Syenite-hosted gold mineralization in the Abitibi belt, Canada

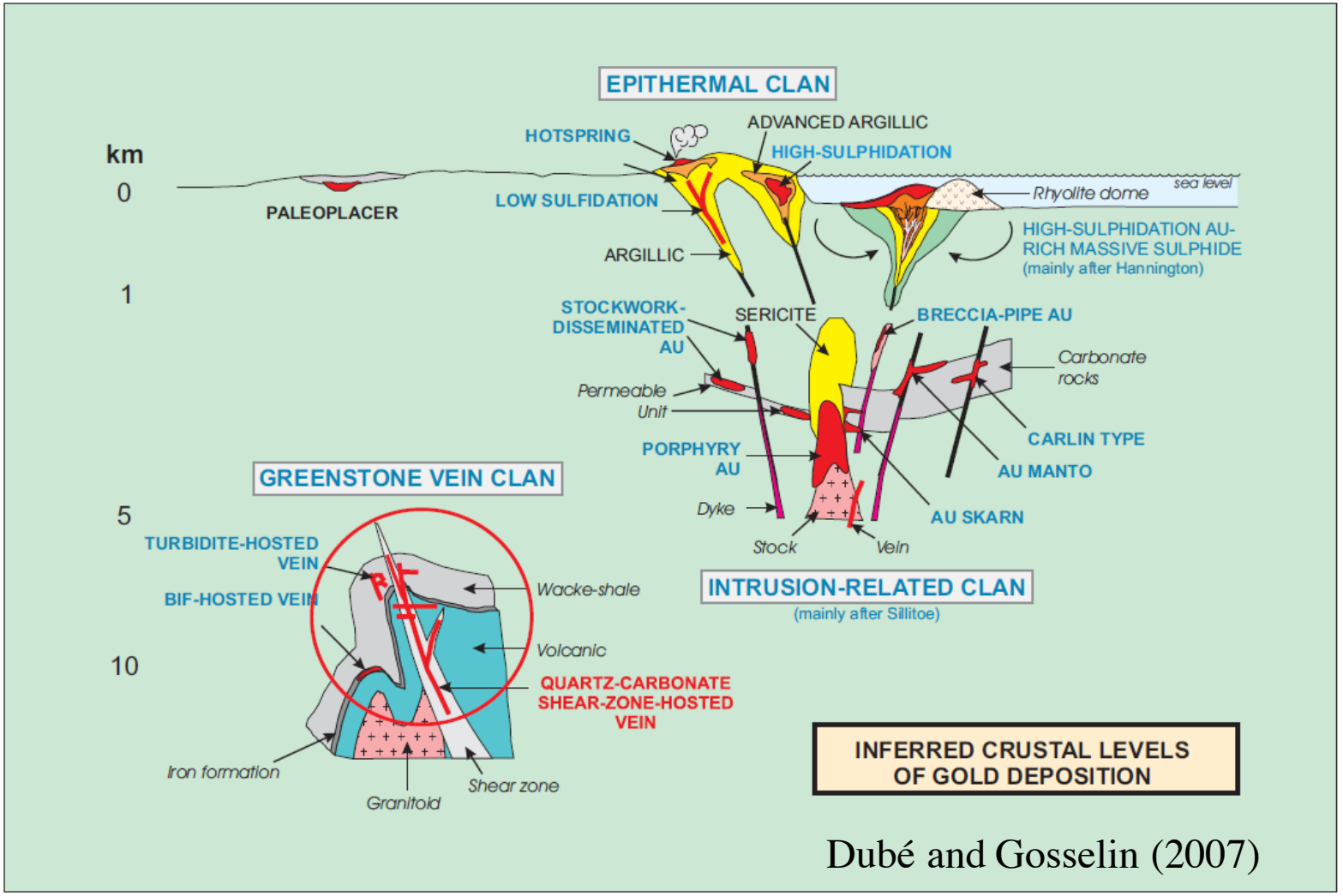
Robert Linnen

A work in progress

Students and Collaborators: Randy Campbell, Don Davis, Luke Howitt, Shoufa Lin, Graham Layne, Niloufar Naderi, Bozwell Wing, Ryan Martin, Jason Zhang

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

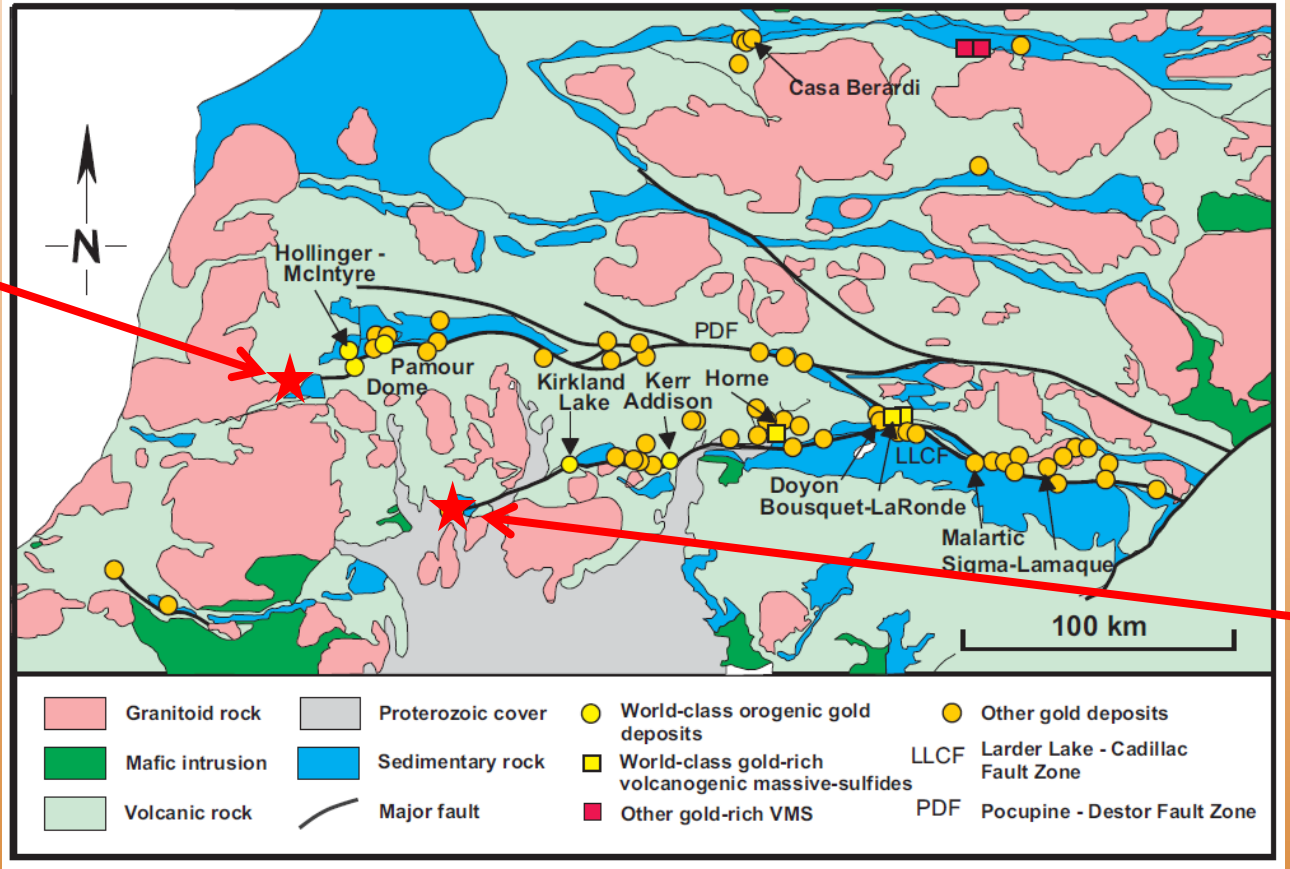


Dubé and Gosselin (2007)

- 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

Timmins West



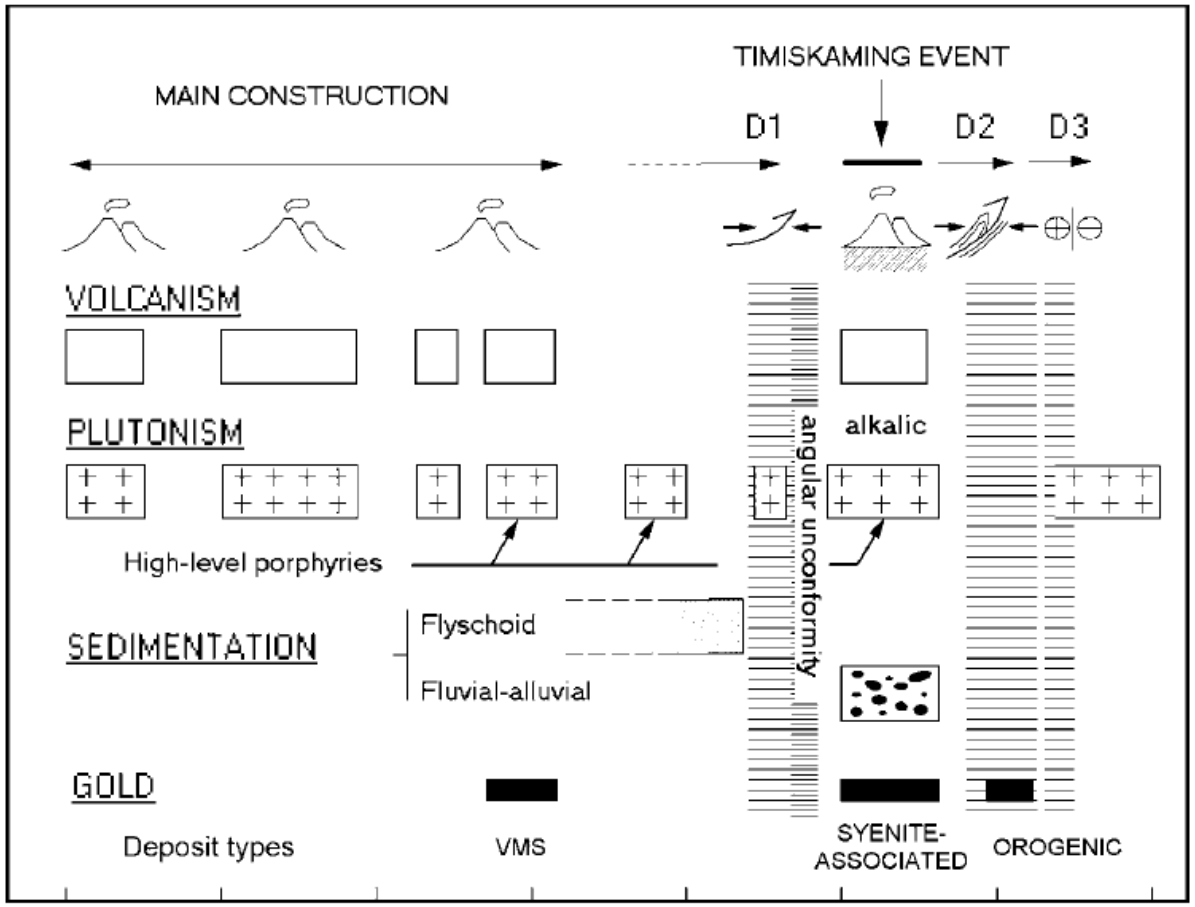
Young-Davidson

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)

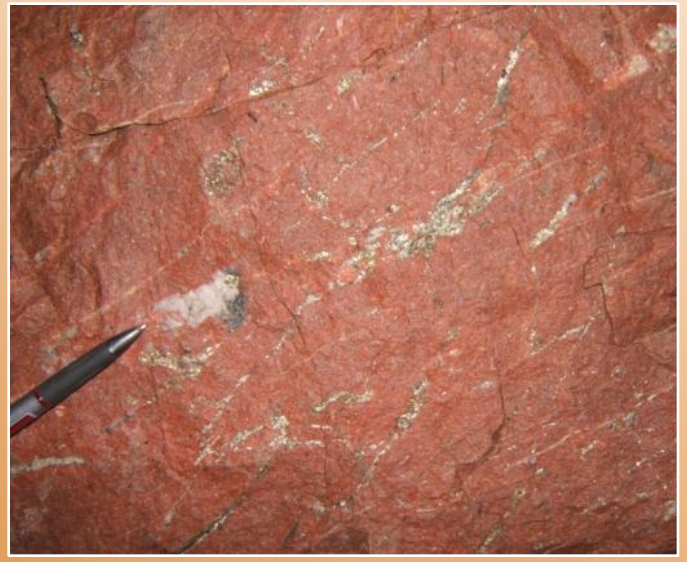
Gold deposits are associated with:

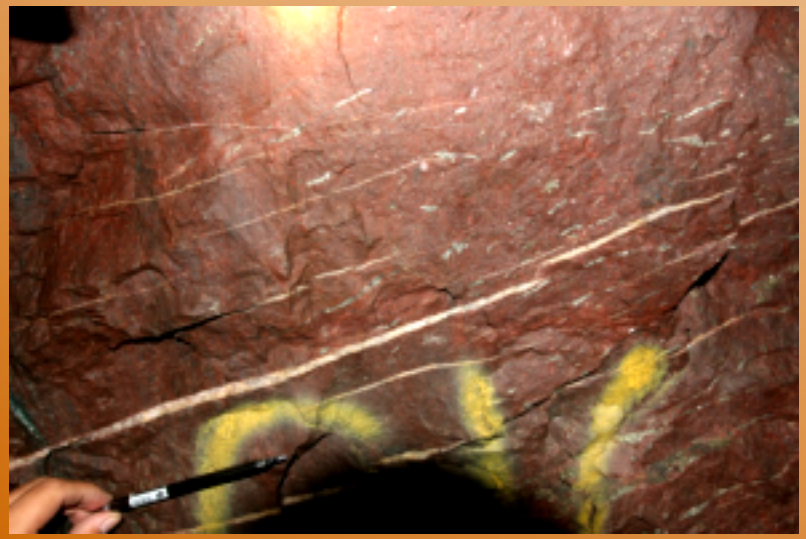
- Regional-scale structures
- Felsic intrusive rocks (including alkalic suites)
- Timmiskaming (rift) sedimentary rocks



These two deposits are remarkably similar in appearance

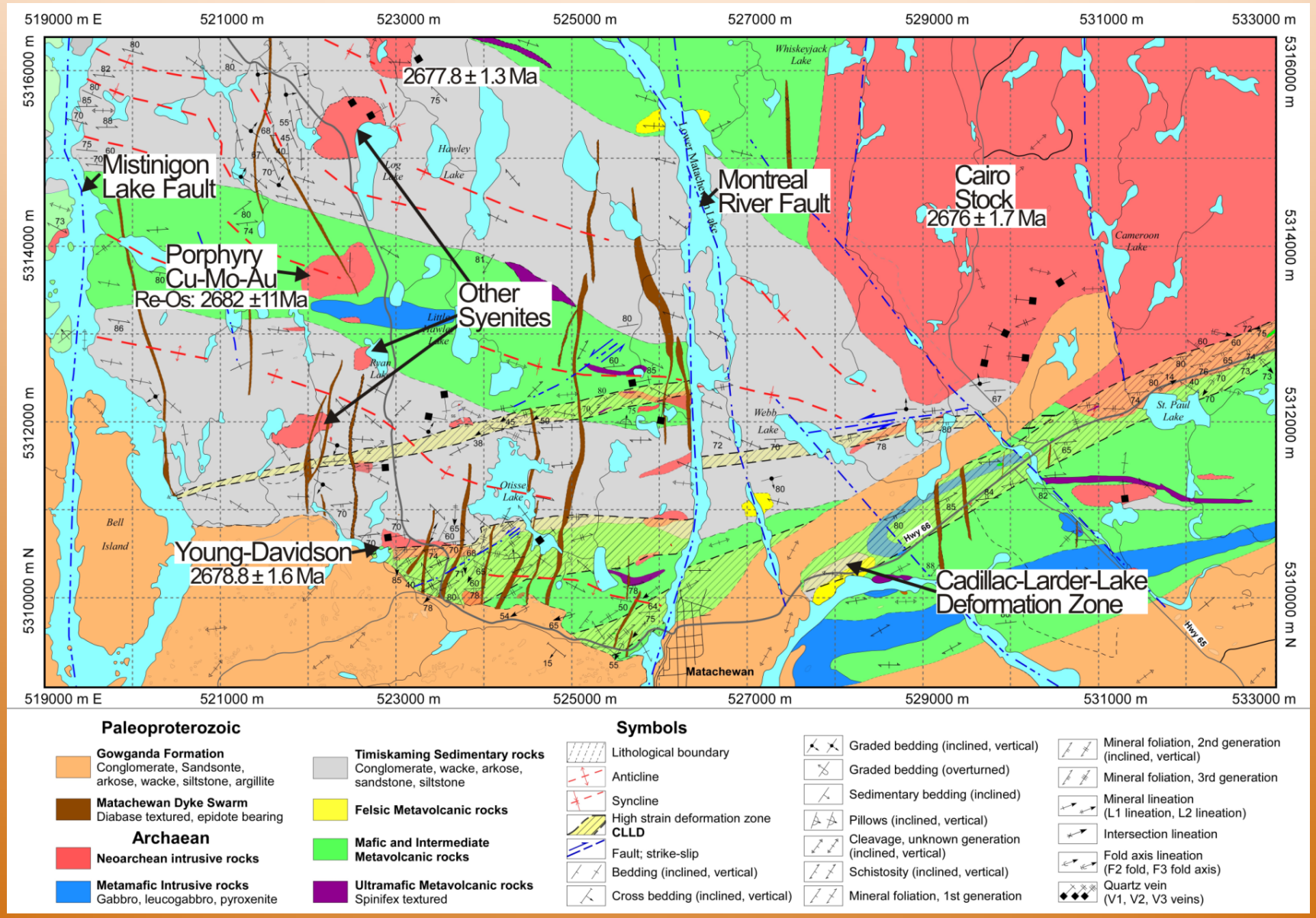
Young-Davidson





Thunder Creek

Geology of the Young-Davidson Deposit



Paleoproterozoic

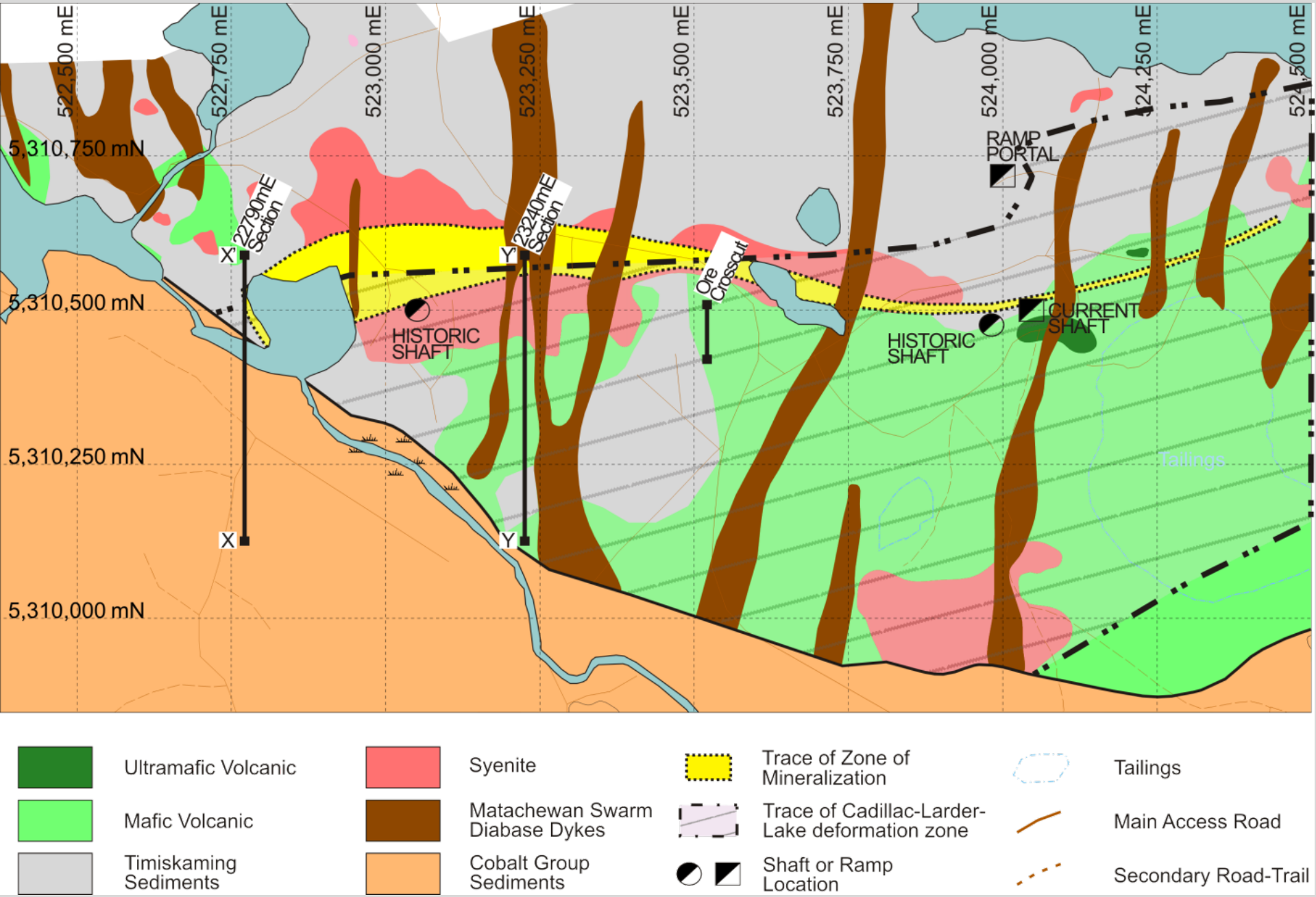
- **Gowganda Formation** — Conglomerate, Sandsonte, arkose, wacke, siltstone, argillite
- **Matachewan Dyke Swarm** — Diabase textured, epidote bearing

