

Hydrothermal Mass Transfer
and Magnetite Mineralization
in Dilational Shear Zones,
western Hudson Highlands, NY

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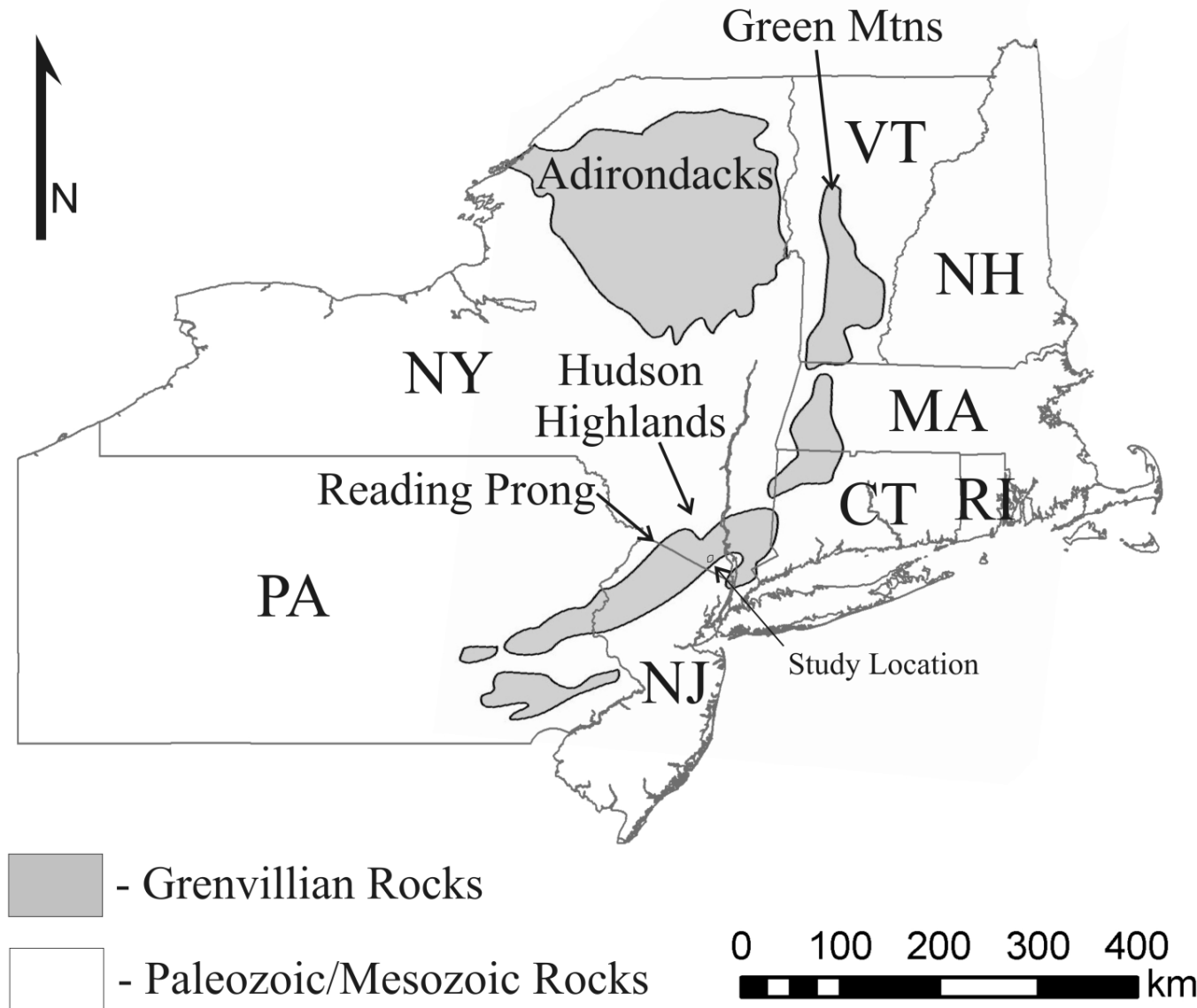
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Alexander E Gates

Introduction

- Bedrock geology
- Shear zones & mineralized veins
 - x3 mineral assemblages, vary by location
- Geochemistry & Mass Transfer
 - Wall rock, bleached zones, & layered assemblages
 - Isocon method – Wall rock / Bleached zone
- Evolution of the fluids
 - Fluid source and fluid fluxes bleached zone alteration
- Model of formation
 - Fault system and evolution vein mineralization
 - Country rock controlled mineral assemblages

