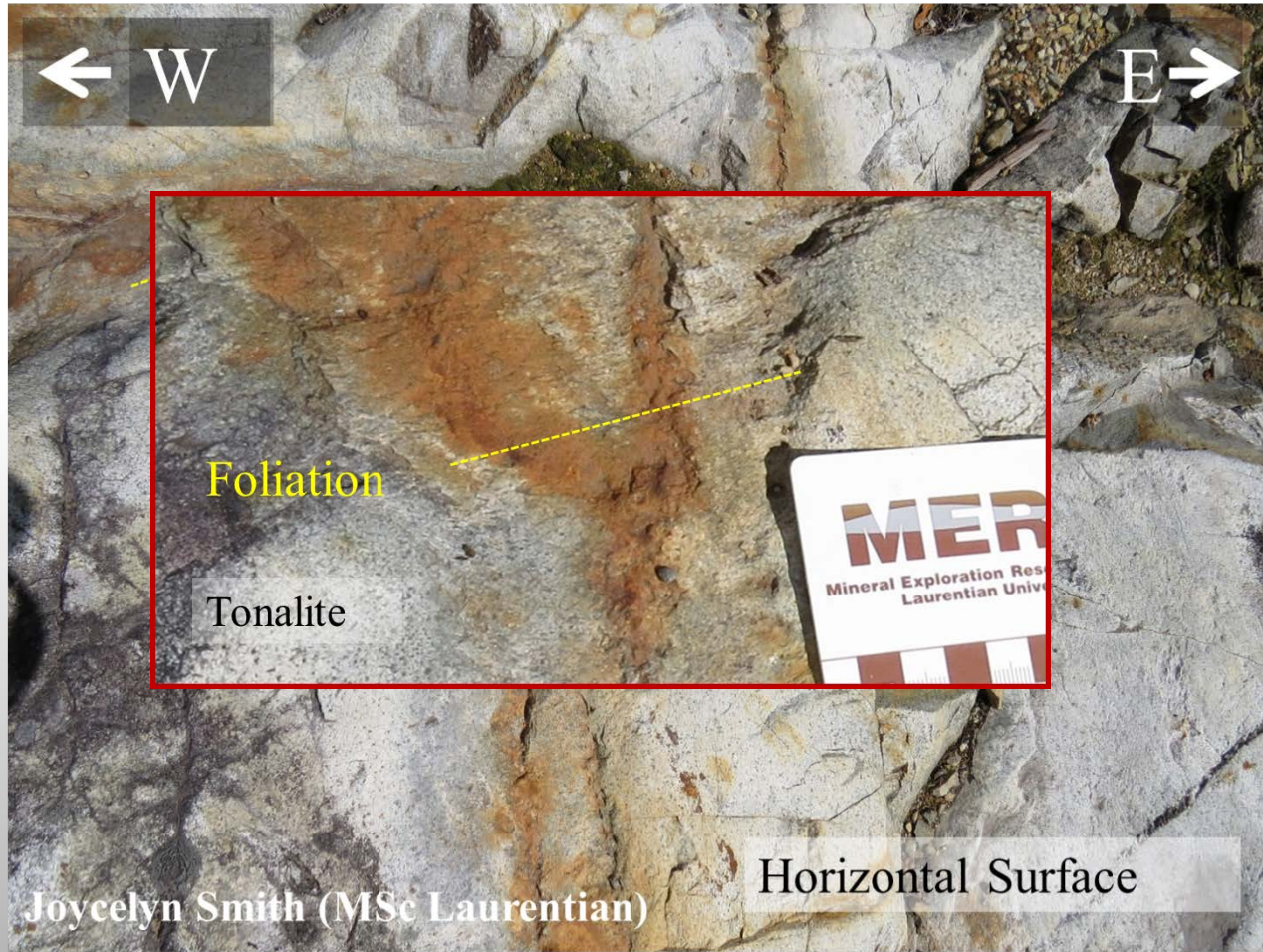
Mylonitic
foliation



**Was mineralization and alteration emplaced
during dextral shearing?**

OR

**Did the shear zones nucleate on structural
weak alteration haloes around veins?**



Joyceelyn Smith (MSc Laurentian)