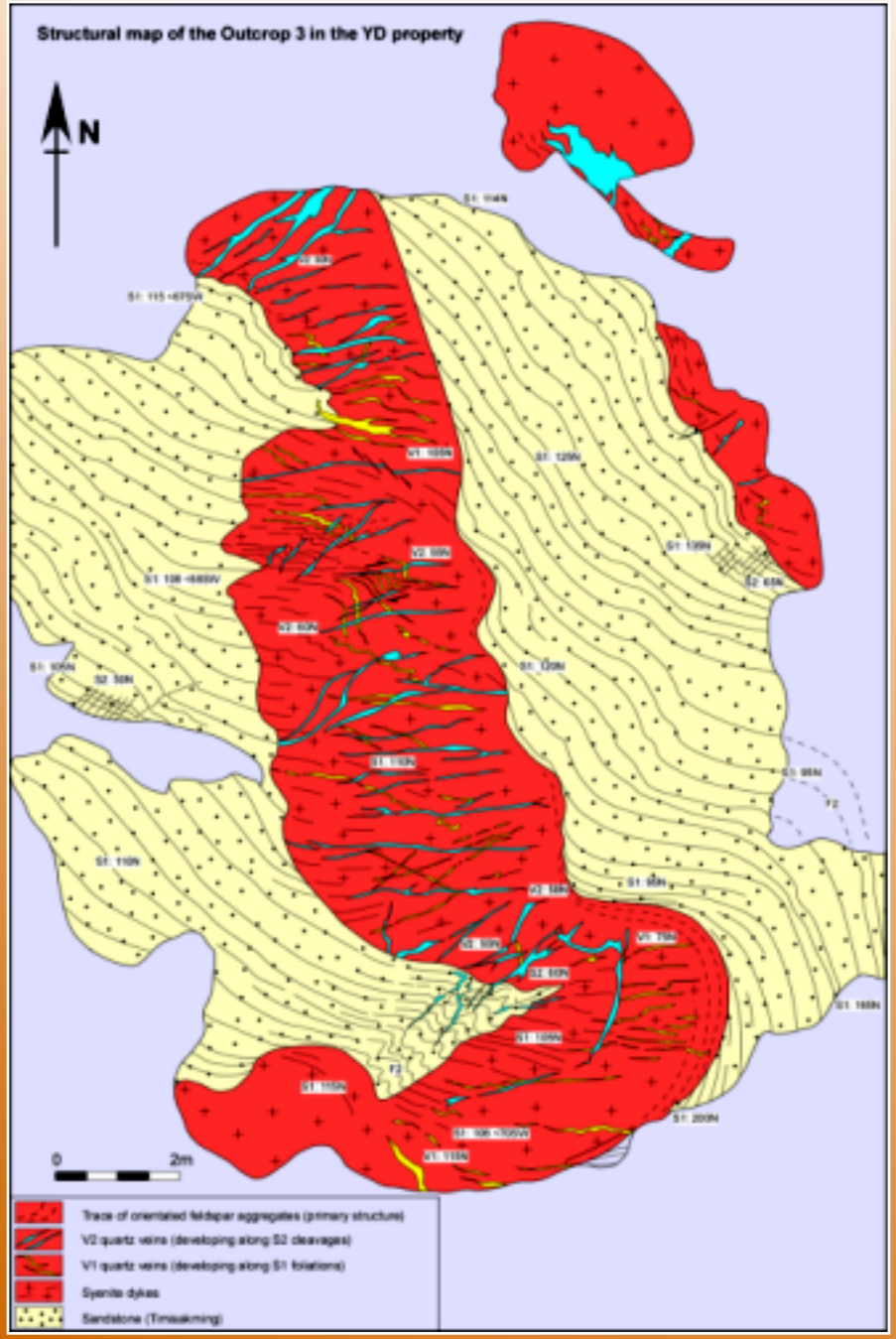
Archaean

- **Neoarchean intrusive rocks**
- **Metamafic Intrusive rocks** — Gabbro, leucogabbro, pyroxenite
- **Timiskaming Sedimentary rocks** — Conglomerate, wacke, arkose, sandstone, siltstone
- **Felsic Metavolcanic rocks**
- **Mafic and Intermediate Metavolcanic rocks**
- **Ultramafic Metavolcanic rocks** — Spinifex textured

Symbols

- Lithological boundary
- Anticline
- Syncline
- High strain deformation zone **CLLD**
- Fault; strike-slip
- Bedding (inclined, vertical)
- Cross bedding (inclined, vertical)
- Graded bedding (inclined, vertical)
- Graded bedding (overturned)
- Sedimentary bedding (inclined)
- Pillows (inclined, vertical)
- Cleavage, unknown generation (inclined, vertical)
- Schistosity (inclined, vertical)
- Mineral foliation, 1st generation
- Mineral foliation, 2nd generation (inclined, vertical)
- Mineral foliation, 3rd generation
- Mineral lineation (L1 lineation, L2 lineation)
- Intersection lineation
- Fold axis lineation (F2 fold, F3 fold axis)
- Quartz vein (V1, V2, V3 veins)

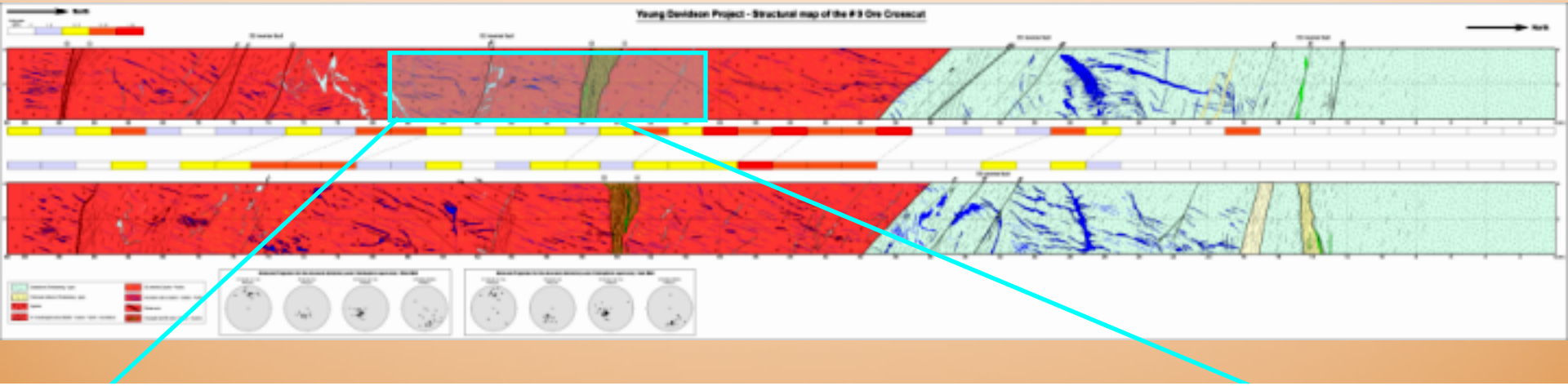

522,500 mE
522,750 mE
523,000 mE
523,250 mE
523,500 mE
523,750 mE
524,000 mE
524,250 mE
524,500 mE
5,310,750 mN
5,310,500 mN
5,310,250 mN
5,310,000 mN
X'
2279OmE Section
Y'
23240mE Section
X
Y
HISTORIC SHAFT
Ore Crosscut
RAMP PORTAL
HISTORIC SHAFT
CURRENT SHAFT
Tailings
Ultramafic Volcanic
Mafic Volcanic
Timiskaming Sediments
Syenite
Matachewan Swarm Diabase Dykes
Cobalt Group Sediments
Trace of Zone of Mineralization
Trace of Cadillac-Larder-Lake deformation zone
Shaft or Ramp Location
Tailings
Main Access Road
Secondary Road-Trail

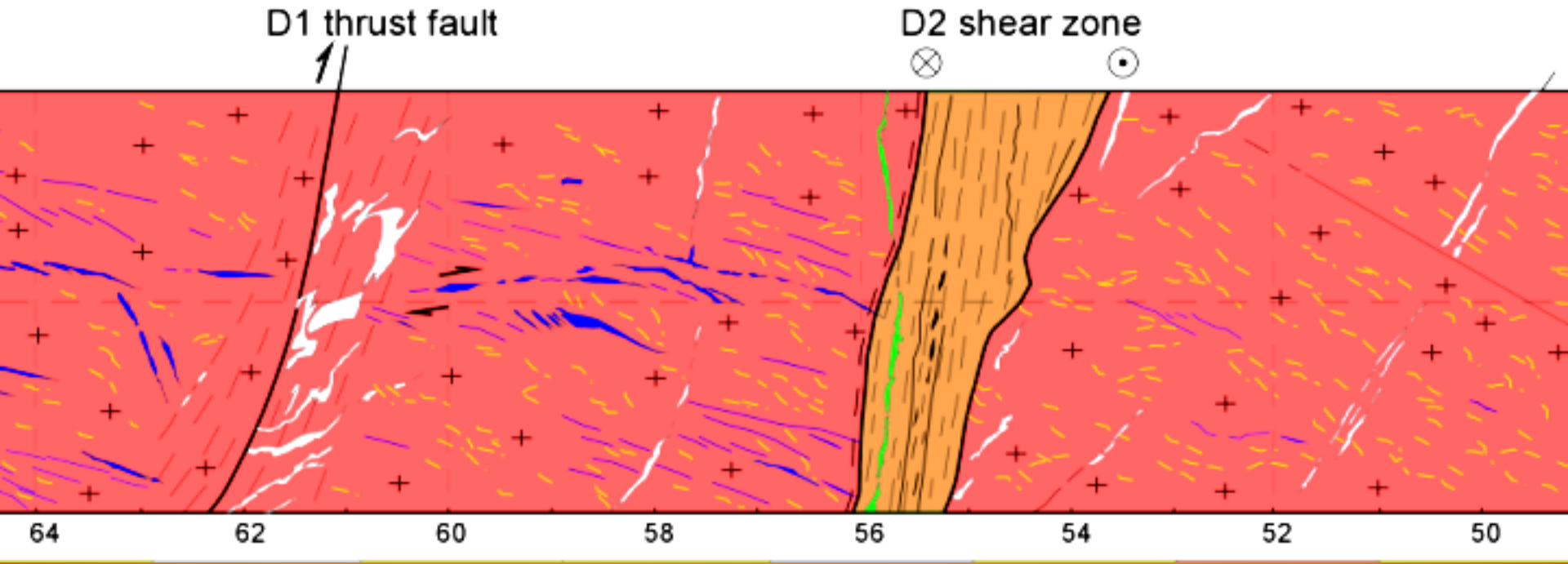


Syenite as a Preferential Host

Veining system in the syenite – underground mapping

Structural map of the #9 ore crosscut

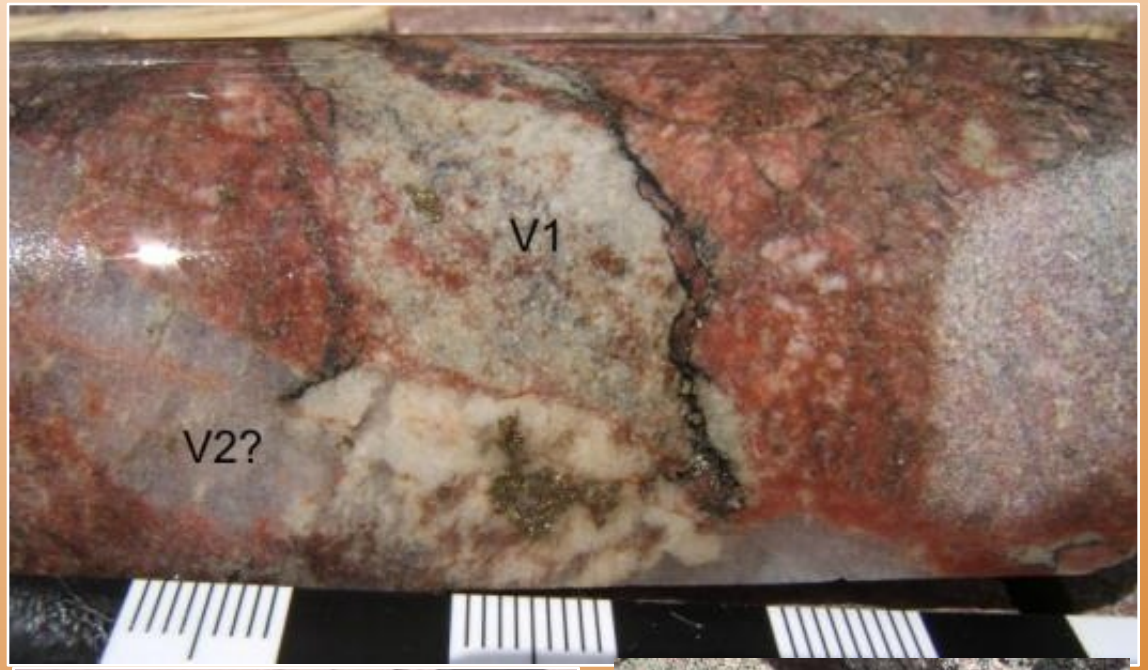


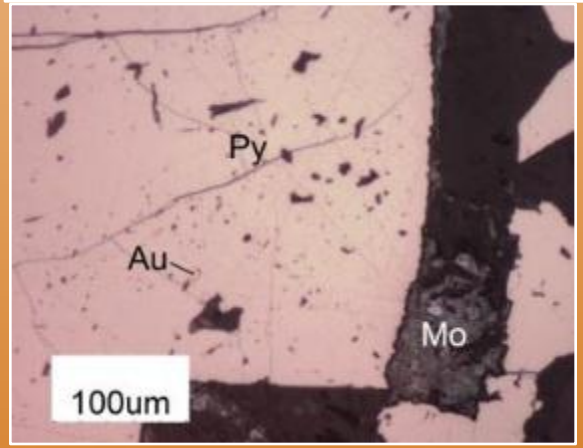


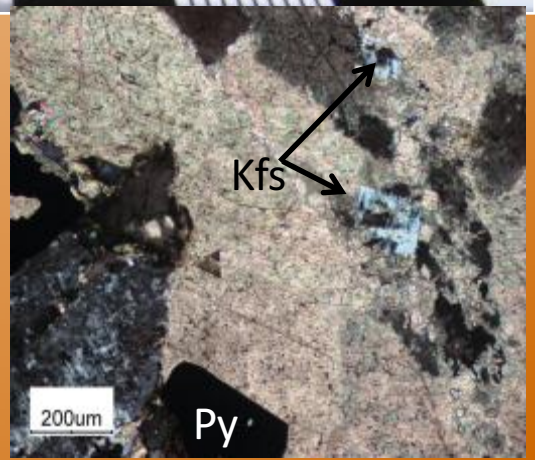
V_1 veins– Truncated by D_1 Thrusts

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

Tartan Twinned K-feldspar; T > 300°C

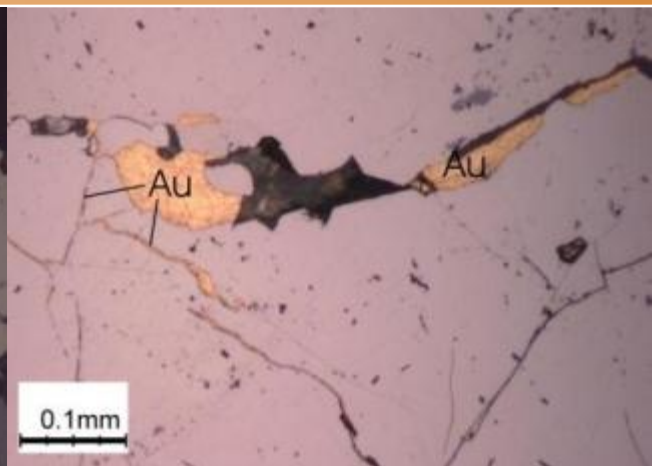






V_2 Veins (syn D_2)

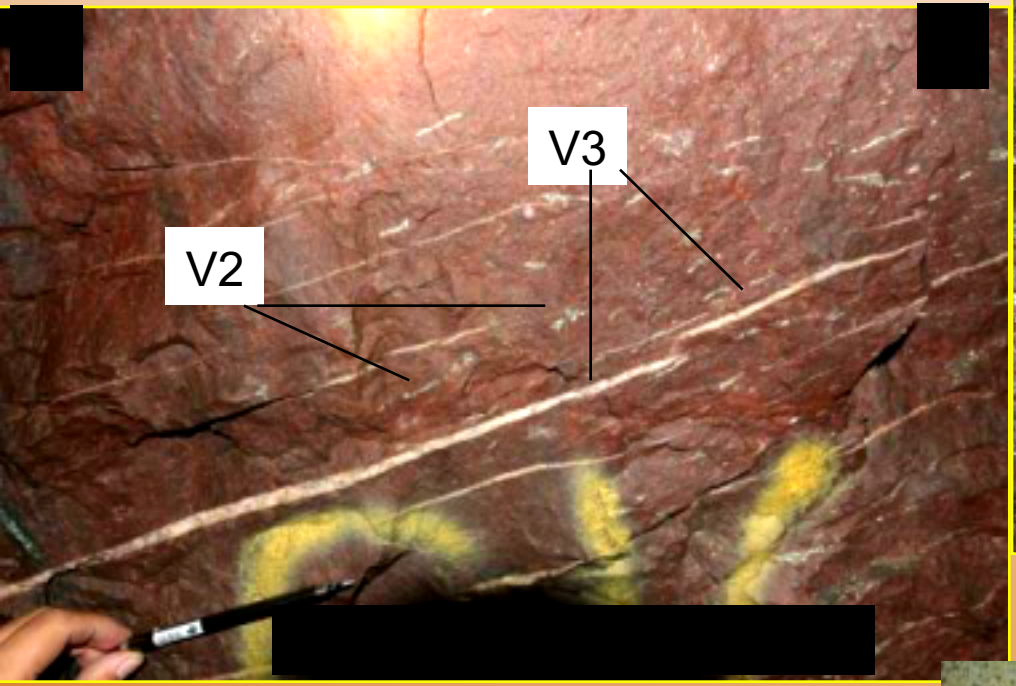
- Shallow dipping, folded quartz-pyrite veinlets ± carbonate and chlorite rim
- Abundant hematite (Hem), magnetite and rutile (Rt) ± chalcopyrite inclusions in vein pyrite
- Au as inclusions and along fractures in pyrite

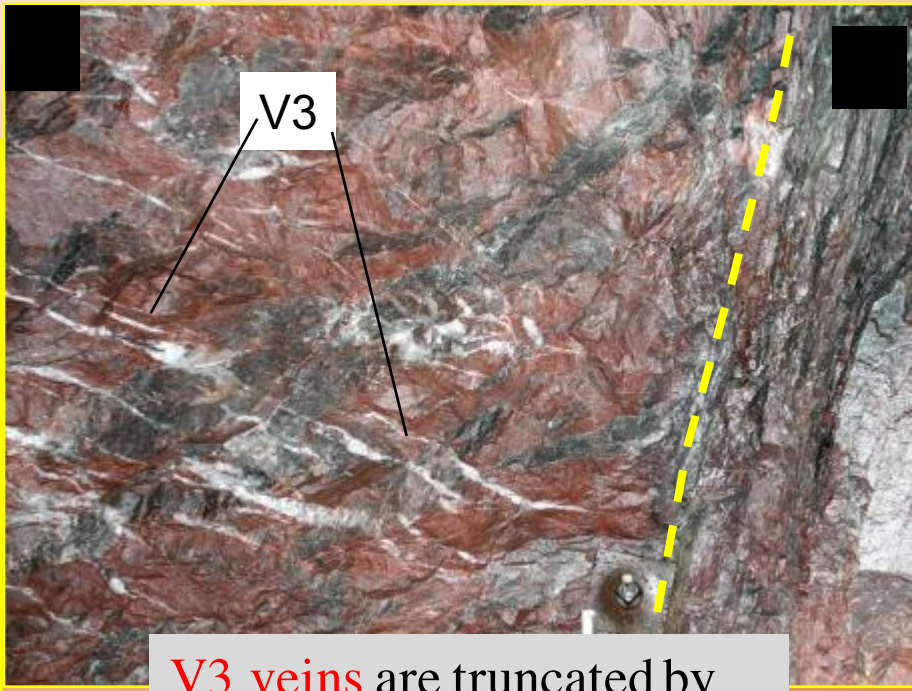


V_3 planar or en echelon veins syn to Pre-D_2

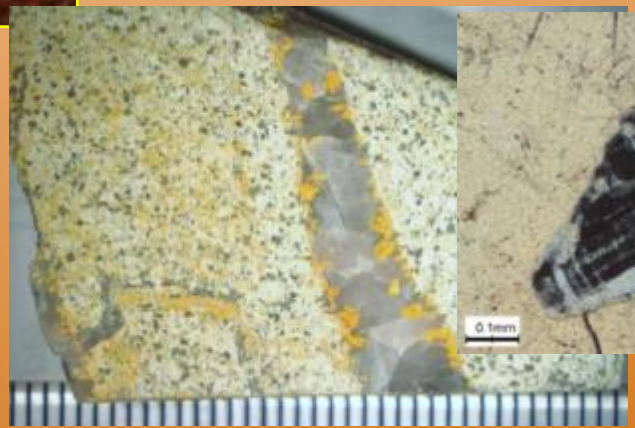
Qtz-Carb-Py-Au-Cp-Sch-Gn-Tour)

