Geology, Mineralization, Alteration, and Geochemistry of the Clementine Porphyry Copper Prospect and Mt Fleecer Area of Southwest Montana.

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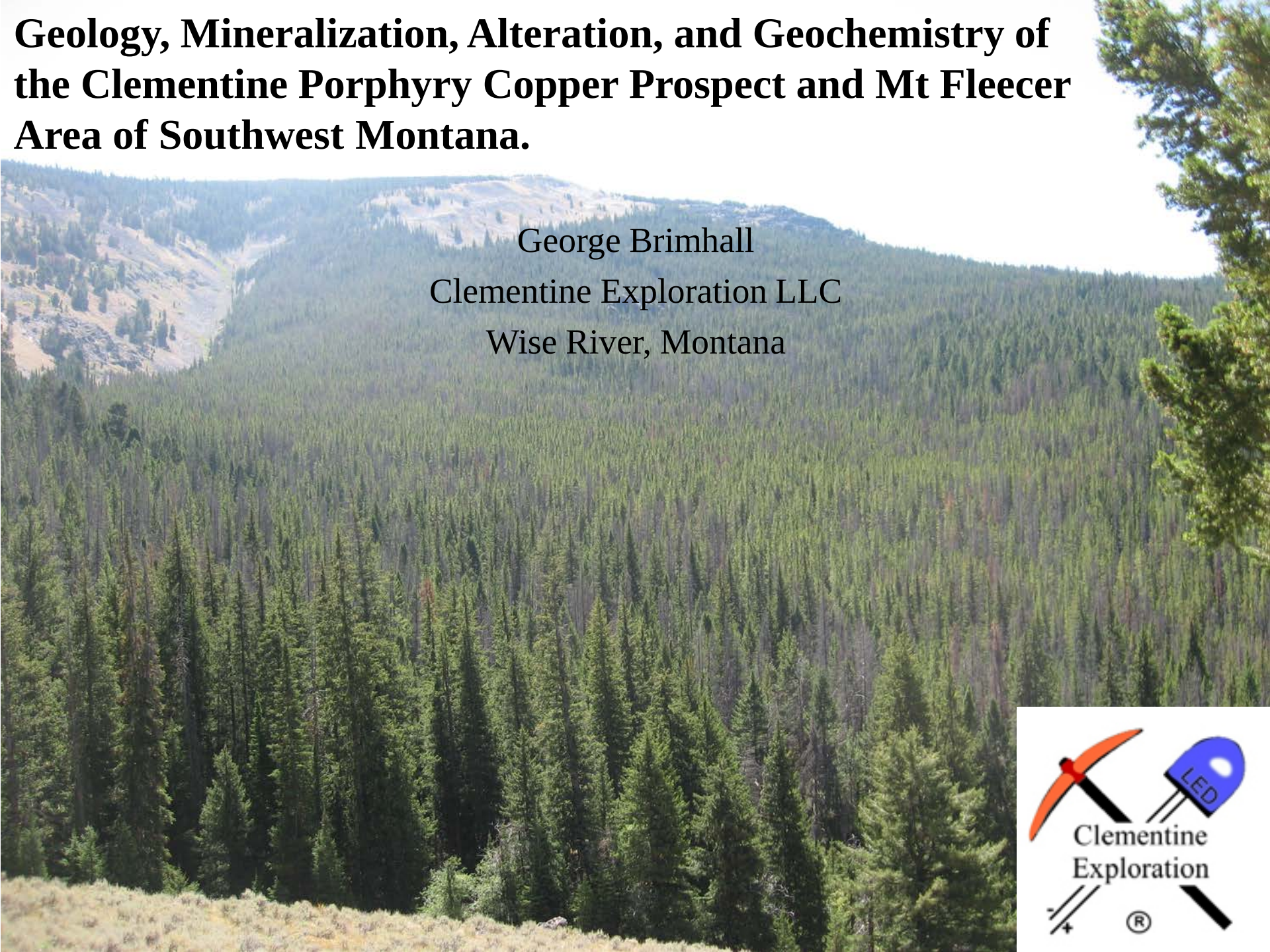
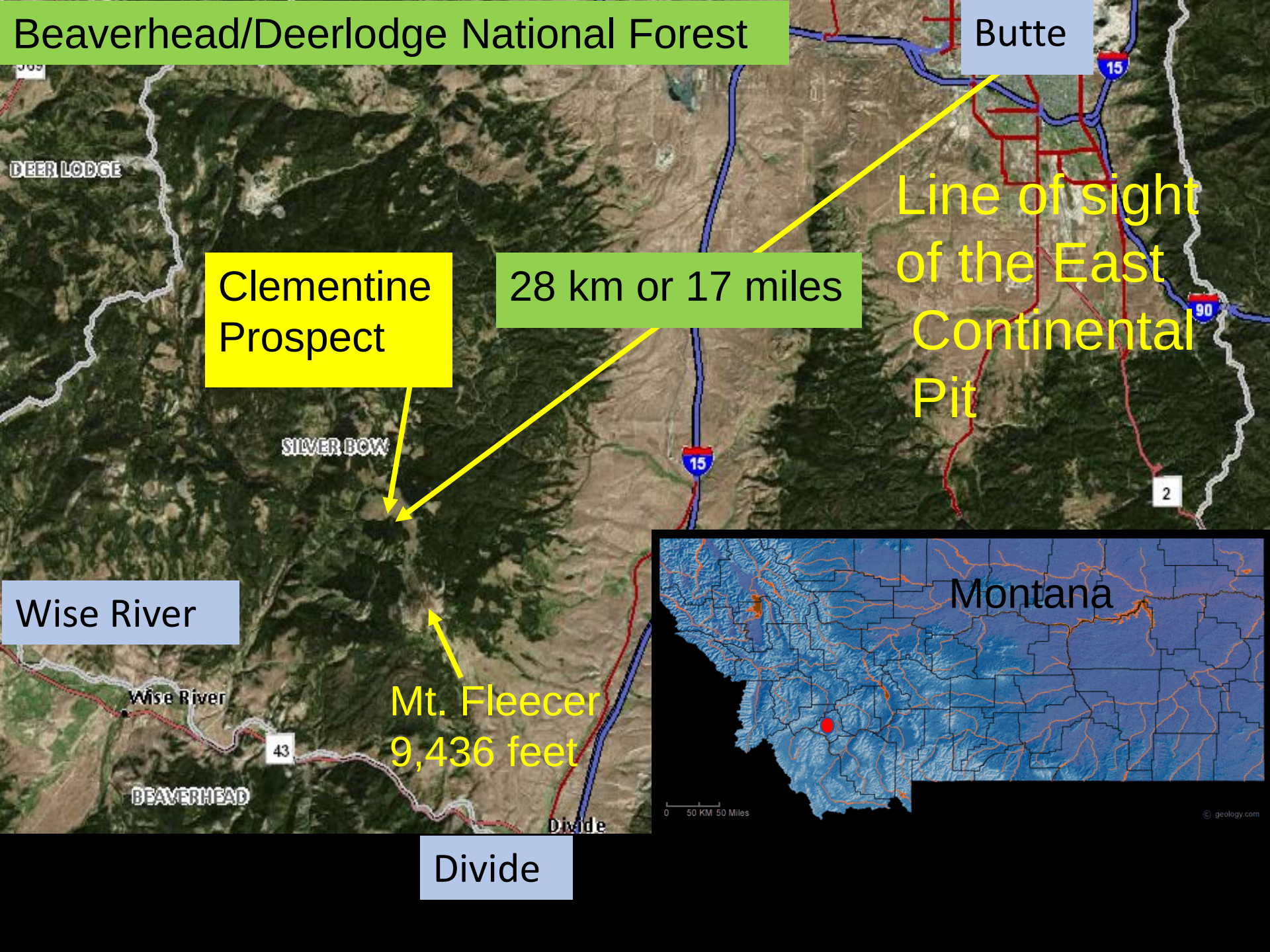
Wise River, Montana




Beaverhead/Deerlodge National Forest
Butte
Line of sight of the East Continental Pit
Clementine Prospect
28 km or 17 miles
DEER LODGE
SILVER BOW
15
90
2
Wise River
Wise River
43
BEAVERHEAD
Mt. Fleecer
9,436 feet
Divide
Divide
Montana
0 50 KM 50 Miles
© geology.com

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Dan Kunz (MT Tech BSc)
Doug Fuerstenau (MT Tech MSc)

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Wise River Community Foundation

Jerry Zieg (Tintina)

Richard Berg (MT Bureau of Mines and Geology)

Susan Vuke- **Geologic Road Map of Montana**

Colleen Elliott- collaboration

A truly delightful and growing group of friends

The Challenge in Exploration Today:

Over the next 26 years, the projected increase in world requirements for copper will require mining more copper than mined in **all prior human history** (Schaffer, 2018)- former President of the PDAC

Junior exploration companies, **not majors**, are expected to account for **70 %** of the discoveries.

The **discovery rate** of major orebodies has been falling from the 1970s onward while **expenditures** have continued to rise.

Opportunities to discover **shallow orebodies** has diminished significantly (Wood, 2016).

We need then to largely abandon a predominantly surface to near-surface target approach and focus instead on **deep exploration** which places a serious challenge on junior exploration companies.

This is a daunting challenge as many types of ore bodies with their tops located 500 to 1,000 m or more below surface are ***unlikely*** to exhibit the obvious signs on the surface useful previously

An effective exploration strategy for Junior exploration companies is required to discern new surficial geological evidence of deep mineralization compelling enough for major companies to enter into partnerships.

This may require understanding features not yet a common part of well-known ore deposit models.

This is a **progress report** on our efforts to **map** geological evidence of a possible deep mineralized system for guiding **geophysical imaging** at depth

Work described here is inspired by:

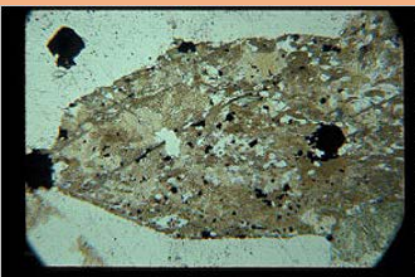
(1) Working in the Butte deep underground mines,

(2) Exploration drilling to define the Pre-MS **zoning**

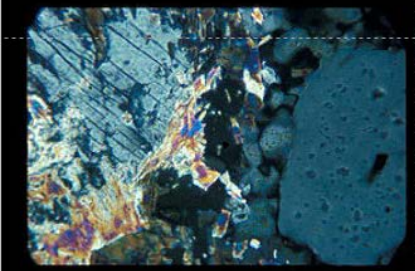
(3) Developing an ore reserve of the western 1/3 of the district, and

(4) Trying to understand the relationships between the high-grade veins and pre-Main Stage

We explore the connection between **Cordilleran polymetallic vein deposits** and **Butte-type veins** and replacement bodies **above porphyry copper systems**, e.g. Yauricocha, Colquilirca, Morococha and Toromocho deposits of Peru.



