The Calvert Mine, Pioneer Mountains, Montana:

A summary of the site geology, pit-lake chemistry, and tungsten-skarn mineralogy

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Montana Tech

Part 1: Geochemistry of the Calvert Pit Lake

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Geochemistry, water balance, and stable isotopes of a "clean" pit lake at an abandoned tungsten mine, Montana, USA

CrossMark

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Mining Pit Lakes

- Form when open pit mines close and dewatering pumps are shut off
- Often contain acidic water with elevated concentrations of metals and metalloids
- Can be a hazard for aquatic life

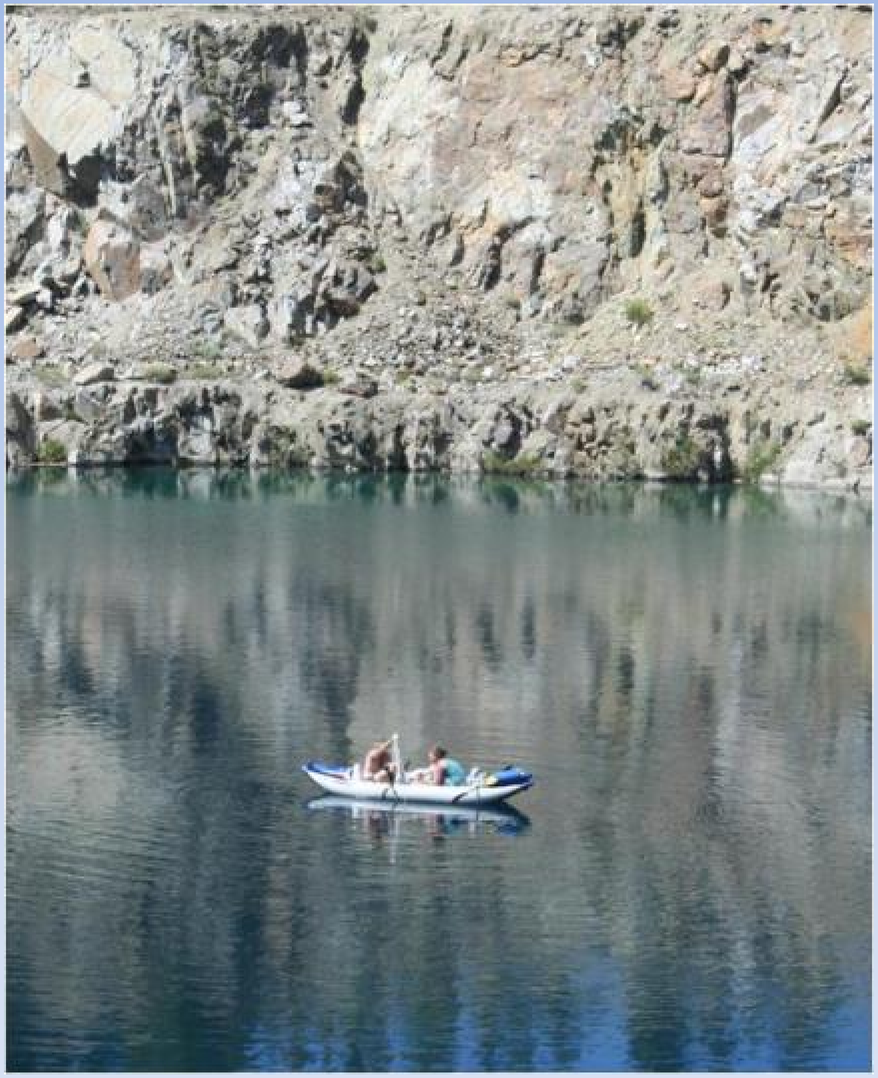
Berkeley Pit lake, Butte, MT
pH 2.6
600 mg/L Zn
1000 mg/L Fe

What about Calvert pit lake?

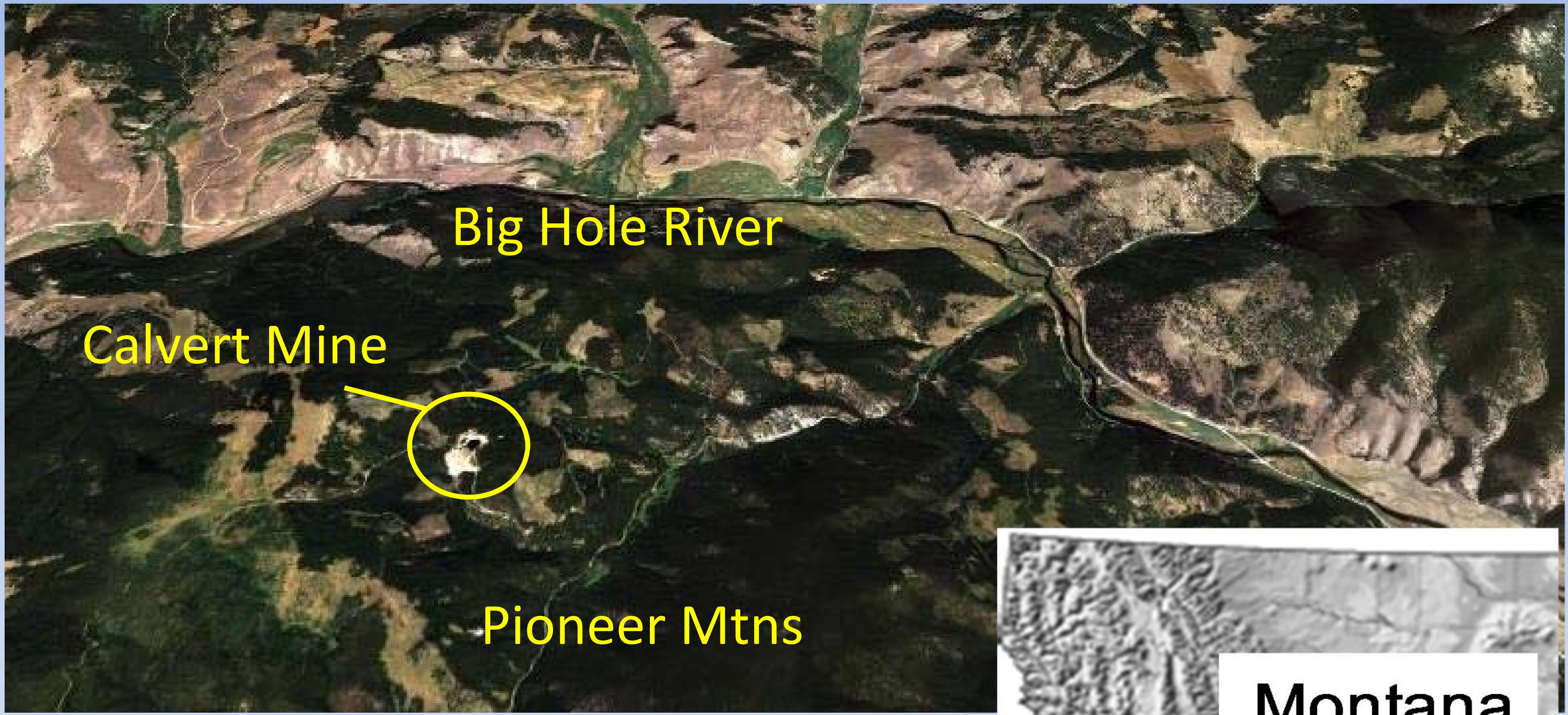
- No pre-existing information
- Visual observations
  - Clear, cold, good visibility.
  - No visible evidence of acid mine drainage.
  - Plenty of aquatic insects. Past reports of trout. Toads (indicator species).
  - Local swimming hole!

Objectives of pit lake study

- Barbara Pape non-thesis M.S. project
- Characterize the chemistry, hydrology, and limnology
- Evaluate seasonal changes in lake stratification
- Identify possible water quality problems



Location



- Beaverhead National Forest
- Elevation ~ 7100 ft

Calvert Mine

Site History

- Open pit tungsten mine
- 110,000 tons of ore mined, 1956 - 1961
- Ore hauled to Melrose, MT for milling
- Average grade roughly 1% WO_3
- Principle ore mineral: Scheelite ($CaWO_4$)
- Main pit lake flooded after mining ceased
- Mine was listed as abandoned in 1983
- Recent interest by small mining company

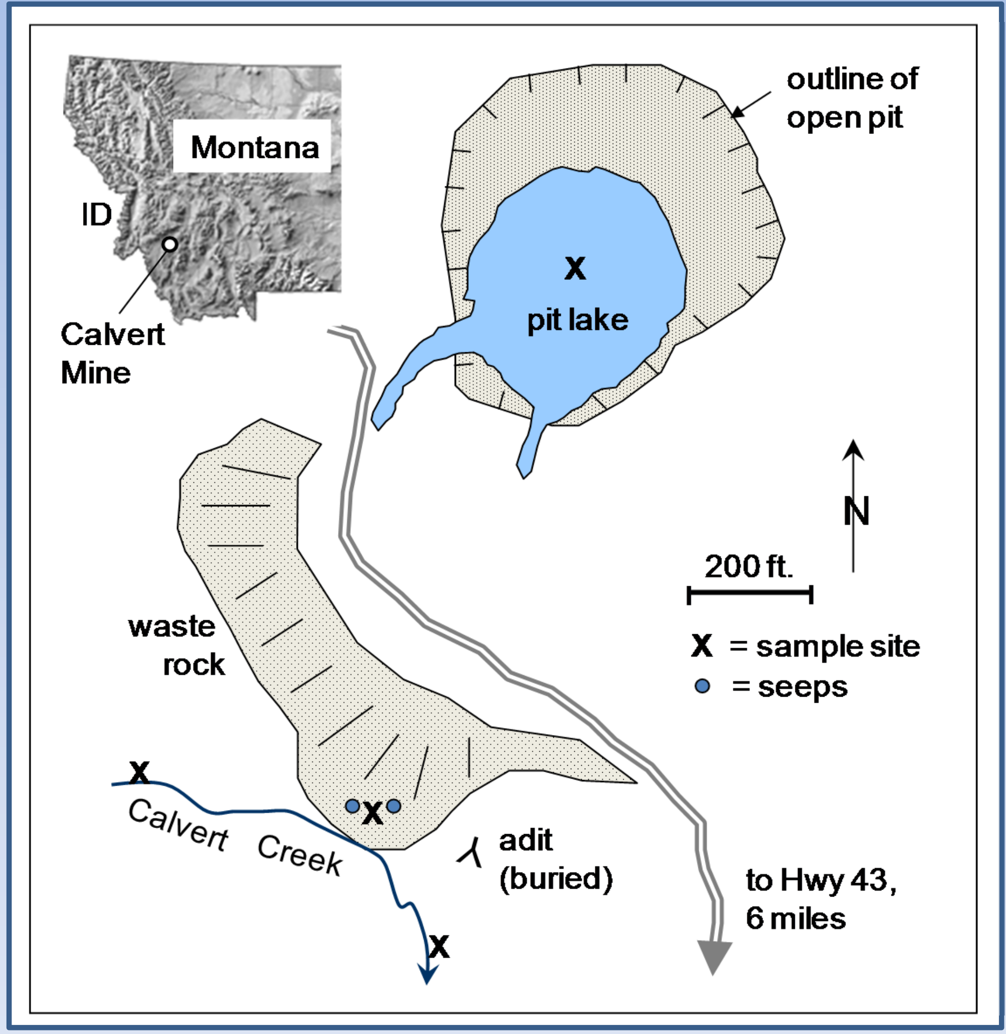
Geology

- Cretaceous tonalite/granodiorite intruding Paleozoic limestone
- Pockets of marble and epidote-garnet skarn (well-known mineral locality)
- Very few sulfide minerals!