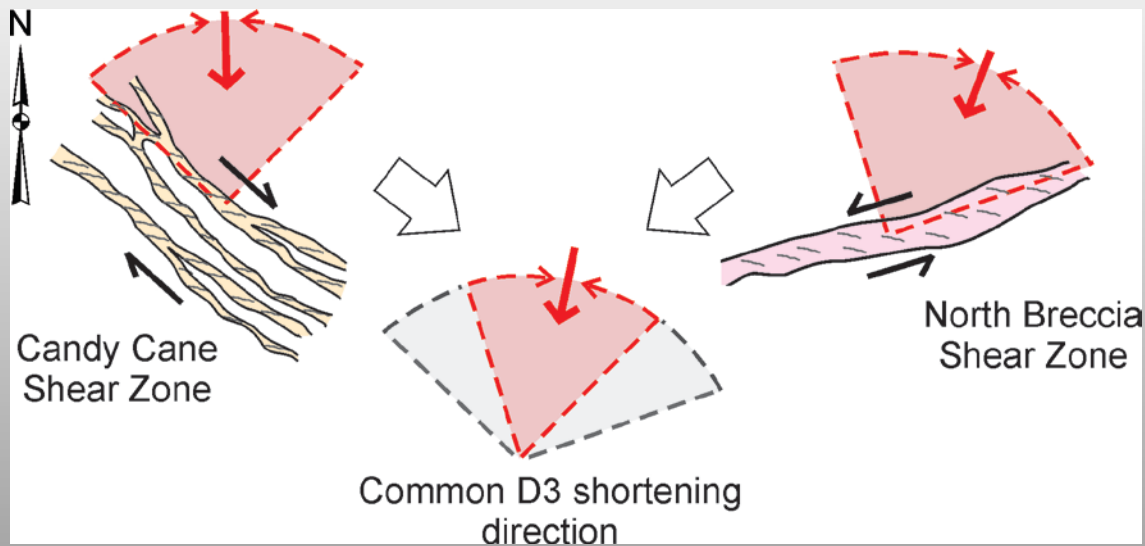
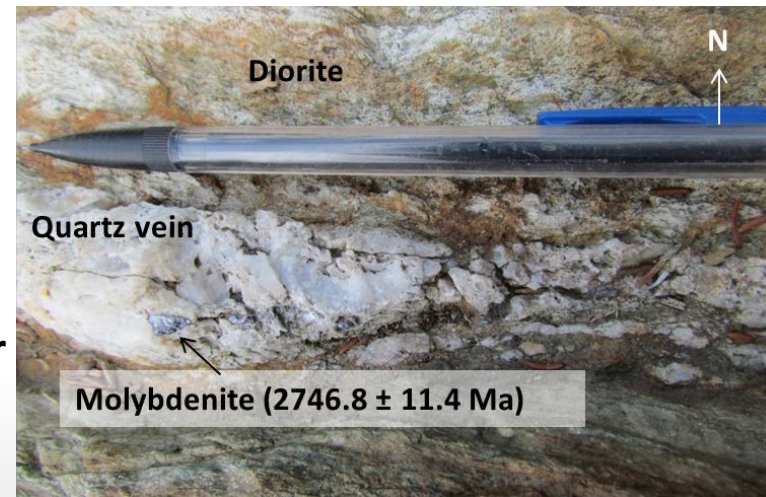
Horizontal Surface

Summary

Regional foliation along the Ridout deformation zone overprint the sheeted veins in Chester intrusive complex so the veins predate regional deformation

Age of the veins is the same as that of the Chester Intrusive Complex hosting the veins.

Sheeted veins are intrusion-related.



Joycelyn Smith
(MSc 2016 *Laurentian*)



How can structural geology be used to differentiate between intrusion- related and orogenic gold deposits?

Intrusion-related gold deposits: Typically formed early during the tectonic history of a greenstone belt. Veins and deposits record most or all the tectonic events that affected the greenstone belt.

Renabie gold deposit: Laminated quartz-gold veins predate the formation of regional cleavage and stretching lineation in the Wawa gold camp.

Côté gold deposit: Sheeted quartz-gold veins predate the formation of the regional cleavage and Ridout deformation zone.

The veins and their weak alteration envelope acted as a planar anisotropy that localize the nucleation and propagation of the shear zones hosting them.

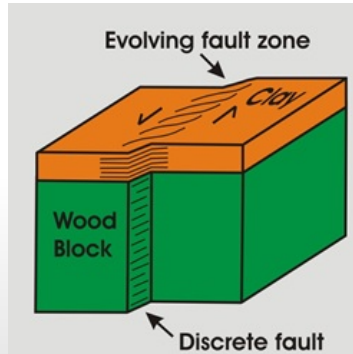
Shear zones are younger than the veins.

How can structural geology be used to differentiate between intrusion- related and orogenic gold deposits?