Regional Location

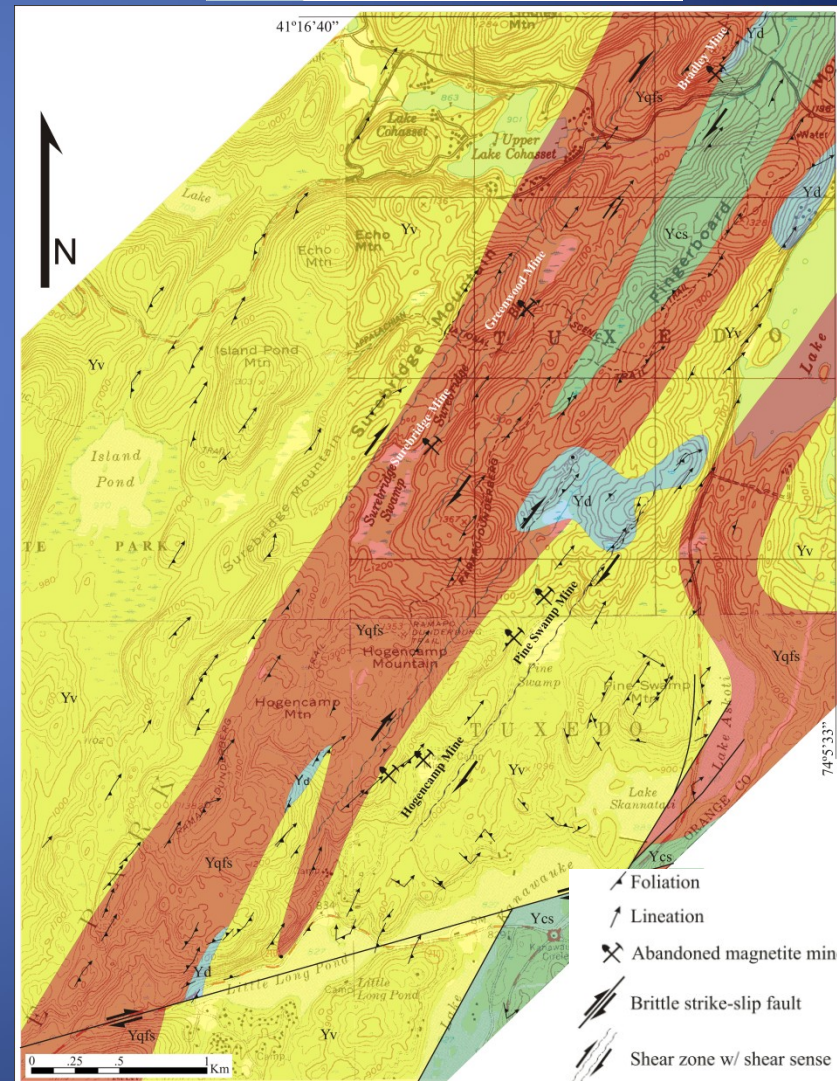


Bedrock Geology

Ycs	Calc-silicate Gneiss
Yv	Metavolcanic Gneiss
Yqfs	Quartzofeldspathic Gneiss
Yd	Lake Tiorati Diorite

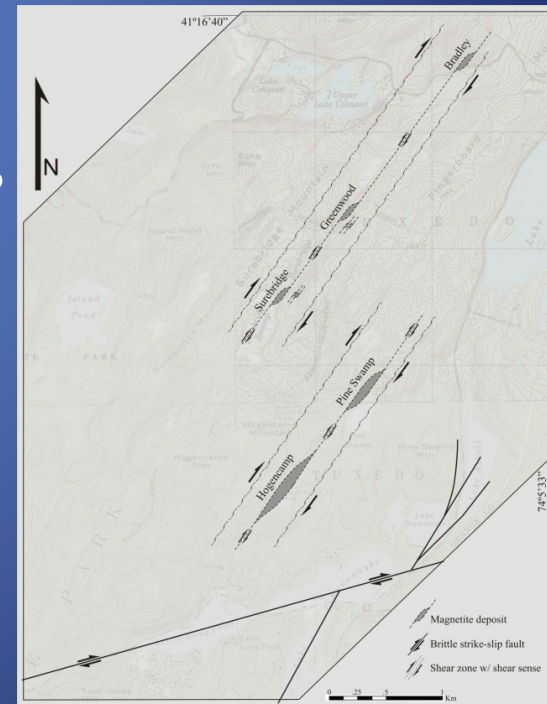
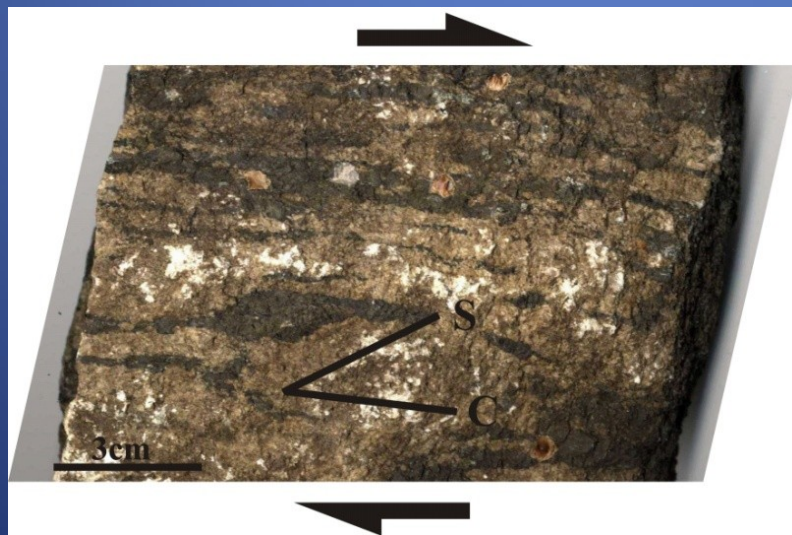
- Calc-silicate Gneiss-
 - Qtz, Pl, Am, Opx, Cpx, & Scp
- Metavolcanic Gneiss-
 - Qtz, Pl, Am, Opx, & Cpx
- Quartzofeldspathic Gneiss-
 - Am, Opx, & Bt
- Lake Tiorati Diorite-
 - Pl, Am, Opx, & Cpx
 - Zircon ~1,008 Ma
 - Granulite facies ~1,024 Ma