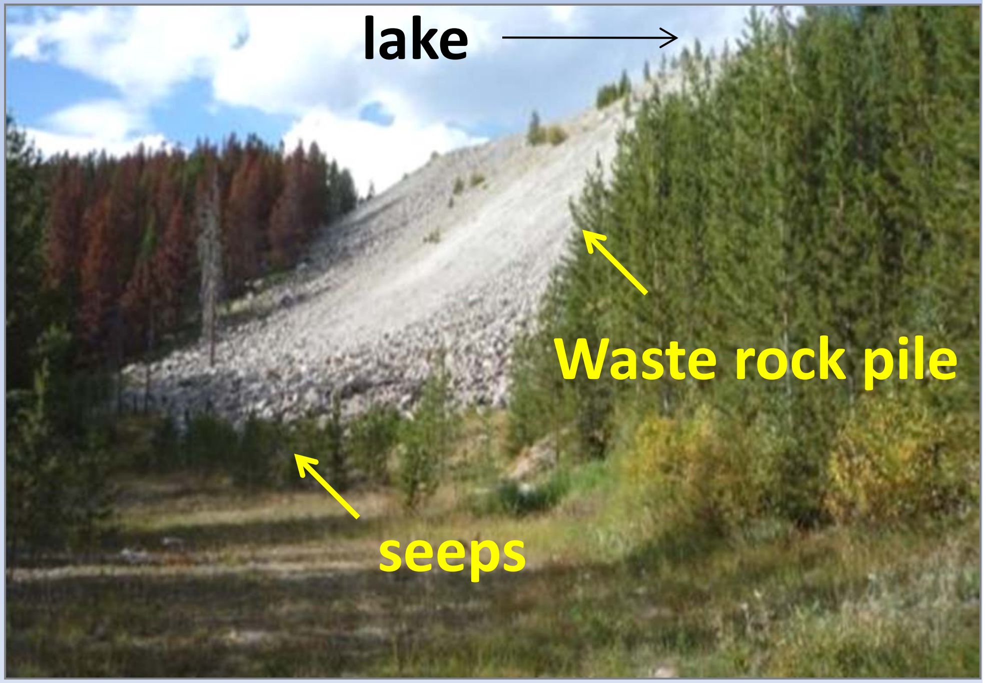
Epidote (green) and calcite (gray)

Site Conditions

- Pit lake
  - 90 ft deep
  - 350 x 410 ft diameter
- No inlet or outlet
  - Fed by groundwater and direct precipitation
  - Evapo-concentration
- Small seeps at bottom of waste rock
  - Contamination?