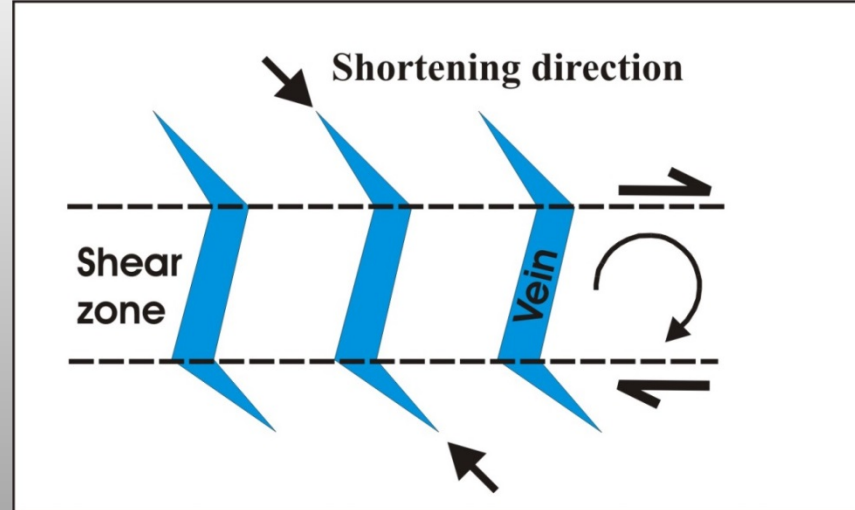
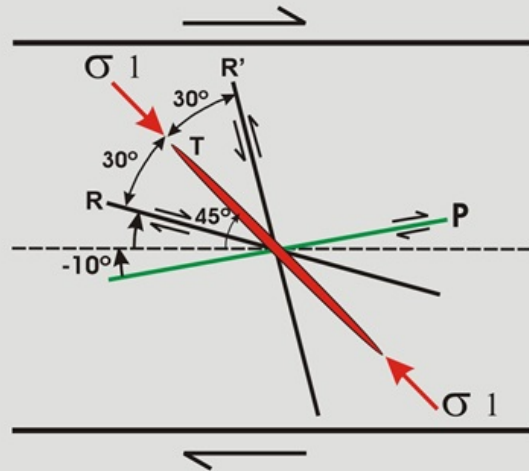
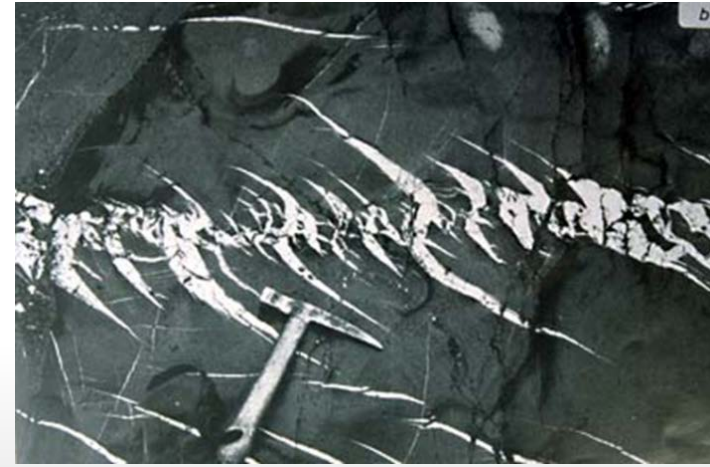
Intrusion-related gold deposits: Typically formed early during the tectonic history of a greenstone belt. Veins and deposits record most or all the tectonic events that affected the greenstone belt.

Orogenic gold deposits: Veins and mineralization are emplaced in active shear zones. Veins must be kinematically consistent with the movement along the shear zones.

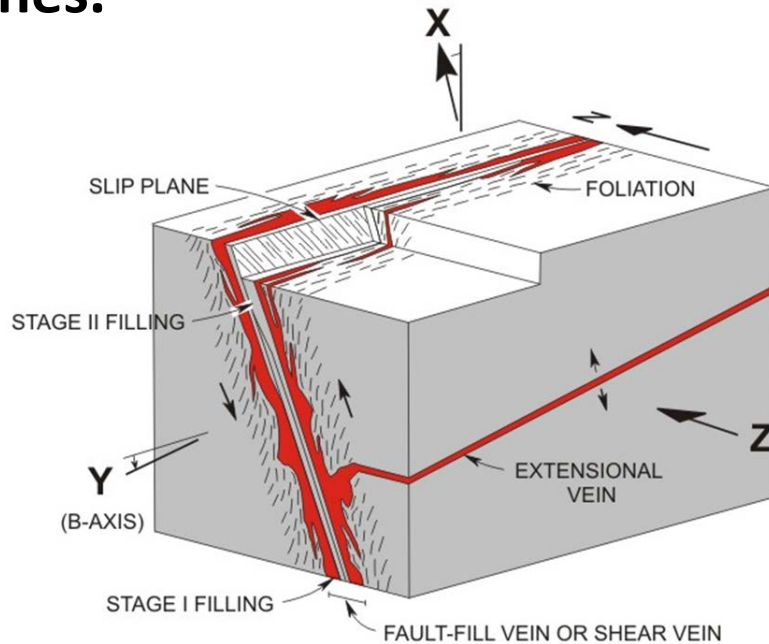
Orogenic gold deposits - Veins must be kinematically consistent with the movement along the shear zones.