-Ottawan phase of Grenville Orogeny-



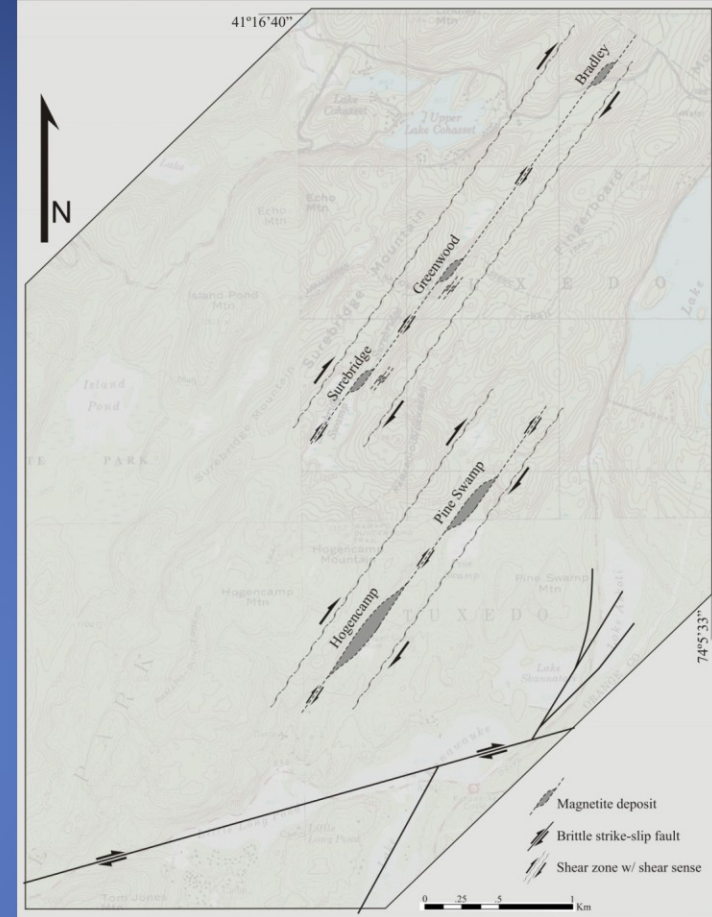
Shear Zones

- Two ~NE trending dextral shear zones
 - ~35 km wide shear system, ~1,008-924 Ma
 - Southeastern and Northwestern zones
 - S-C fabrics, porphyroclasts, & shear bands
 - Steep foliations - shallow lineations
 - Semi-concordant Mag vein deposits



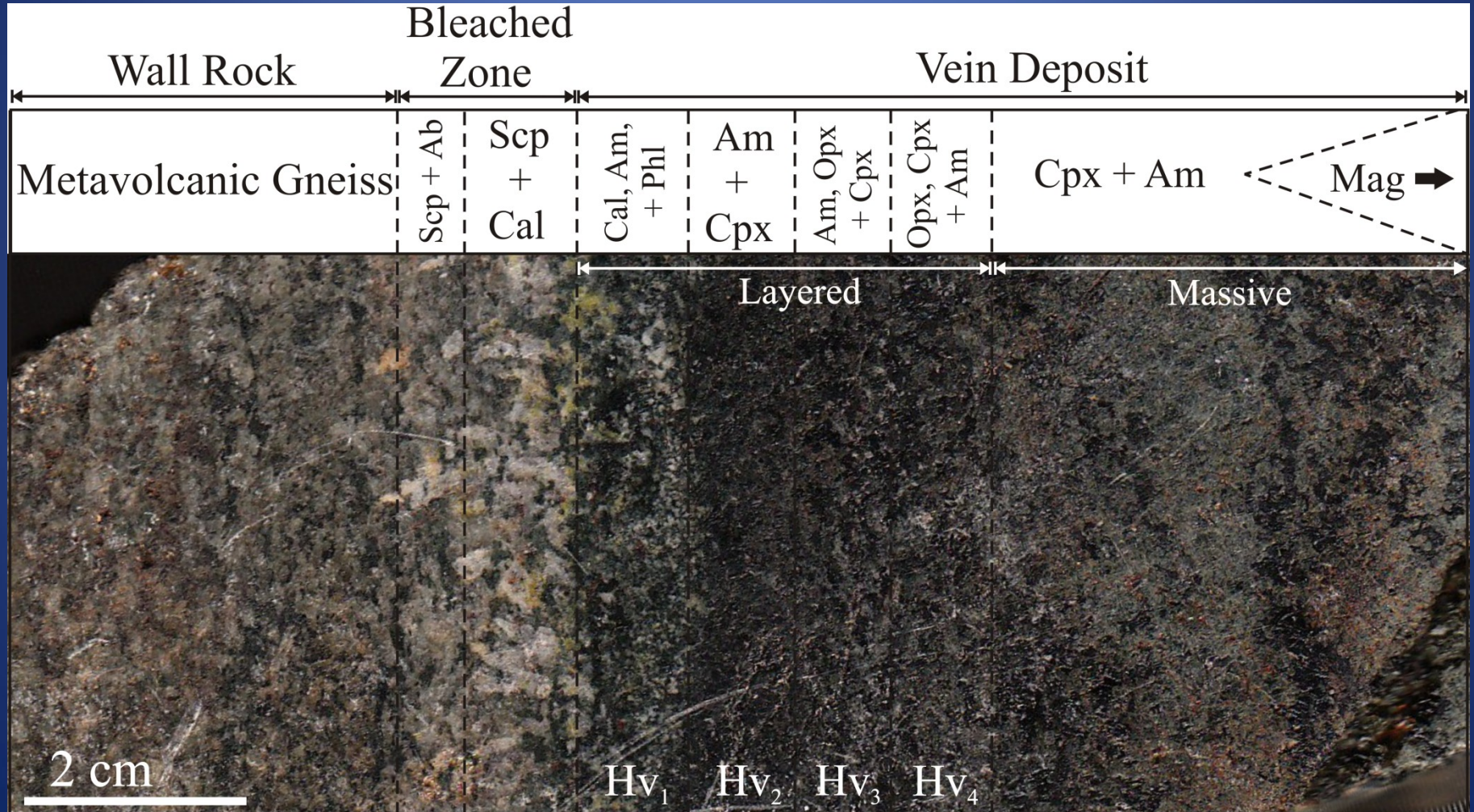
Magnetite Deposits

- Exposed at several mines
 - Southeastern Zone
 - Hogencamp & Pine Swamp
 - Northwestern Zone
 - Surebridge, Greenwood, & Bradley
 - Connected by narrow zones -
- x3 distinct mineral assemblages
 - **Bleached zone*** – Altered wall rock
 - **Layered vein** – Fine-md grained bands of minerals
 - **Massive vein** – Coarse to massive Mag & gangue