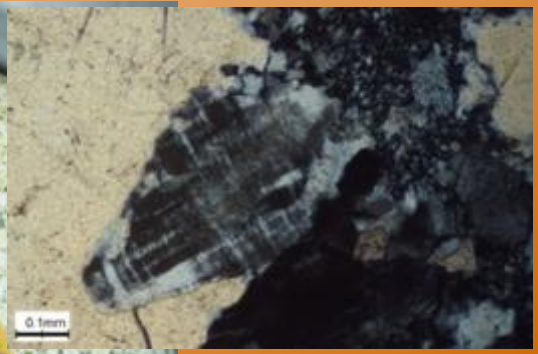
Much less deformed, Tartan twinned Ksp





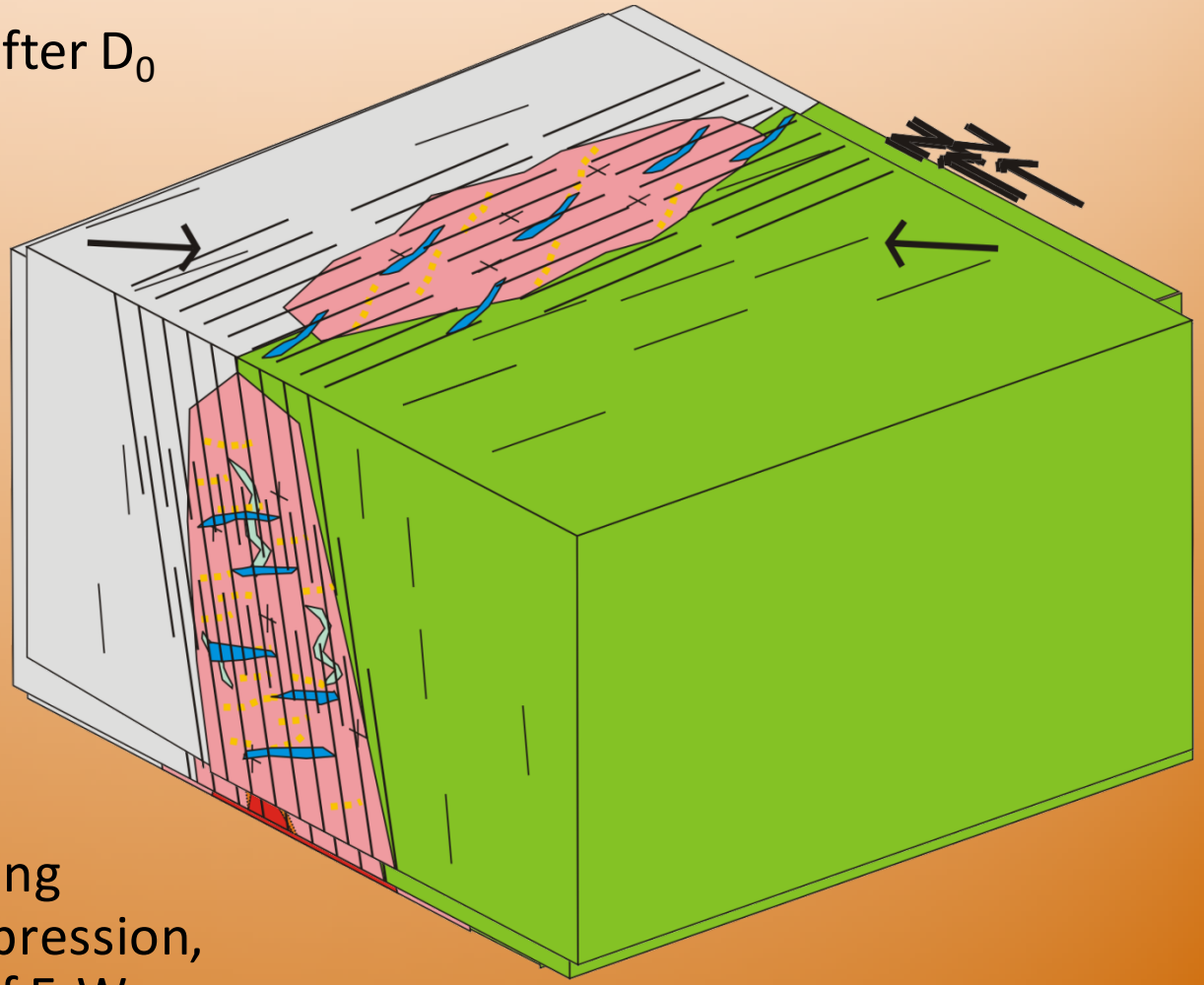
V3 veins are truncated by Late D2 ductile shear zones



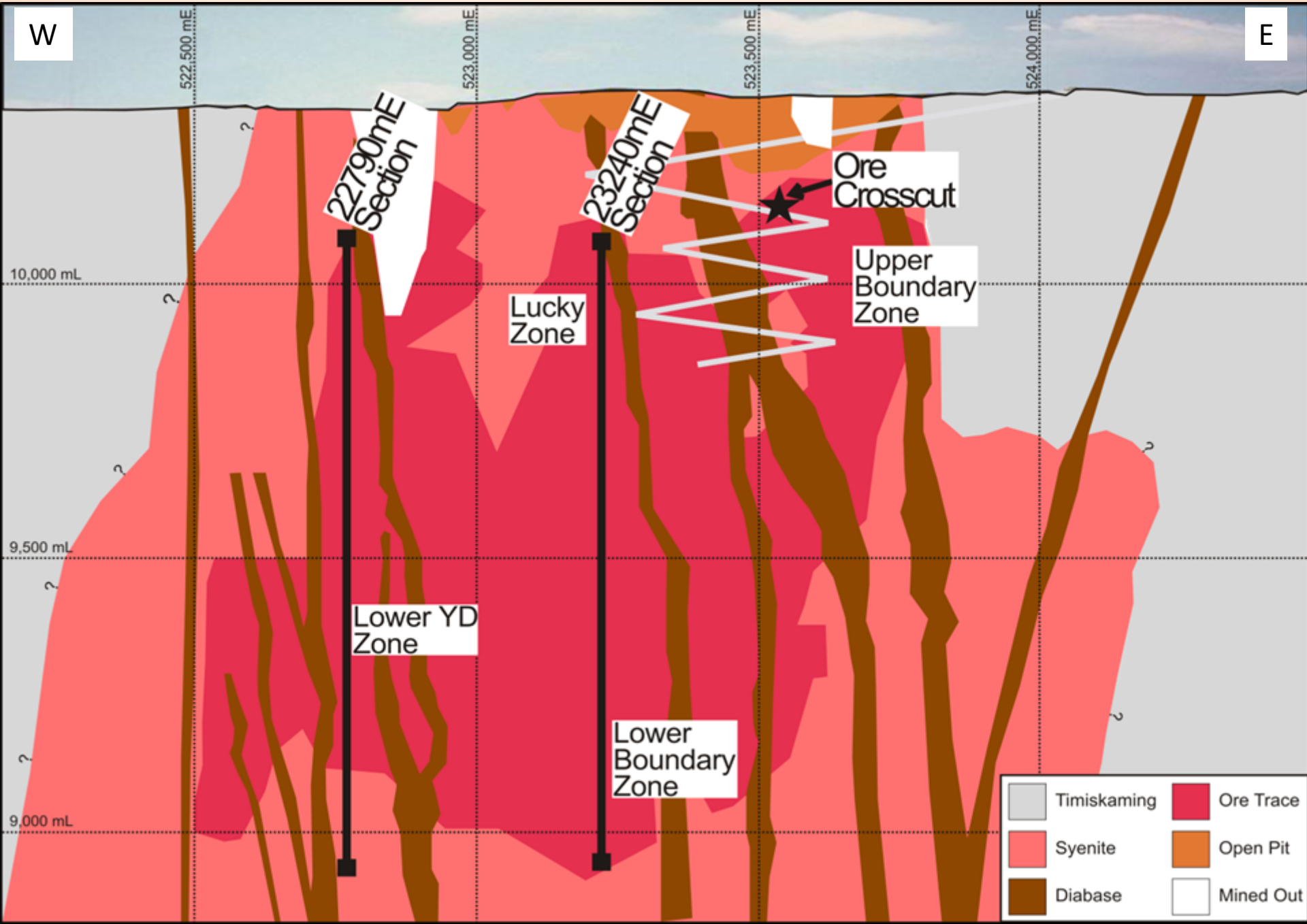


Formational Model

- 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

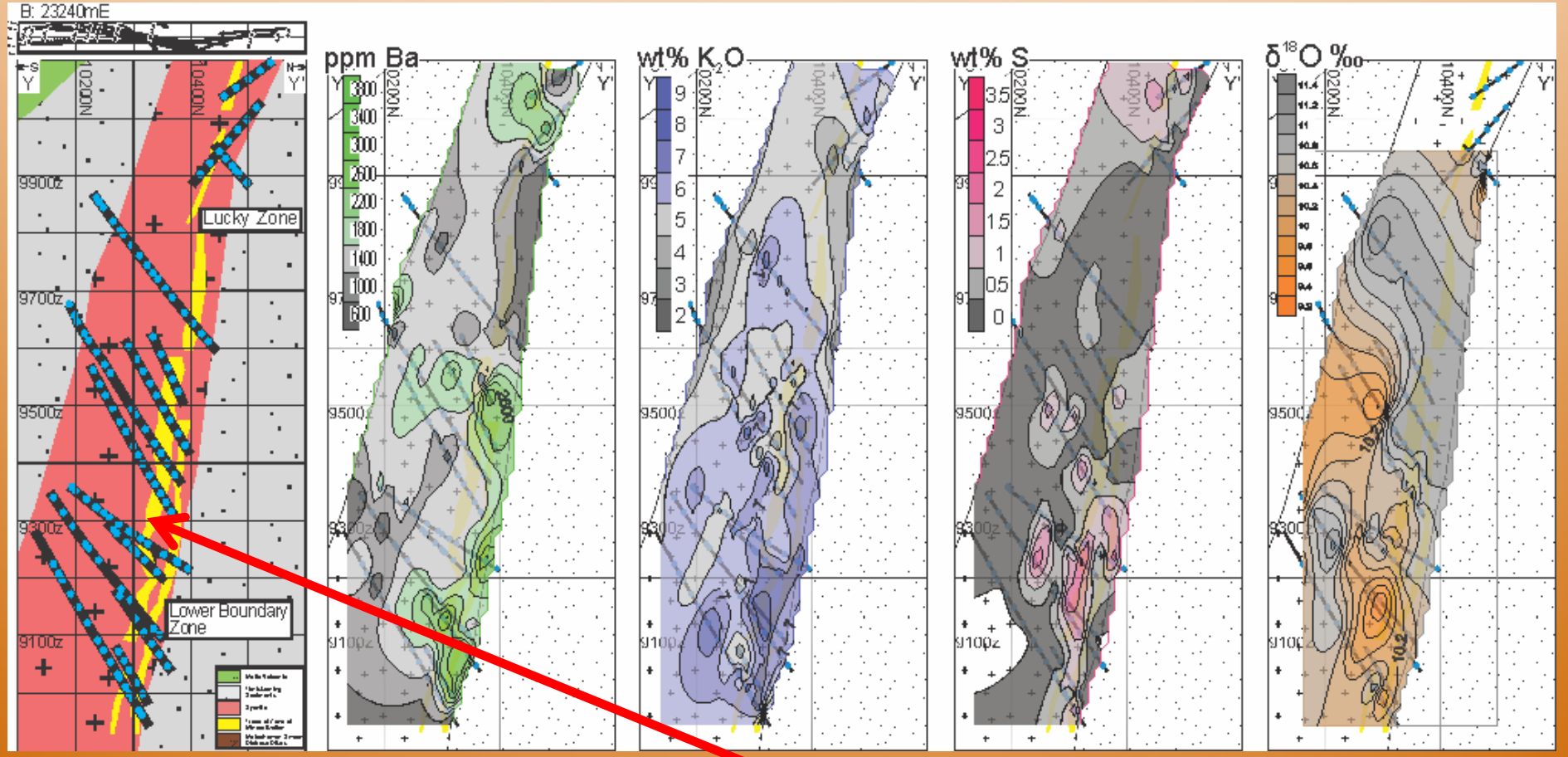


Schematic long section (looking north) through mineralization



Alteration (vein-free syenite)

Potassic (Kspar)-Hematite-Carbonate (ankerite) Associated with Au enrichment of Au, K_2O and Ba during alteration and $\delta^{18}O$ lows

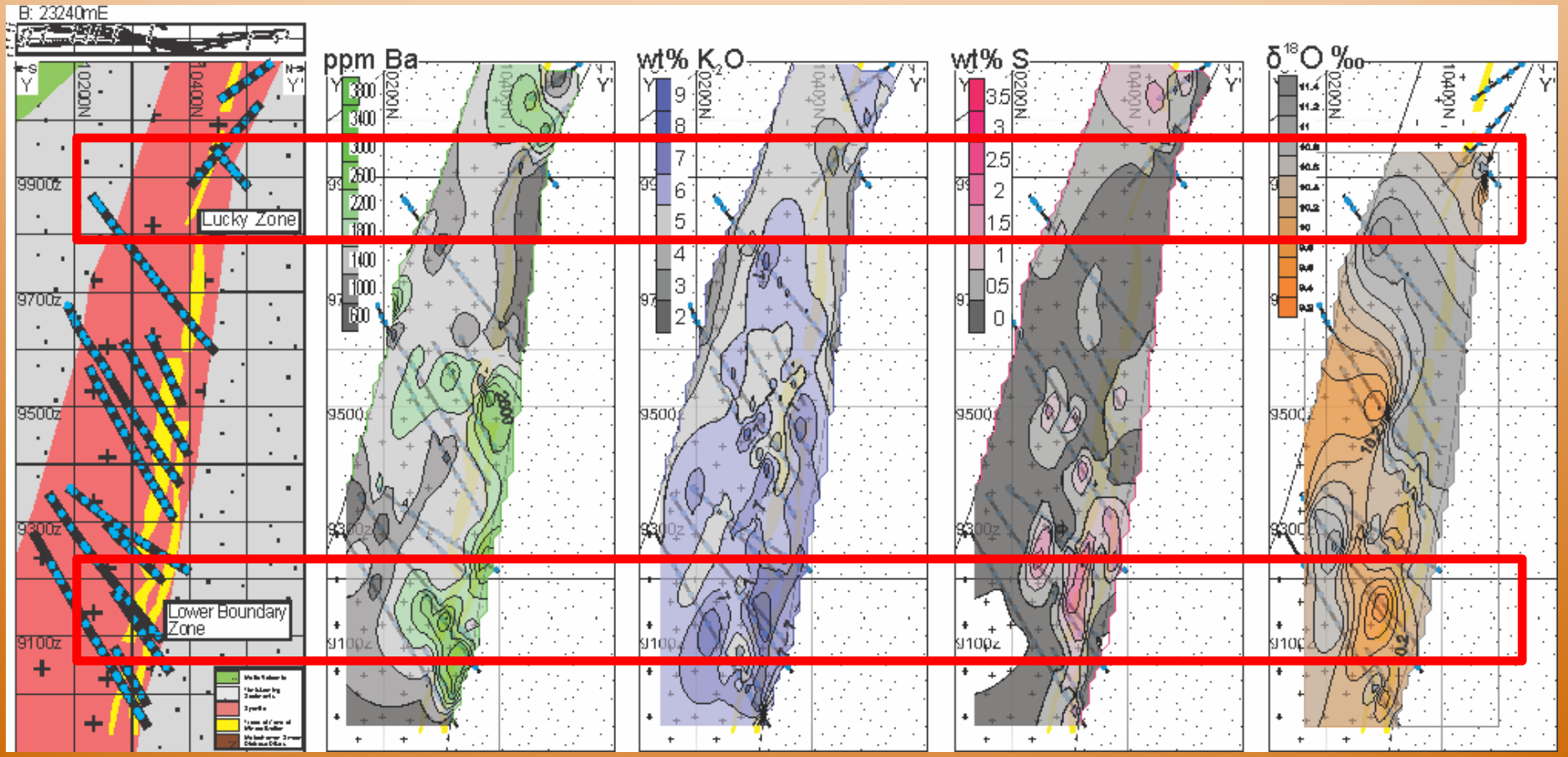


Yellow denotes mineralization

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_2O or S



Oxygen Isotope Thermometry

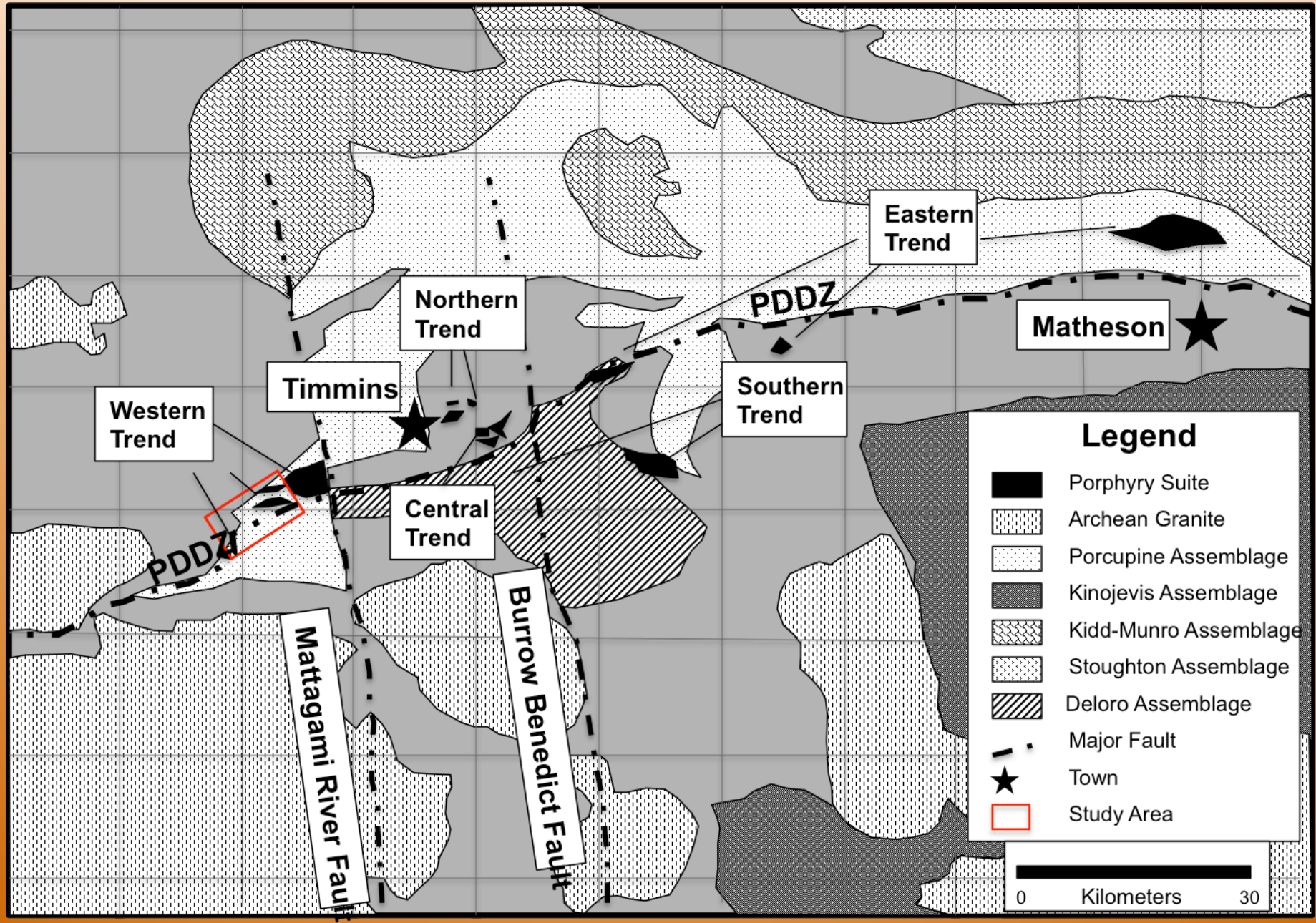
- 43 mineral separates of quartz, hematite, potassium feldspar, tourmaline, biotite, chlorite, scheelite, calcite and ankerite.

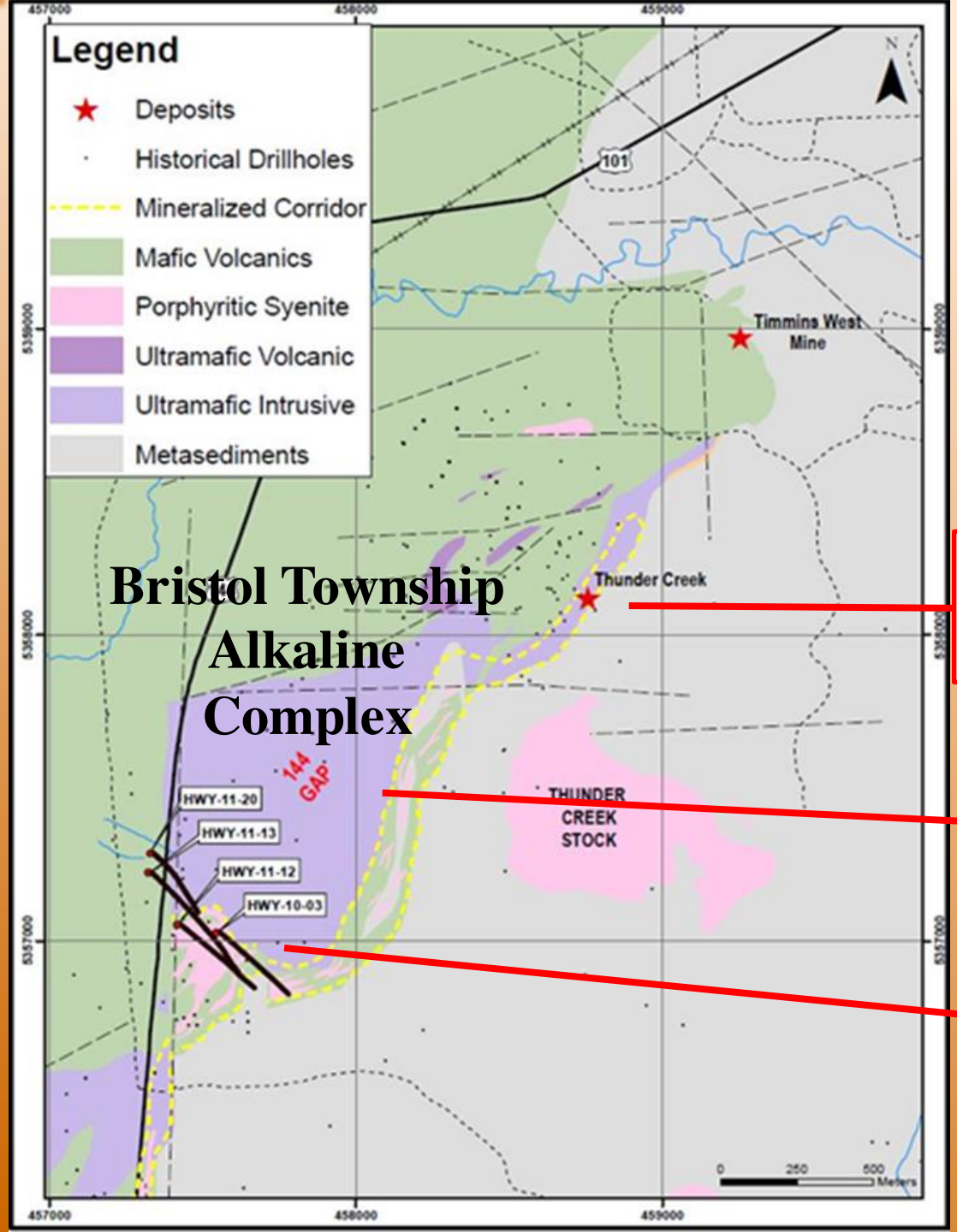
- V_1 veins: 322 ± 25°C to 428 ± 18 °C
  V_2 veins: 408 ± 28°C to 431 ± 30°C
  V_3 veins: 351± 17° C to 379 ± 26°C .

