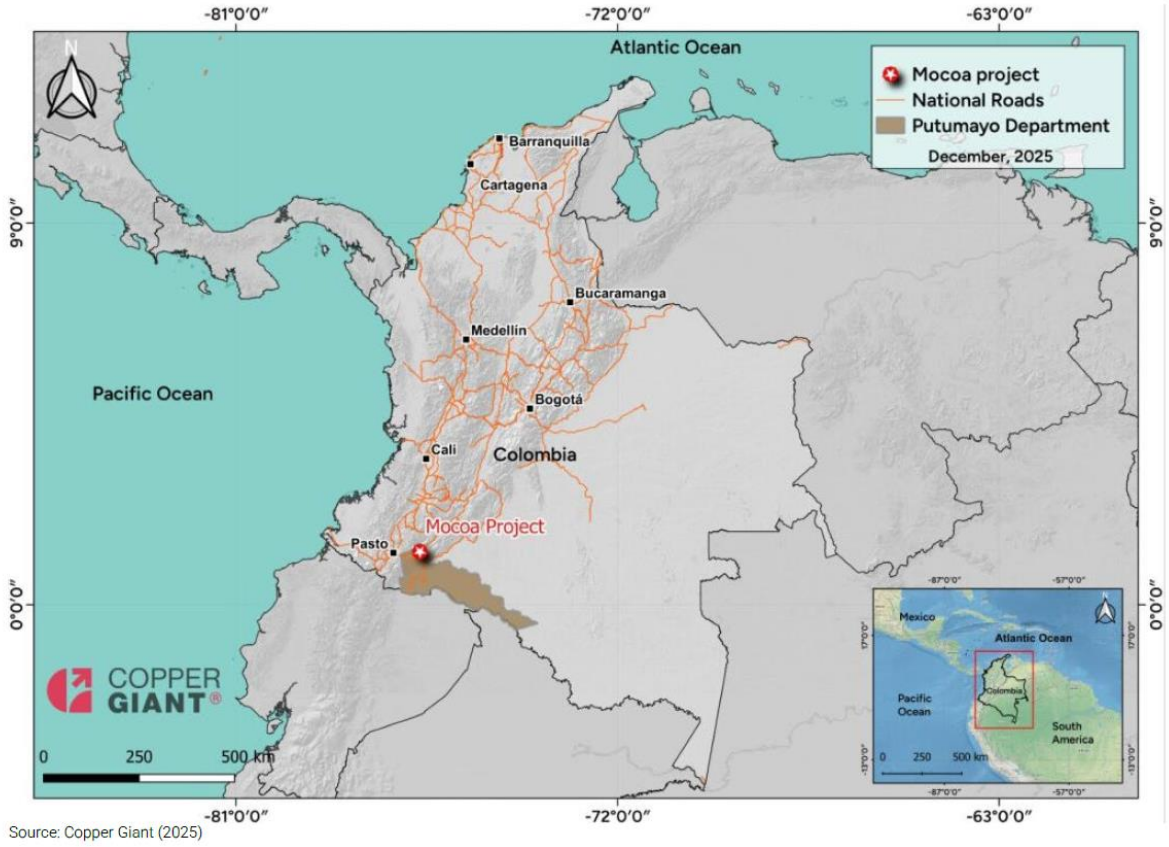
A Mineralogical Model of Mocoa Porphyry Cu-Mo deposit derived from 4 acid digest ICP data using the Comet software



Source: Copper Giant (2025)

About Mocoa

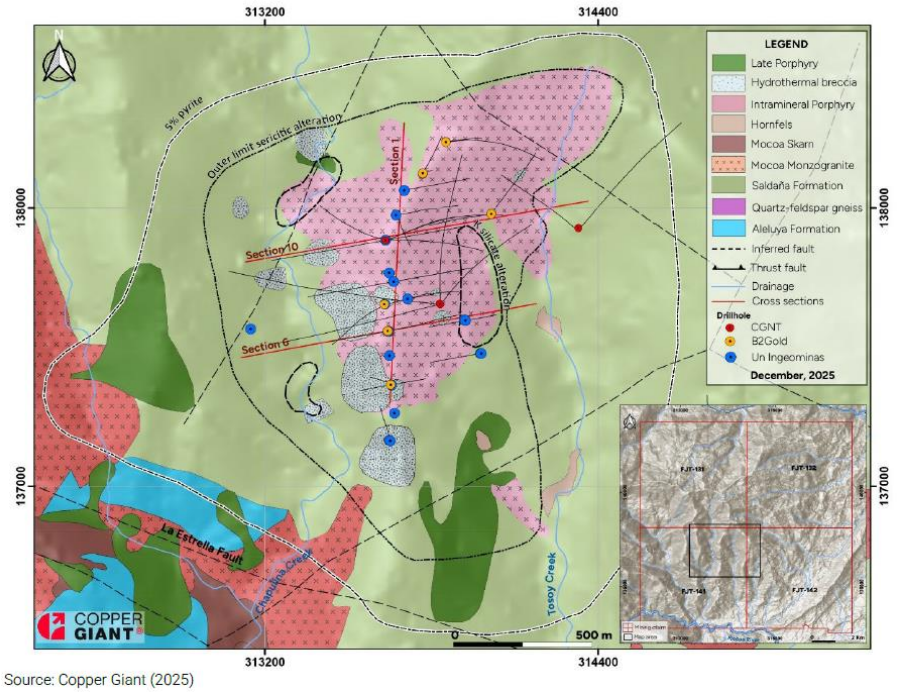
Mocoa is a large undeveloped Cu-Mo deposit in southern Colombia. The project is owned by TSXV listed Copper Giant Resources Corp. (TSXV: CGNT, OTCQX: CGNRF, FRA: 29H0). Mocoa has its first Indicated Mineral Resource of 290 Mt at 0.54% CuEq* (0.33% Cu and 0.038% Mo), and an Inferred Mineral Resource of 1.6 Bt at 0.40% CuEq* (0.27% Cu and 0.025% Mo), reported at a 0.15% CuEq* cut-off within the conceptual pit shell and a 0.40% CuEq* cut-off below it (effective date 24 September 2026; APEX Geoscience Ltd., Qualified Person Warren Black, M.Sc., P.Geo.). Mineral resources are not mineral reserves and do not have demonstrated economic viability.