Hogencamp Mine

Wall rock, bleached zone, layered & massive vein



Mineral Assemblages

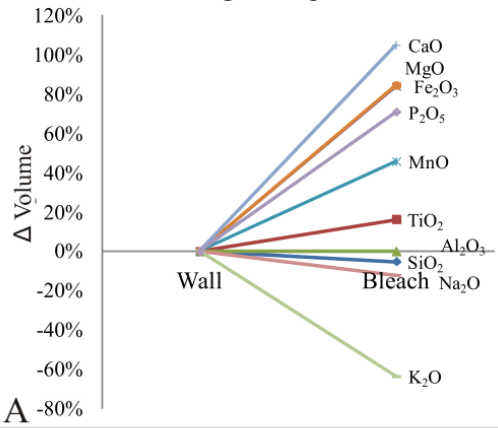
<u>Deposit</u>	<u>Wall Rock</u>	<u>Bleached Zone</u>	<u>Vein Deposit</u>		<u>Interstitial</u>
			<u>Layered</u>	<u>Massive</u>	
Hogencamp	Metavolcanic	Cal	Am	Mag	Cal
	Calc-silicate (Marble)	Scp	Cpx	Cpx	
		Am	Opx	Am	
		Phl	(Cal)	Bt	
		Ab	(Phl)		
	(Ap)	(Bt)			
Pine Swamp	Quartzofeldspathic	Am	Opx	Mag	Py
	Metavolcanic	(Scp)	Am	Opx	Po
		(Bt)	Qtz	Am	
		(Ap)			
Surebridge	Quartzofeldspathic	Am	Am	Mag	Qtz
	Metavolcanic	Ab	Opx	Am	Py
		(Scp)	Mag	Opx	Po
		(Ser)	Qtz		
		(Mag)			
Greenwood	Quartzofeldspathic	Not Present	Am	Mag	Qtz
			Opx	Am	(Py)
			Ab	Opx	(Po)
			Qtz		
			Mag		
Bradley	Calc-silicate	Di	Cpx	Mag	Cal
	Marble	Scp	Phl	Cpx	
		Cal	Cal	Cal	
		Phl	(Py)		

Geochemistry & Mass Transfer

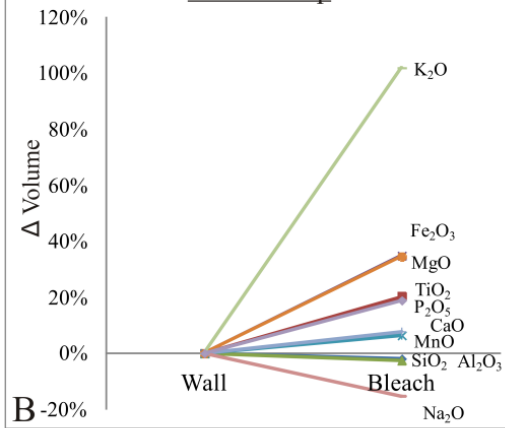
- Geochemistry
 - x12 Samples analyzed - major elements (ICP-OES)
 - x7 Samples analyzed - trace elements (ICP-MS)
 - Wall rock - bleached zones analyzed separately
 - Hogencamp layered vein assemblages (Hv₁-Hv₄)
- Mass Transfer - Isocon Analysis
 - Grant (1987), after Gresens (1967)
 - Assume constant aluminum/titanium
 - Assume gains and losses buffered into fluids
 - Results multiplied by wall rock geochemistry
 - $\Delta g / 100g$ wall rock into the bleached zone
 - Results averaged at each deposit

Mass Transfer - Results

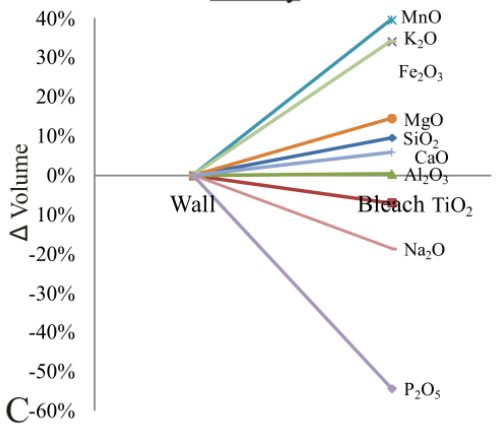
Hogencamp



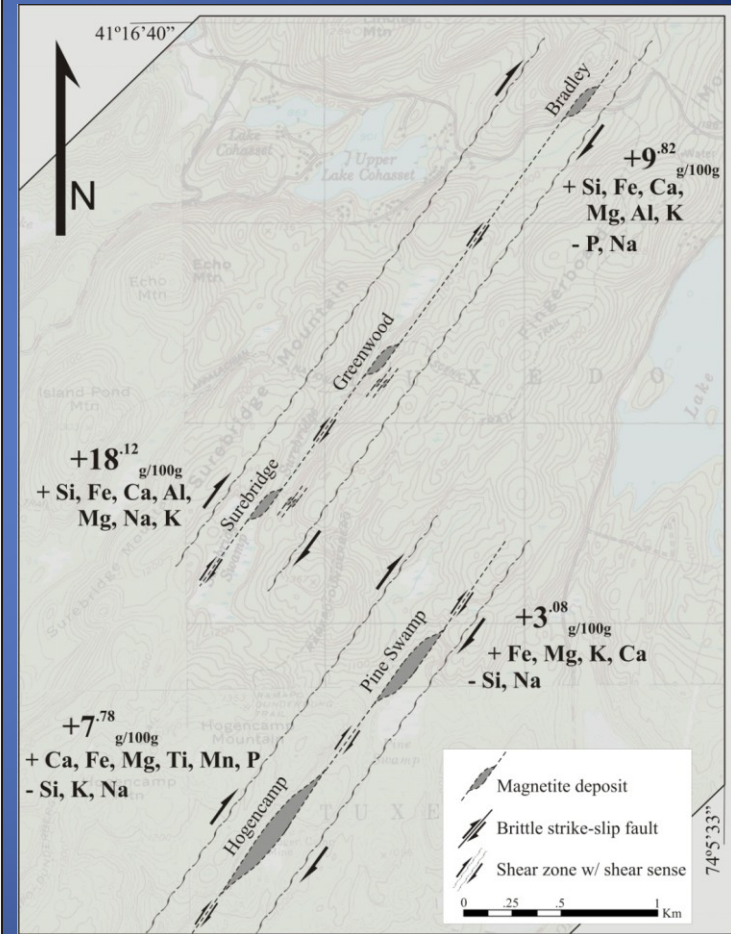
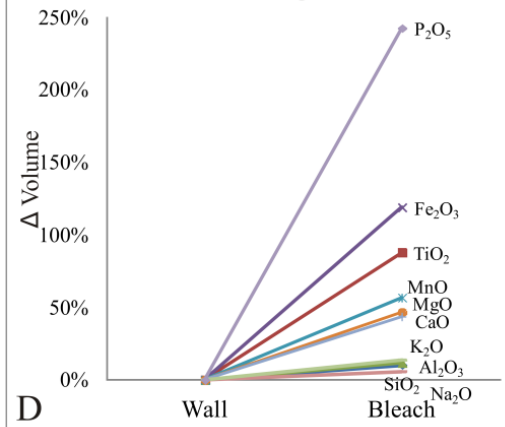
Pine Swamp