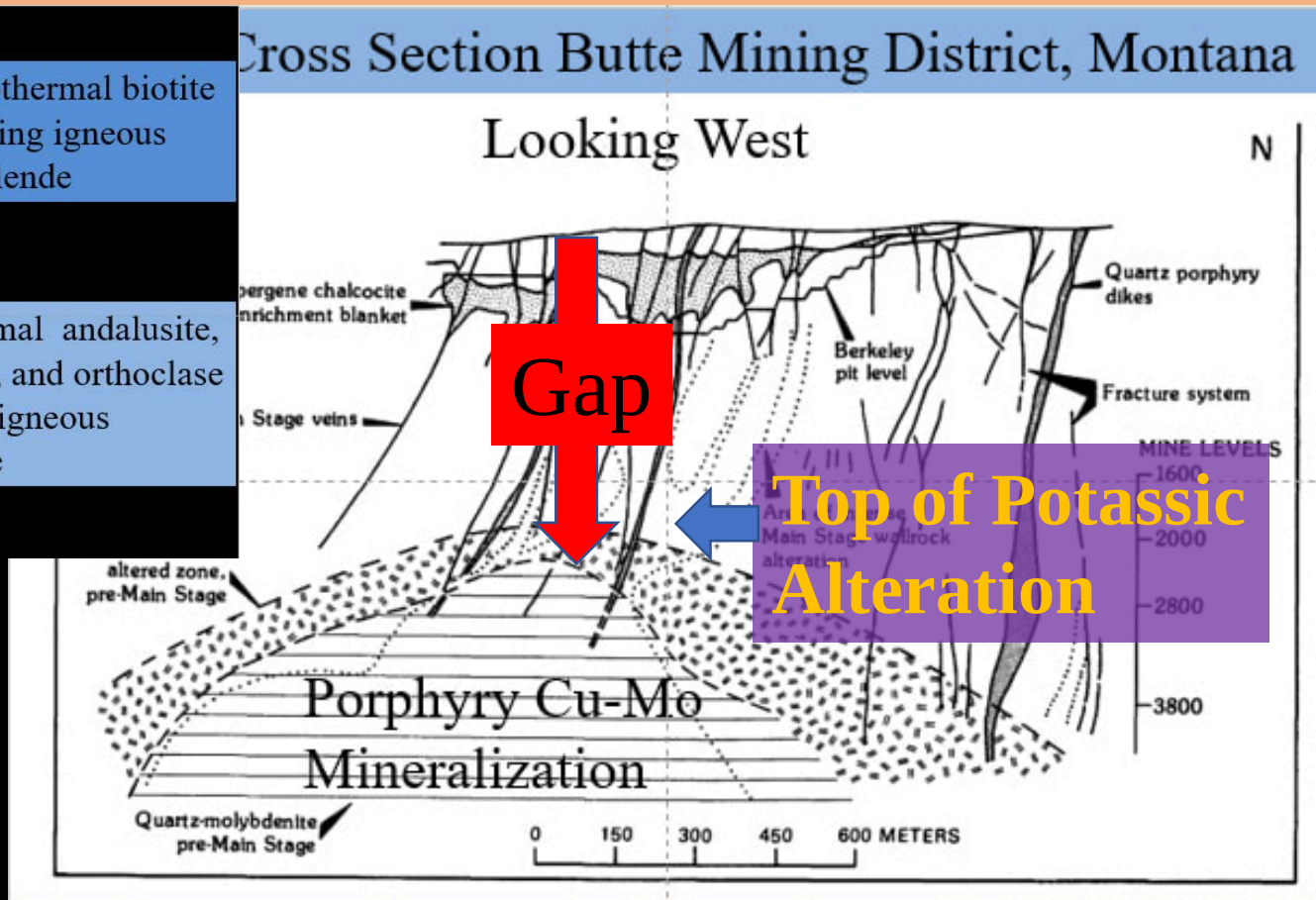
Hydrothermal biotite replacing igneous hornblende



Hydrothermal andalusite, Muscovite, and orthoclase Replacing igneous plagioclase

Homogeneous Wall rock- facies

Roberts, 1973; Brimhall, 1977; and Brimhall et al, 1985



Our approach focusses on the observation that Cordilleran base metal vein systems may have genetically-related porphyry copper deposit roots with **high-grade zones** amenable to underground mining methods.

With the shift to deeper exploration, there has been an evolution of mining technology away from open pit to underground mining techniques which are both economic and are also more deserving of a social license for mining to operate.

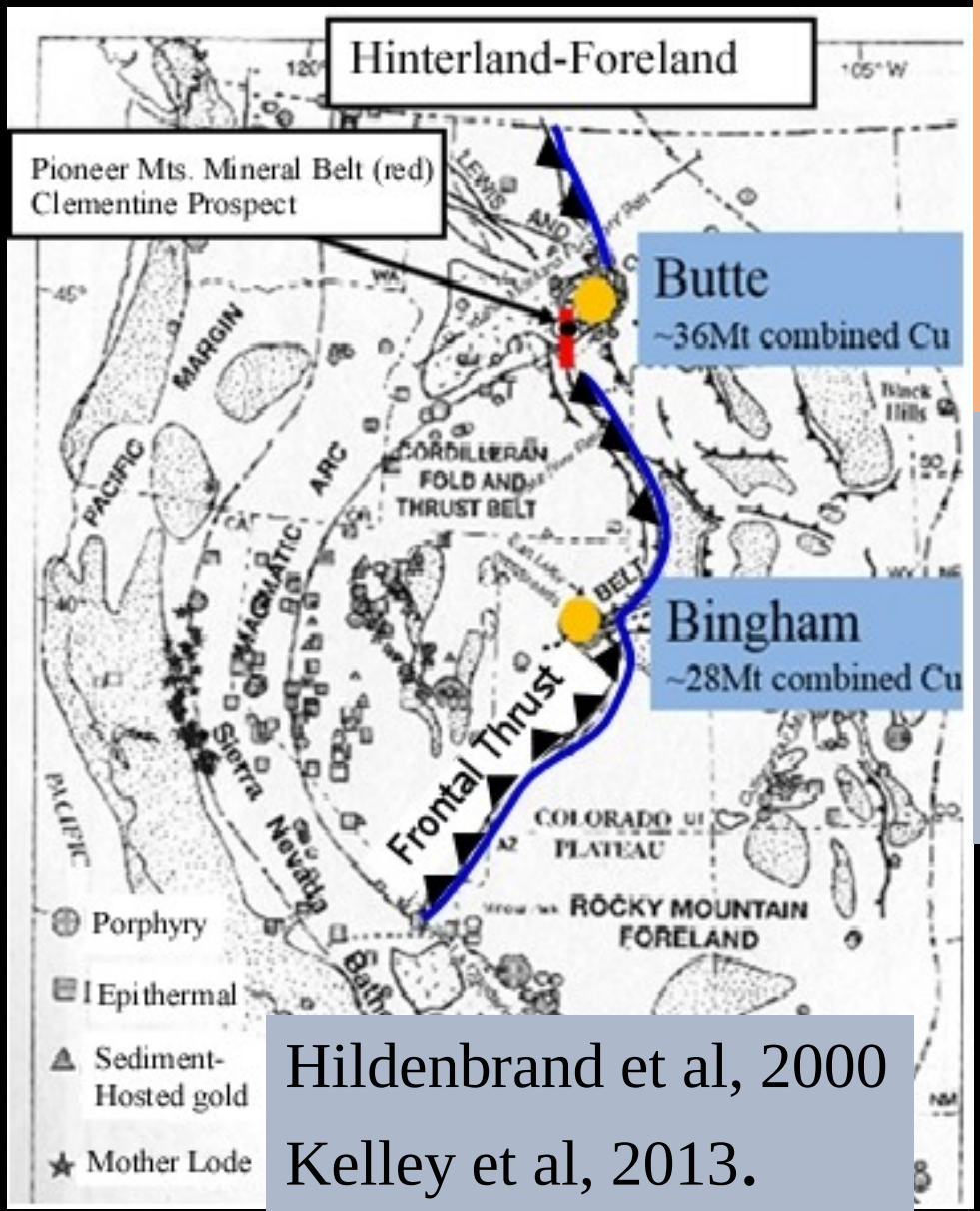
Cemented, paste backfill and tailings reduce potential environmental issues with water (Zieg at Black Butte)

The mine life cycle must address the full range of concerns including earning a social license with all stake holders, and ensuring that the environmental quality of the mined land surface and hydrological system be maintained day to day and ultimately be restored to nature in perpetuity as a functional ecosystem.