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

Timmins West Mine





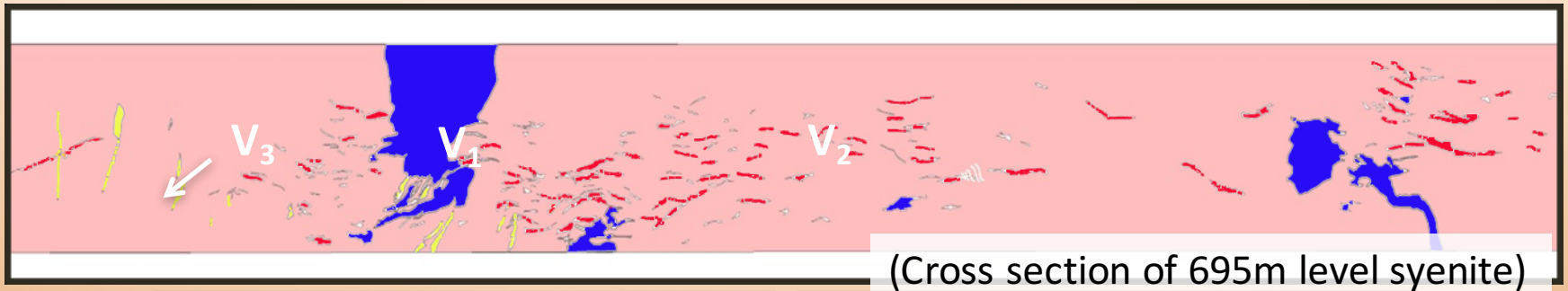
Initial study compared the Thunder Creek mine with the Hwy 144 prospect

Thunder Creek (syenite-hosted **Au mine**)

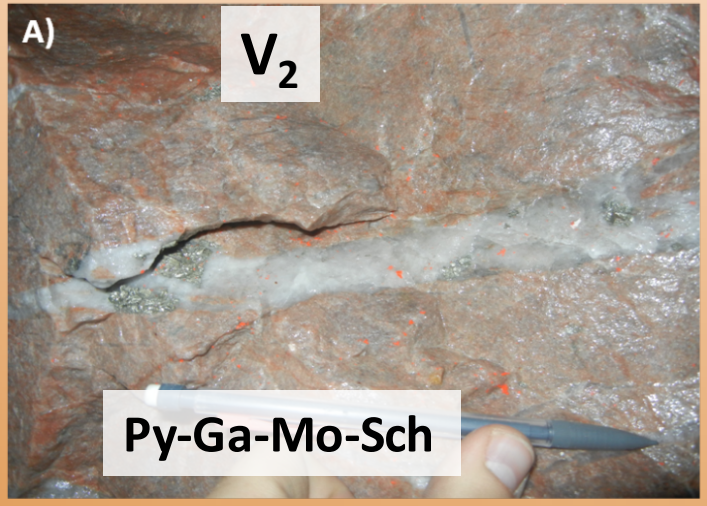
Gap Zone (**development**)

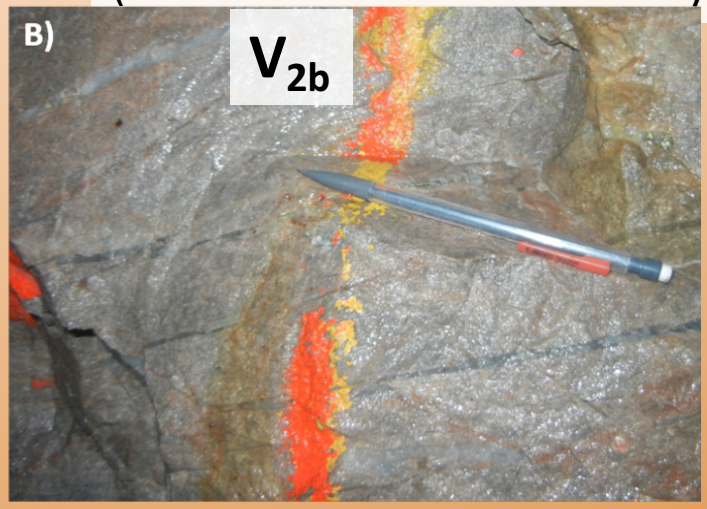
Hwy 144 syenite-hosted Au **prospect**

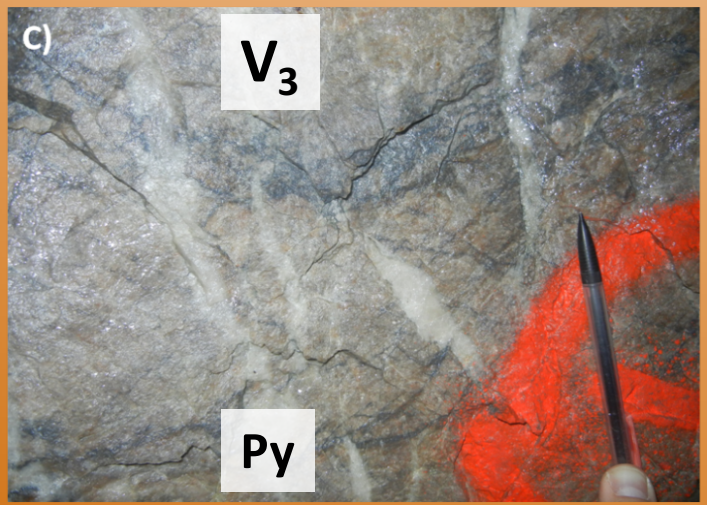
Thunder Creek Mine – Mineralization Style Similar to YD

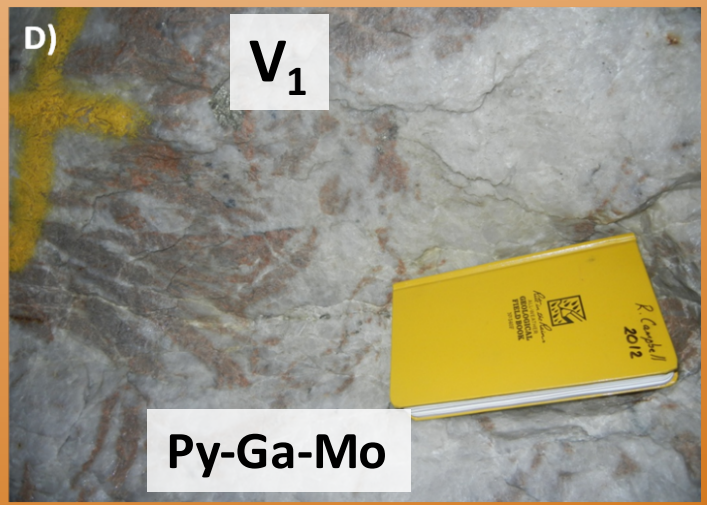


(Cross section of 695m level syenite)

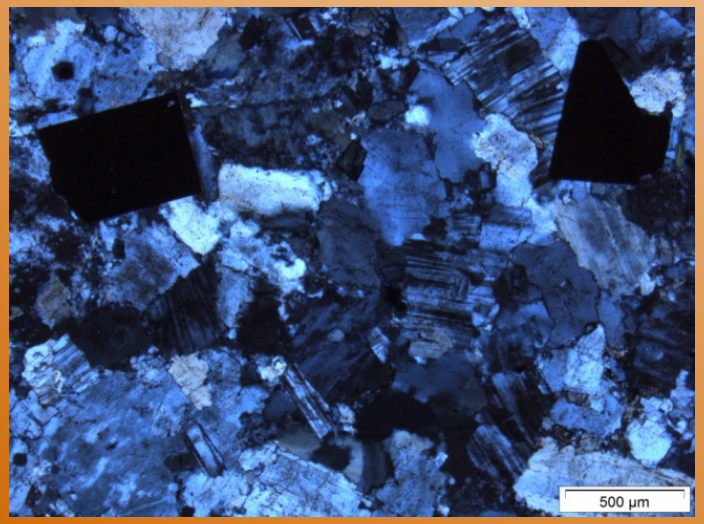


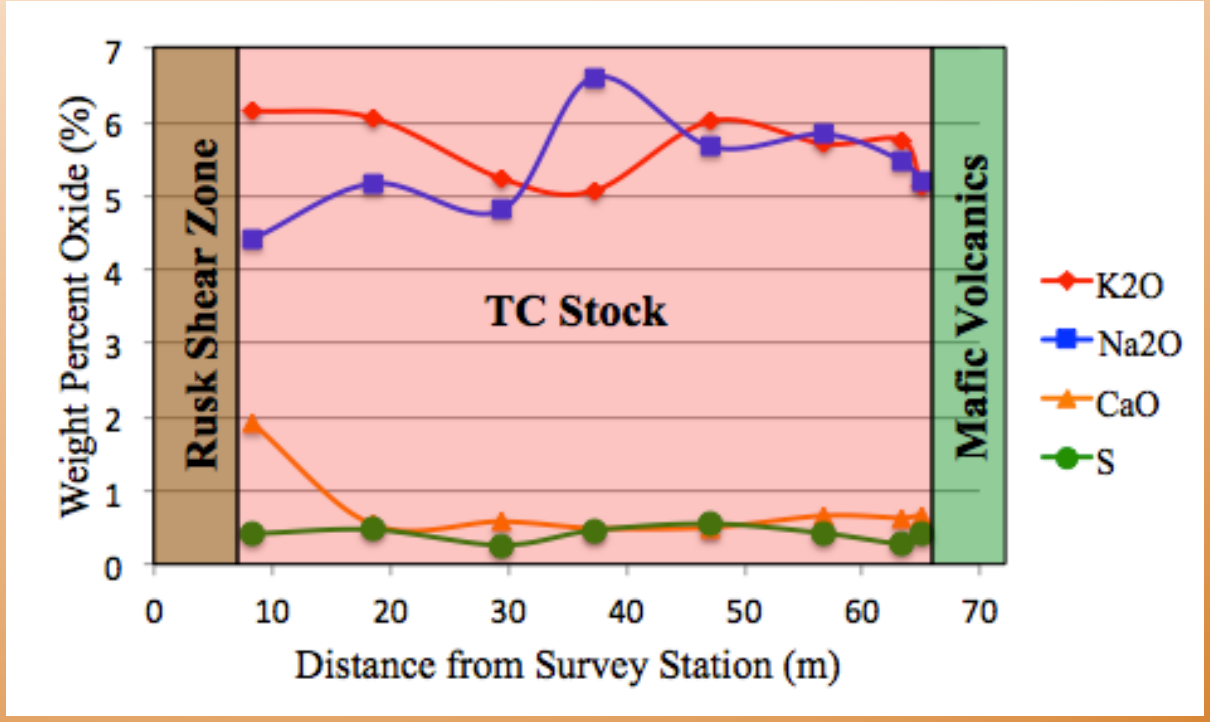






Thunder Creek Alteration is Different
little potassic or carbonate alteration





- 2 Feldspar alteration implies high temperature
- Disseminated pyrite implies pervasive fluids

Hwy 144 – Mineralization Style Similar to TC & YD

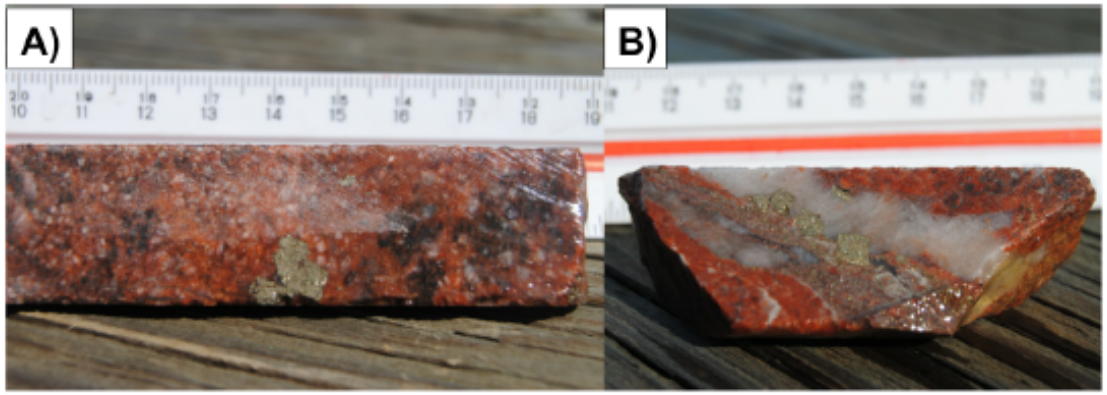
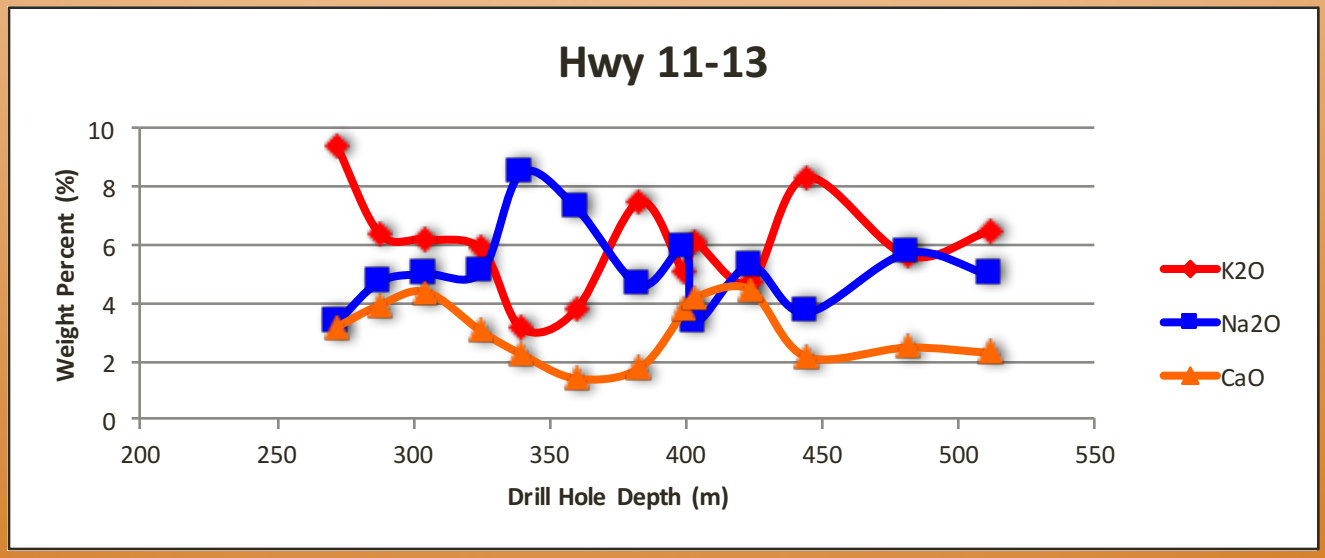
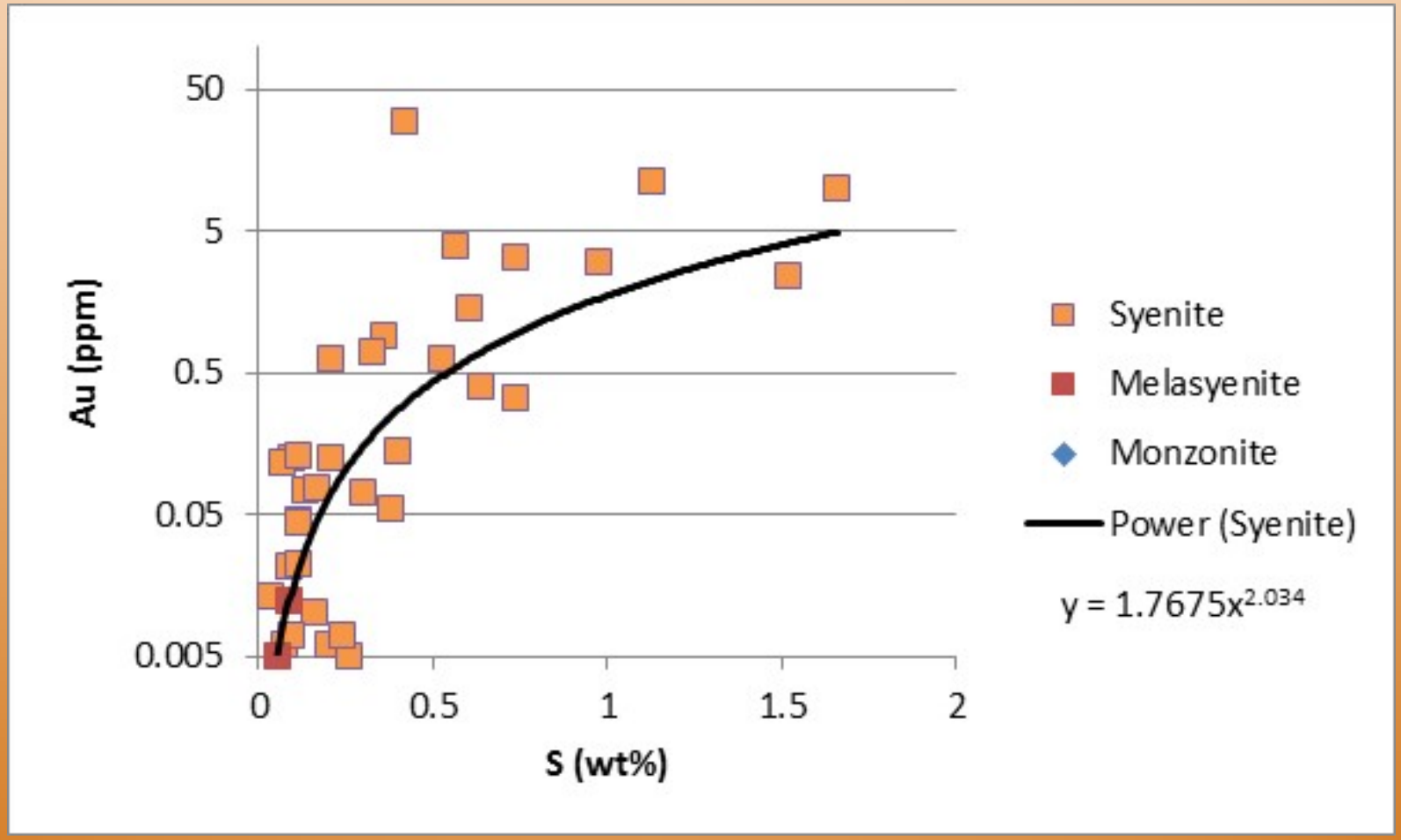


Figure 6.9: Hand sample photographs of Hwy-144 mineralization. A) Coarse grained disseminated pyrite. B) Medium to coarse-grained vein-hosted pyrite.

Hwy Alteration more similar to YD: Feldspathic & carb alteration



Strongest Association of Gold is with Pyrite



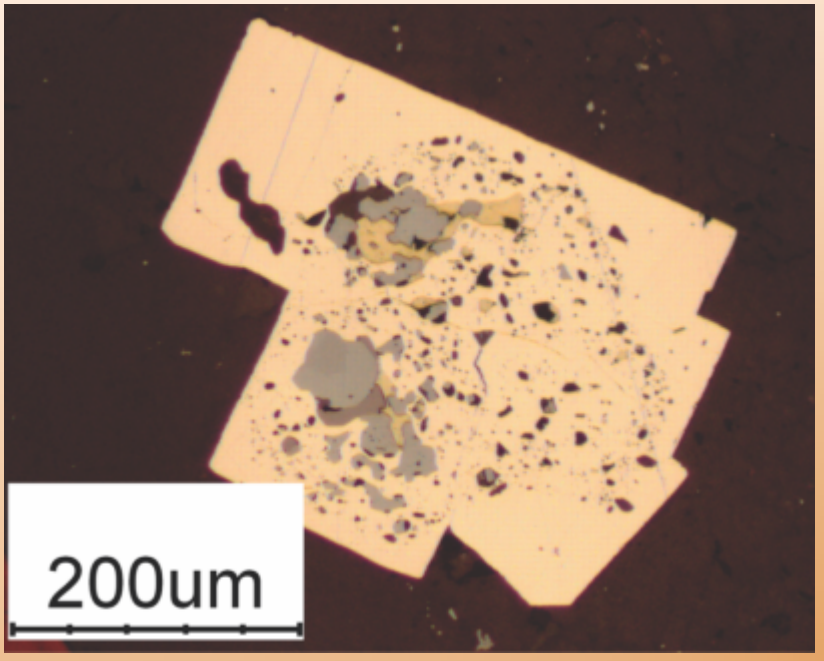
Summary: Similar to Young-Davidson

- 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

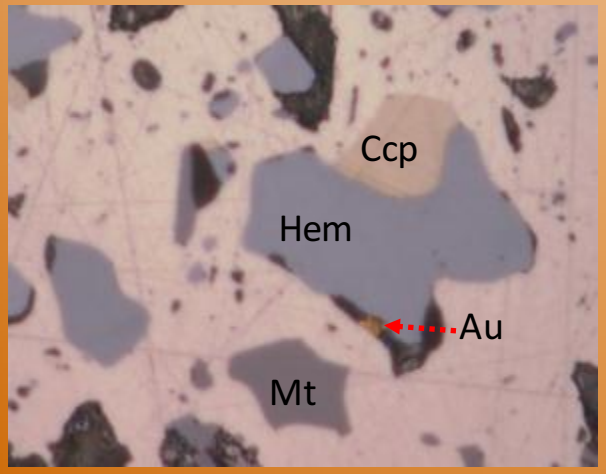
Young-Davidson:
2 Types of Pyrite

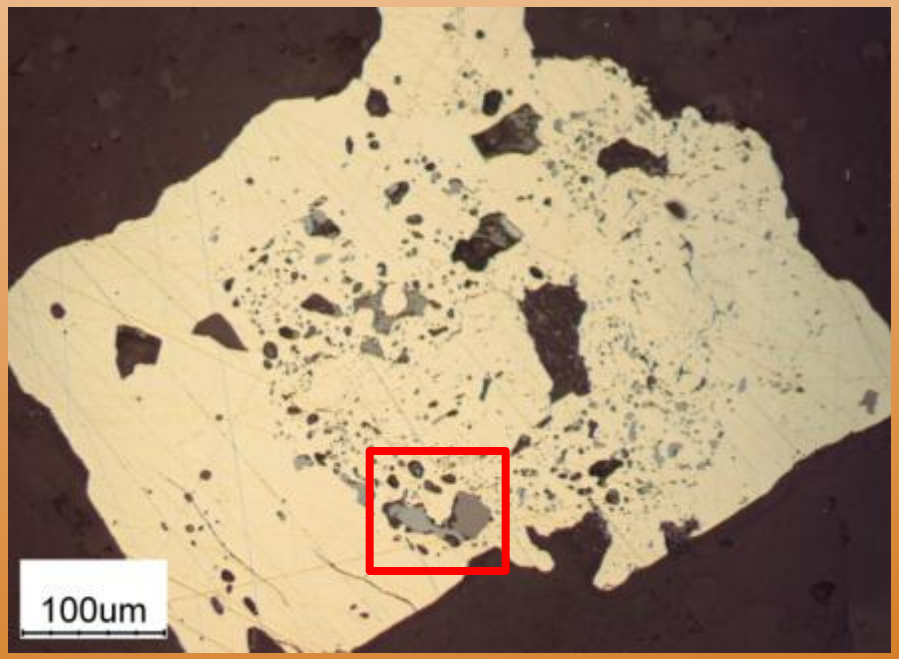
Pyrite



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





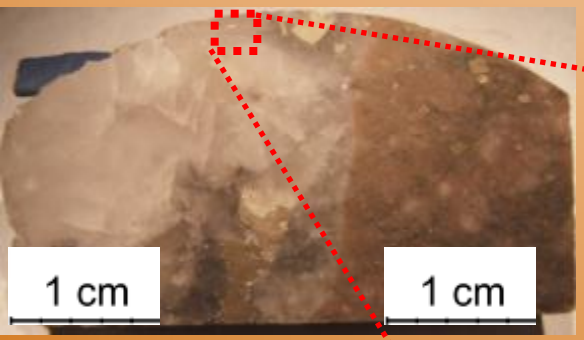
Pyrite

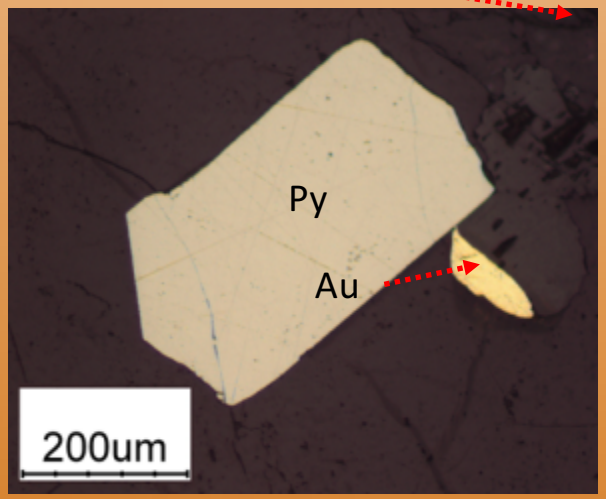
Type 2 Pyrite:

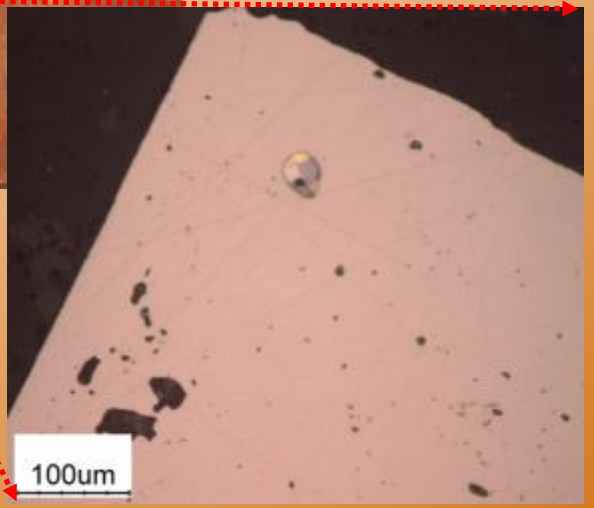
Euhedral, minor inclusions
(gangue, ccp, gn, ± rt ± hem)

Minor proportion of disseminated pyrite, mostly V_3 vein pyrite

Associated with free gold and V_3 veins







Pyrite Minor Elements by EMPA

Similar for both textural types

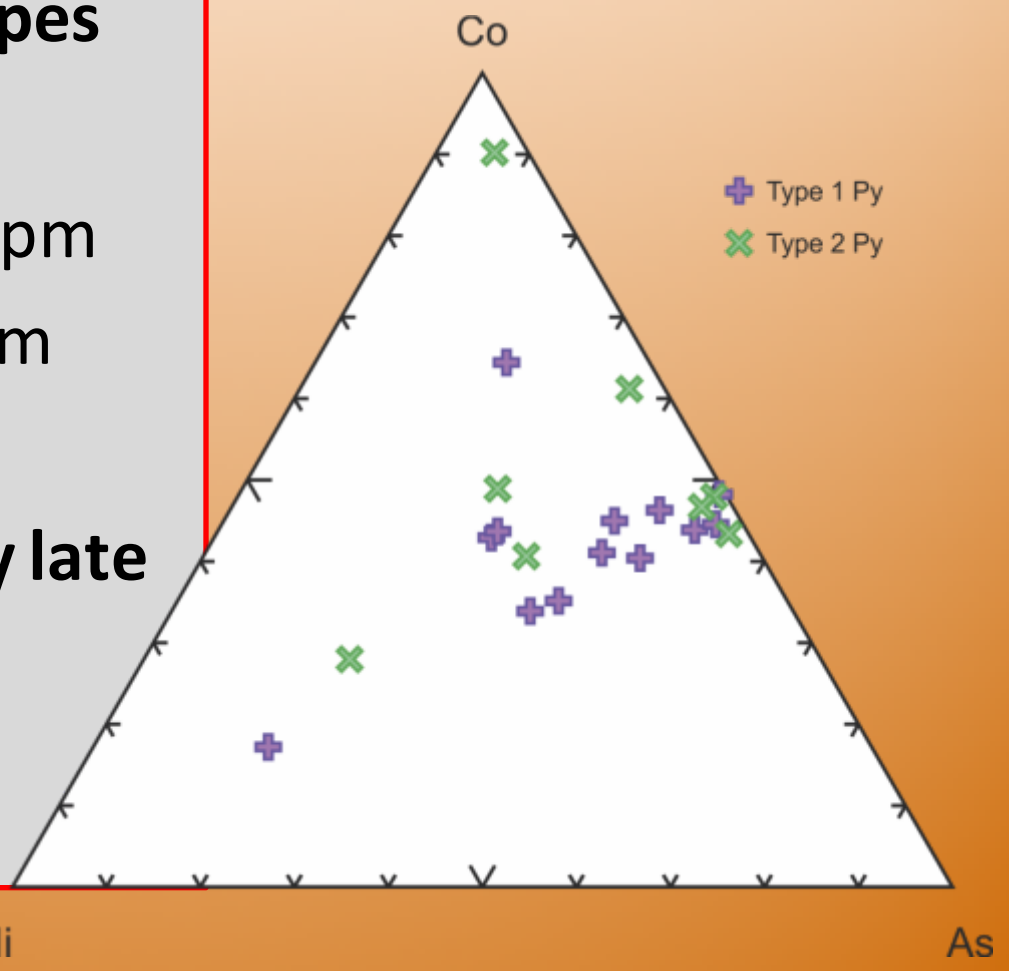
Ni: ~100 to 2600 ppm

Co: 600 ppm to 15000 ppm

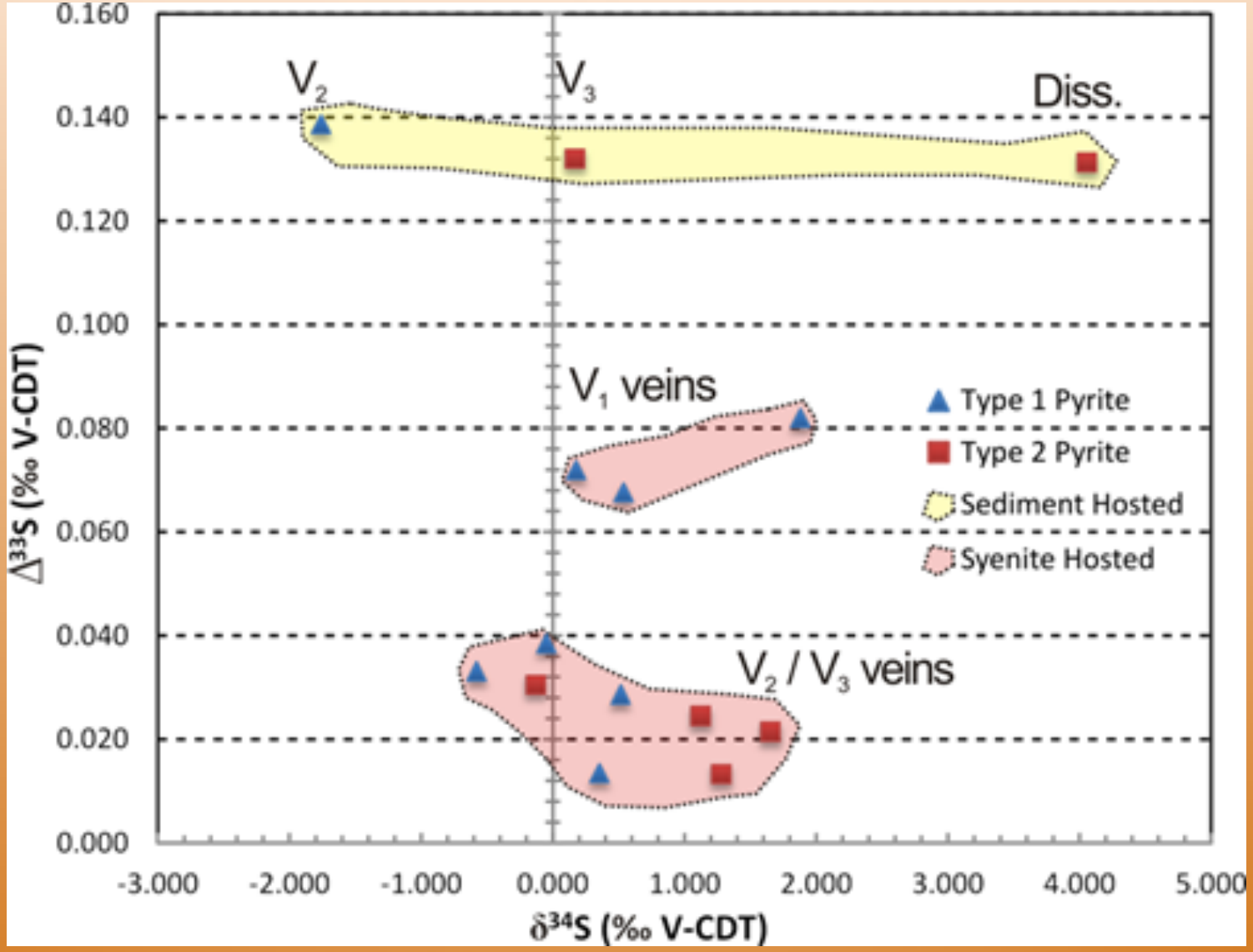
As: 700 ppm to 4300 ppm

Type 2 pyrite is typically late

Thus the similarity of compositions suggests repetitive fluids

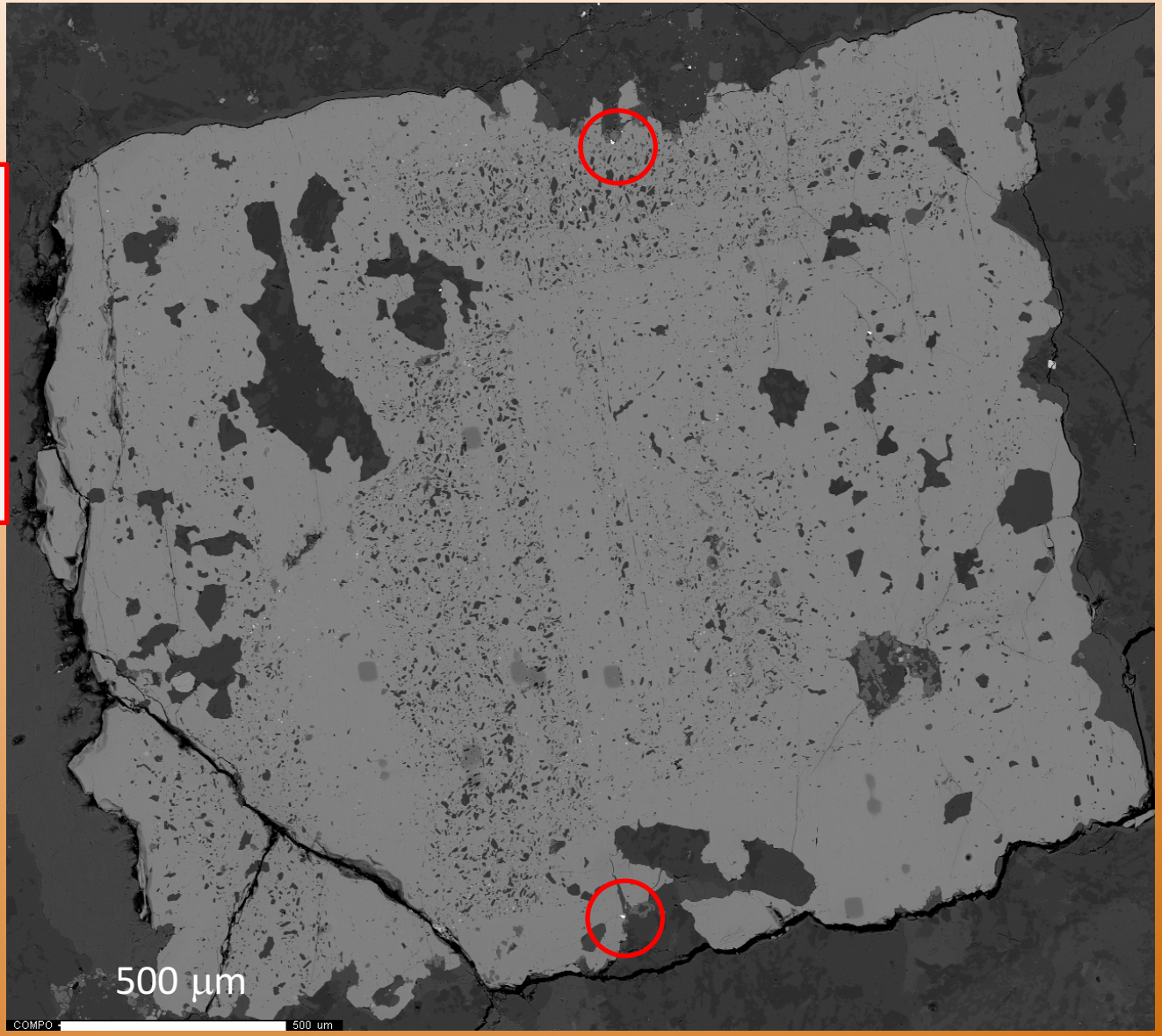


Sulphur Isotopes



Backscatter Image of Pyrite

Note:
- Au nearly absent
- Strong zoning
- Corrosion and secondary porosity

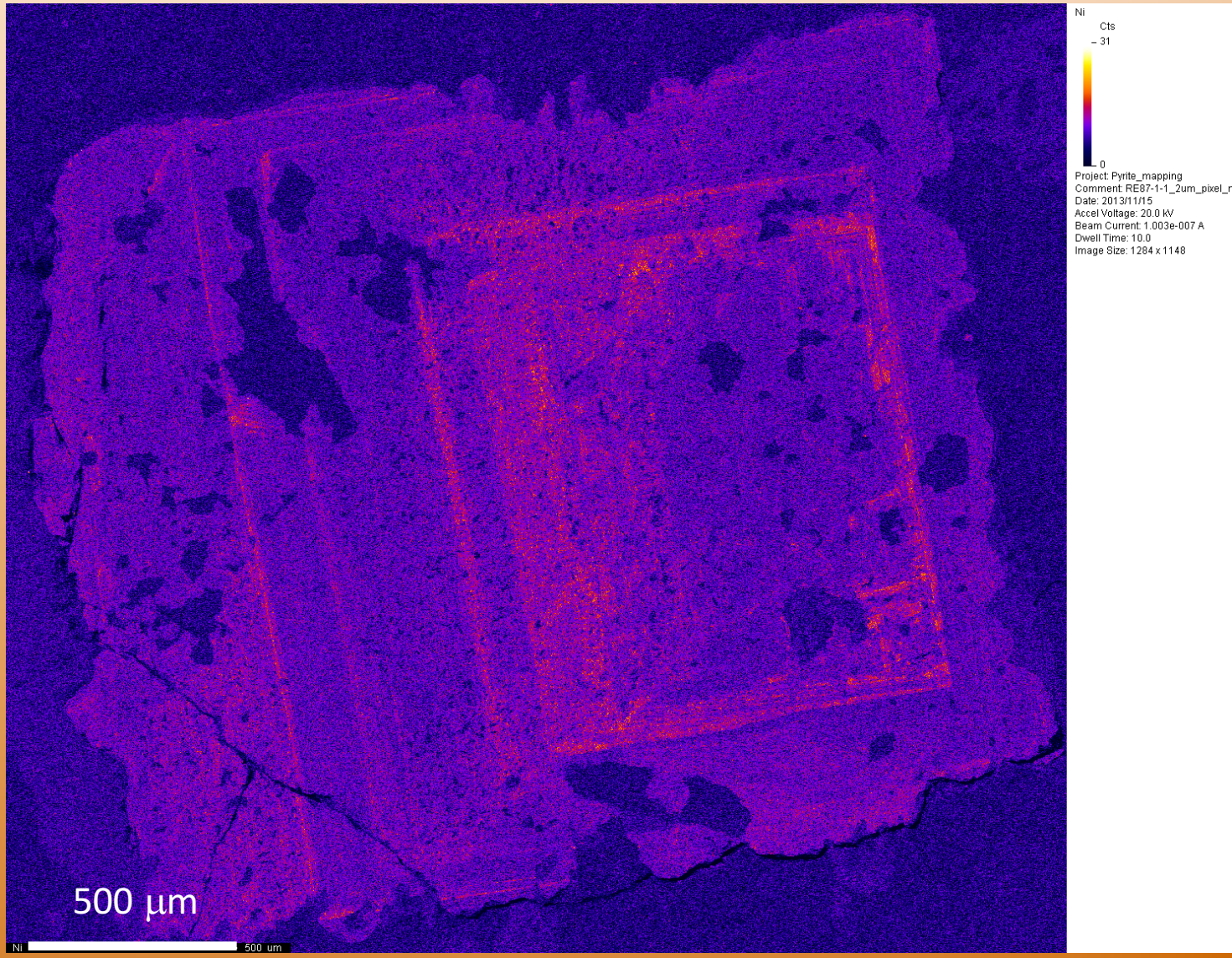


EMP-WDS Ni Map

Ni contents range from 30 to 2760 ppm

Co zoning overlaps with Ni 10 to 1375 ppm

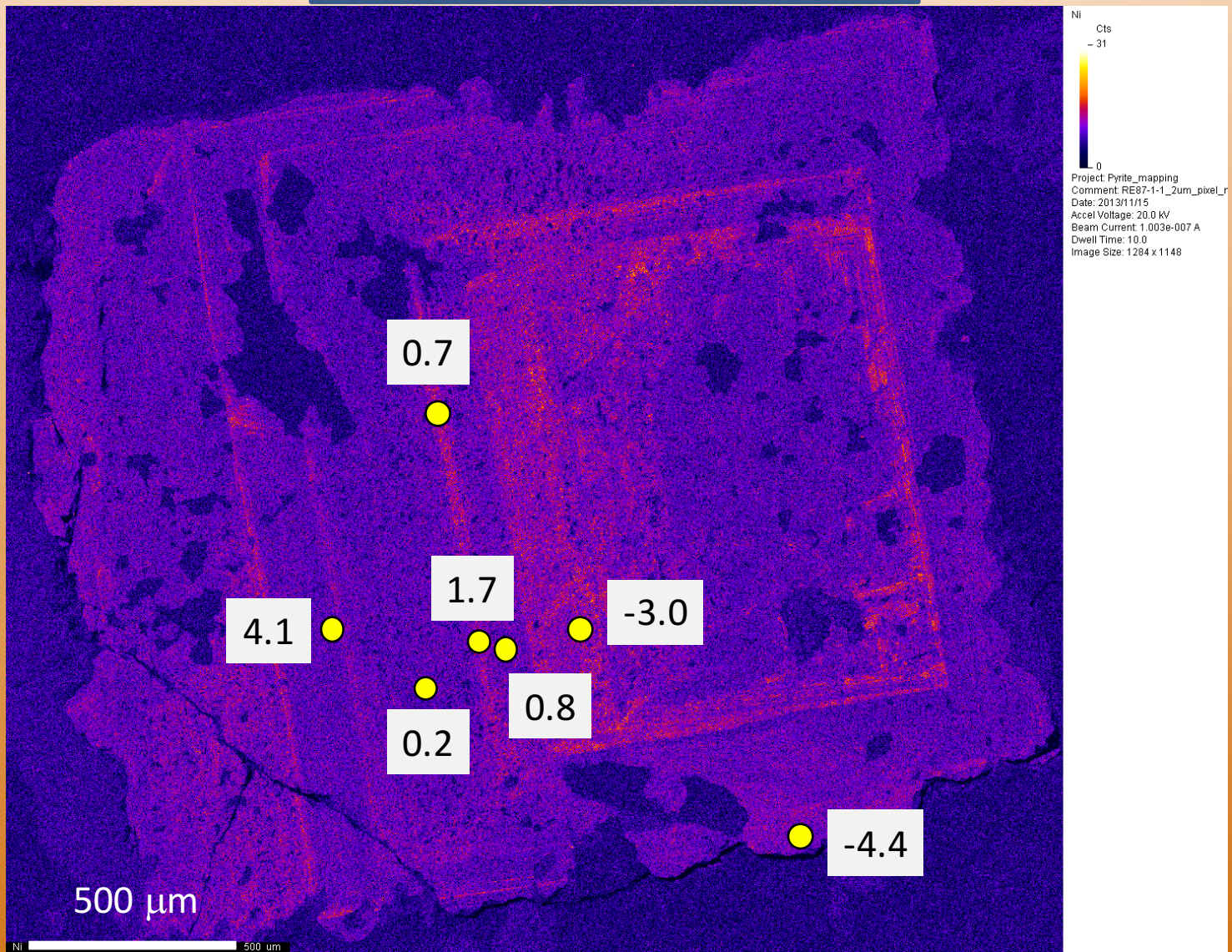
Low As contents <40 to 640 ppm



In Situ Analysis of Pyrite:

Sulphur Isotopes: SIMS

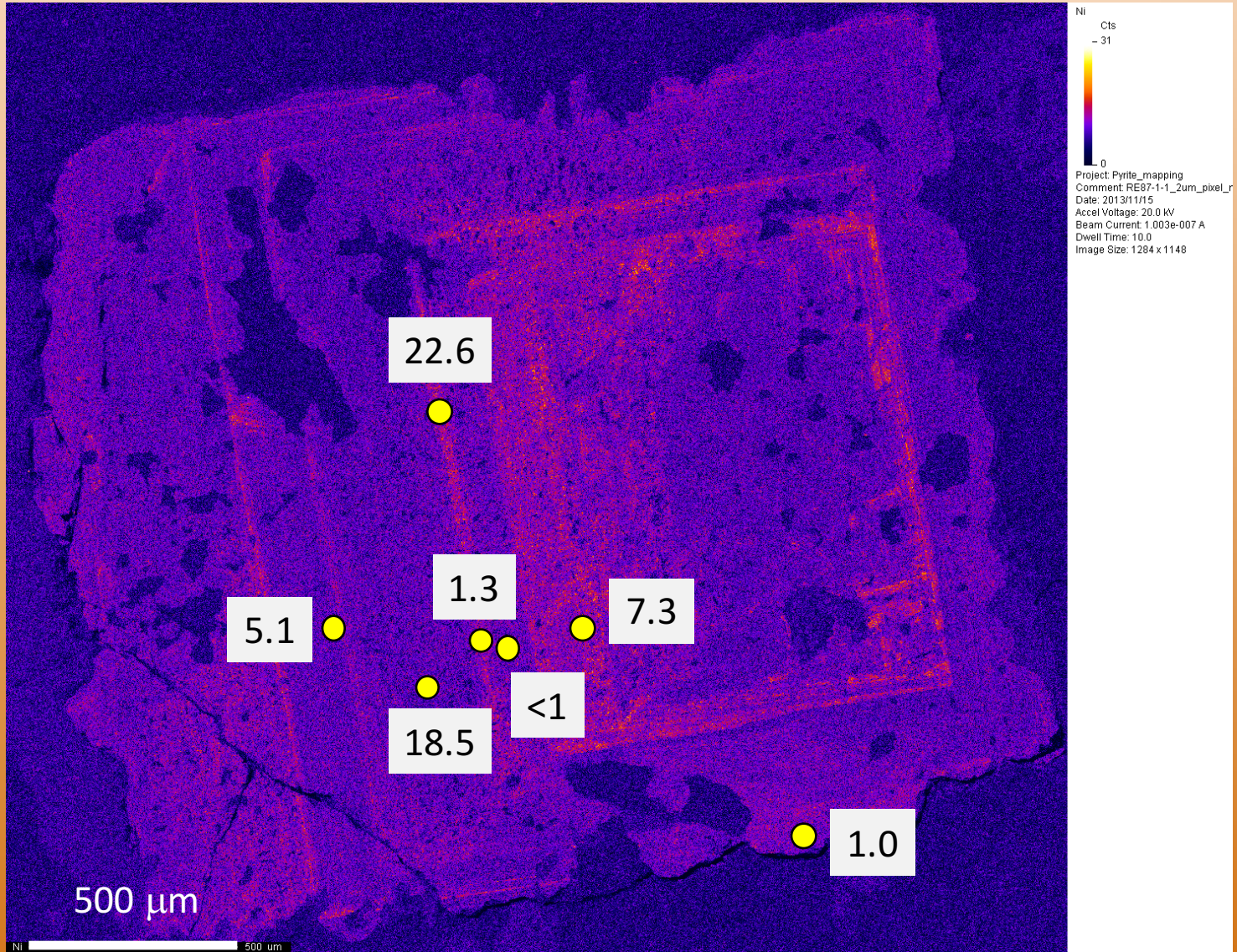
-4.4 to 4.1‰ variation

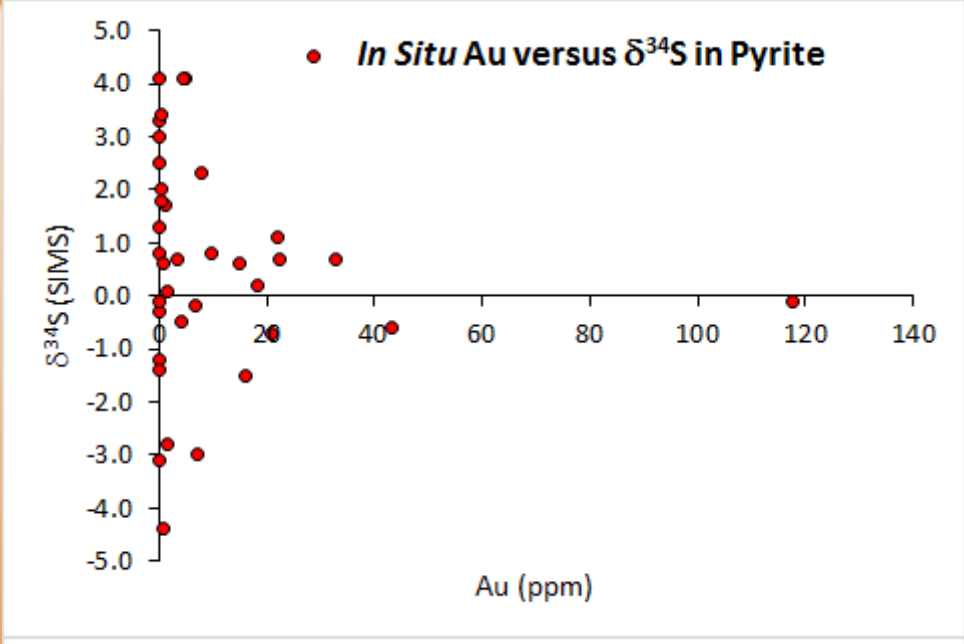


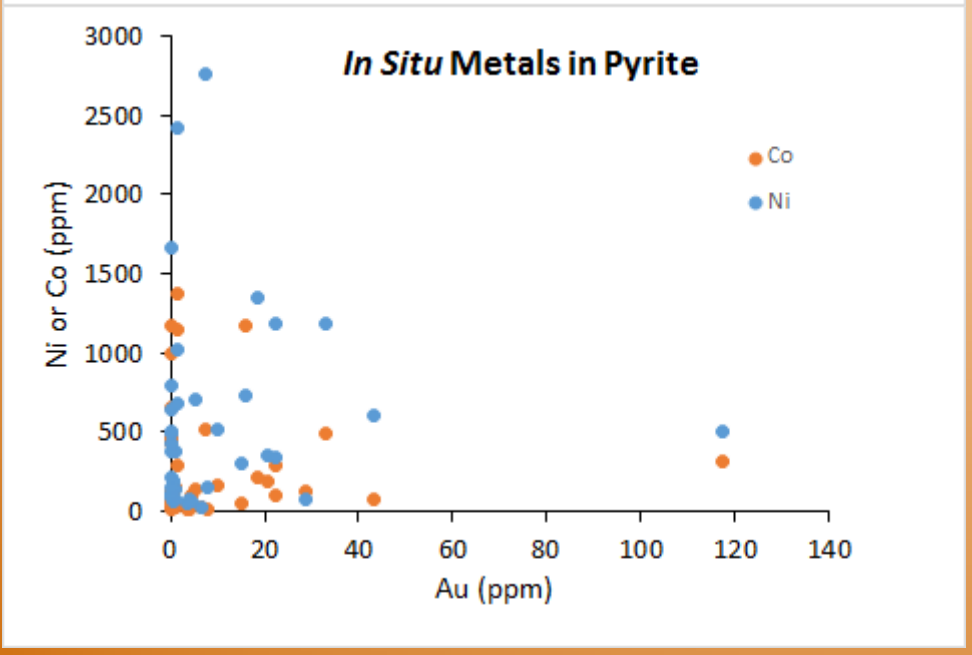
In Situ Analysis of Pyrite:

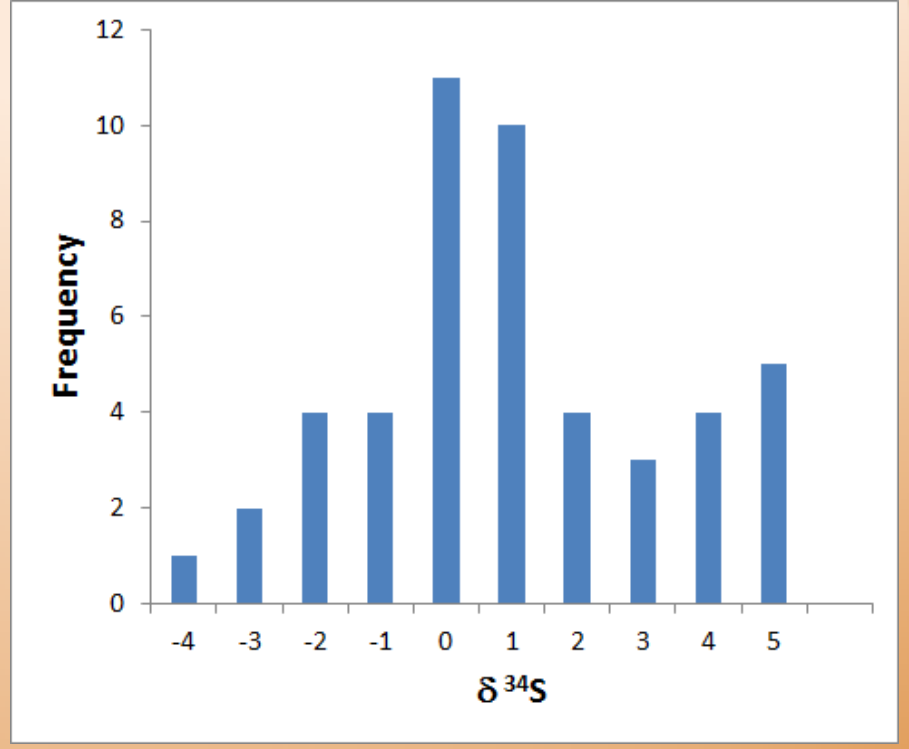
Trace elements: LA-ICP-MS (spot analyses)

Au ranges from <1 to 22.6 ppm





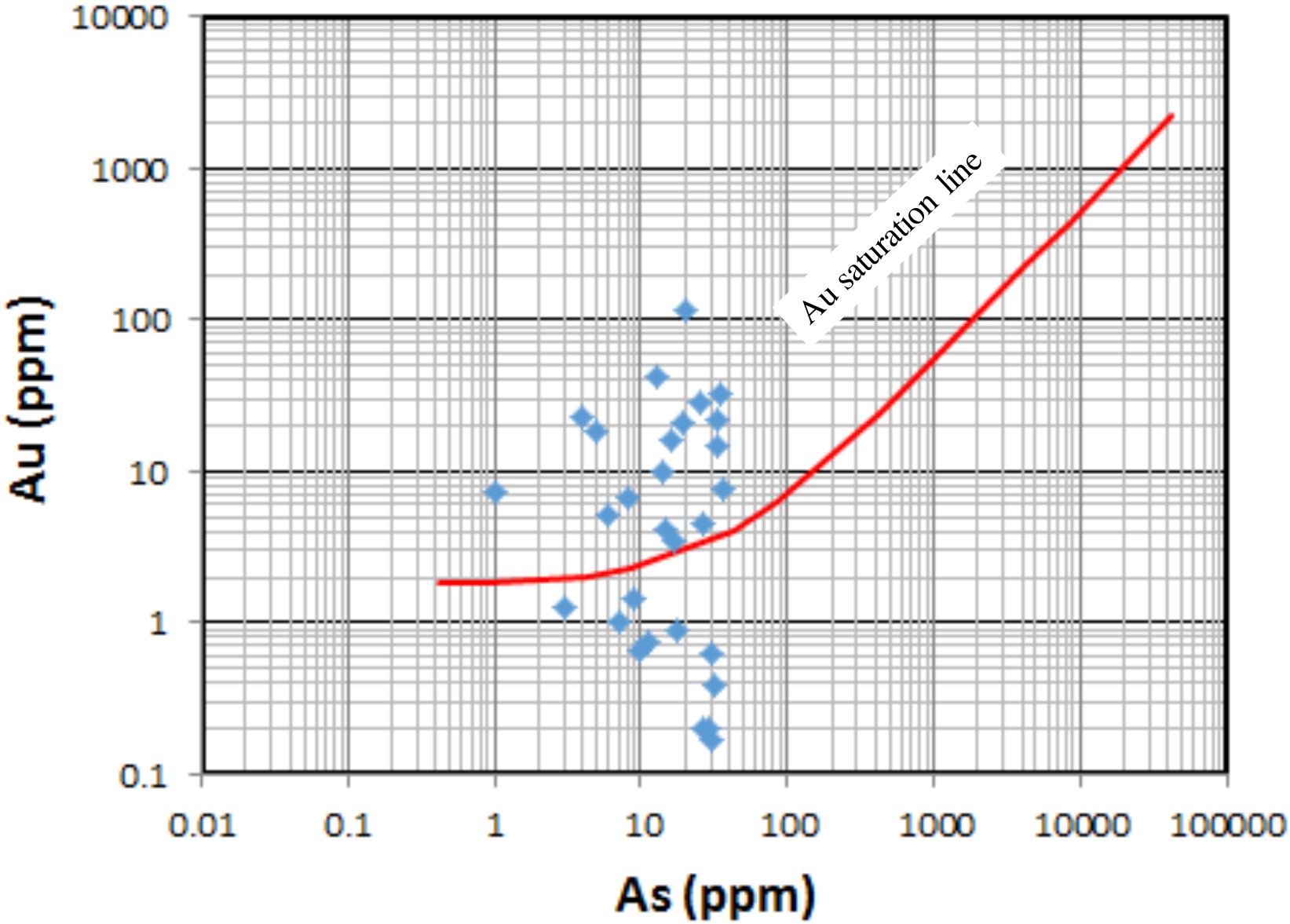




Overall Au Correlates with

- $\delta^{34}S$ values of near zero
- low Ni-Co contents
- no correlation with As

Au-As Contents in YD Pyrite

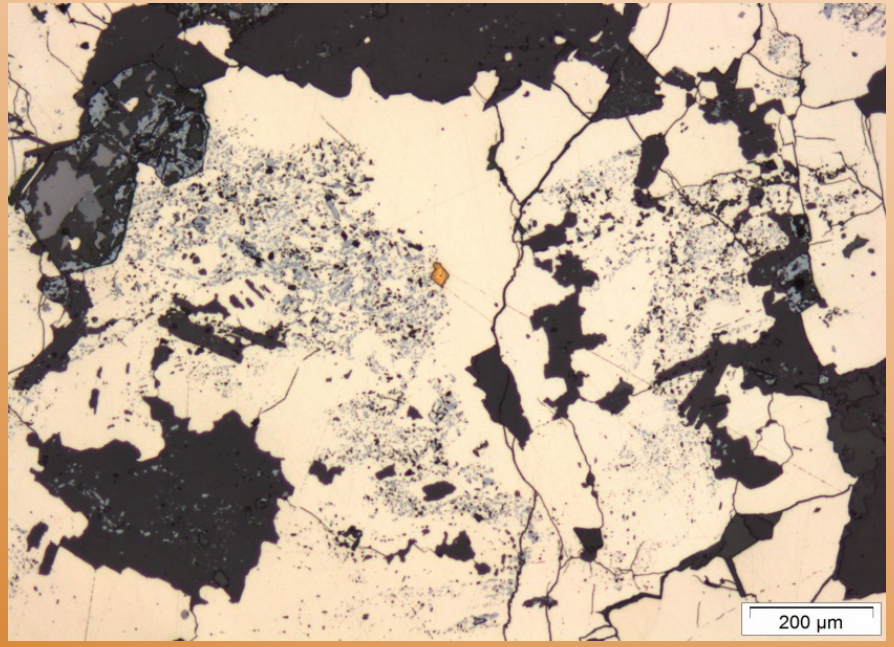


Au saturation line from Reich et al. (2005)

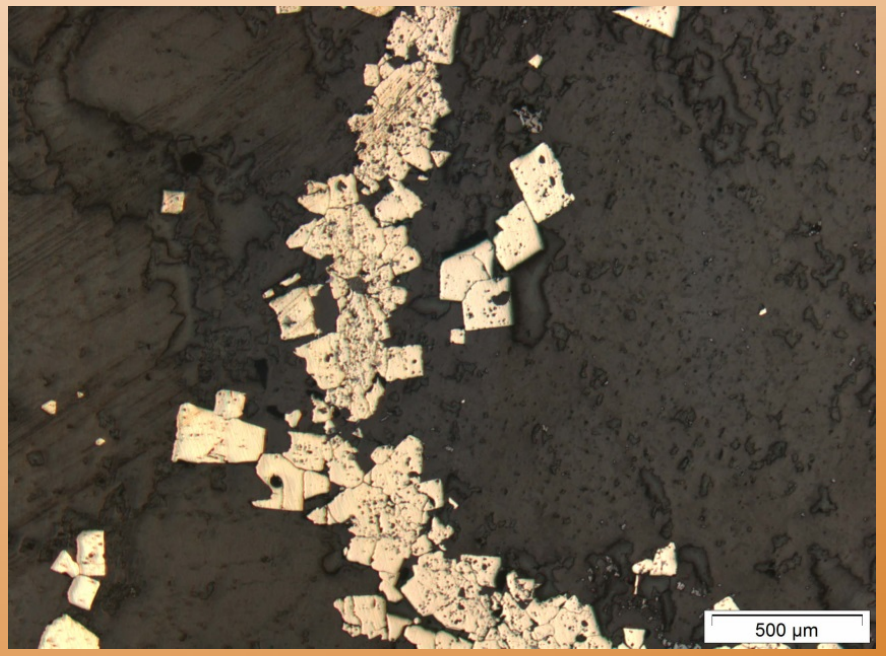
Conclusions About Young-Davidson

- 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

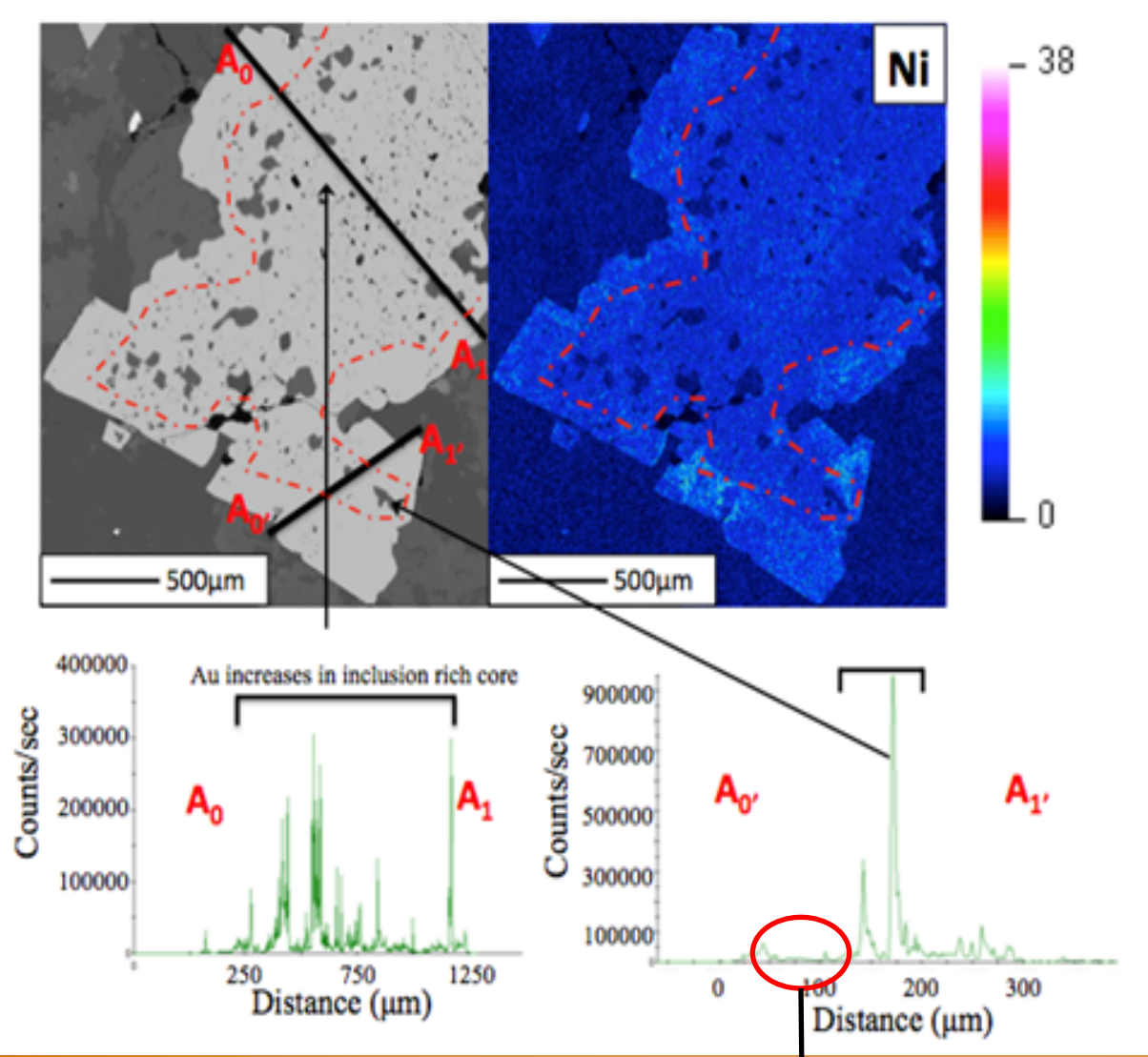


Euhedral

Sulphur Isotopes (SIMS)
Thunder Creek & Hwy 144

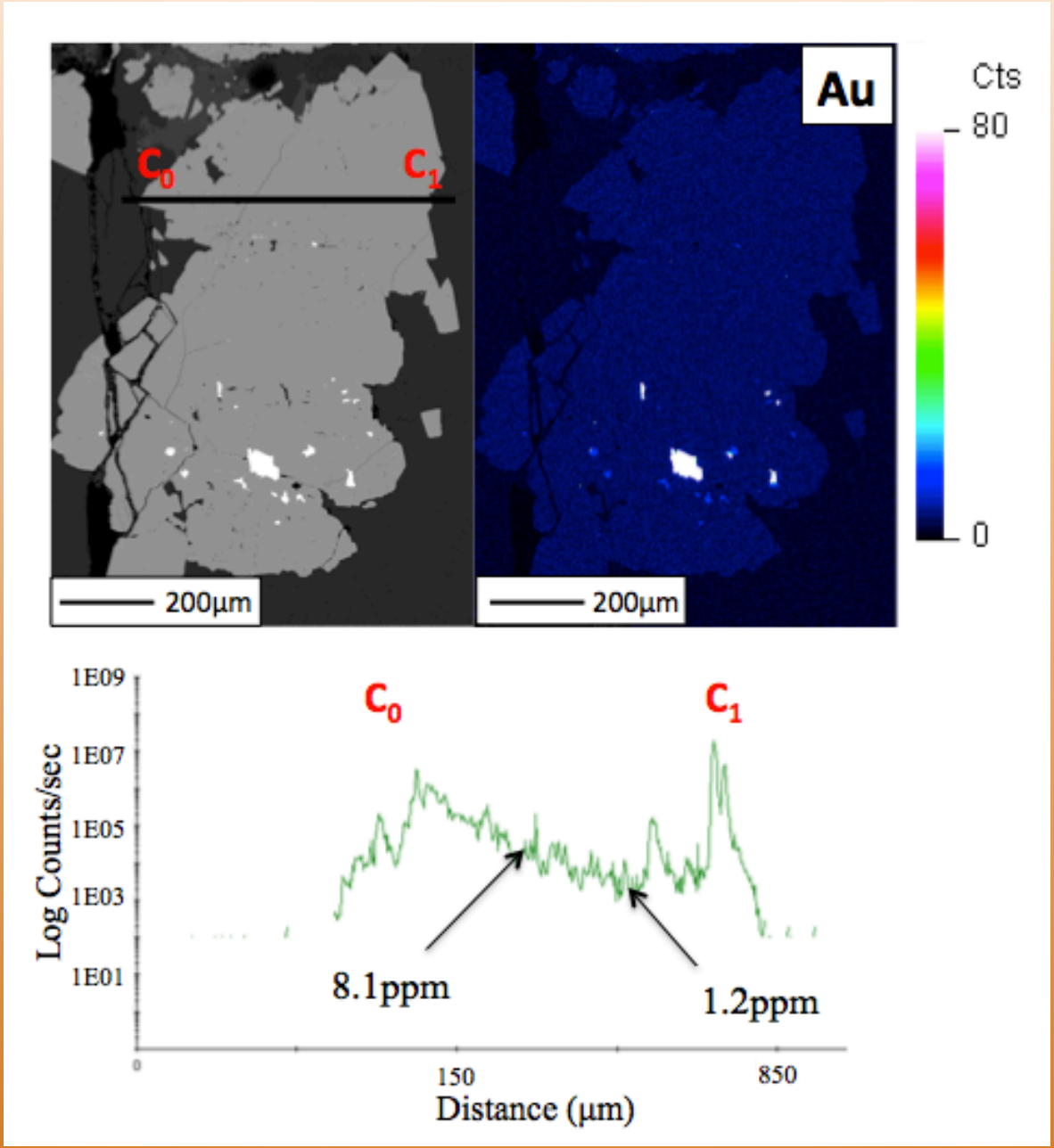
Location	Generation	$\delta^{34}S$ Range	Avg. $\delta^{34}S$	n
Thunder Creek	Disseminated	-3.0 to -6.1	-4.7	8
Thunder Creek	Vein-Hosted	-3 to -5.3	-4.3	14
Hwy-144	Disseminated	-1.8 to -3	-2.4	2
Hwy-144	Vein-Hosted	-0.1 to -3.3	-1.5	8
Hwy-144	Fracture Filling	-1.4 to -6.9	-3.7	9