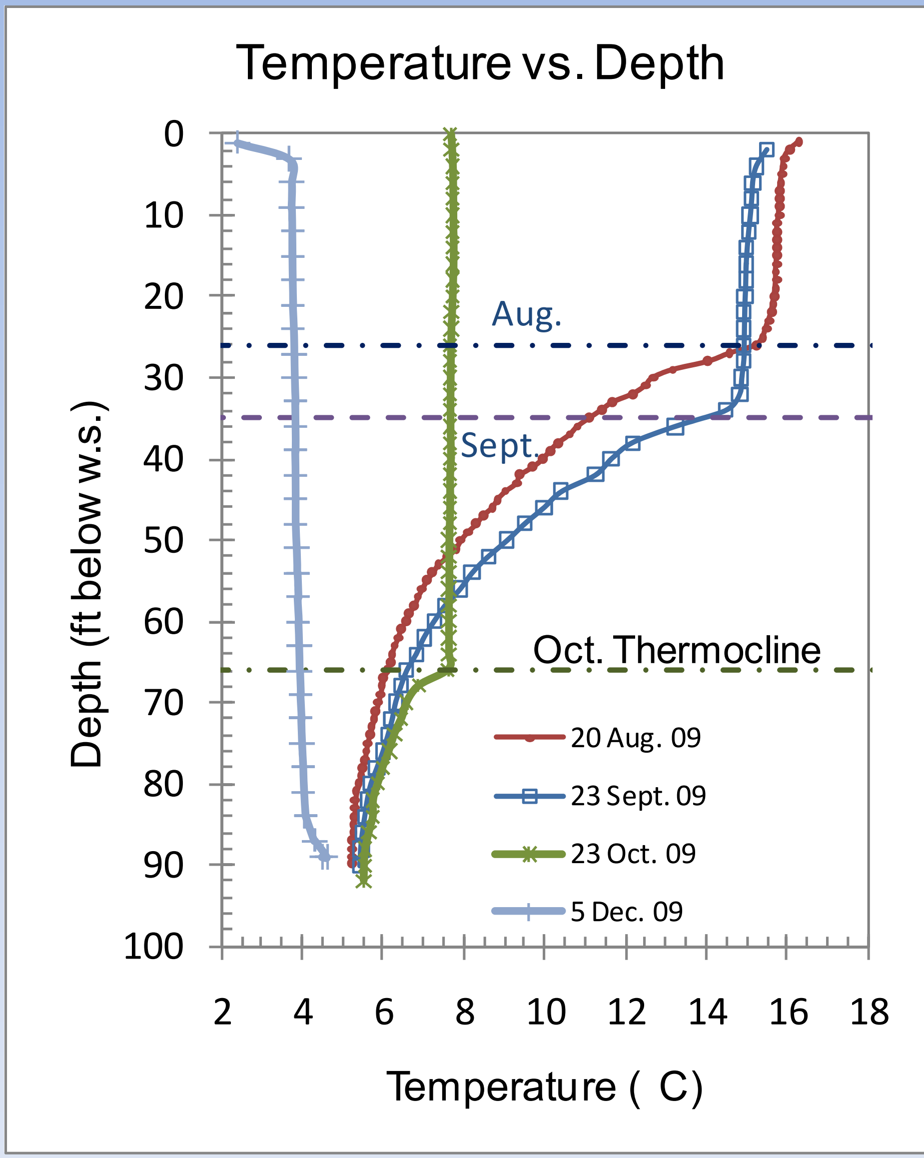

Calvert Creek

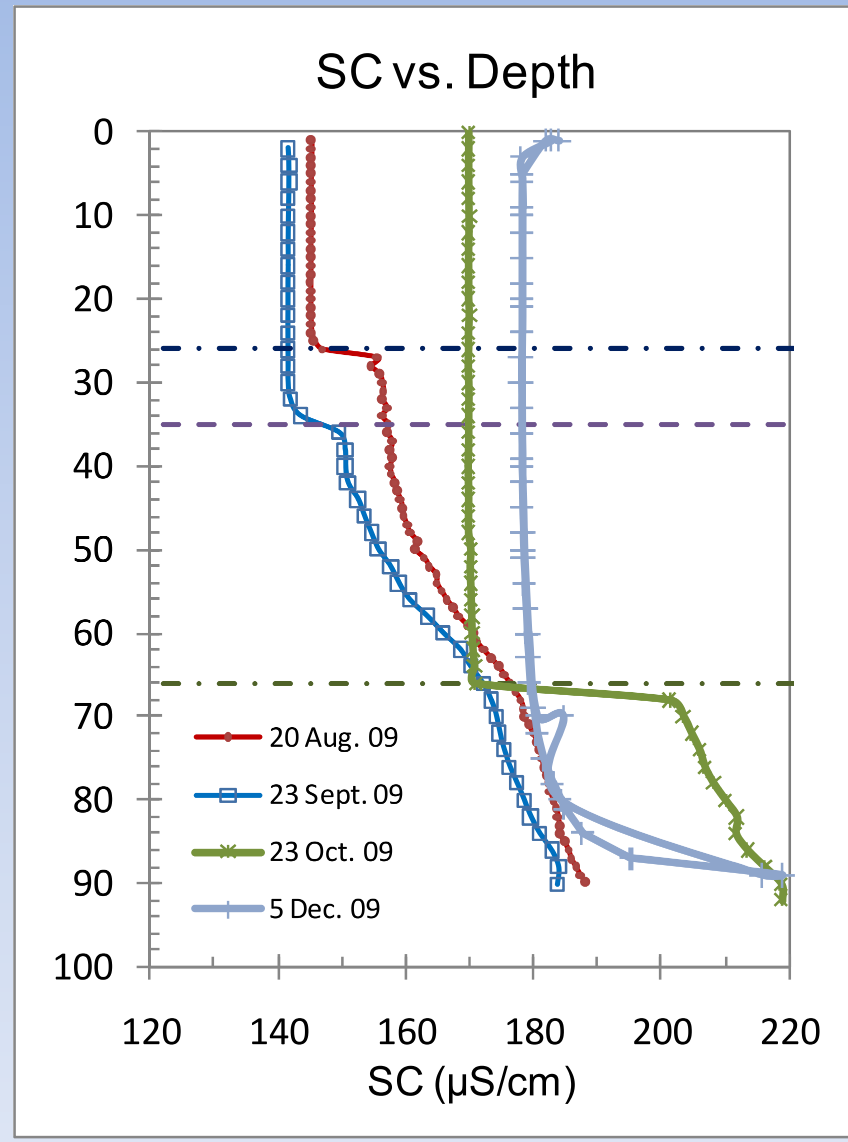

lake
Waste rock pile
seeps

Methods: Barb Pape M.S. study

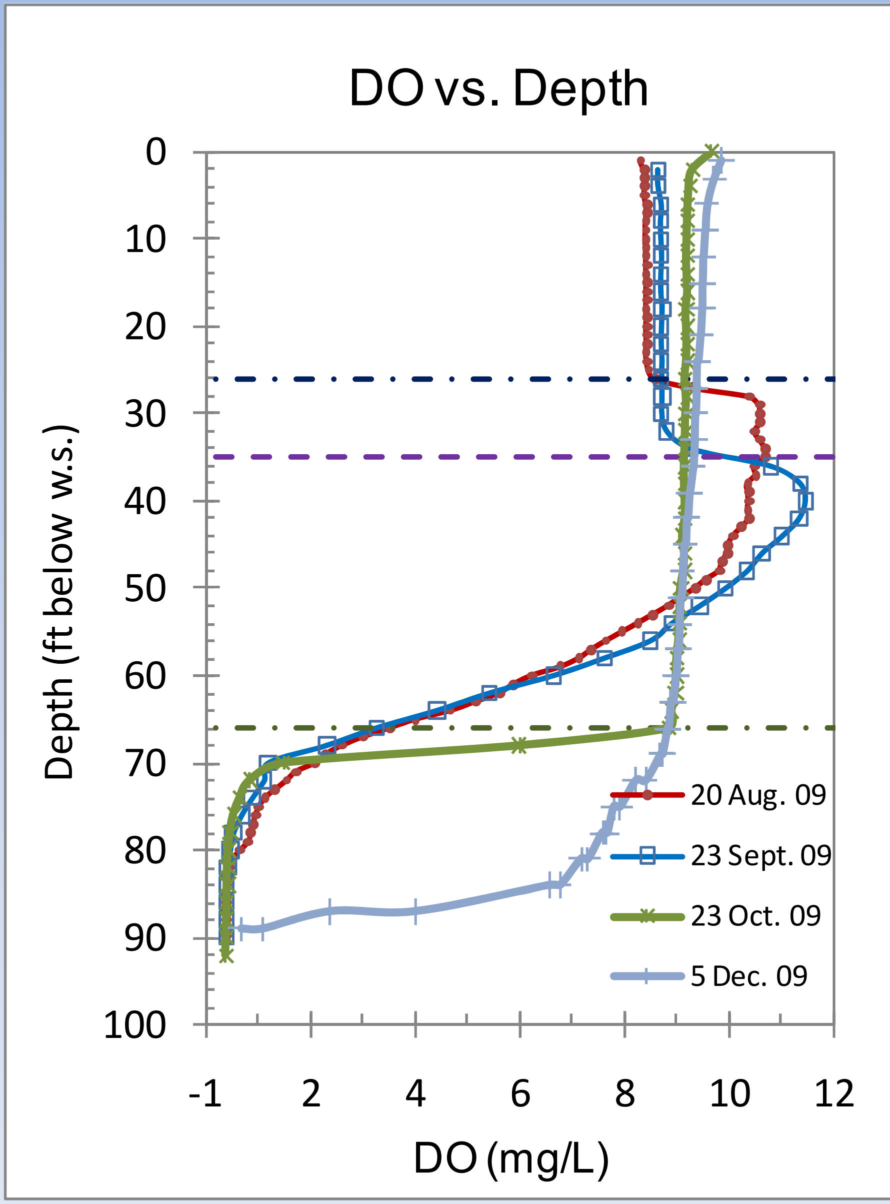
- Field Data Collection
  - Aug., Sept., Oct., Dec. 2009.
- Field Methods
  - Lake Depth Profiles
  - Seeps and Creek
- Laboratory Methods
  - Metals by ICP-AES (EPA Method 200.7)
  - Anions and nutrients by IC (EPA Method 300.0)
  - $\delta^{18}O$ and δD of water, $\delta^{13}C$ of DIC by IRMS
  - $\delta^{18}O$ of dissolved oxygen