Bradley



Surebridge

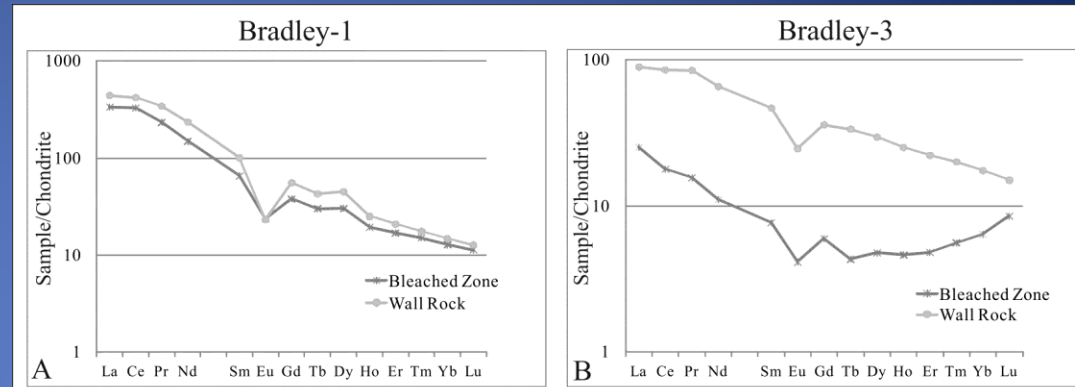


Geochemistry

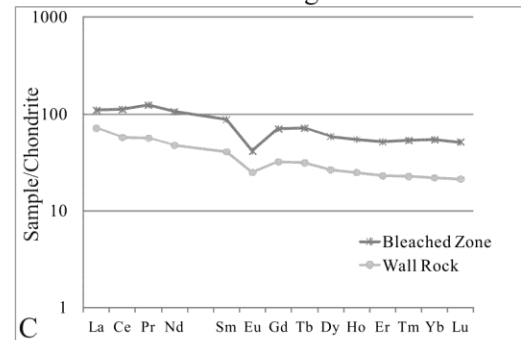
REE Spidergrams

Southeastern

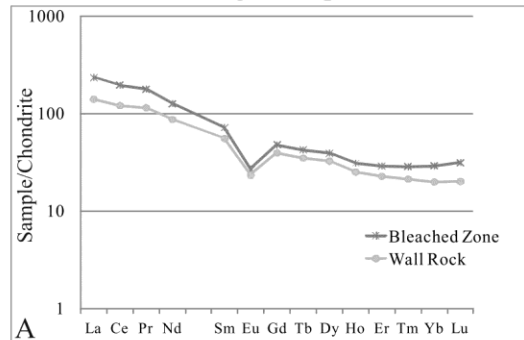
Northwestern



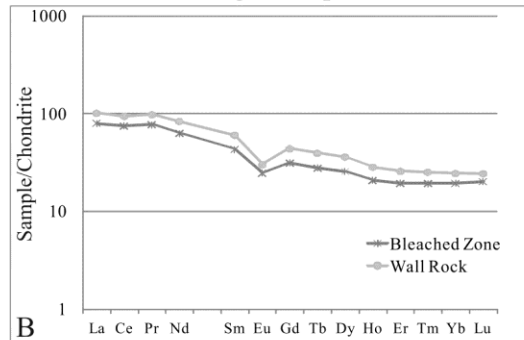
Surebridge-1



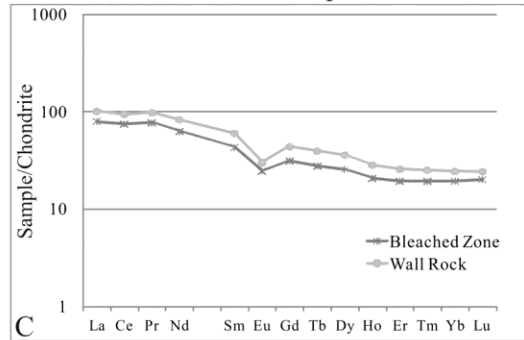
Hogencamp-1



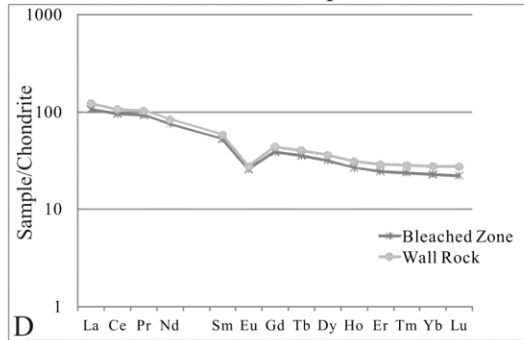
Hogencamp-2



Pine Swamp-1

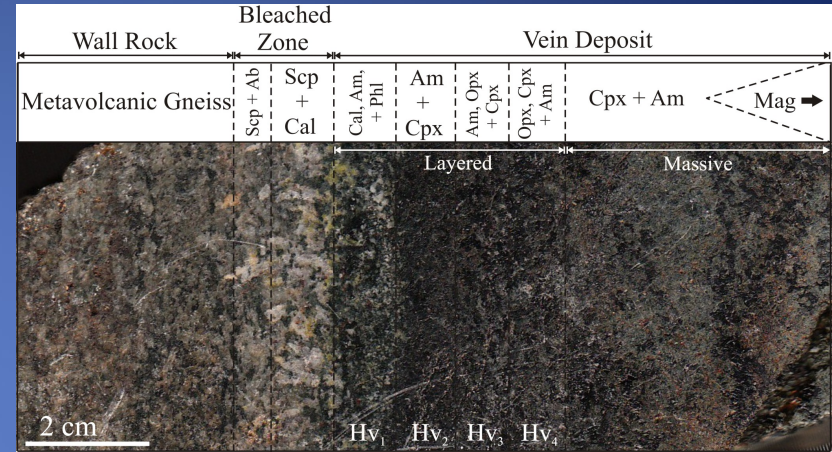
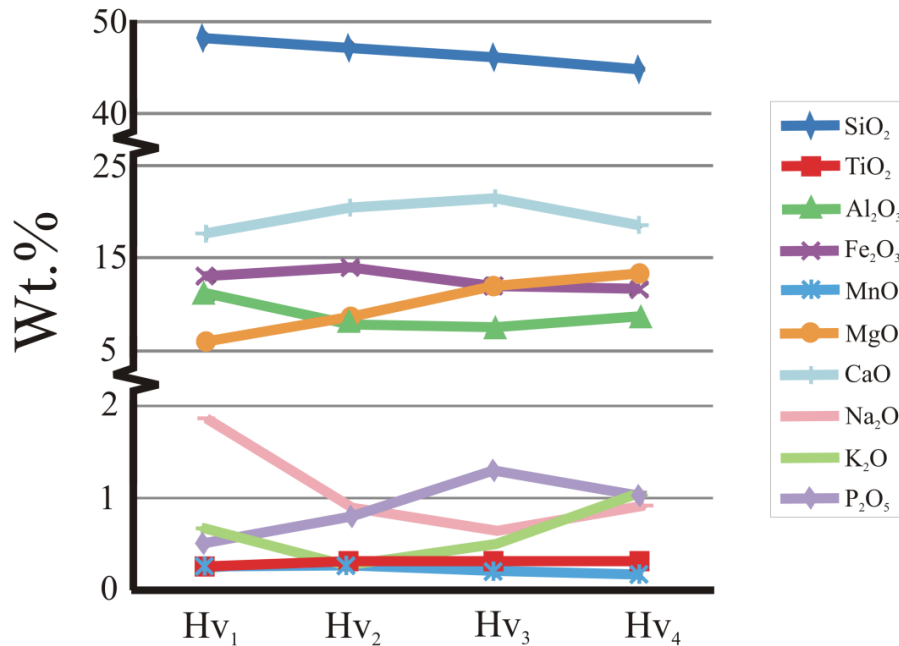


Pine Swamp-2

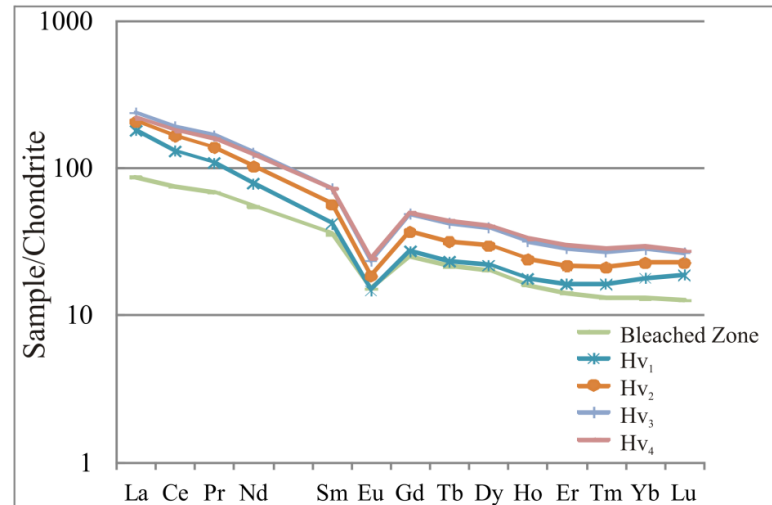


Geochemistry - Layered Vein

Hogencamp Vein



Hogencamp Vein

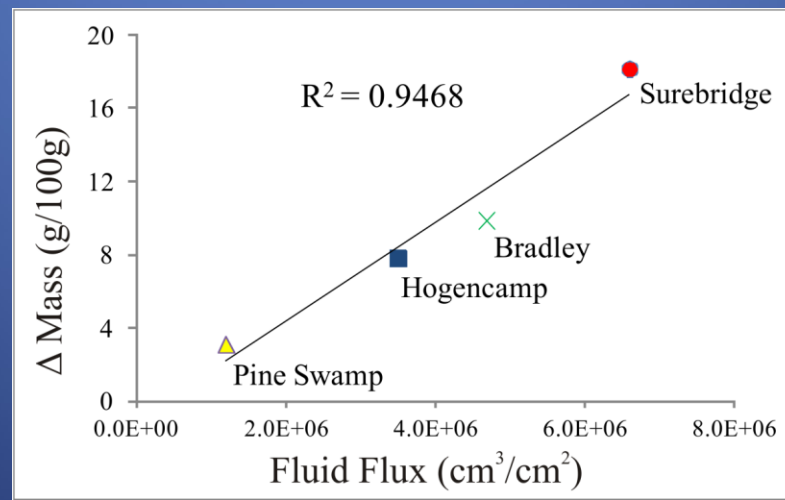


-Majors – Fluctuate

-REE – Parallel Wall rock & Bleached zone

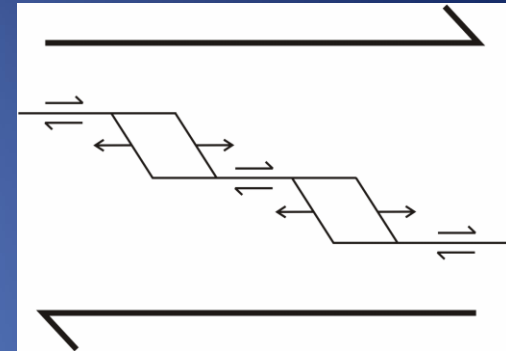
Fluids

- Acidic fluids derived from metavolcanic C-Rx
 - Granulite dehydration Rnx ~1,024 Ma, Diorites ~1,008 Ma
 - Liberated Fe from ferromagnesian minerals C-Rx
- Fluid Flux – Bleached zone assemblages
 - Based on silica mobility (Dipple & Ferry, 91/92)
 - » 1.2 to 6.6 x 10⁶ cm³/cm²
 - 10⁶ to 10⁸ cm³/cm² for major element metasomatism
- δ¹⁸O (Cal from Hogen & Bradley) 13.6 - 14.6 v. MSOW
 - Meta fluid range δ¹⁸O 5 – 25, Granulite facies for carbonates



Model of Formation

- Strike-slip shearing ~ 1,008 – 924 Ma
 - Dilational, right-stepover ‘jogs’ formed
 - Linked by brittle fractures, acted as conduits
 - Captured and channeled fluids – Regional scale
 - Seismic events acted as a pumping mechanism
 - Mixed fluids, control variable open/closed sys behavior
 - Faults sealed via mineralization – Closed system behavior
 - » Internal chemical buffering
 - REE – Closed system behavior
 - Majors (Hogencamp layered vein) – Fluid mixing
 - Further displacement – re-open fault zones
 - Mineralization promoted by
 - Lower pressure, fluid mixing, & neutralization rxn



Model of Formation

– Bleached Zone

- Acidic fluids - Exchange rxn altered wall rock
 - Not observed at the Greenwood deposit
 - » Dilated later, lower T, higher pH, low fluid fluxes?

