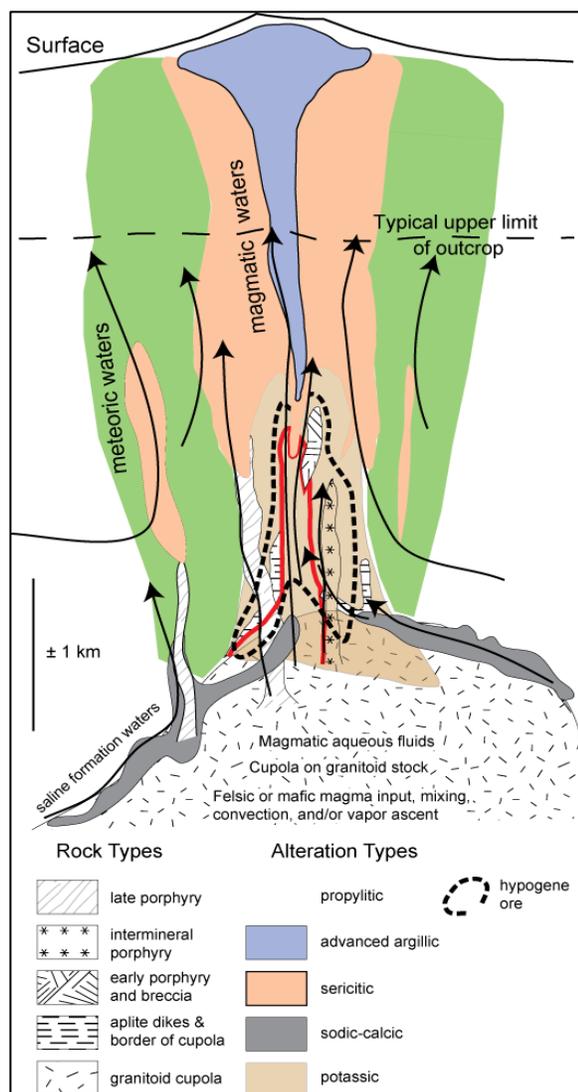




# Mineral Mapping

Scott Halley, 28/06/2016

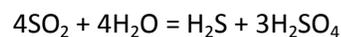
## Pathfinder element patterns in porphyry copper systems.



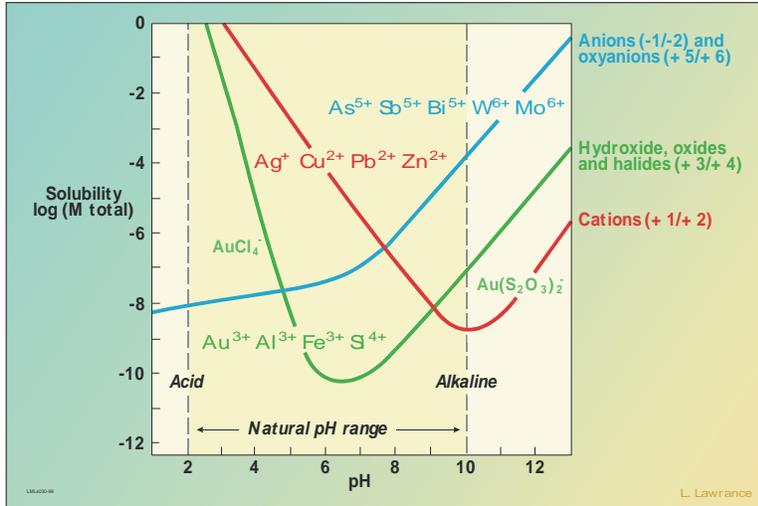
Porphyry copper systems are formed from very oxidized, sulfur-rich magmas.

Sulfur exsolved from the magma is in the form of  $\text{SO}_2$

Between 450 and 350°C,  $\text{SO}_2$  is converted to  $\text{H}_2\text{S}$ .

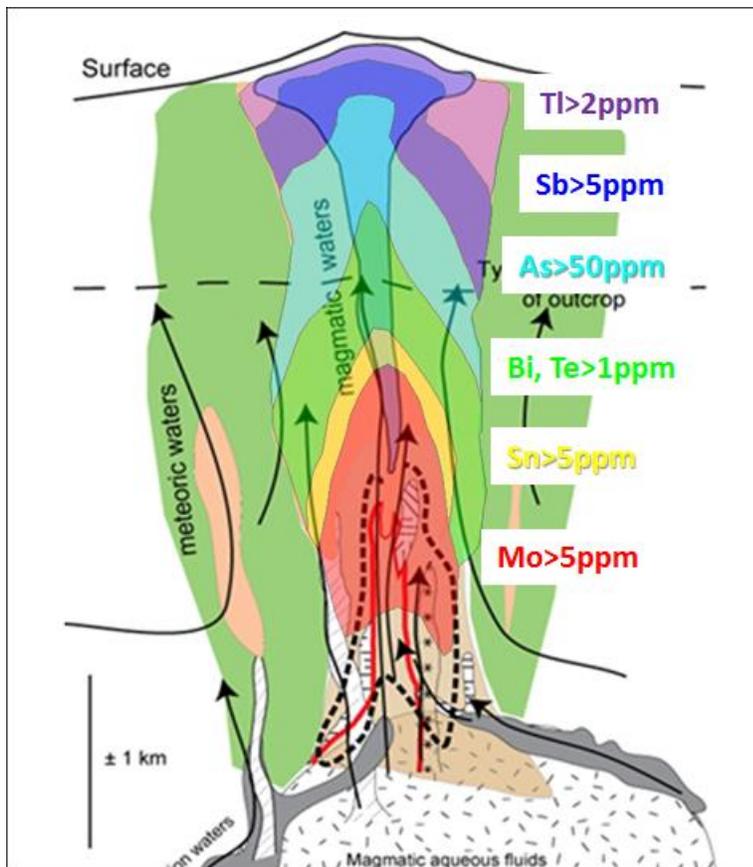


This creates acid. Above the ore zone,  $\text{H}_2\text{S}$  generated from the  $\text{SO}_2$  produces pyrite, and the accompanying acid produces sericite. The most acid alteration forms around the outflow zones.