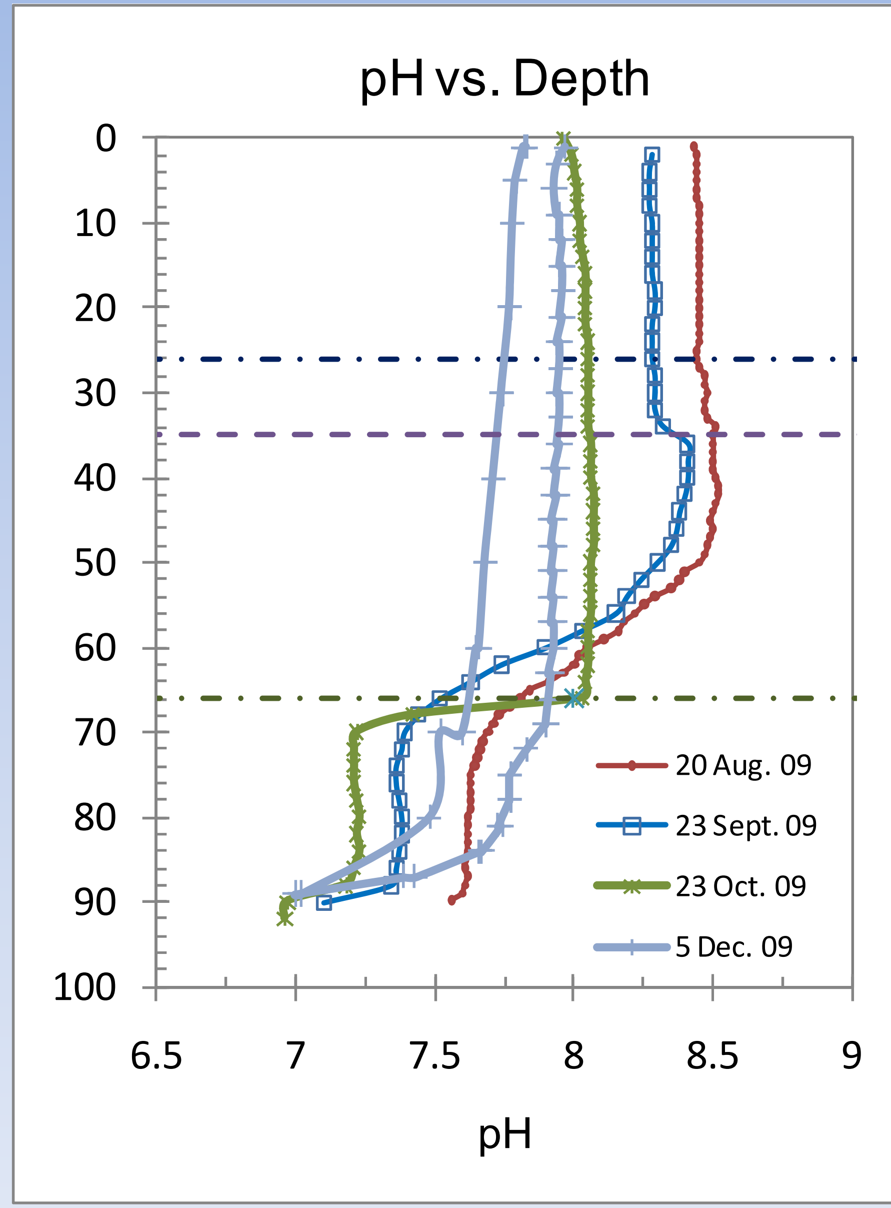
Results: Water Quality Profiles

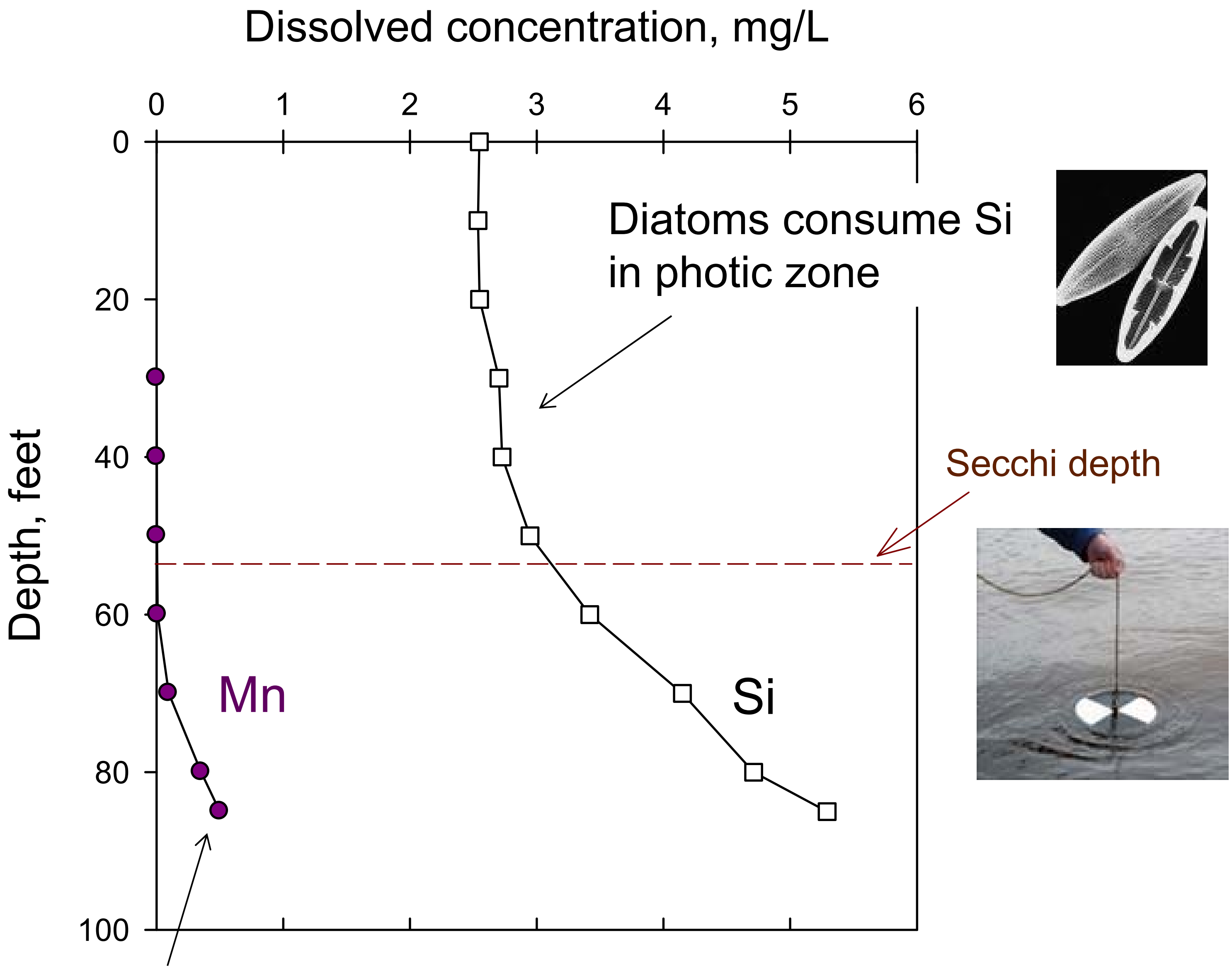




$$CO_2 + H_2O \leftrightarrow CH_2O(org) + O_2$$







Mn-reducing bacteria in anoxic bottom water

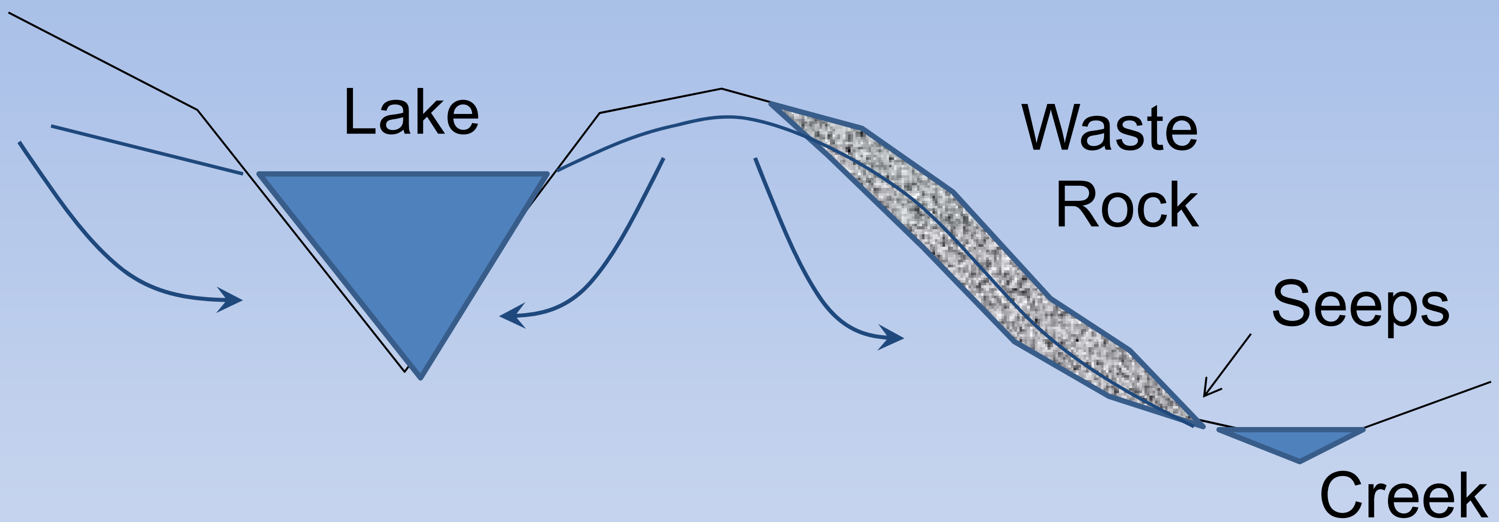
$MnO_2 + \frac{1}{2} C_{org} + 2H^+ \rightarrow Mn^{2+} + \frac{1}{2}CO_2 + H_2O$

Other trace metals in the lake*

Element	Concentration, μg/L
As	1.5 to 1.7
Cd	< 0.05
Co	< 0.1
Cu	< 0.4
Mo	3.5
Ni	< 0.1
Pb	< 0.15
Se	0.11 to 0.14
U	3.1 to 3.3
W	14 to 26
Zn	< 0.9

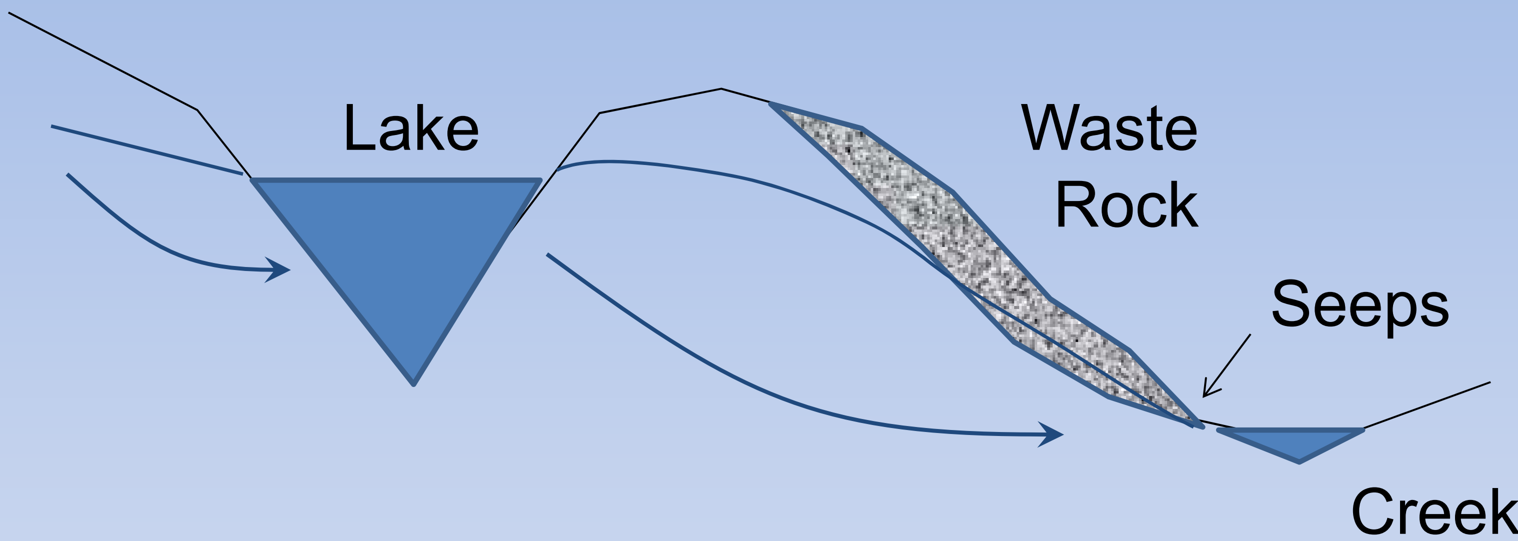
* Metal concentrations in the seeps also very low (data not shown)

Is the pit-lake connected to the creek?



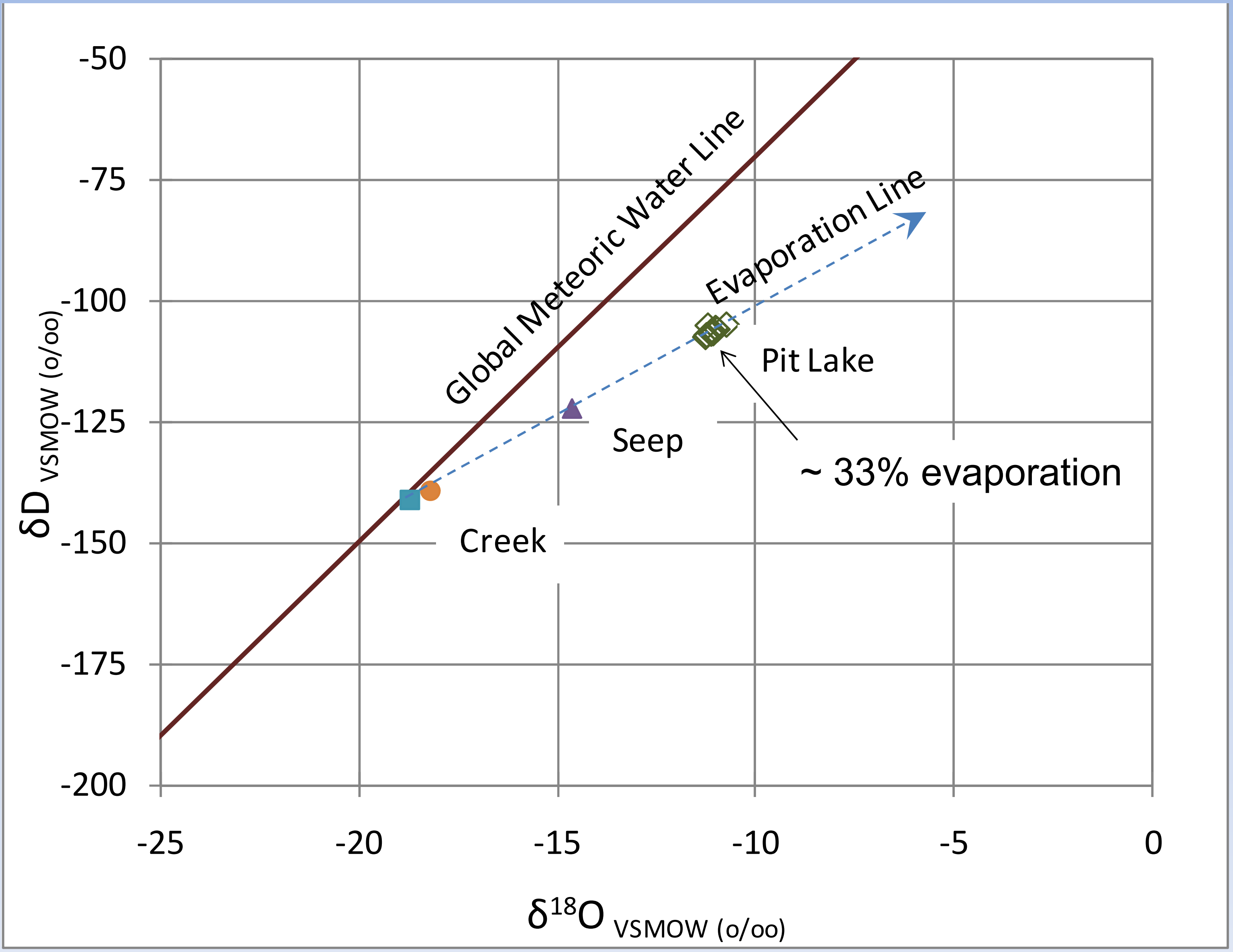
"Terminal Lake" scenario

Is the pit-lake connected to the creek?