– Layered Vein

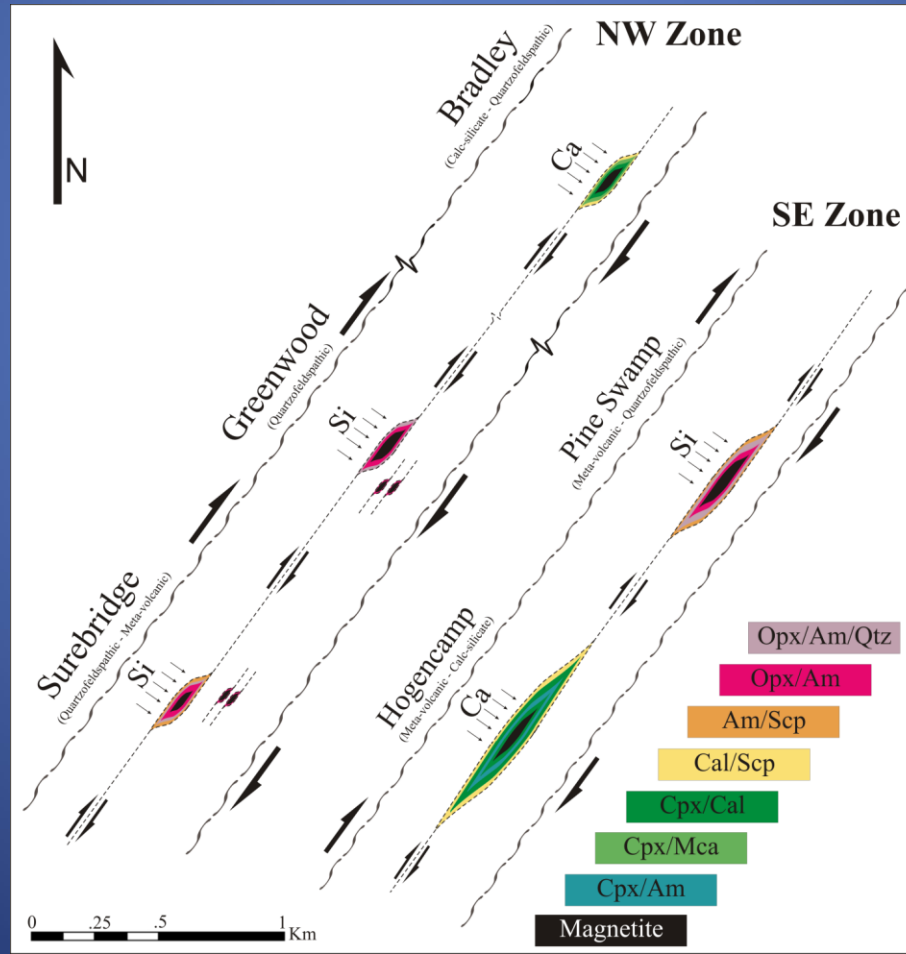
- Nucleation sites primarily along the walls of the vein
- Local fluid mixing within fault zones

– Massive Vein

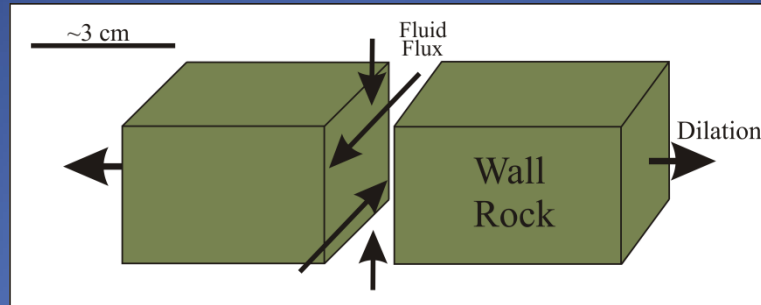
- Fluids became Fe- and volatile-rich
 - Oxides depleted via mineralization, high fluid fluxes
 - Coarse-massive crystallization in fluid filled cavities
 - Overprinted by locally buff fluids – interstitial cement minerals
 - » Calcite, quartz, and sulfides

Vein Assemblages

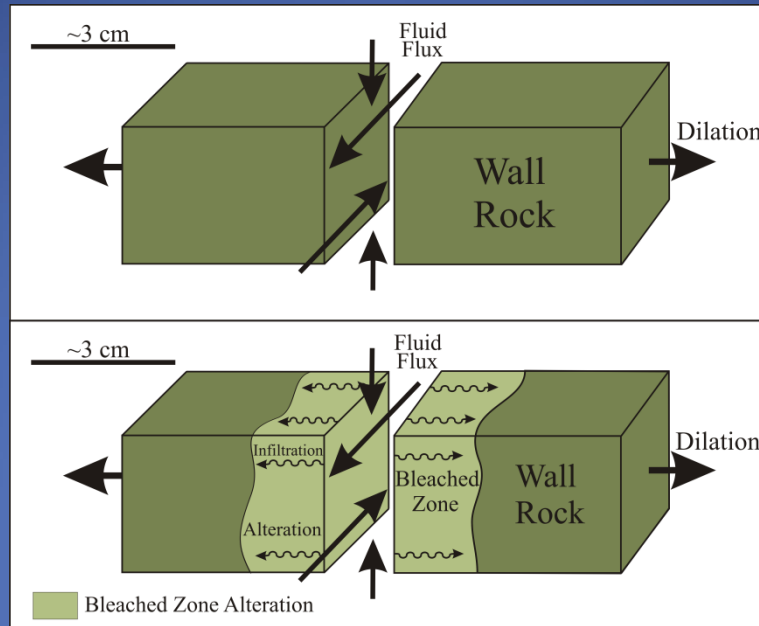
- Local country rock composition controlled assemblages
 - Fluids buffered to composition of country rock
 - Elements in abundance in C-Rx, buffered into fluids
 - Fluid chemistry controlled local assemblages



