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
Clementine Prospect

28 km or 17 miles

Wise River

Mt. Fleecer
9,436 feet

Divide

Beaverhead/Deerlodge National Forest

Butte

Line of sight of the East Continental Pit

Montana
USFS: Erik Torgeson, Licette Hammer, Sonny Thornborrow for compliance through science

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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, Colquirirca, 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 stakeholders, 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 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

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.

Hildenbrand et al, 2000
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.

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.

Porphyry “parent” intrusive too small to account for Cu.

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

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

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

Regional N-S trending Anticlinorium in red

Frontal Thrust 7 km spacing

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

Calcite

Actinolite
Hydrothermal Titanite (Sphene) 200 $\mu$m long grains-amenable to \textit{in situ} SIMS (Ion Micro-Probe) U/Pb age date using a 10-40$\mu$m beam diameter

Makes possible: Direct radiometric age dating of hydrothermal alteration and mineralization
Micro-veinlets (biotite)

Evidence of Potassic Alteration
Interplay of BX, Veins, and Orb Zones

Over-pressured Hydraulic Fracturing

Migmatites
Permeability dominated
Ground water flow today
And Hydrothermal flow
Causing elevated As in springs

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

https://petrowiki.org/Diagonalizing_the_permeability_tensor

Orbicular Zone

Highly anisotropic diagonalized 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 hydrothermal 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 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.