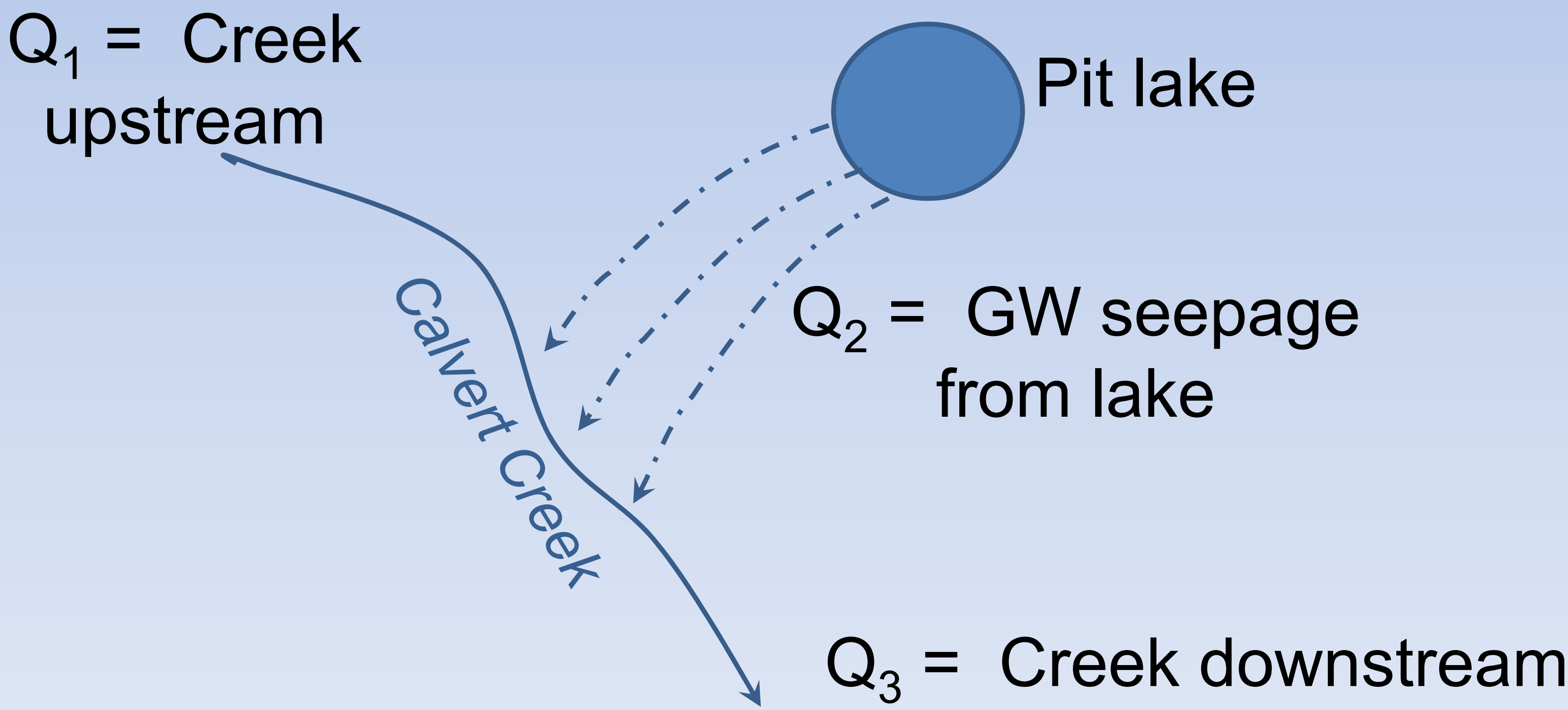
“Flow-through” or “Leaky Lake” scenario

Water Isotope Analyses – δD, $\delta^{18}O$



Estimate seepage from lake to creek

1. $Q_1 + Q_2 = Q_3$
2. $Q_1 \cdot \delta^{18}O_1 + Q_2 \cdot \delta^{18}O_2 = Q_3 \cdot \delta^{18}O_3$



Results

- An estimated 1 L/sec of lake water enters Calvert Creek
- This is probably fairly steady year round
  - lake elevation only changes a few feet seasonally
- Estimated residence time of water in pit lake is about 2.5 years
- Through-flow of water through the lake helps to maintain excellent water quality

Conclusions: Part 1

- This mining lake has very good water quality!
- Lake is seasonally stratified but mixes annually
- Geology buffers lake chemistry to neutral pH
- Isotopes show evidence of evaporation
- Lake is connected to Calvert Creek
- Very low metal & nutrient concentrations
  - Mn, Si, P increase near bottom of lake

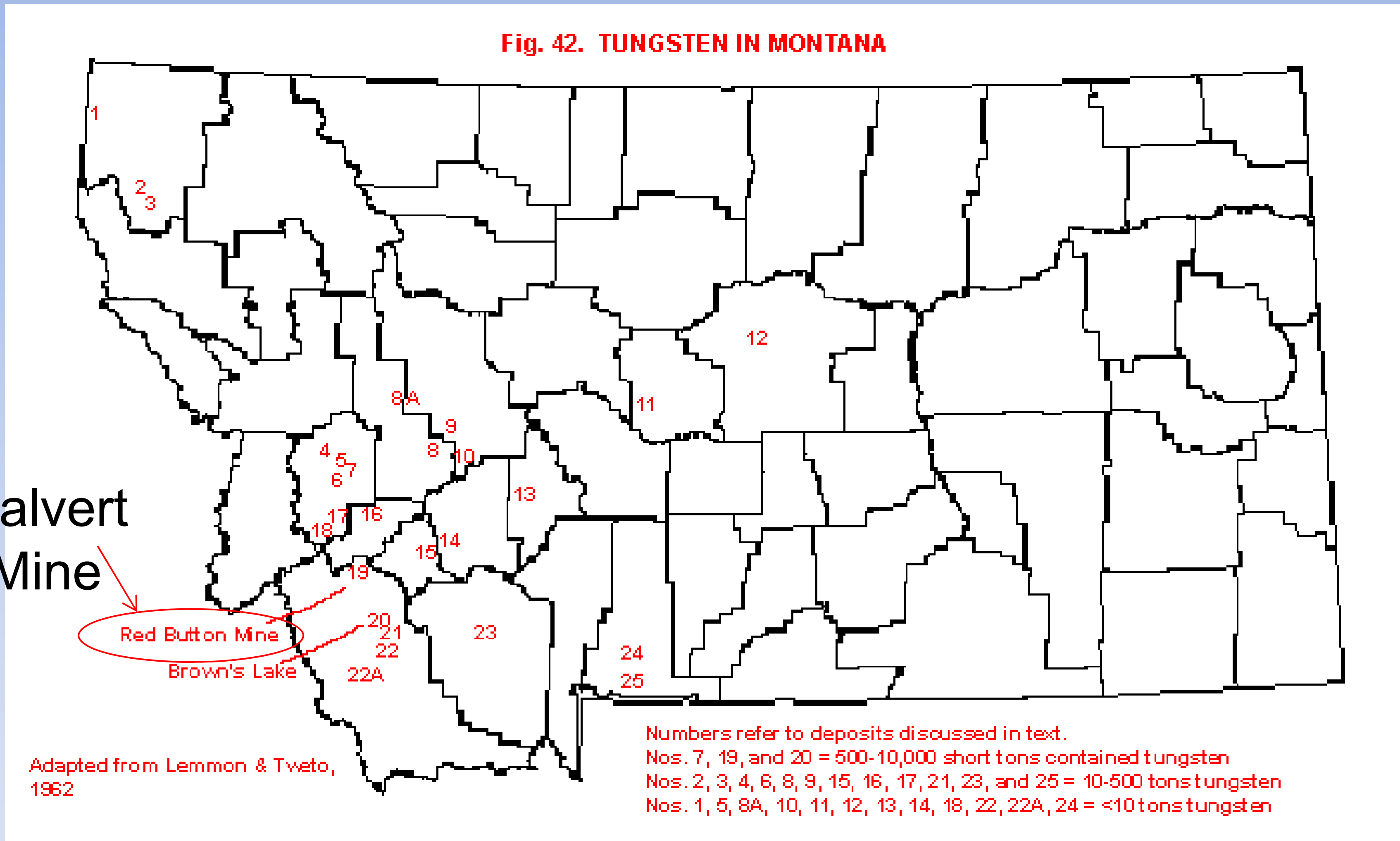
Part 2

Mineralogy & geochemistry of Calvert skarn

M.S. student Josh Messenger (in progress)

Tungsten deposits of Montana (mostly skarns)