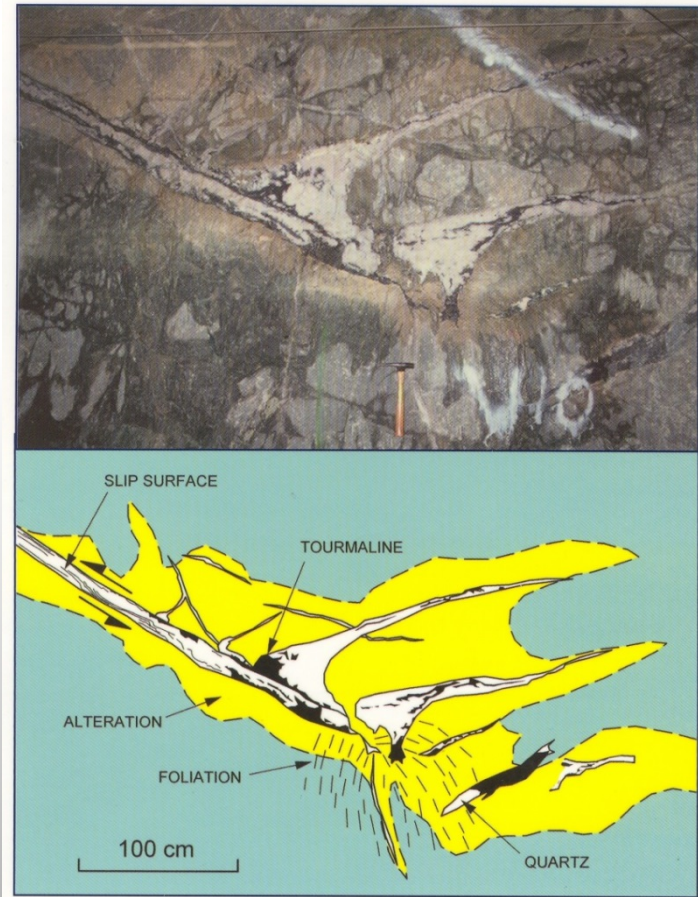
En echelon sigmoidal veins in brittle-ductile shear zone, Cornwall (Paul Karabinos, Williams College)



Orogenic gold deposits - Veins
must be kinematically consistent
with the movement along the shear
zones.

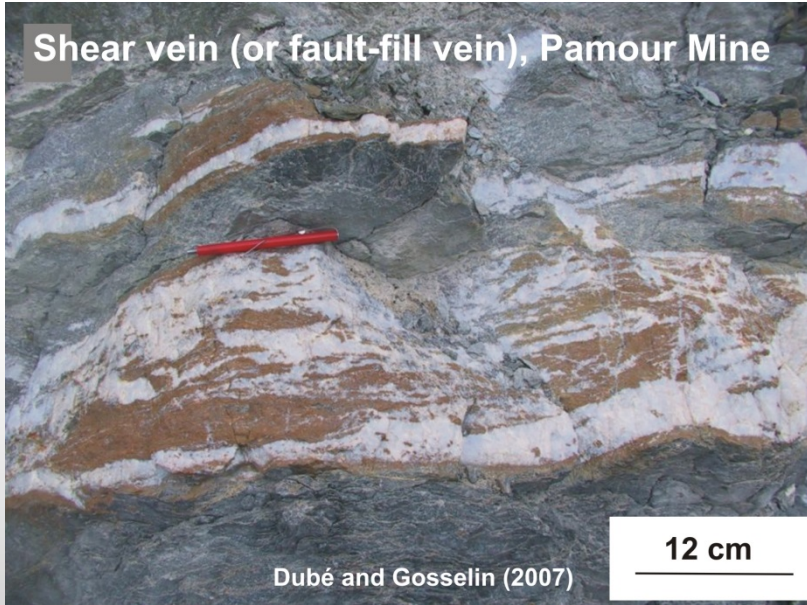


Modified after Dubé and Gosselin (2007)