Thunder Creek Pyrite

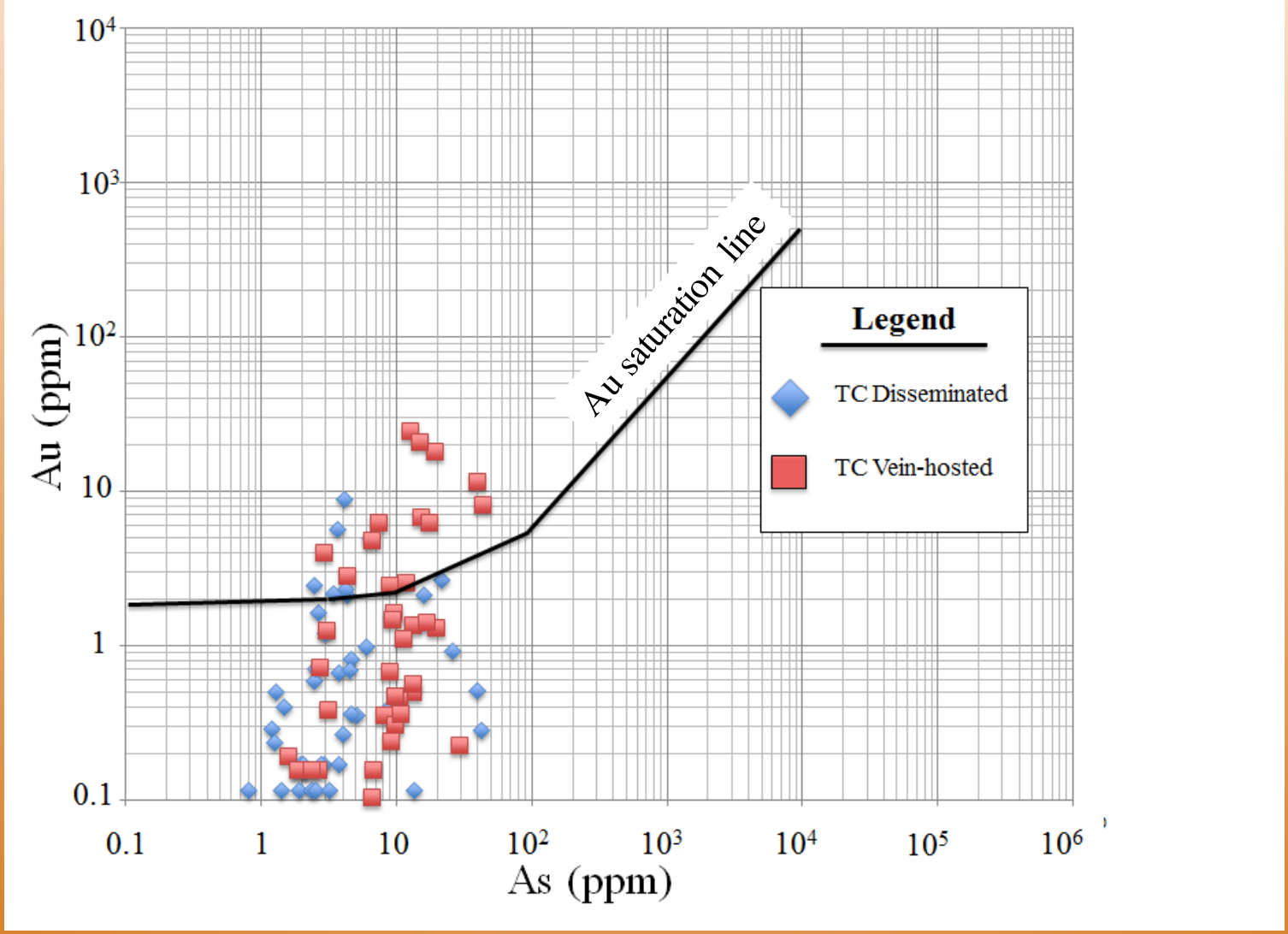


- Poorly zoned and low concentrations of Ni-Co
- Abundant micro-nanonuggets of Au
- 'Background' Au

Thunder Creek Pyrite

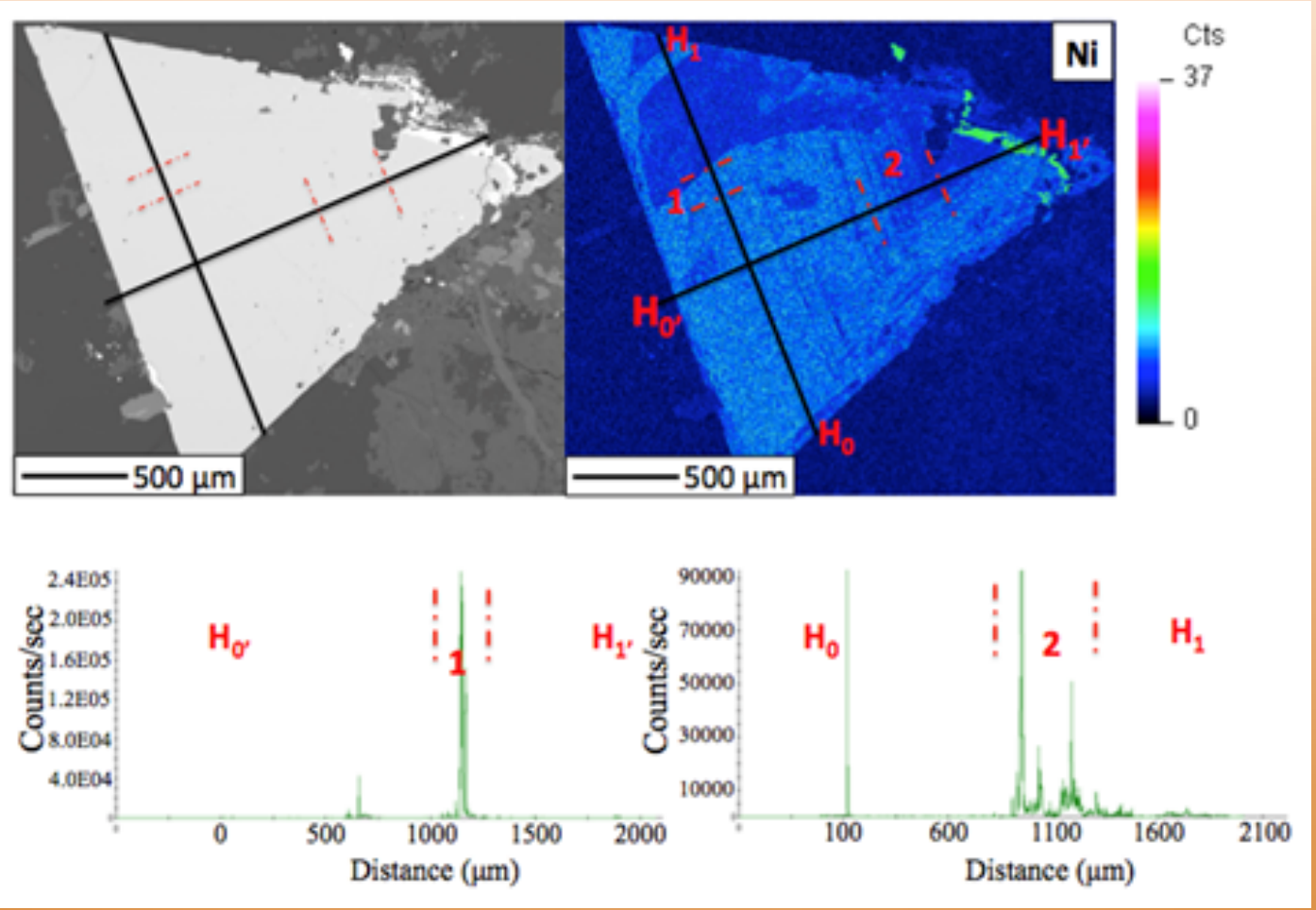


Thunder Creek Pyrite

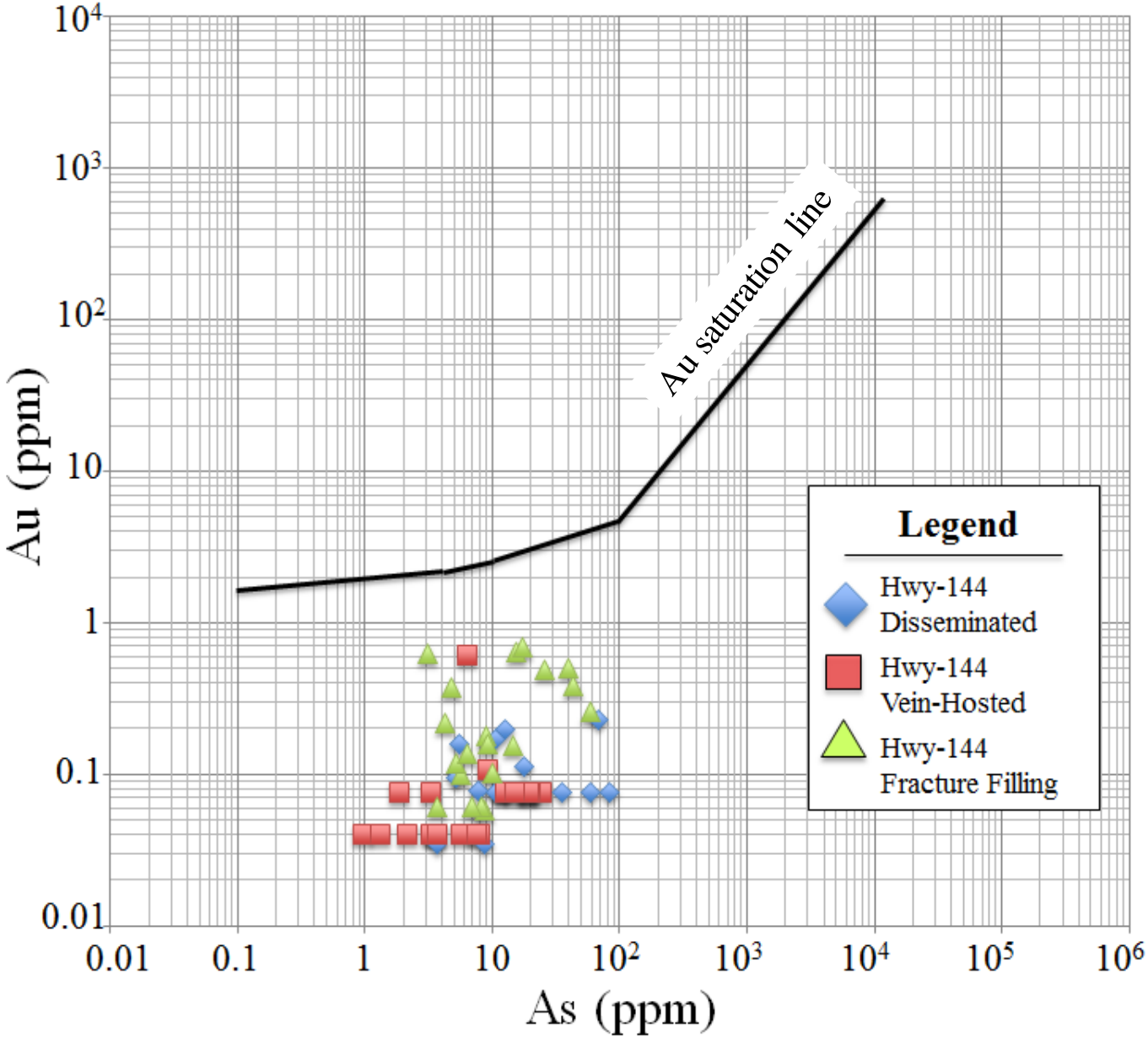


Au saturation line from Reich et al. (2005)

Hwy 144 Pyrite



Hwy 144 Pyrite



Au saturation line from Reich et al. (2005)

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**

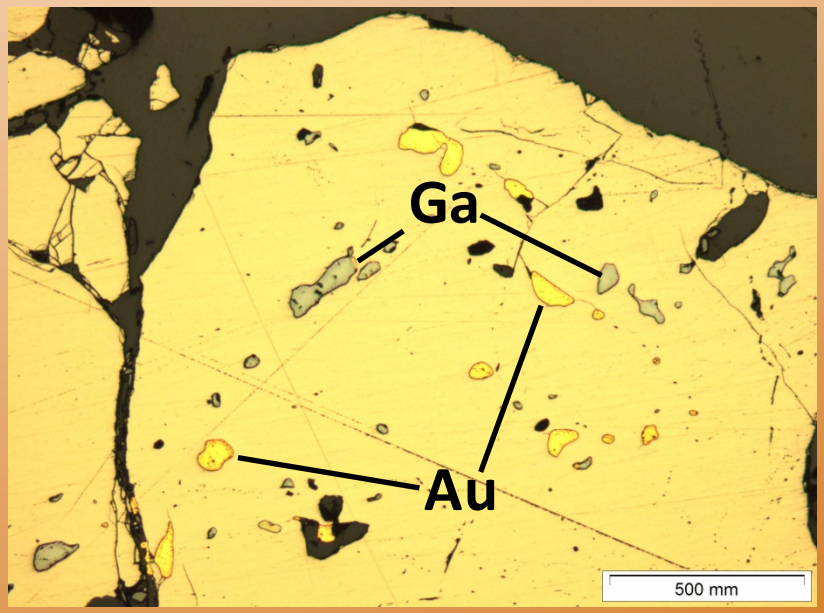
- Fluids are too hot to be metamorphic (regional greenschist facies)
- Oscillatory zoning suggests supersaturation via fluid mixing
- Fluid mixing may also be supported by S isotopes (but redox changes can't be discounted
- Au contents of pyrite have potential to indicate the fertility of systems

What’s Next?

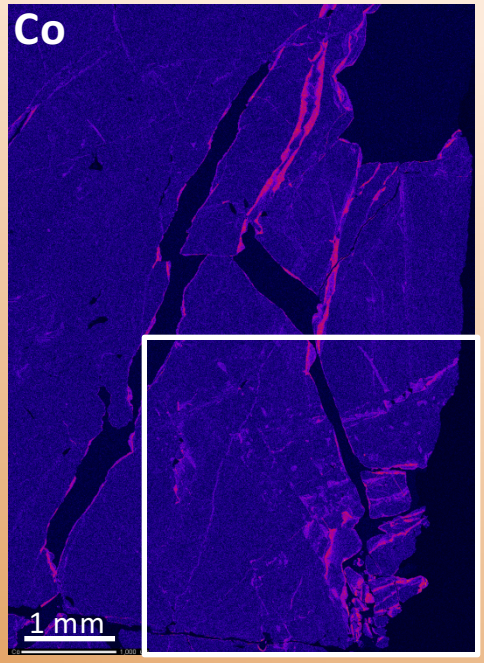
More Petrography-Pyrite Mapping

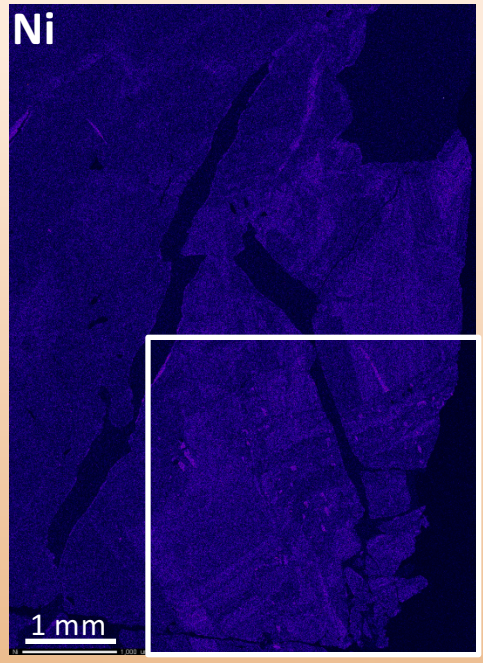
At Least 2 Stages of Au

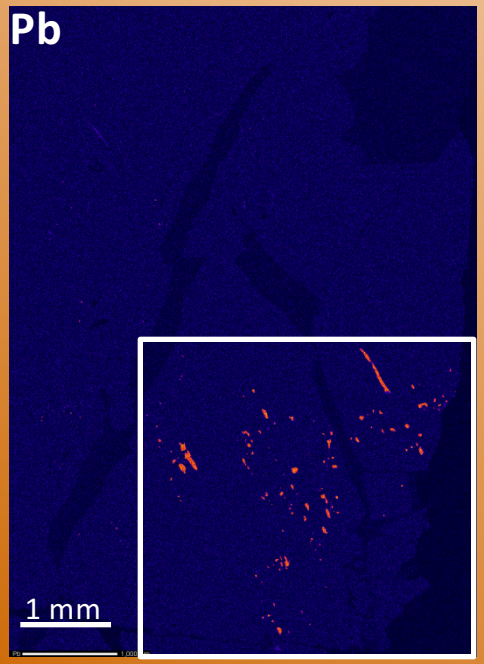
Au inclusions in pyrite, or free Au – possibly early