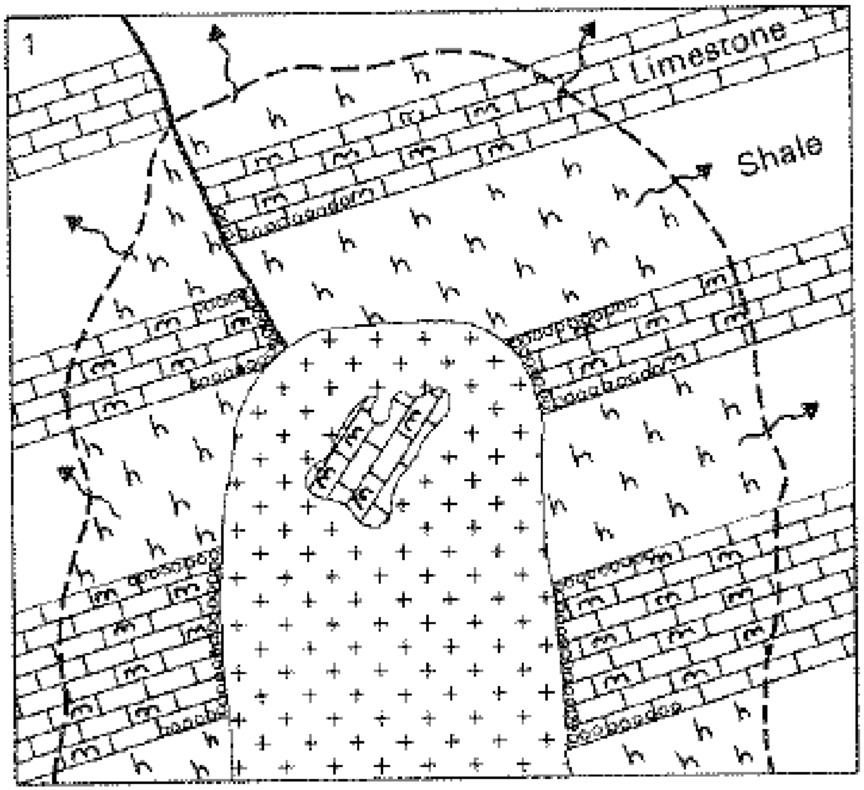
Calvert Mine

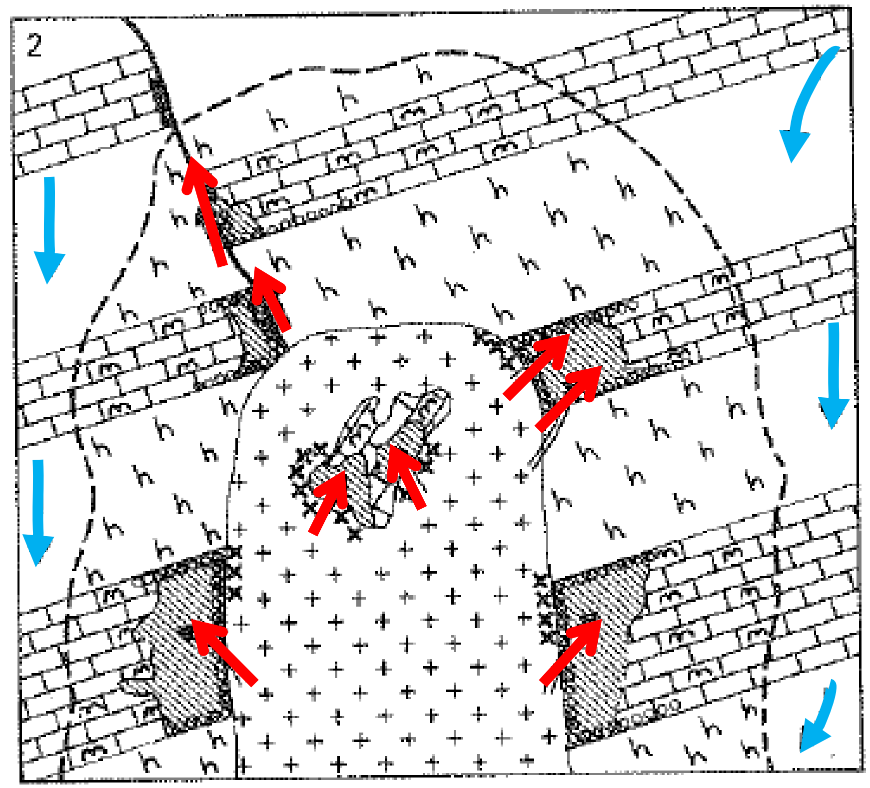


http://www.mbmg.mtech.edu/sp28/minm-sod.htm

1. Heat creates contact metamorphic aureole.

2. Prograde skarn



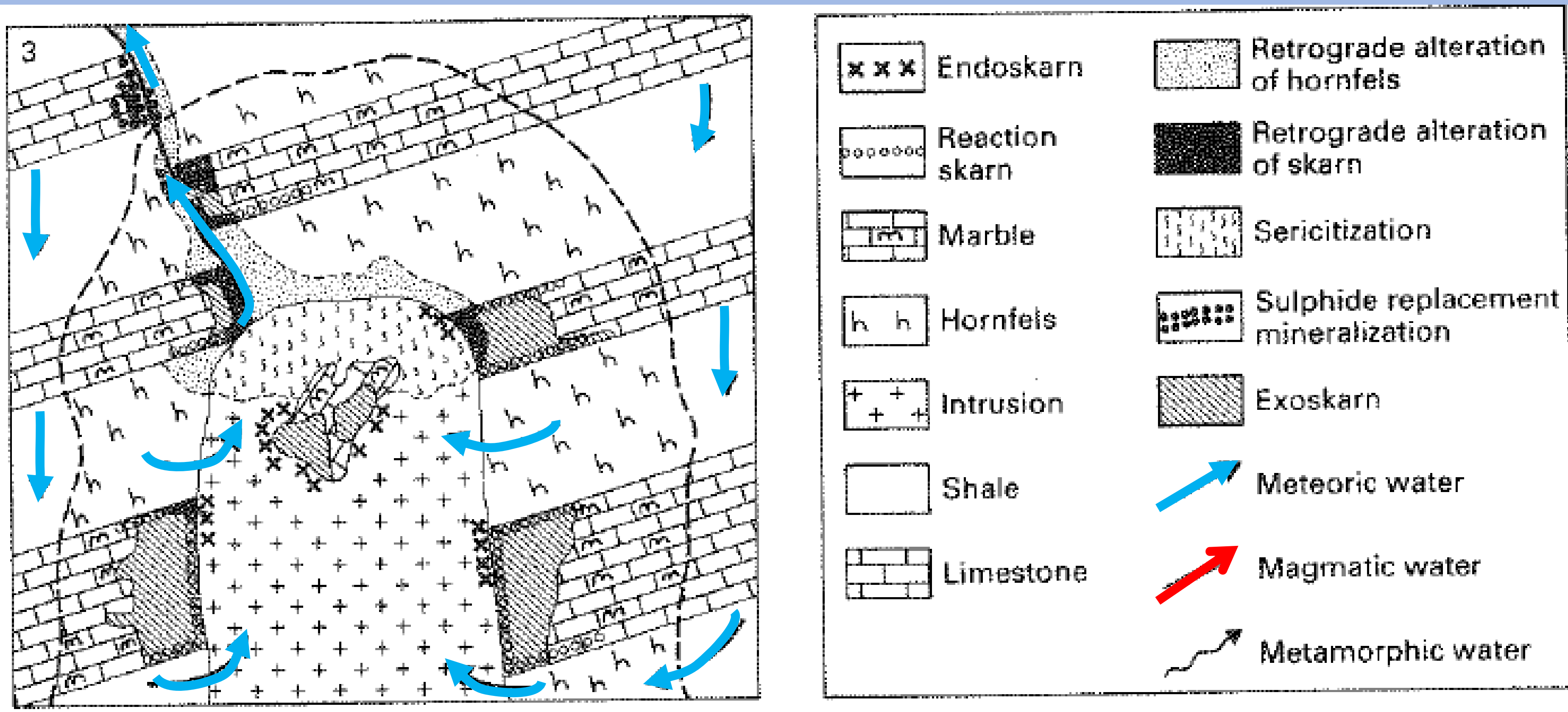


Metamorphic water (+ CO_2) expelled from rock
Note “roof pendant” of marble

Magmatic fluids (red) mineralize **exoskarn** (shaded) and **endoskarn** (xxx pattern).

from Evans (1993) textbook

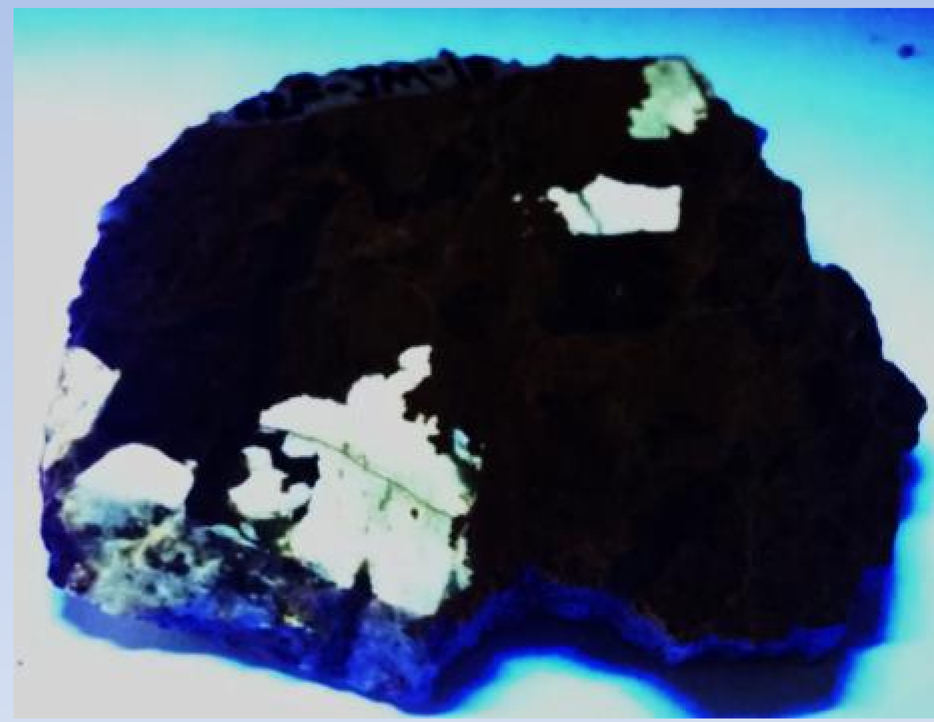
3. Retrograde skarn



Meteoric fluids (blue… heated groundwater) add H_2O back to the rock… form hydrous skarn minerals. May re-distribute some metals (e.g., gold).