Challenge: We are immersed, not so much in what is known about ore deposit models, but how they interact what with **their surroundings- What isn't known**

It is necessary to make daily decisions based upon **incomplete** and **imperfect data** and create new knowledge day by day. **AND learn from deadends**

Regional Ore-Forming Model- presented last Fall



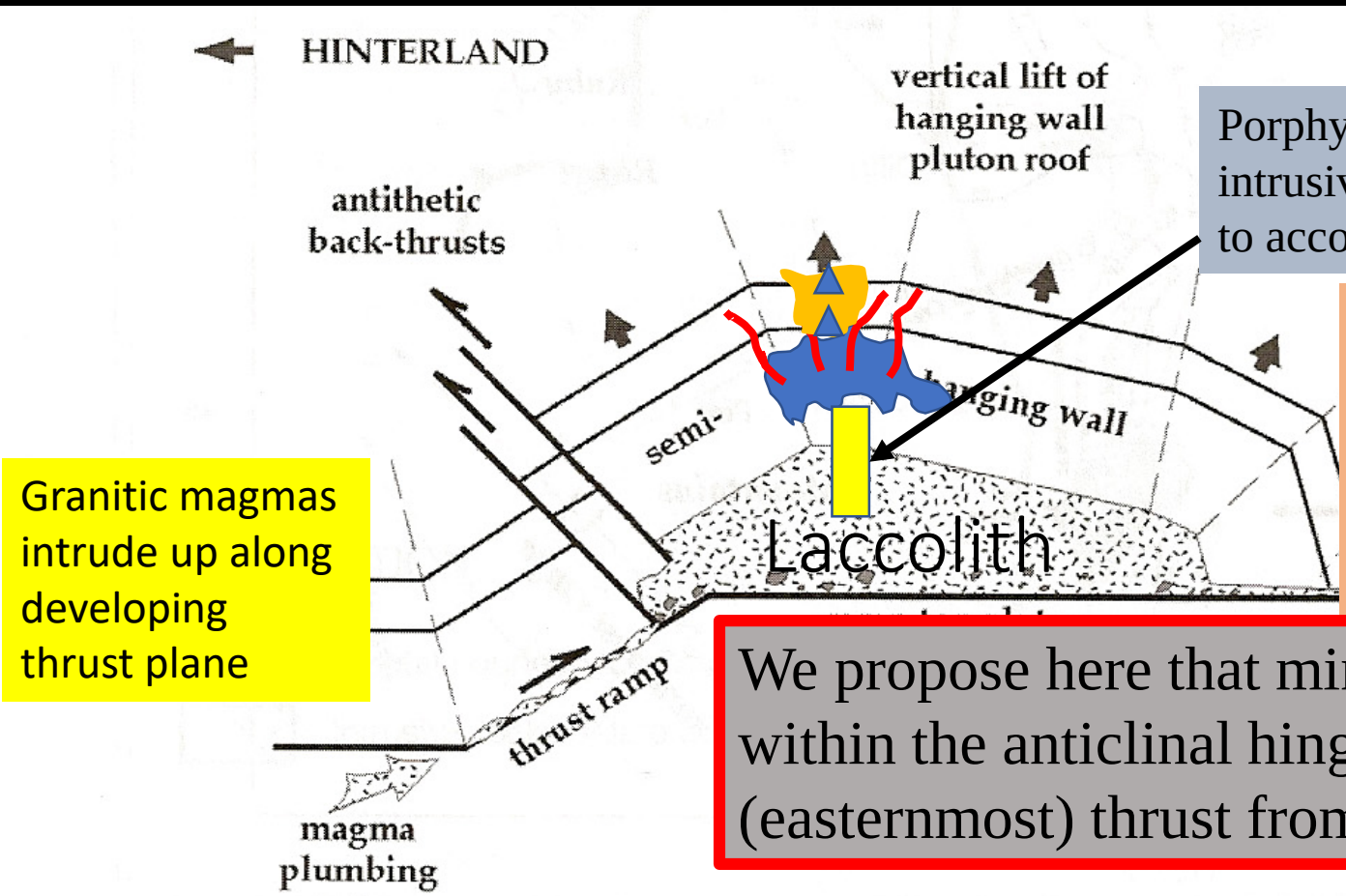
Hildenbrand et al, 2000

Kelley et al, 2013.

During or **soon after thrusting**, igneous plutons ascended fault ramps within the **hinge** of the frontal anticline of the fold and thrust belt

Magmas ascending the footwall of the thrust **invariably encountered the thrust plane**

Kalakay et al, (2001) proposed a crustal cross section with syn-compressional pluton emplacement at the tops of frontal thrust ramps within hanging wall, fault-bend anticlines



Porphyry "parent" intrusive too small to account for Cu

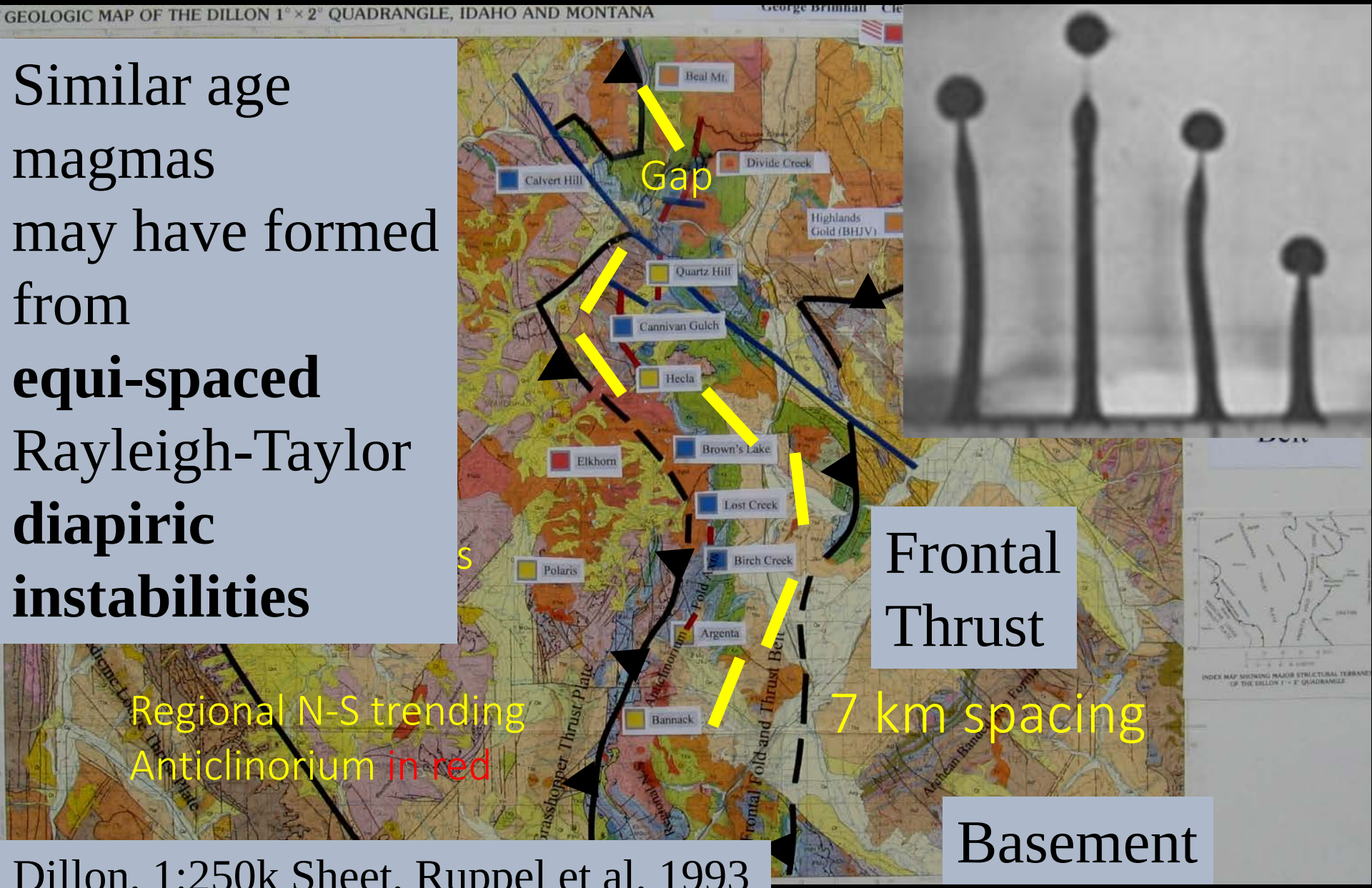
Seek a **closed** NOT an **Open** System (Oyarzun & **Sergio Rivera**): **Giant** vs Small PCD

Granitic magmas intrude up along developing thrust plane

We propose here that mineralization occurs within the anticlinal hinge of the Frontal (easternmost) thrust from a laccolith source

First proposed by Schmidt, Smedes, and O'Neil (1990)
USGS Boulder Batholith Project

Butte-Pioneer Mts. Mineral Belt (Brimhall and Marsh, 2014)



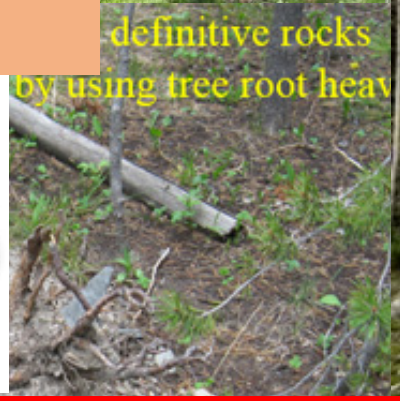
Similar age magmas may have formed from **equi-spaced** Rayleigh-Taylor **diapiric instabilities**

Dillon, 1:250k Sheet, Ruppel et al, 1993
Ruppel et al, 1993 (Thrust Faults)

Exploring under cover

Mouse type GNSS- benefited from development of **car navigation** systems through "**Urban canyons**" in **obstructed** environments

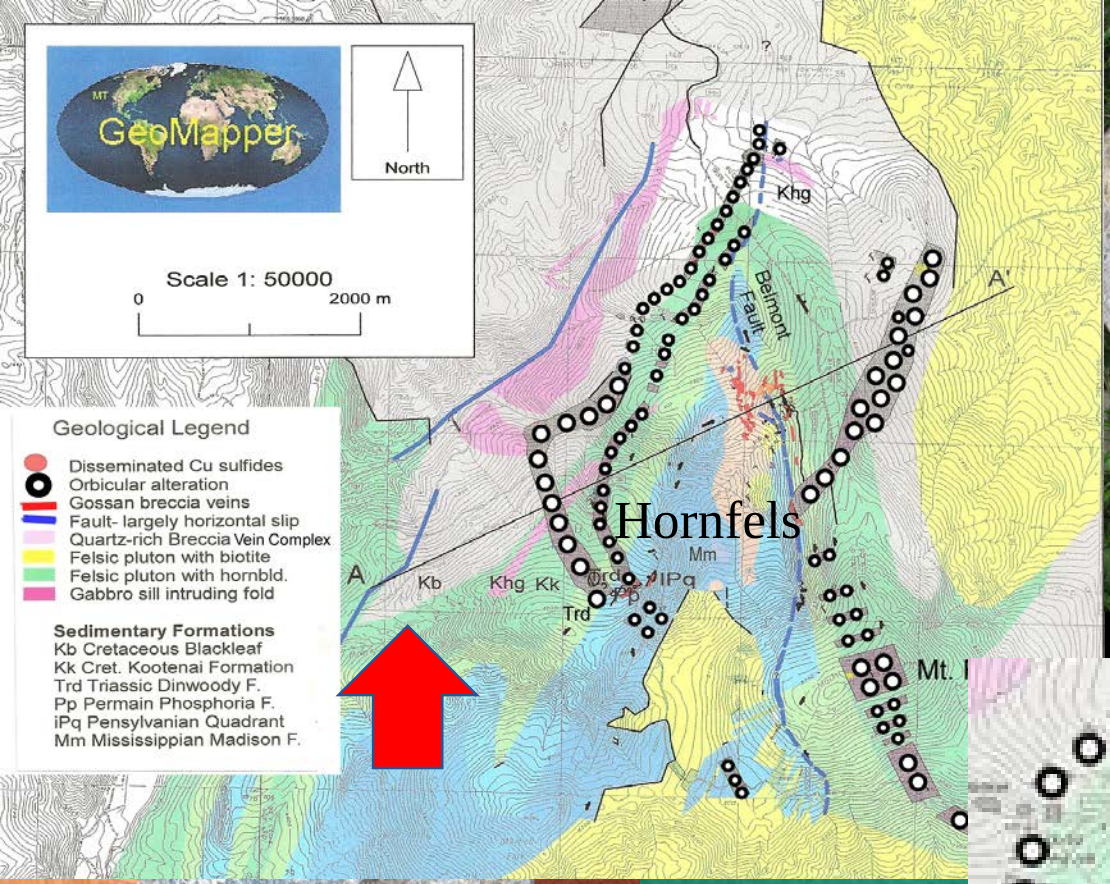
48 to 72 channel US-GPS, + Russian GLONASS + Chinese Beidou + Japanese QZSS