Robert and Poulsen (2001)

Shear vein (or fault-fill vein), Pamour Mine



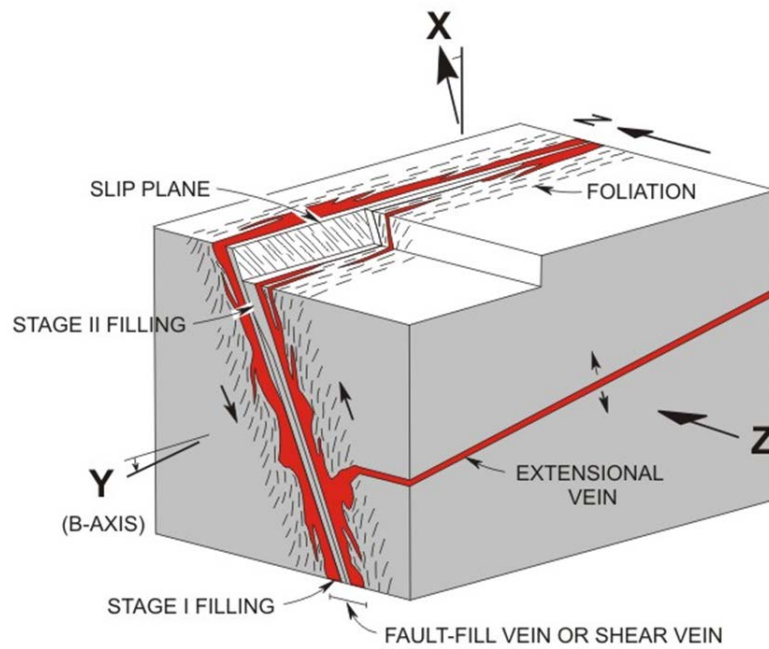
Dubé and Gosselin (2007)

12 cm

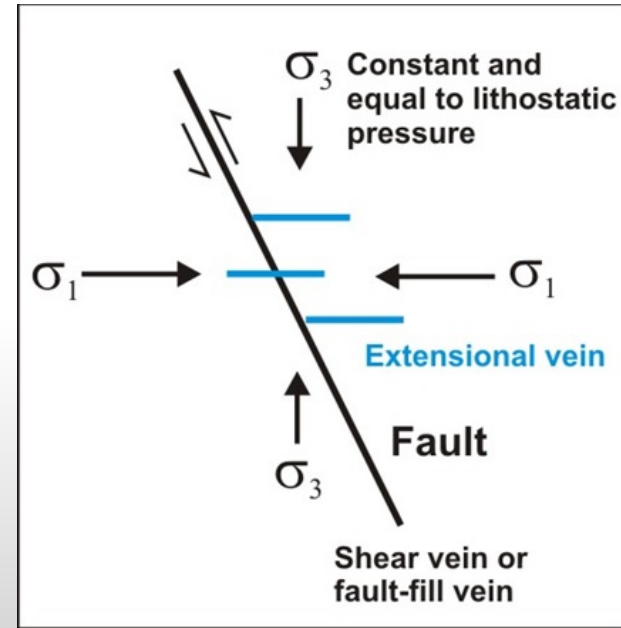
Fibrous qtz-tourmaline vein, Sigma Mine



Dubé and Gosselin (2007)



Modified after Dubé and Gosselin (2007)



Veins are syn-kinematic with slip along fault zone because:

- Intersection lineation between steep & shallow vein is perpendicular to slip lineation along fault.
- Principal maximum stress direction as given by orientation of shallow extensional vein is consistent with slip direction along fault
- Drag or rotation of shallow extensional vein consistent with slip direction

Conclusions

Intrusion-related gold-bearing veins: Veins and deposits typically formed early during the tectonic history of a greenstone belt. Veins and deposits record most or all the tectonic events that affected the greenstone belt.

The veins and their weak alteration envelope acted as a planar anisotropy that localize the nucleation and propagation of the shear zones hosting them.

Orogenic gold-bearing veins: Veins and mineralization are emplaced in active shear zones. Orogenic veins are kinematically consistent with the movement along the shear zones.

Alteration and emplacement of the veins are syn-shearing.

Using basic structural geometrical relationships, shear zone-hosted veins associated with intrusion-related gold deposits can be differentiated from orogenic veins.