from Evans (1993) textbook

Example hand samples
Garnet-scheelite prograde skarn

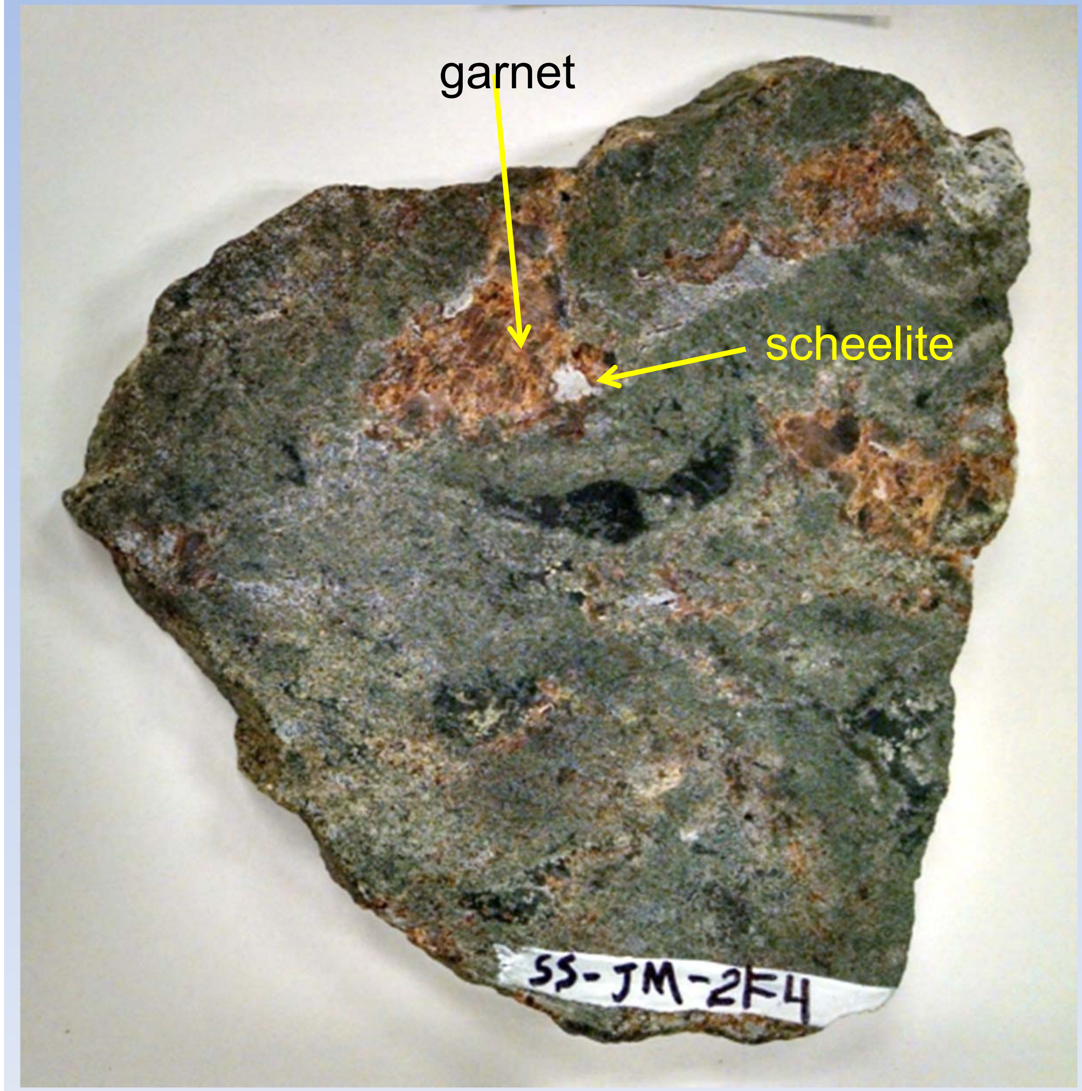


Normal light

(10 cm sample)