Situational Awareness with **continuous work flow** of movement, mapping, checking panorama view

Matchstick deadfall

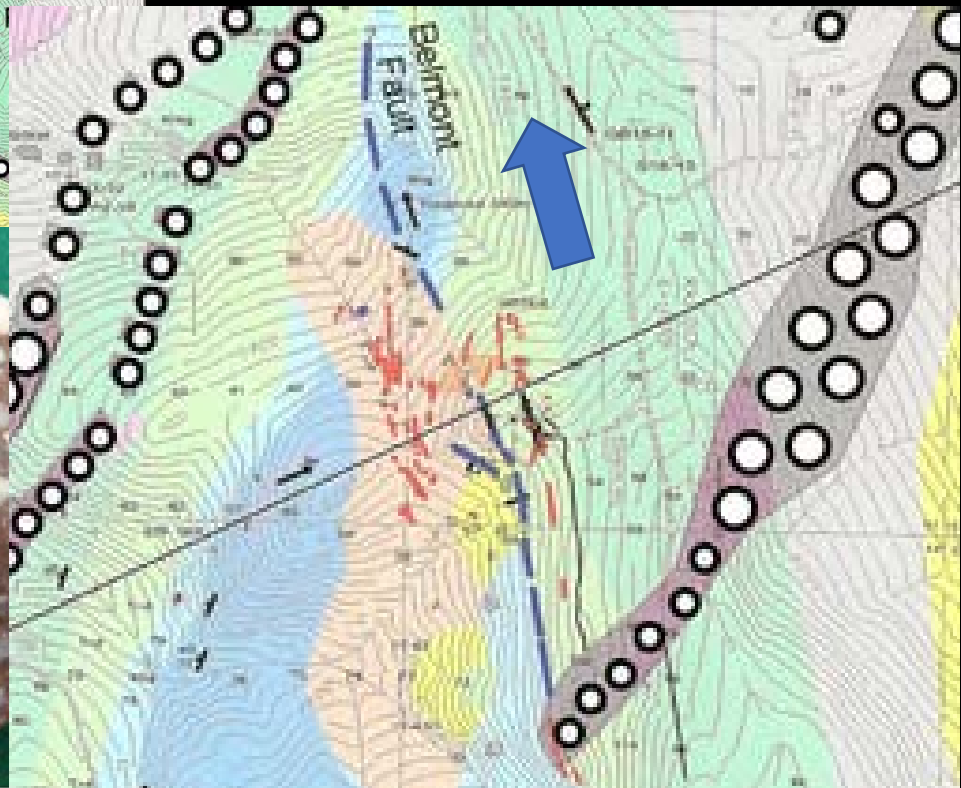
Pen Tablet- Digital geological mapping with state of the art GPS and **GNSS**

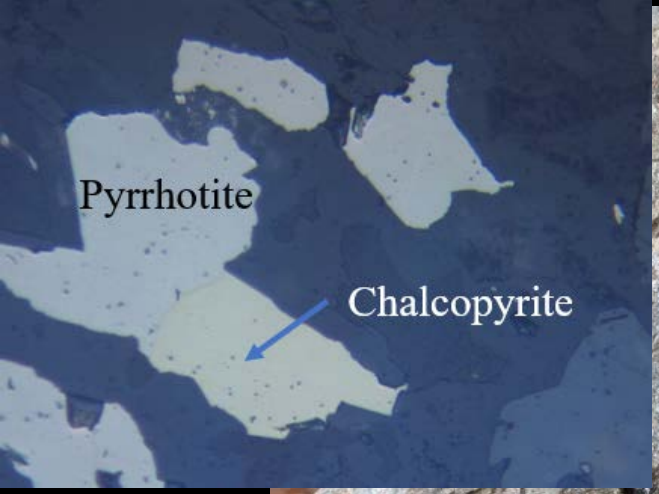

GeoMapper
North
Scale 1: 50000
0
2000 m
Geological Legend
Disseminated Cu sulfides
Orbicular alteration
Gossan breccia veins
Fault- largely horizontal slip
Quartz-rich Breccia Vein Complex
Felsic pluton with biotite
Felsic pluton with hornbld.
Gabbro sill intruding fold
Sedimentary Formations
Kb Cretaceous Blackleaf
Kk Cret. Kootenai Formation
Trd Triassic Dinwoody F.
Pp Permain Phosphoria F.
iPq Pensylvanian Quadrant
Mm Mississippian Madison F.
Khg
Belmont Fault
A'
A
Kb
Khg Kk
Trd
Mm
iPq
Mt.
Hornfels


Fault Restoration:
540 meters North
140 meters West
190 meters UP
Fault Slicks pitch
20 degrees south