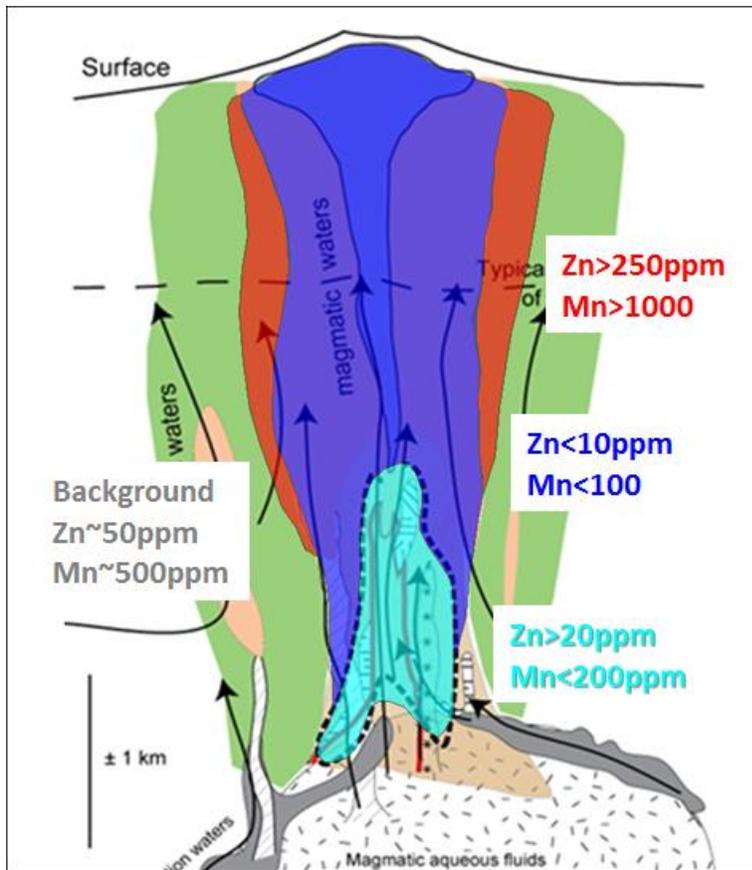
There are two distinctly different suites of pathfinder elements in magmatic-hydrothermal systems. Metals that form oxyanion complexes (Mo, Sn, W, Bi, Te, As, Sb, Tl) have very different behavior from those that form chloride complexes (Zn, Mn, Cu, Pb, Ag, Co, Ni). The metals that form oxyanion complexes are soluble in alkaline solutions, but become increasingly insoluble as the pH declines. Thus they precipitate in the acid outflow zones from porphyry

copper systems. The metals that form chloride complexes become increasingly soluble as pH declines. Thus they are stripped from the acid parts of the system and do not reprecipitate until they reach an environment where the acidity is neutralized.



Within the phyllic and advanced argillic alteration zones around and above porphyry copper deposits, there is a very consistent and very predictable zoning pattern in the pathfinder elements. Outwards from the copper shell, the metals are zoned from Mo to Sn to Se to Bi to Te to As to Sb to Tl. At low levels, these metals substitute into the lattice of pyrite. The zoning pattern is indicative of the temperature control on metal substitution in the pyrite lattice. Because of the pyrite host, there is very low variance from one sample to another, so the footprints and patterns are usually very coherent. Anomalous threshold levels are around ten times average crustal abundance. Many of these metals have a very low natural abundance. ICP-MS is the only analytical method that can measure these elements down to background

levels. Some of these metals require a 4 acid digest to achieve a total dissolution. **Therefore it is highly recommended to use ME-MS61 for reconnaissance geochemistry work.**



Divalent Mn, Zn, Co, Ni and most of the other first-row transition metals have chemical properties similar to Fe. In unaltered rocks they substitute for Fe in amphiboles and pyroxenes.

In the potassic alteration zone where primary hornblende is altered to biotite most of the Zn and Mn go into solution rather than being incorporated into biotite. In the phyllic and advanced argillic zones where all of the hornblende is altered to chlorite and then sericite, all of the Mn and Zn is stripped from the rock. On the margins of the acid alteration where there is some relict feldspar to neutralize the acid, a “doughnut” of Mn and Zn enrichment forms. If there is no reduced S left in the fluid, then Zn and Mn substitute into chlorite. If there is some S, base metal sulfides

precipitate. If there is CO<sub>2</sub> in the fluid, manganese-bearing carbonates will precipitate. Co, Ni and Cr also show patterns like Zn and Mn, but don’t have quite the same degree of mobility.

Note that the background levels of Mn and Zn are quite dependent on the composition of the host rock.

## References

LAWRANCE, L. M., 2004. Part 1: Exploration Regolith Geochemistry in SEG 2004 Workshop 1, How to look at, in and through the regolith for efficient predictive mineral discoveries, workshop notes: Perth, Western Australia, SEG 2004, 57p.

Halley, S., Dilles, J.H., and Tosdal, R.M., 2015, Footprints—Hydrothermal alteration and geochemical dispersion around porphyry copper deposits: Society of Economic Geologists (SEG) Newsletter, v. 100, p. 1–17.