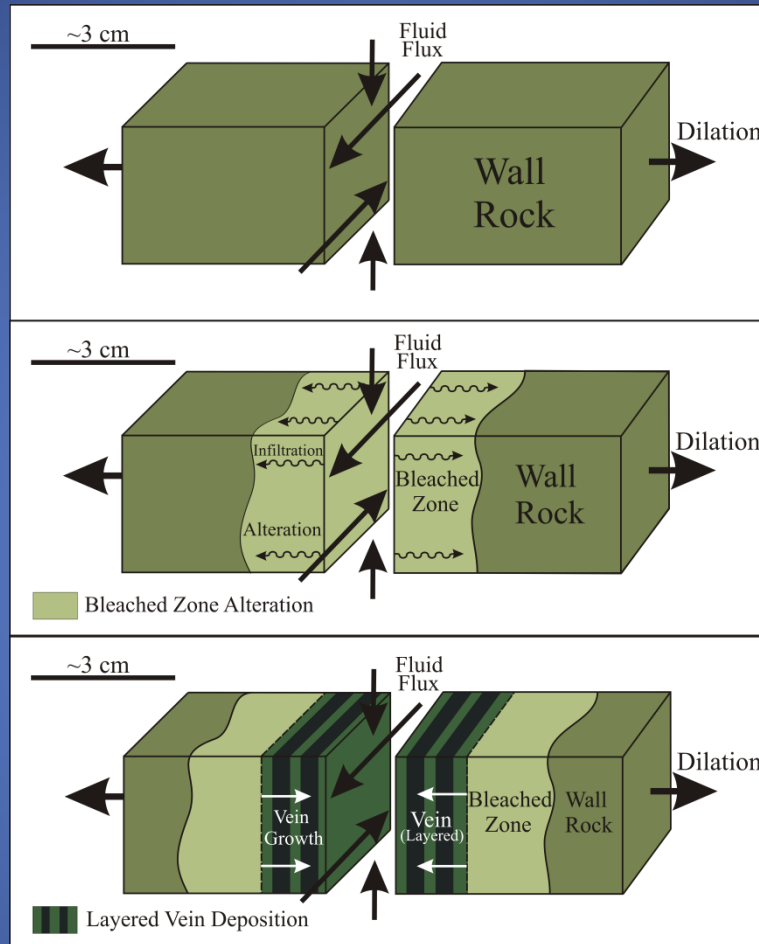
Conclusion



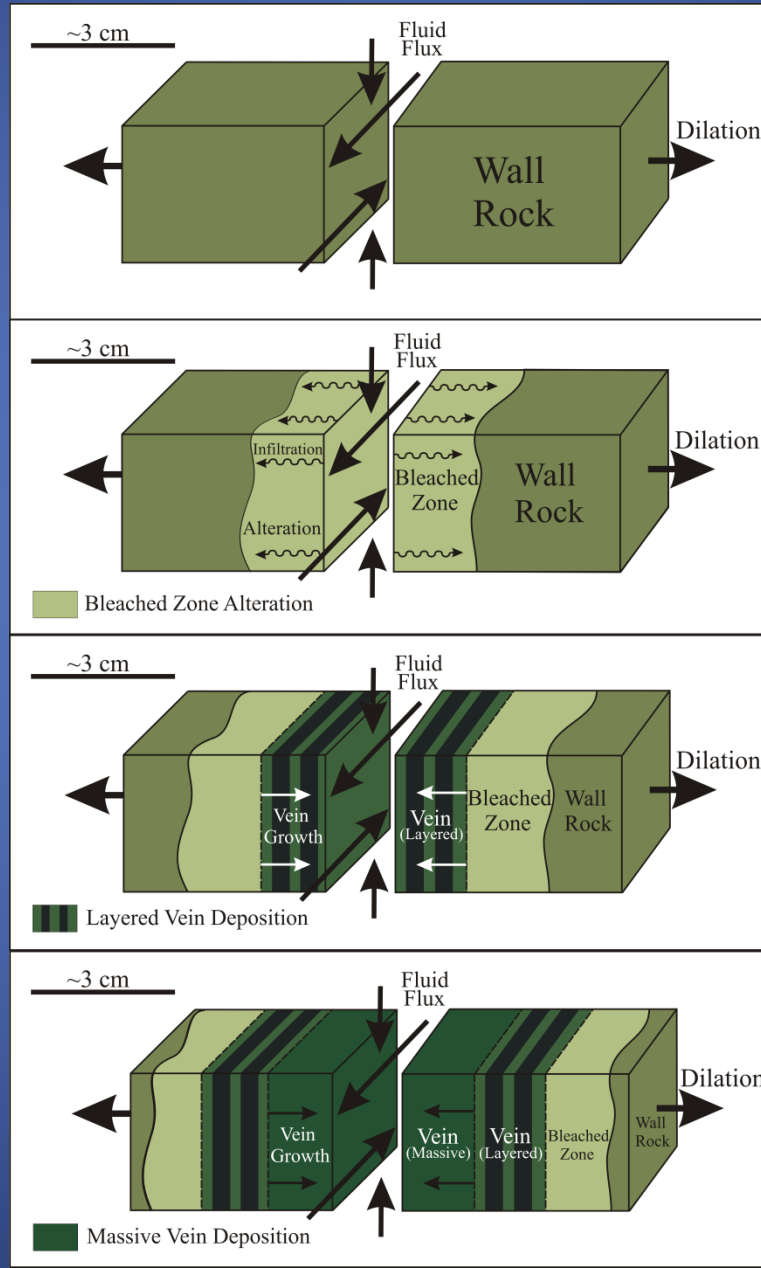
Conclusion



Conclusion



Conclusion



Thank You