6813-20D


A

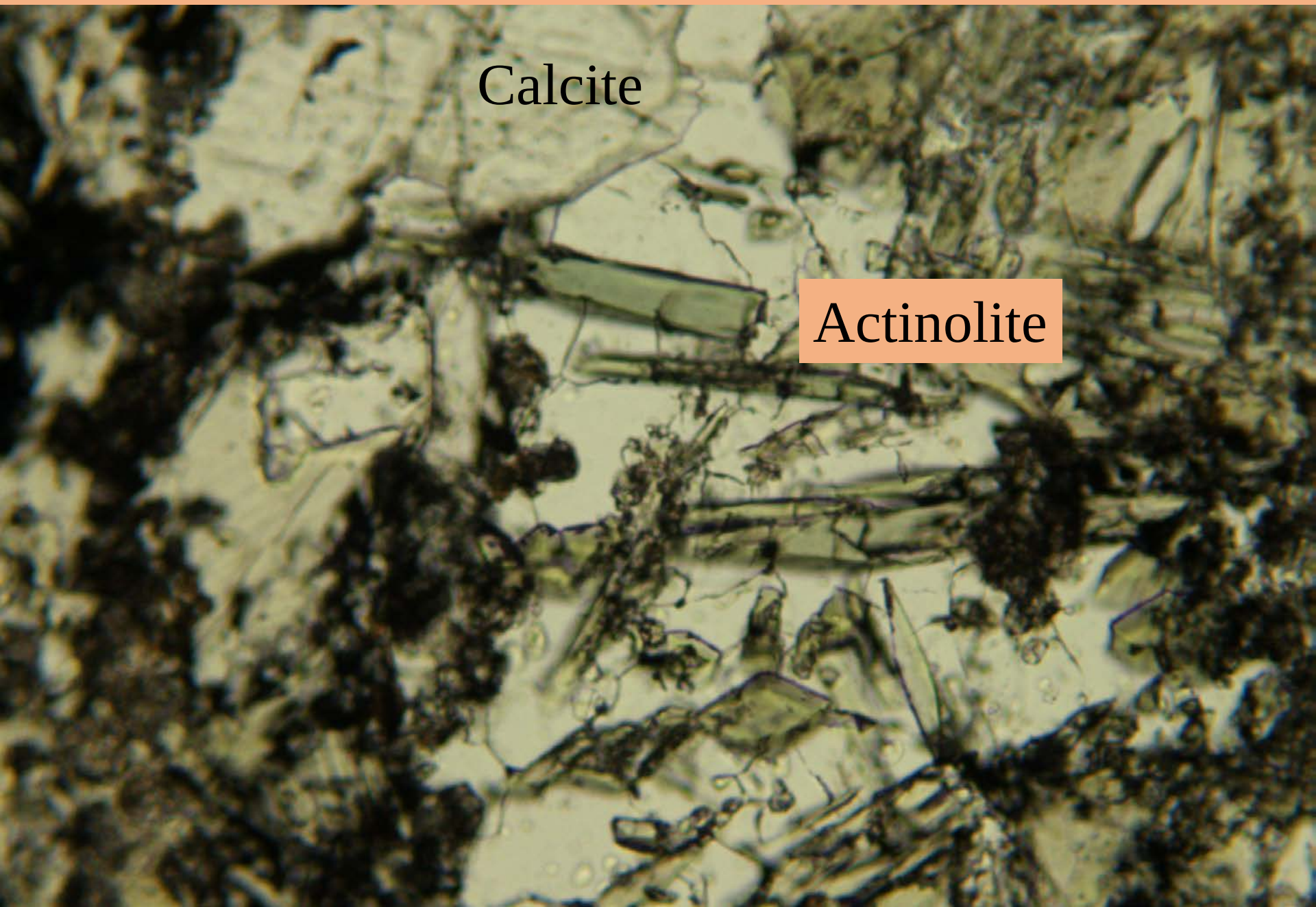

Belmont Fault



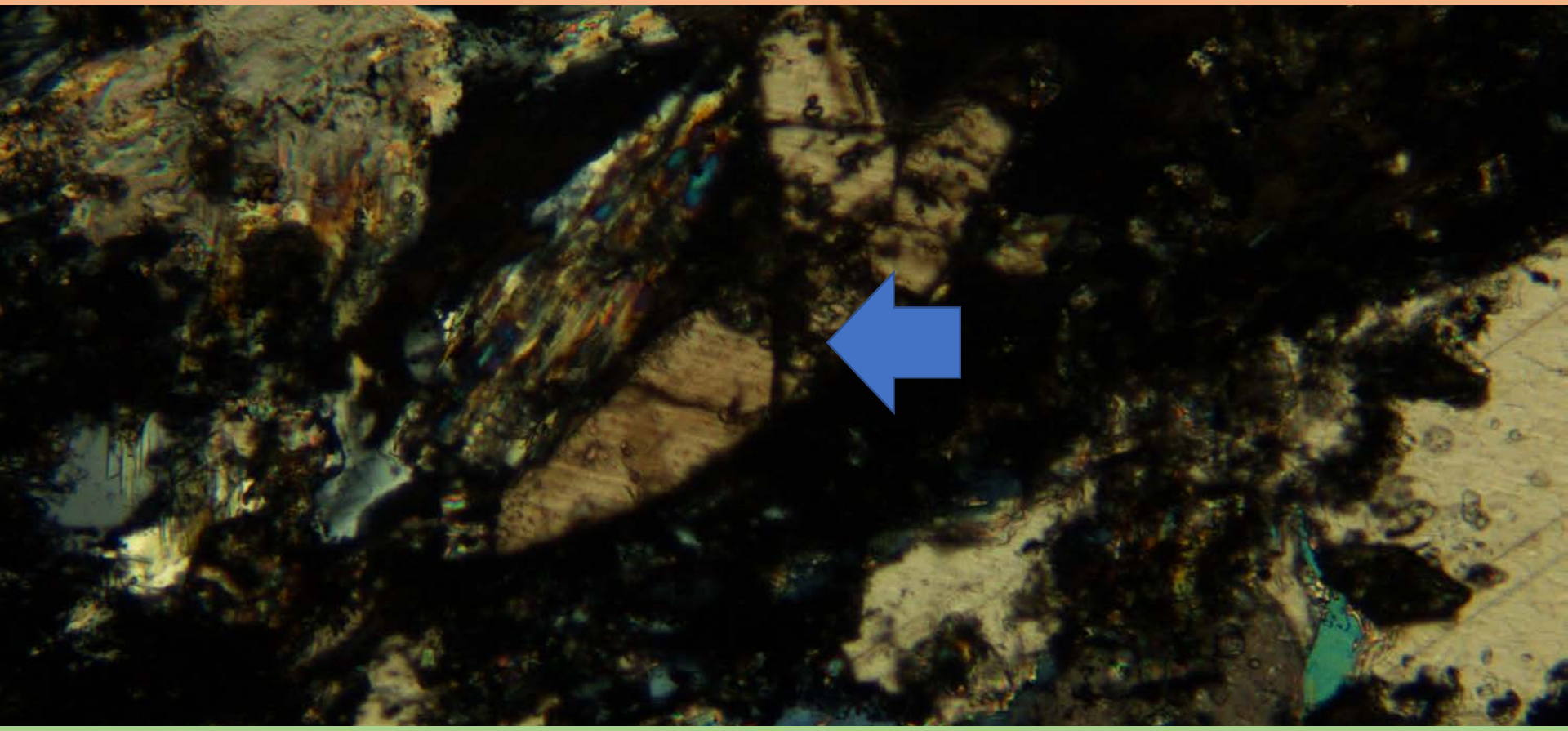
Orbicular alteration recognized in the **Carr Fork** area of the **Bingham District**, Utah (Atkinson & Einaudi, 1978) and at, Cananea, Mexico (Meinert, 1982**)- Actinolite Replacing Dopside**

Beal Mt Gold deposit (Wilkie, 1996) as replacement of clay balls

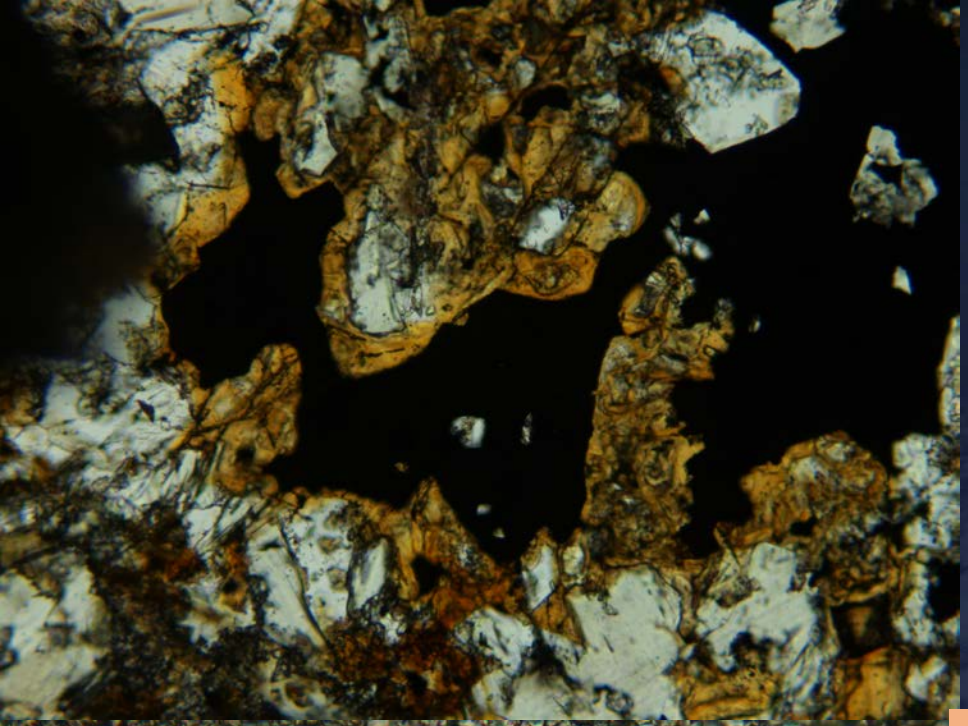
Petrography- all minerals confirmed with SEM-EDAX

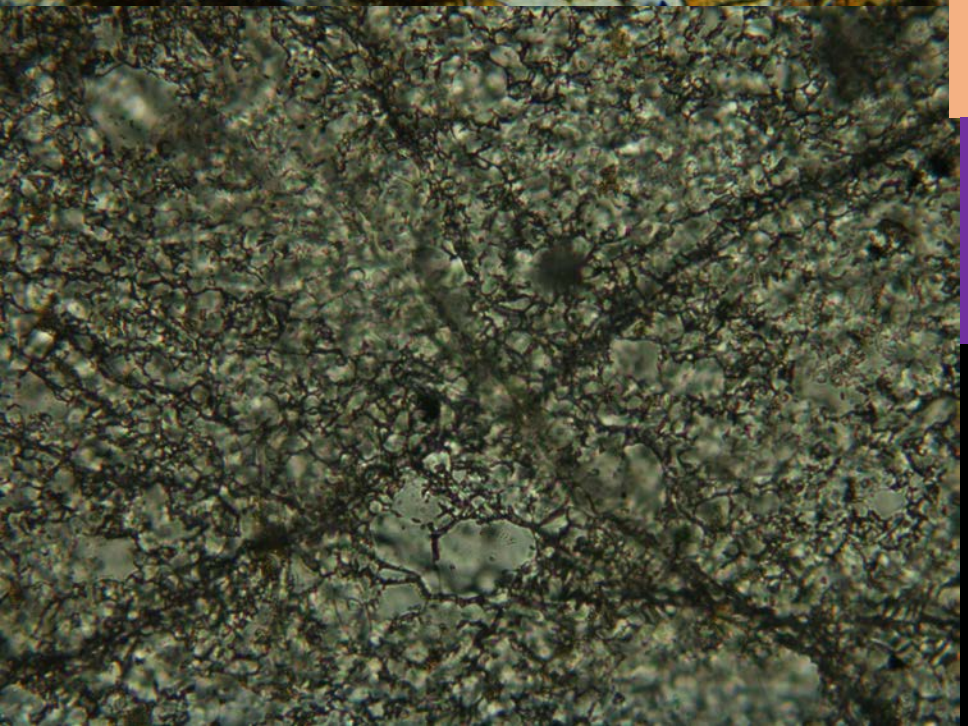


Hydrothermal Titanite (Sphene) **200 μ** long grains- amenable to **in situ** **SIMS (Ion Micro-Probe) U/Pb age date using a 10-40**μ beam diameter



Makes possible: D**irect radiometric age dating of hydrothermal alteration and mineralization**