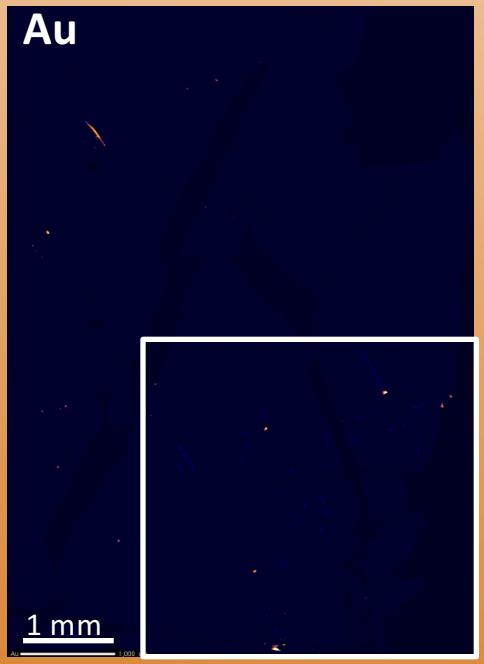


Au with galena in pyrite in mineralized syenite





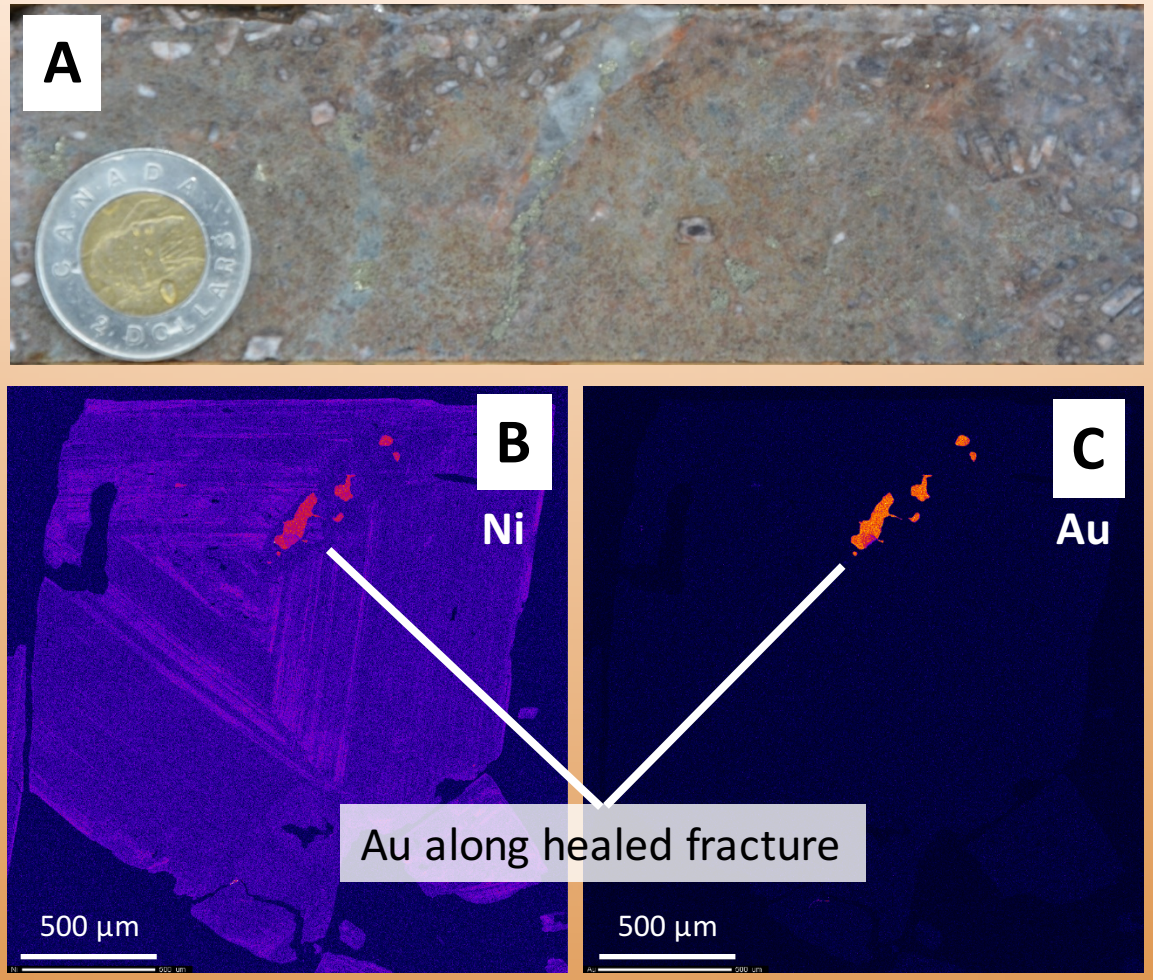




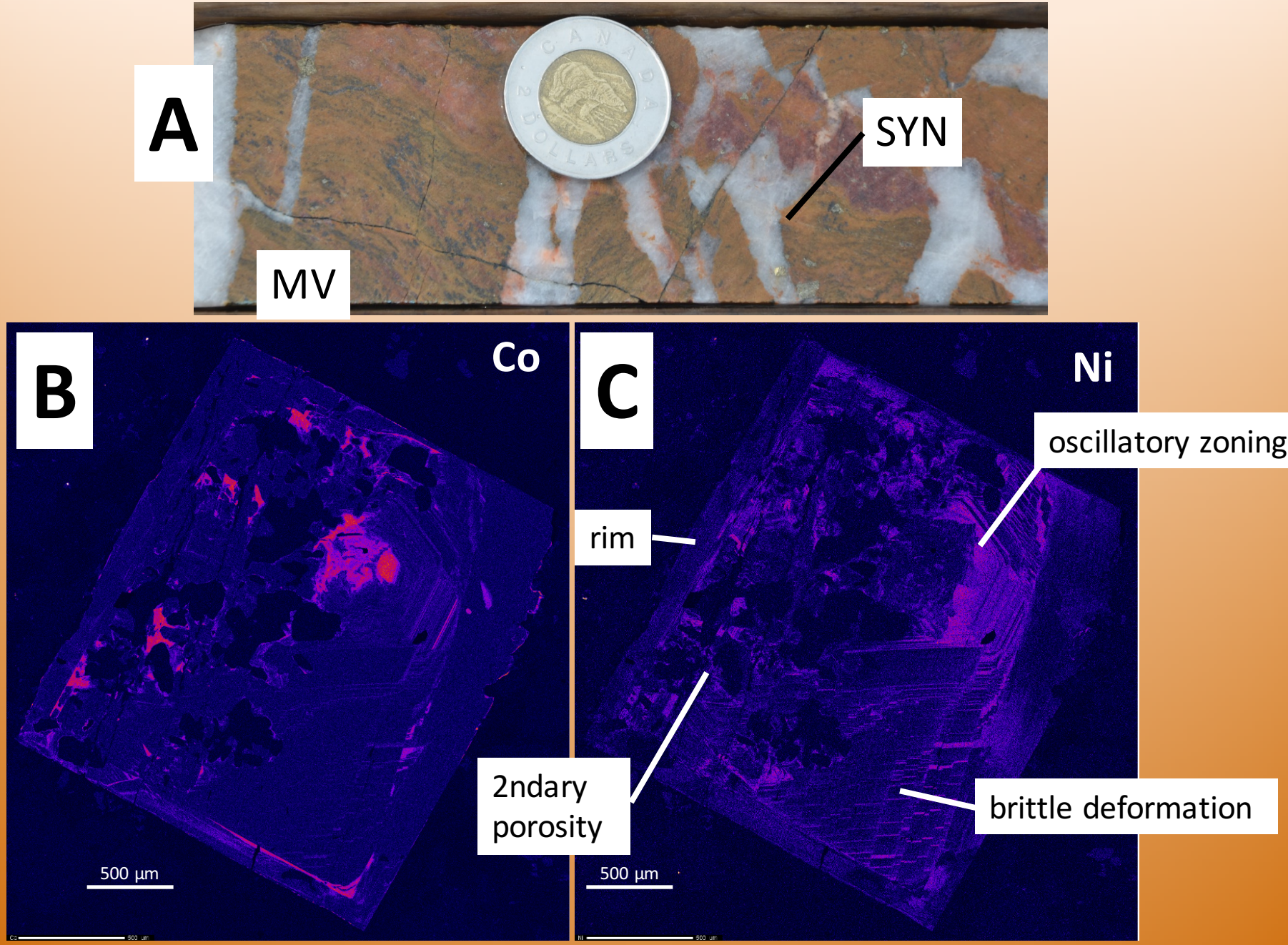
Mineralized Syenite

- Co-Ni zoning
- Ga-Au inclusions

Au-Pb seems to be synchronous with primary pyrite zoning

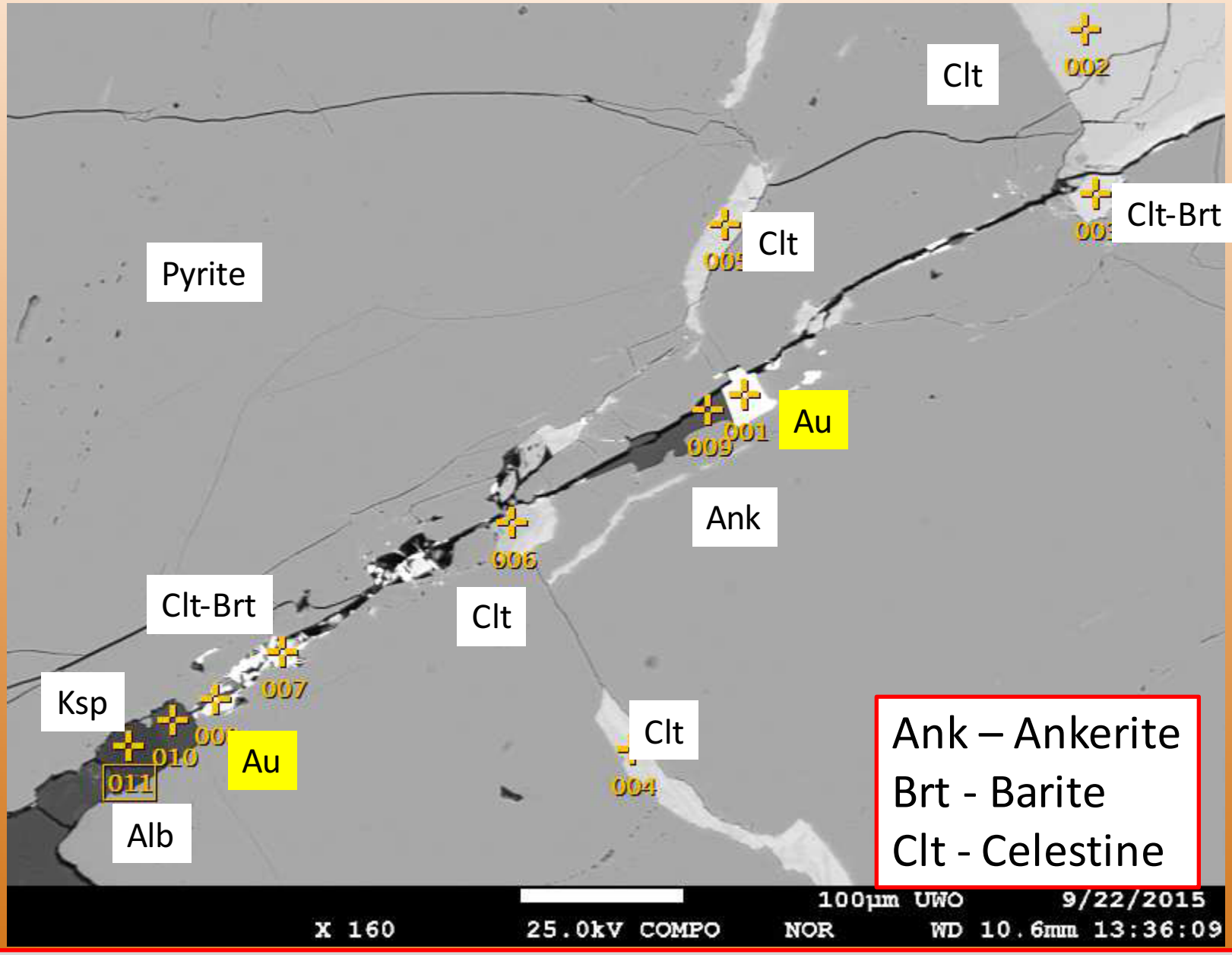


Disseminated Pyrite in Mineralized Syenite Porphyry



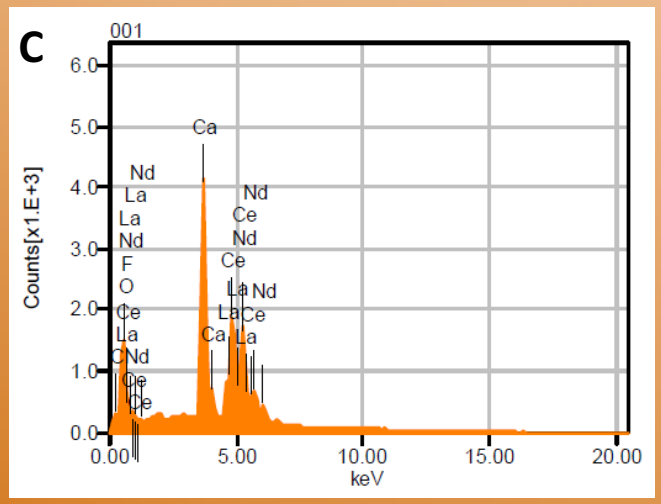
Mafic volcanic-strong ankerite alteration (1.65 ppm Au)

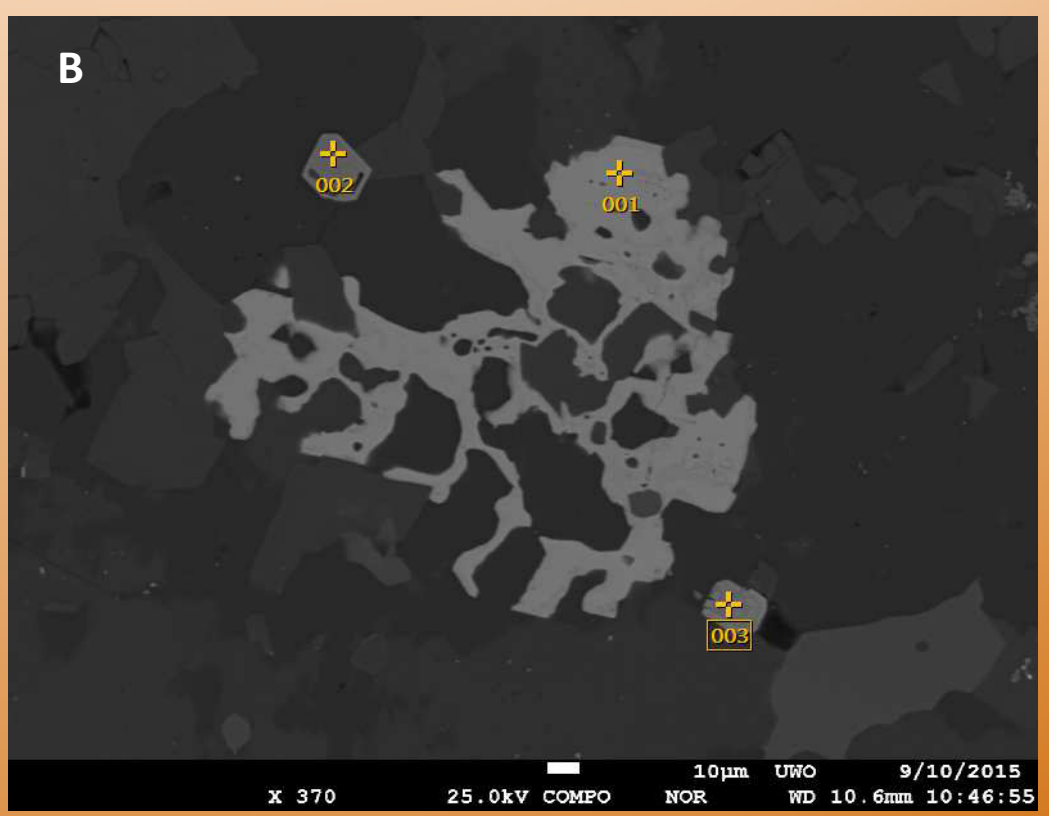
Late Sulfate Association



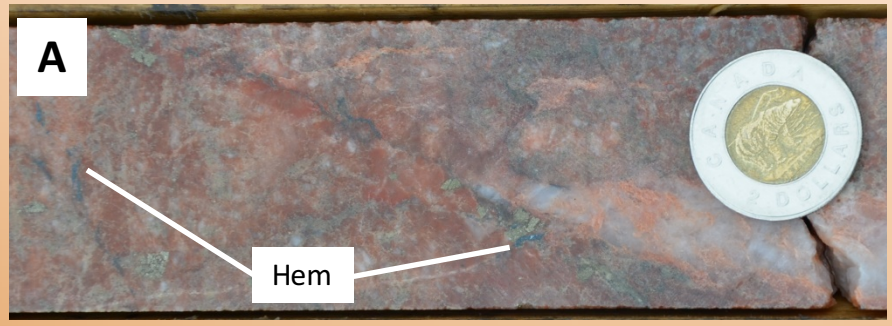
Late fracture assemblage Au-celestine-barite-ankerite-Kfeldspar-albite. Disseminated Py in syenite

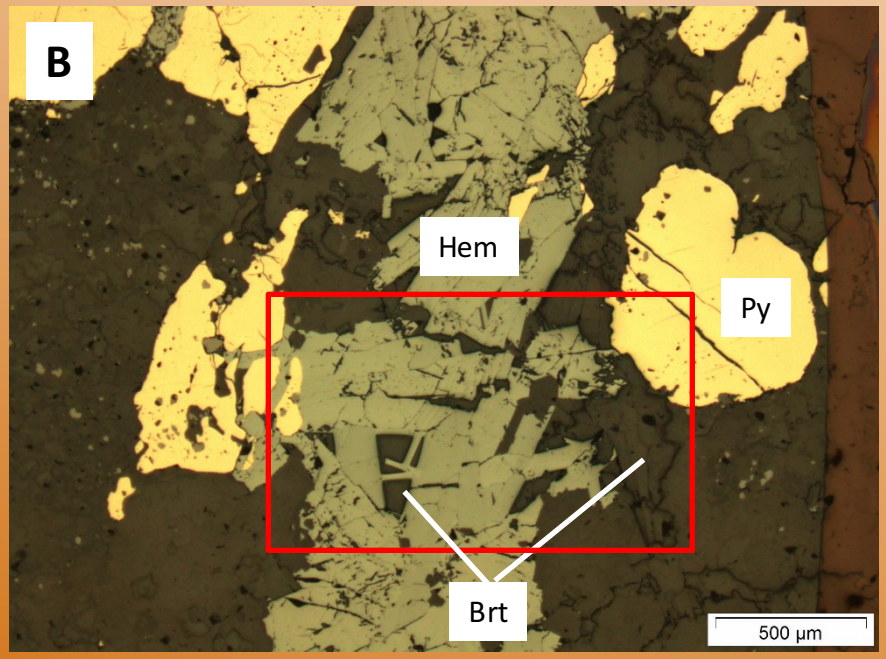
CaREE fluorcarbonate (pt 1-Synchisite/Parisite?) associated with Fe oxide (pt 2) and zircon (pt 3). Weakly mineralized syenite (0.7 ppm Au)

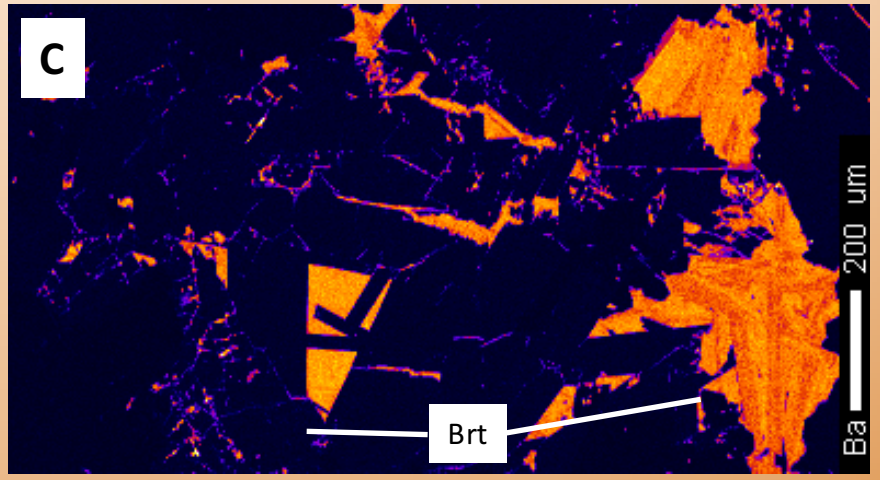


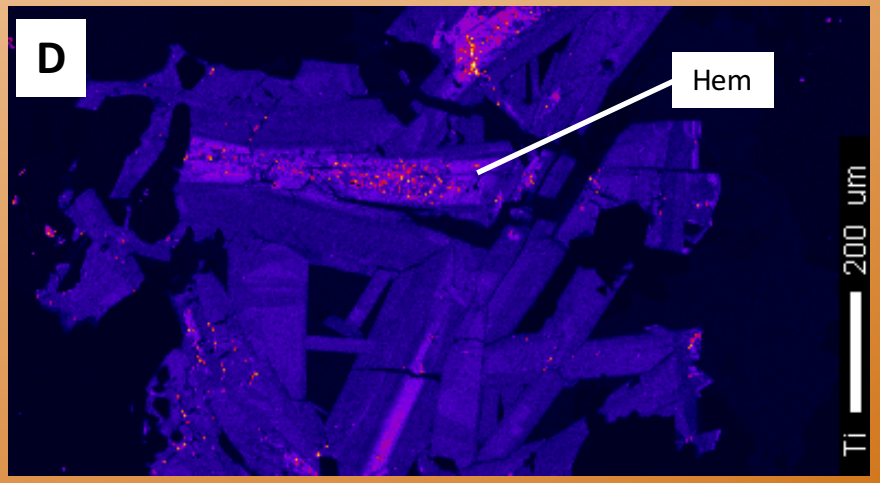


Au association with oxidation

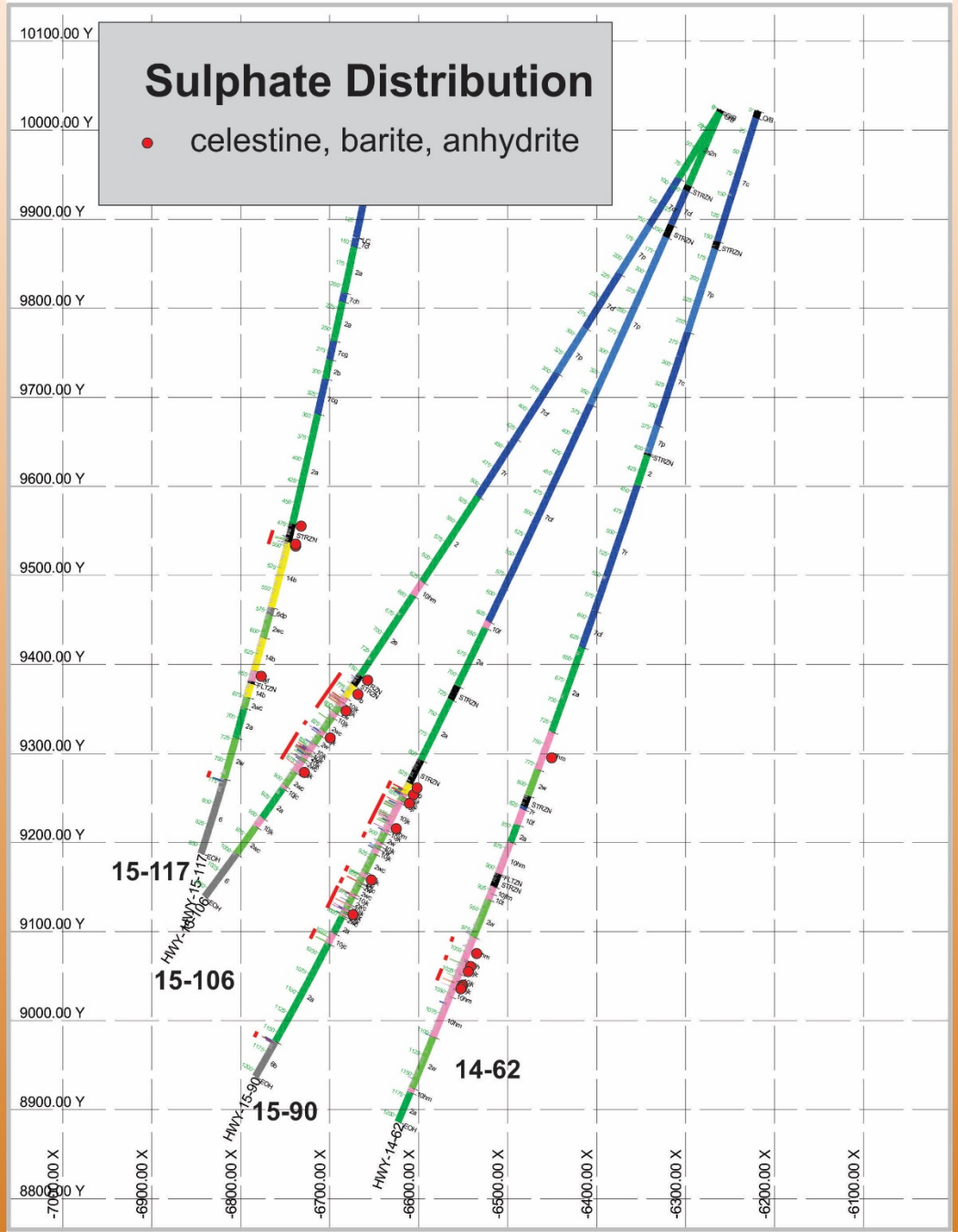








Section 8550



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

Is this a magmatic signature?

Acknowledgements

(Northgate, Aurico)

(Lake Shore Gold)