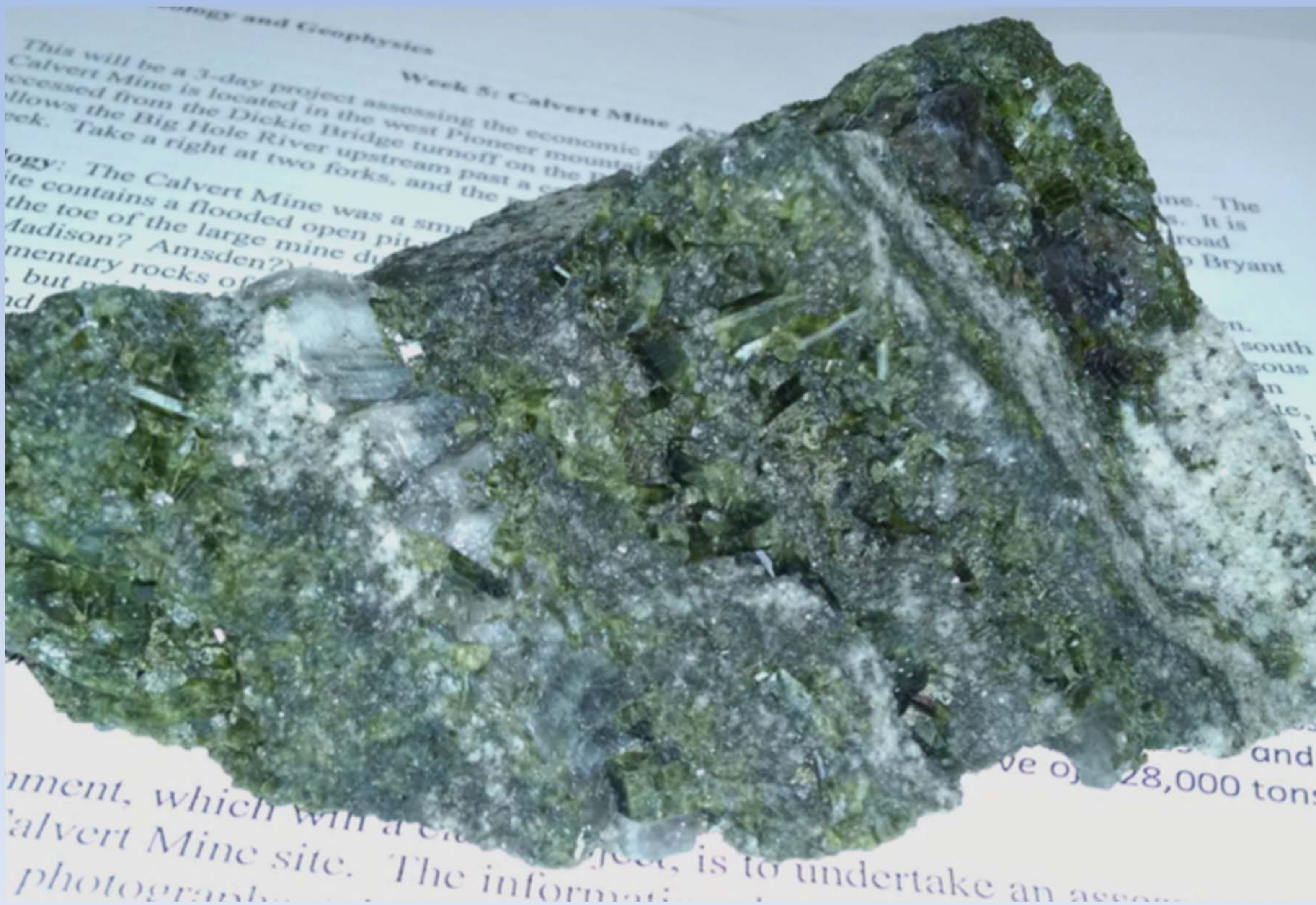
UV lamp

Retrograde skarn

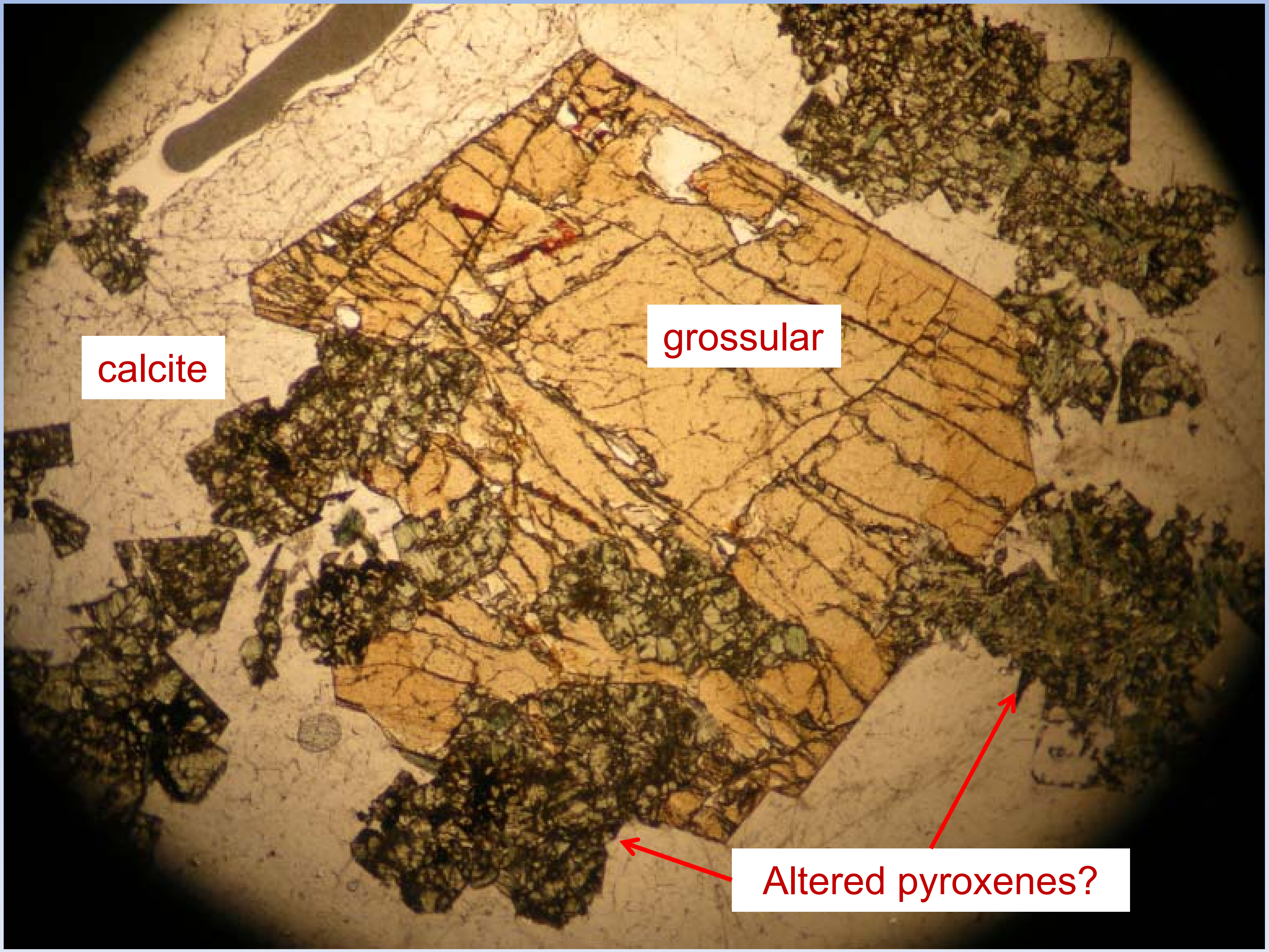


- All pyroxene altered to actinolite (green)
- Some garnet and scheelite remains

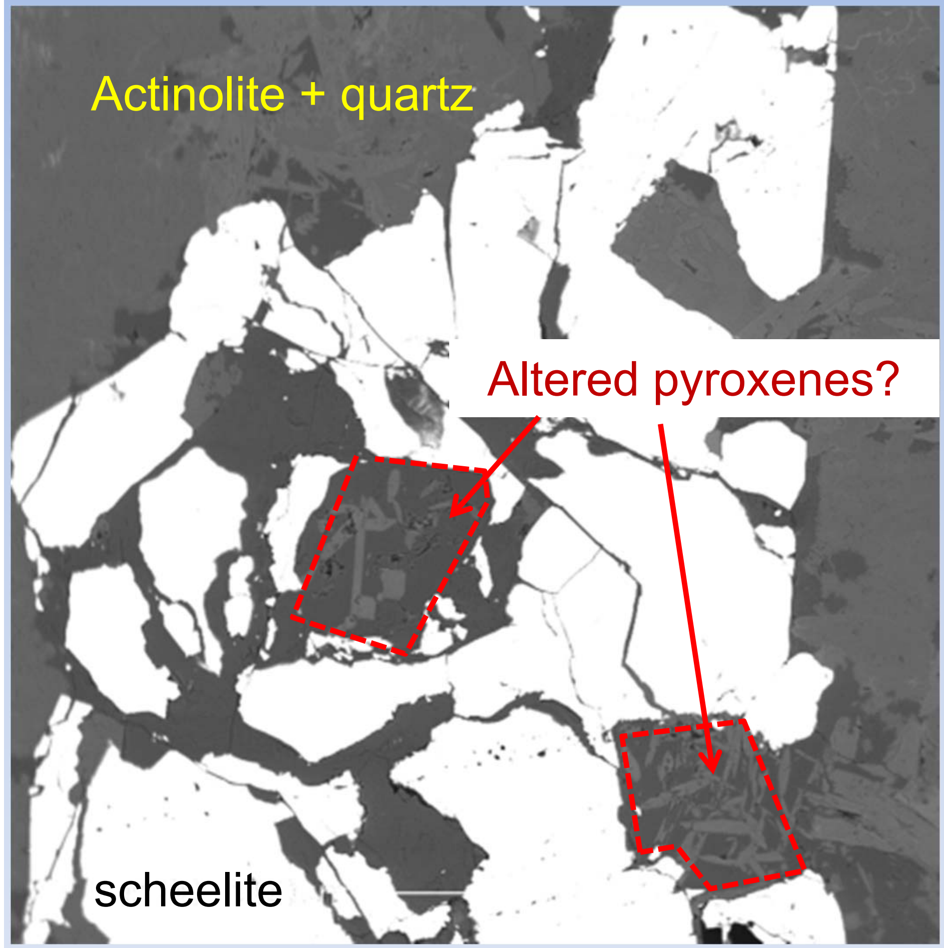
Epidote-rich endoskarn

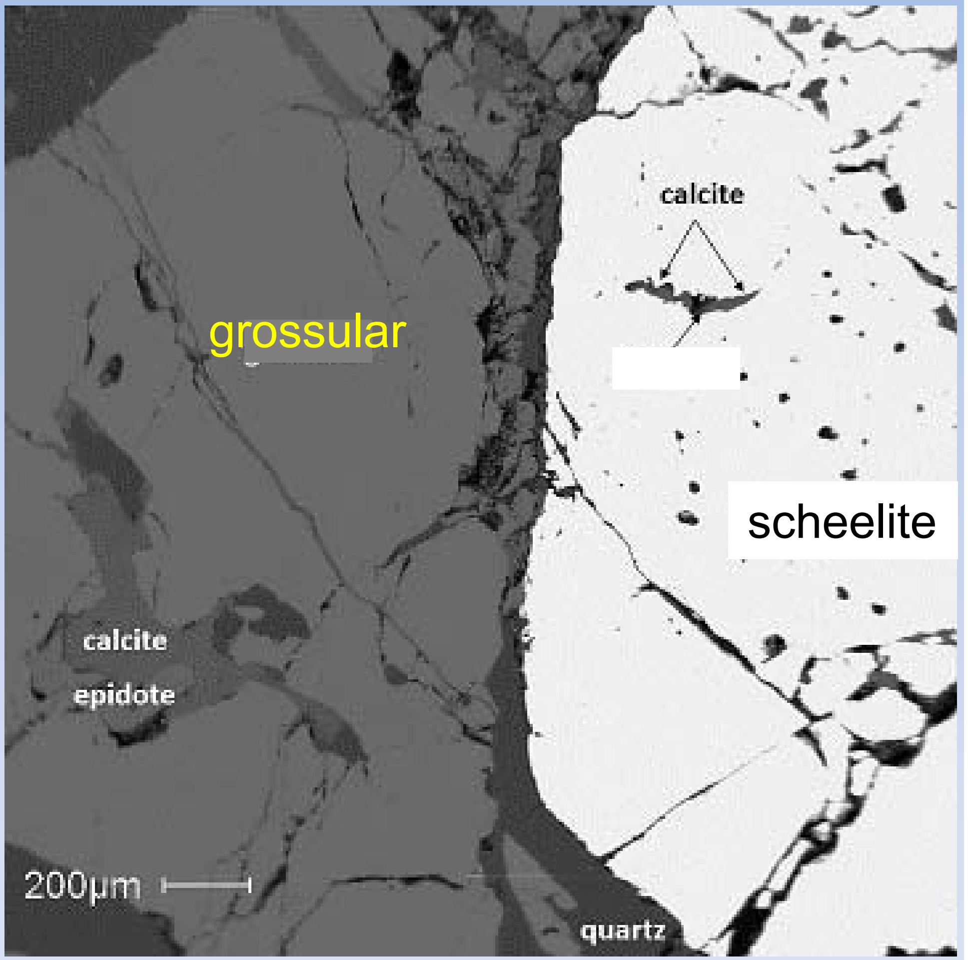


Example thin section



Example SEM-BSE photos





Skarn paragenesis at Calvert Mine

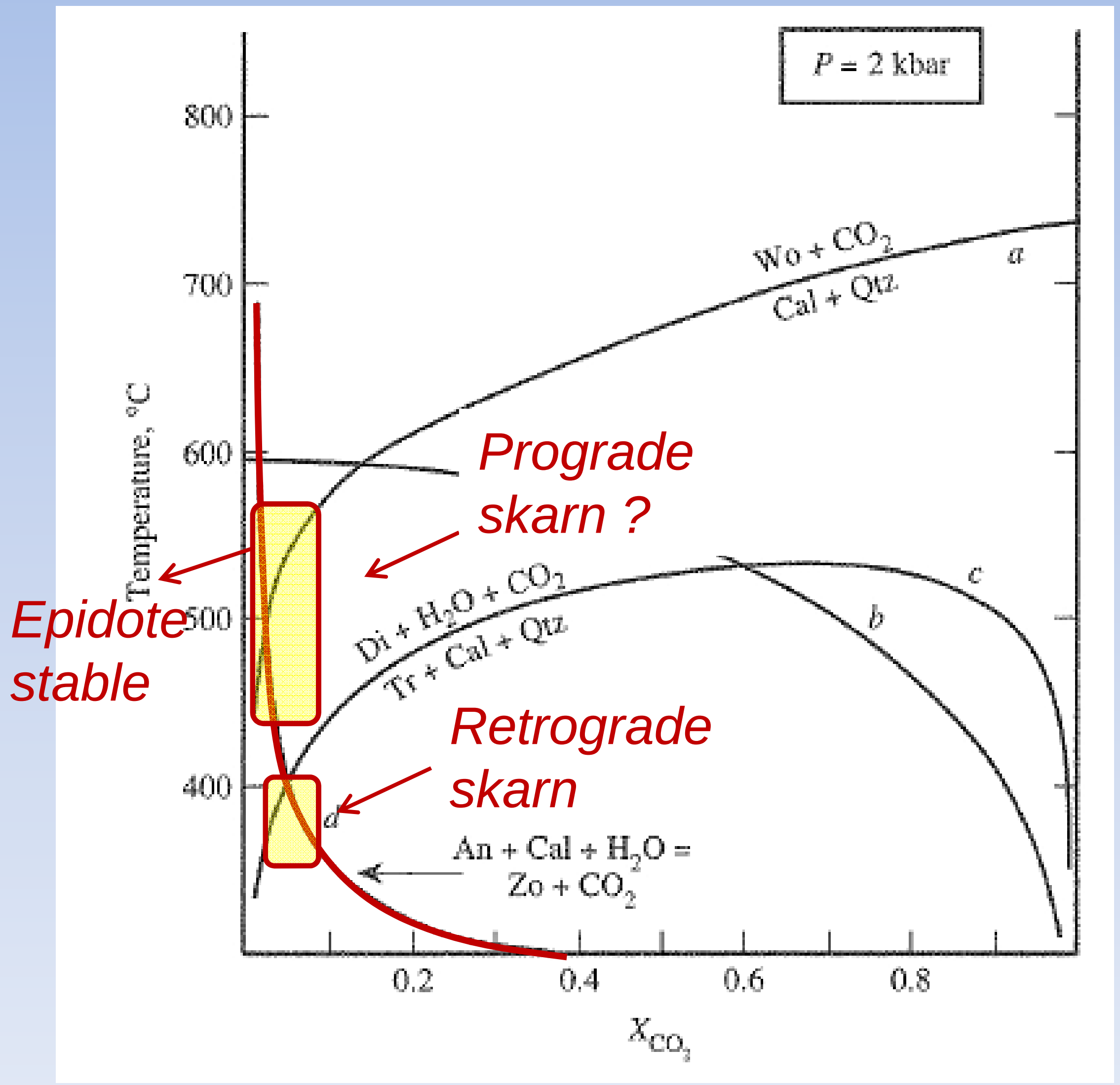
Prograde	Early Retrograde	Late Retrograde
grossular	epidote	muscovite
epidote	actinolite	hematite
pyroxene	apatite	Mn-oxide
wollastonite	siderite	Mn-silicate
magnetite	quartz	chlorite
quartz	calcite	quartz
calcite		calcite

scheelite
zircon
barite
titanite

NO SULFIDES!

Josh Messenger study, future work

- C, O-isotopes of marble and skarn calcites
- Fluid inclusions in scheelite, quartz
- P-T-XCO_2 phase diagrams →



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Questions?