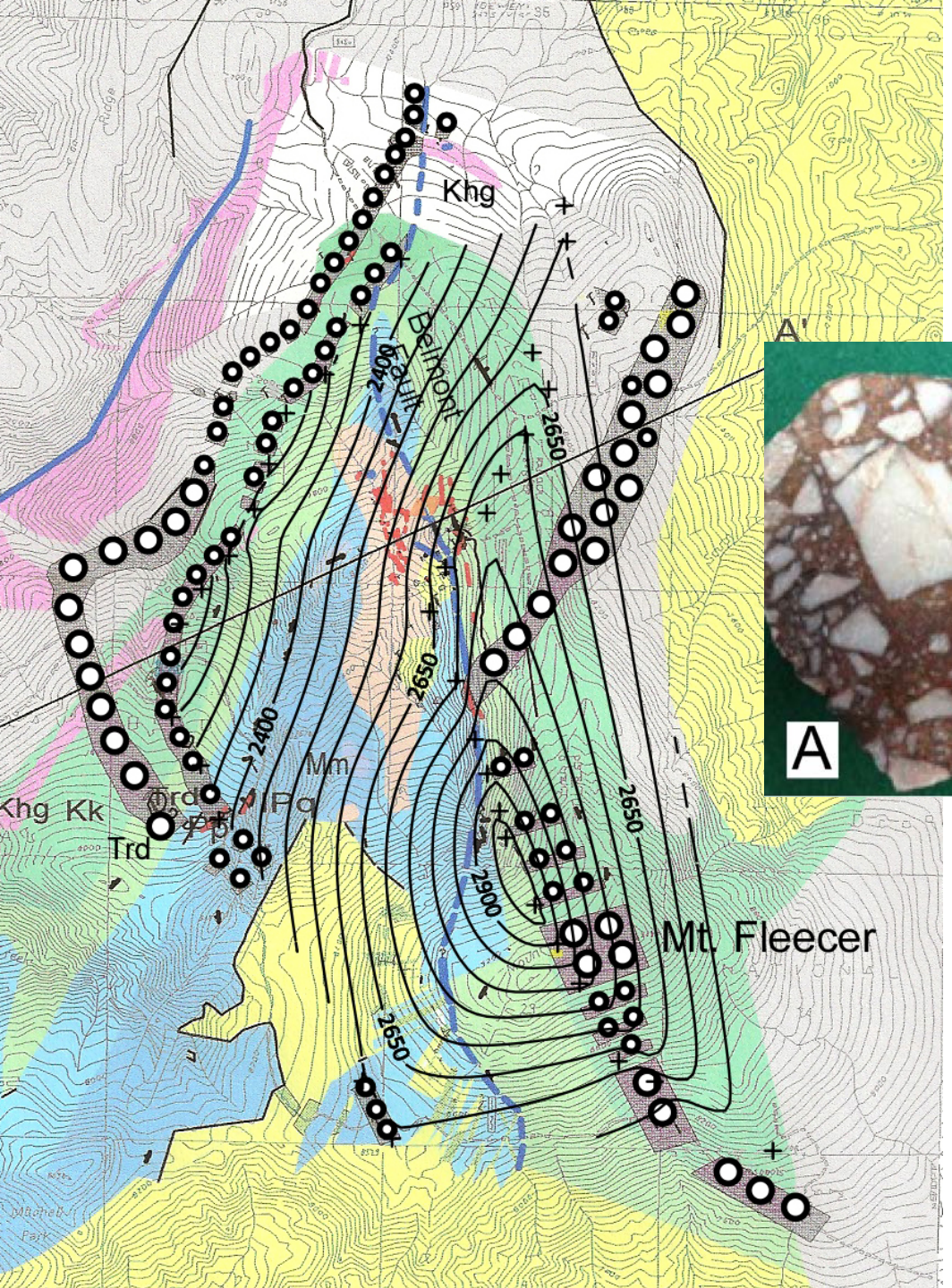


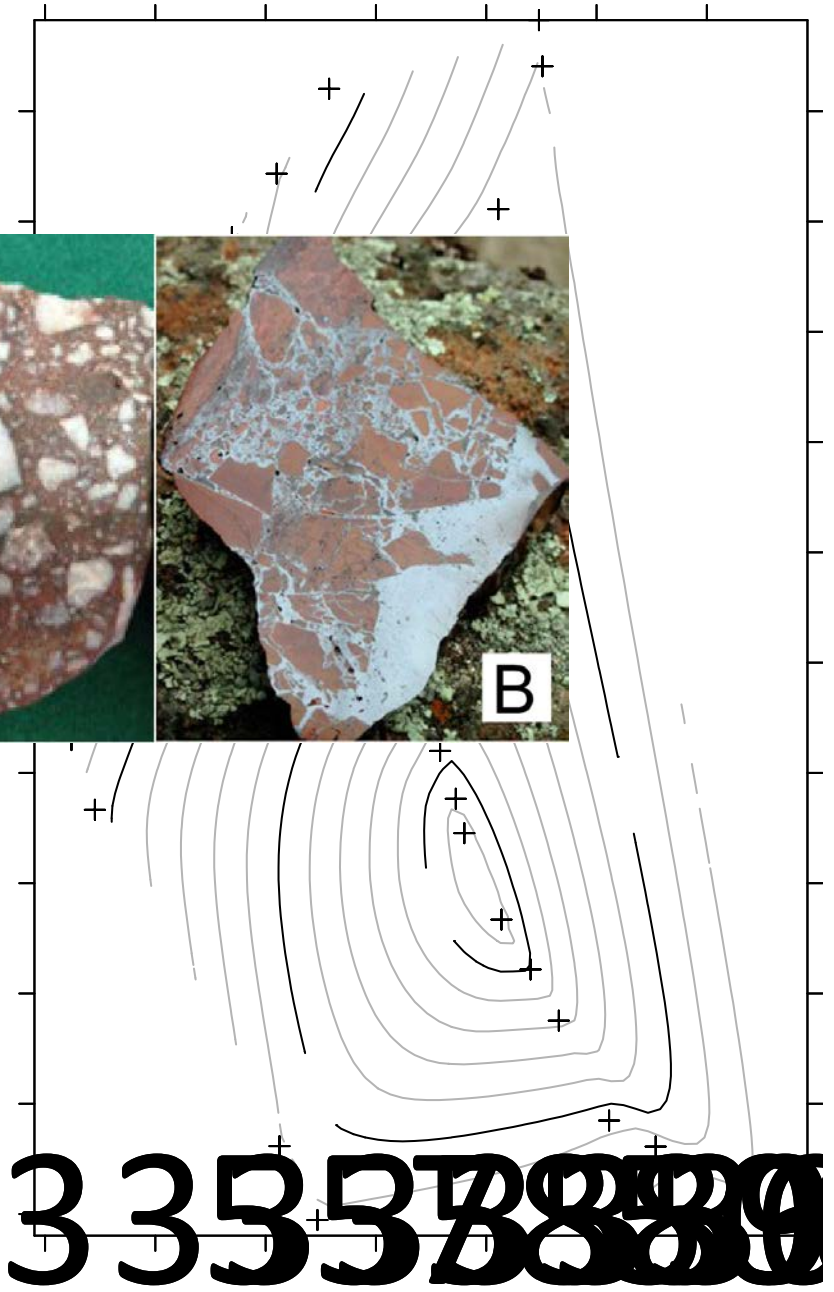


Micro-veinlets (**biotite**)

Evidence of Potassic Alteration

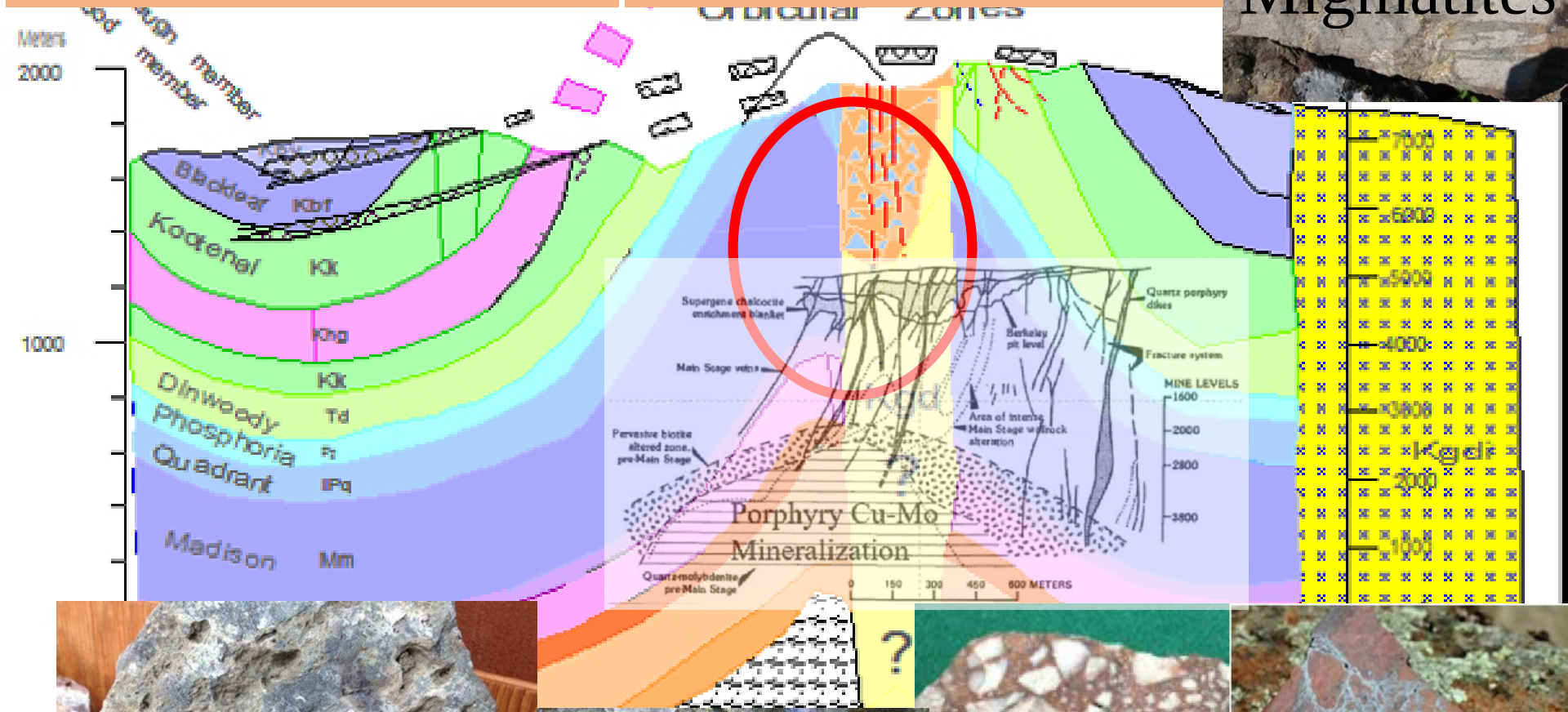
Restored Fault

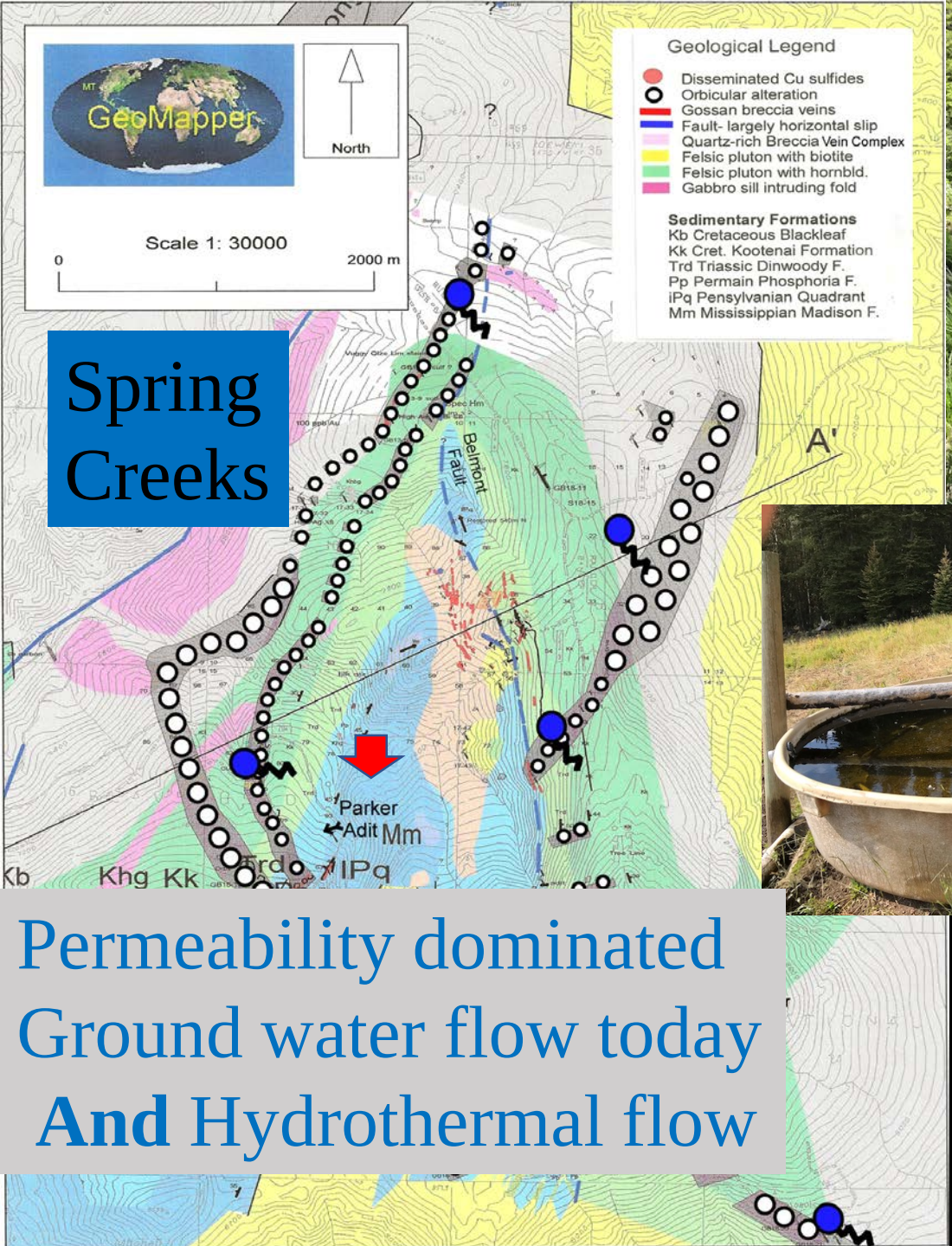




Interplay of BX, Veins, and Orb Zones

Over-pressured Hydraulic Fracturing

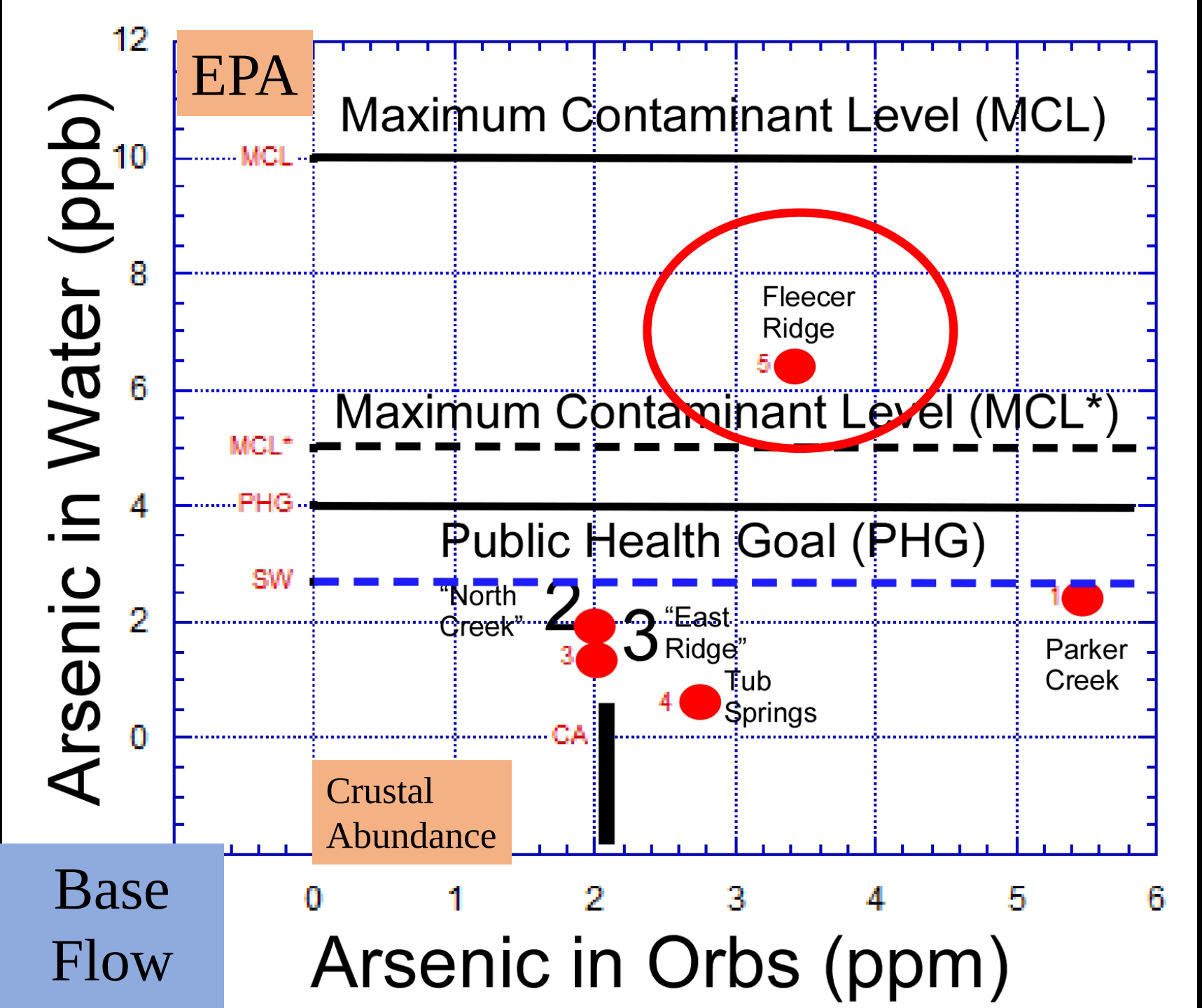




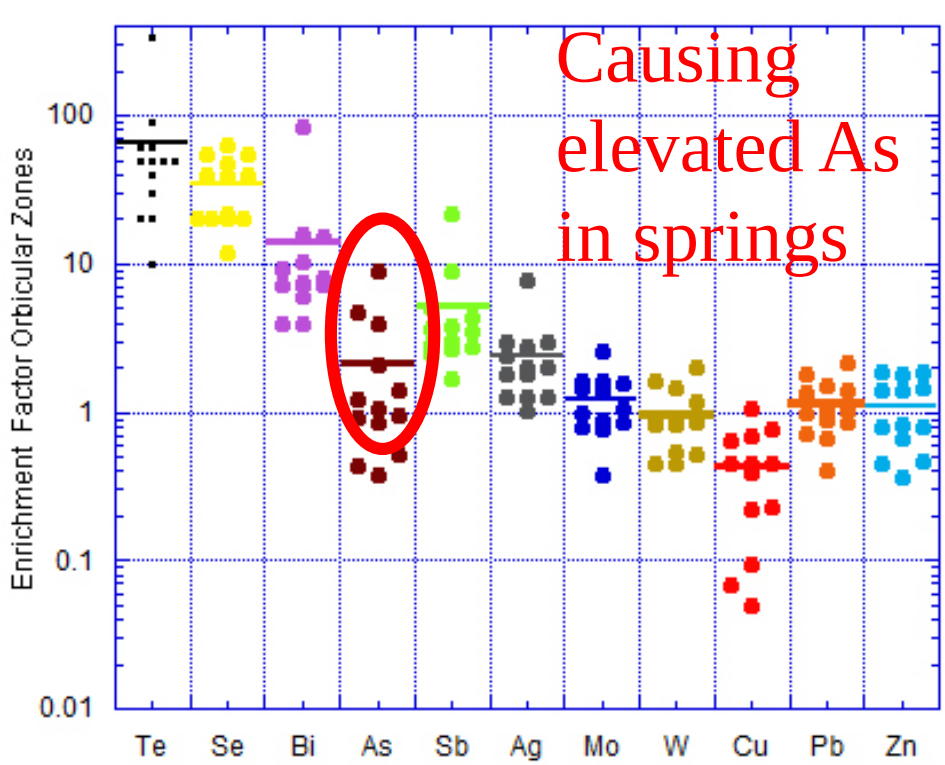
Spring Creeks

Permeability dominated
Ground water flow today
And Hydrothermal flow

Baseline Geochemistry

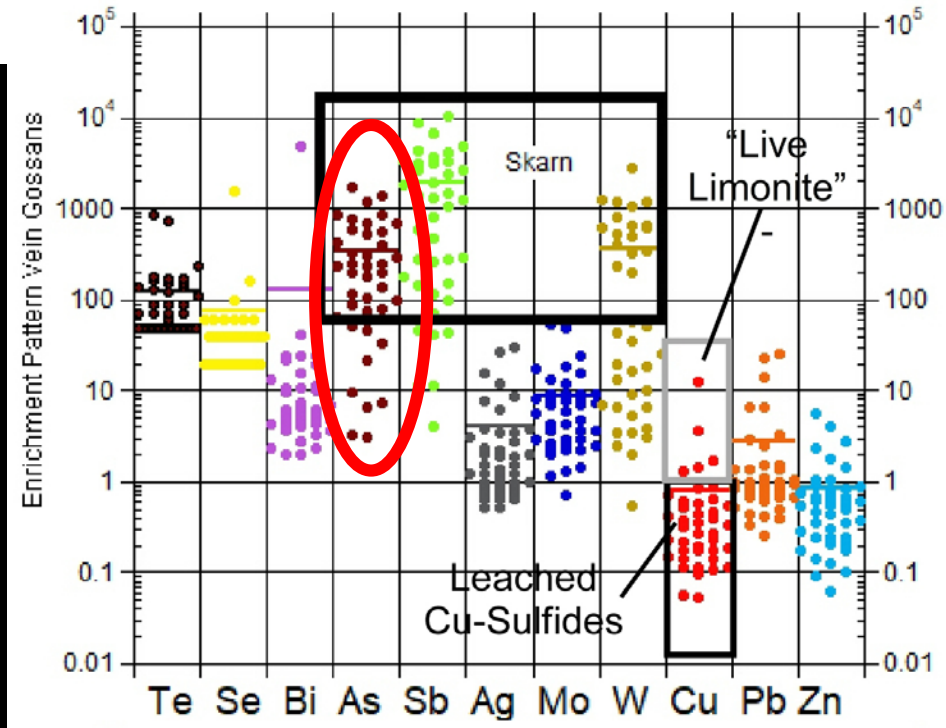

EPA
Maximum Contaminant Level (MCL)
MCL
Fleecer Ridge
5
Maximum Contaminant Level (MCL*)
MCL*
PHG
Public Health Goal (PHG)
SW
"North Creek"
2
3
"East Ridge"
Tub Springs
4
1
Parker Creek
CA
Crustal Abundance
Arsenic in Water (ppb)
Arsenic in Orbs (ppm)
0
2
4
6
8
10
12
0
1
2
3
4
5
6

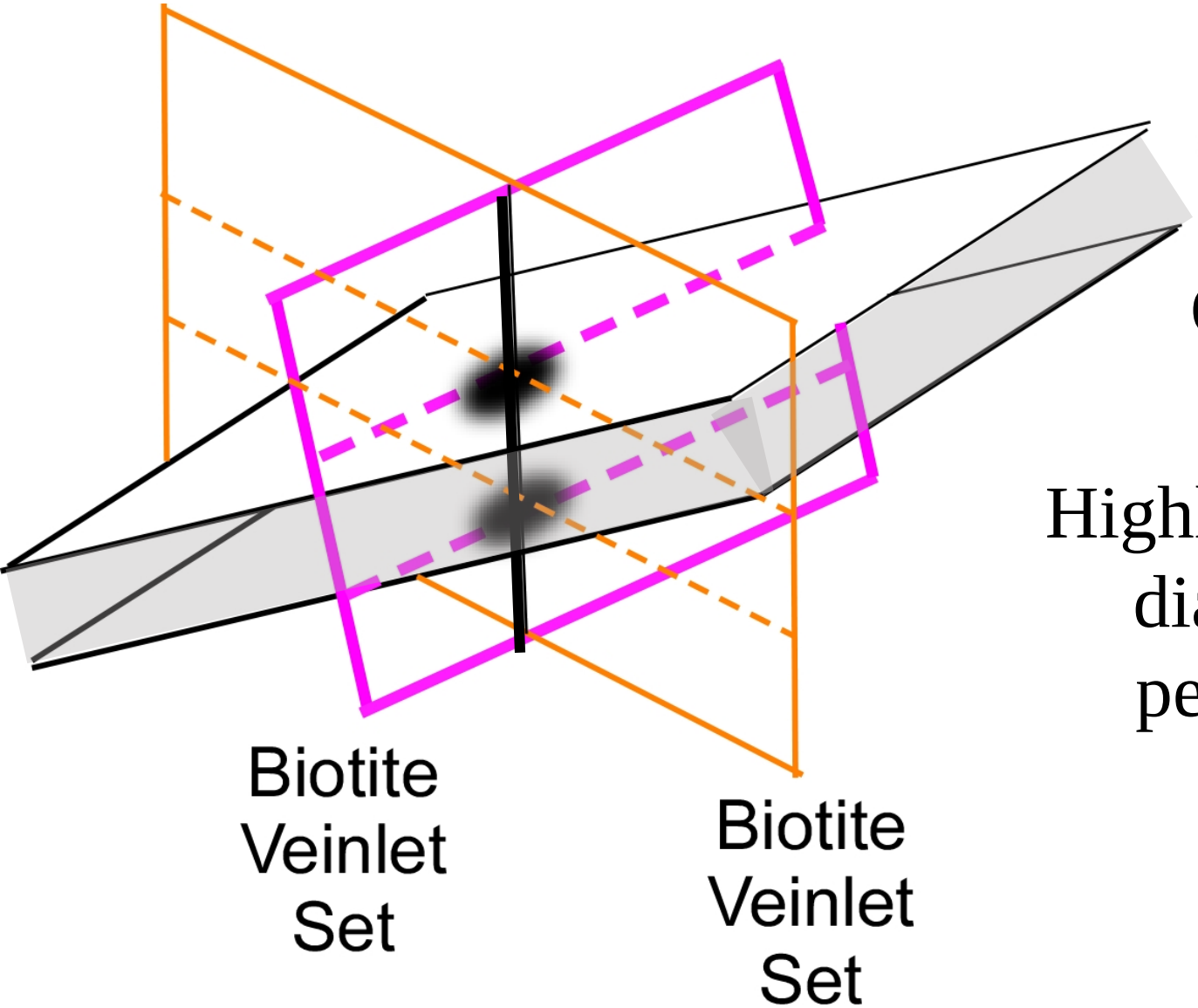
Base Flow



Arsenic-rich veins Do NOT cause the elevated As in springs

Arsenic in **spring creeks** is controlled by the **high permeability** of the **orbicular Zones; their chemistry and** and their **distribution**





Highest
Continuous
Permeability
Orbicular Zone

Highly anisotropic
diagonalized
permeability
tensor

Union of: Cp+Po, Potassic Alteration and Vein element suite

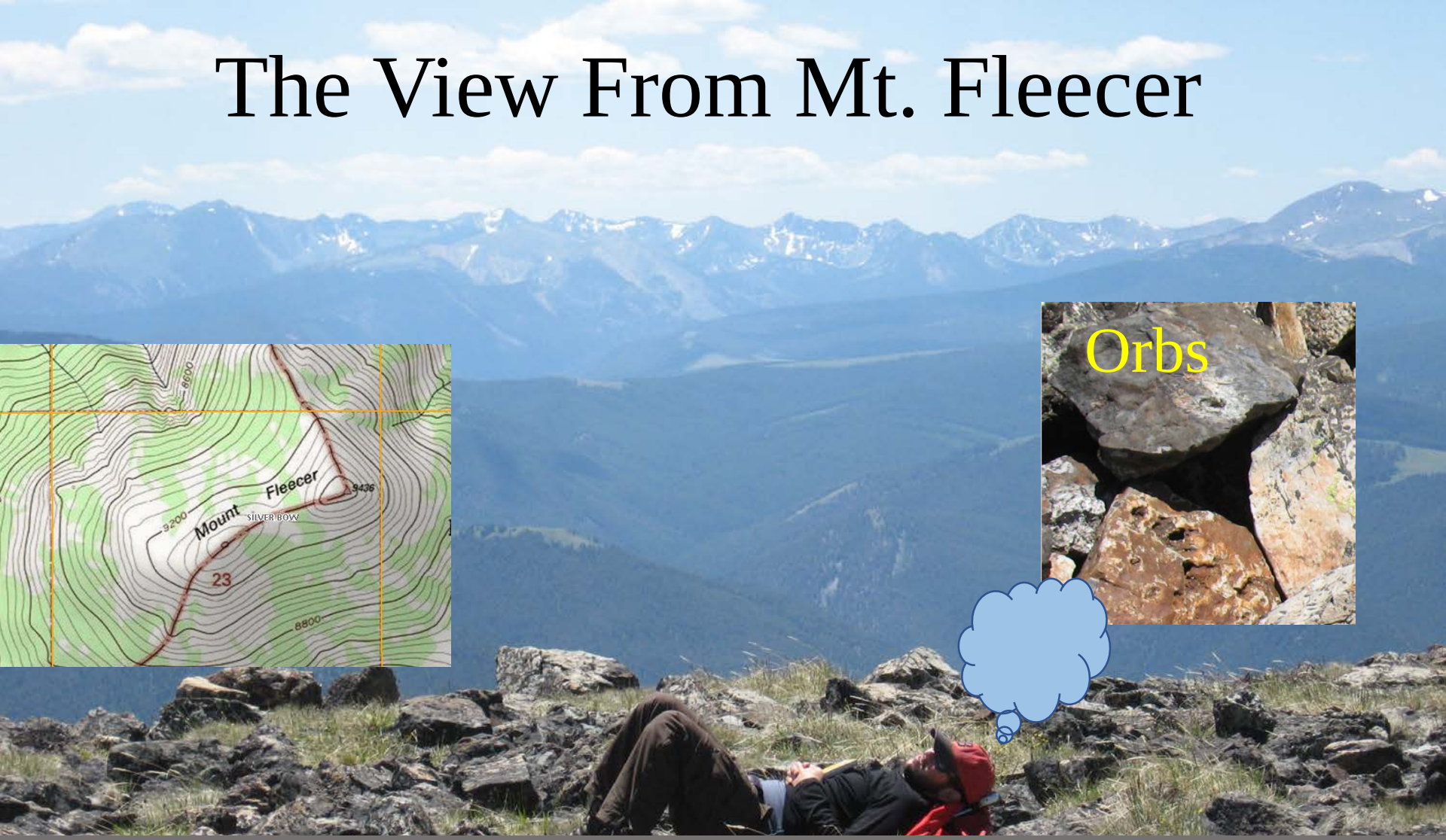
https://petrowiki.org/Diagonalizing_the_permeability_tensor

Fluid flow at Clementine was confined by both the syn-tectonic frontal thrust fault-bend **anticline** in the foot wall of the Grasshopper thrust plate and the overlying hanging wall Missoula Group Belt series.

The uppermost and largest manifestation of hydro-thermal processes at Clementine are the orbicular zones **surrounding the central zone** with **veins** and **nearby plutons**.

The orb alteration **cupola** we view as being due to axially symmetric, sub-horizontal, **confined**, **fluid over-pressured hydraulic fracturing zones** causing a **flow aquifer pathway guiding alteration and sulfide deposition.**

The View From Mt. Fleecer



The axially symmetric **orbicular cupolas**, base metal vein system, and plutons are signs of a deeper and potentially large porphyry Cu-Mo deposit with **smaller, minable high grade zones within thick reactive carbonate wall rocks that could meet environmental compliance.**