https://coppergiant.com/Press%20Release/2026/2026%2010%2014%20NR_Mocoa_MRE_2026_FINAL.pdf, (technical report filed on SEDAR, to be released at the end of November)

Cut-Off (% CuEq*)	Classification	Tonnage (Bt)	CuEq* (%)	Cu (%)	Mo (%)	Contained Cu (Blbs)	Contained Mo (Blbs)
Mineral Resources Within the Conceptual Pit Shell							
0.15	Indicated	0.29	0.54	0.33	0.038	2.13	0.24
0.15	Inferred	1.48	0.40	0.26	0.025	8.46	0.82
Mineral Resources Below the Pit Shell							
0.40[8]	Inferred	0.12	0.48	0.34	0.025	0.90	0.07
Total Mineral Resources							
0.15	Indicated	0.29	0.54	0.33	0.038	2.13	0.24
0.15/0.40[8]	Inferred	1.60	0.40	0.27	0.025	9.36	0.89

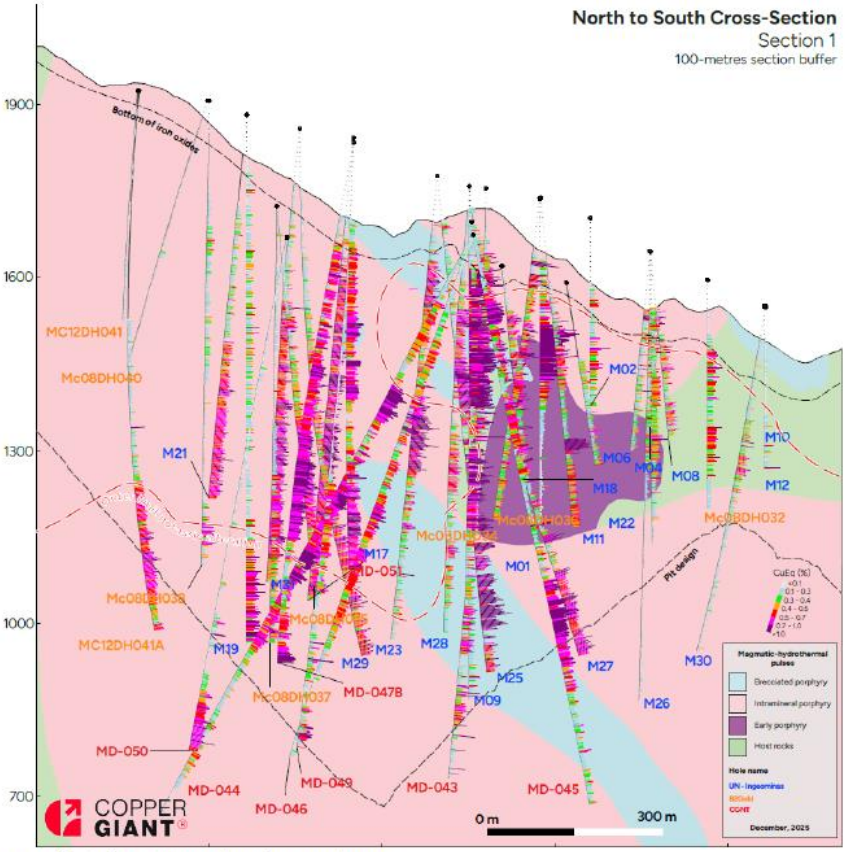
To date, it has 35,000m of drilling. Almost 13,000 samples have 4 acid digest ICP analyses. From these analyses, the Comet software was used to calculate mineral abundances and build an alteration model.

Figure 10.4 Plan view geology, drillholes and cross section locations, Mocoa Deposit (WGS1984, Zone18N).



Source: Copper Giant (2025)

Figure 10.5 North to south cross section, Mocoa Deposit.



Note: Red dashed line shows outer limit of potassic alteration.
Source: Copper Giant (2025)

About Comet

Comet is a mass balance calculation system.

The input is 4 acid digest ICP analyses of major elements Al, Ca, Fe, K, Mg, Na and S and significant minor elements As, Ba, Cu, Mn, P, Pb, Ti, Zn

To perform the mass balance, a list of minerals present in the system is created. There are default mineral selections based on the deposit type. The list is easily editable based on SWIR data or petrology information available to the user.

The software contains methods to predict likely solid solution variations of mica, chlorite and feldspar compositions. Estimating the solid solution compositions of white micas has a significant effect on the relative percentages of mica, feldspar and quartz that are calculated.

It runs on an optimization routine that estimates mineral abundances such that the sum of the components of the minerals is equal to the whole rock totals for the elements.

Why do we want a mineralogy model?

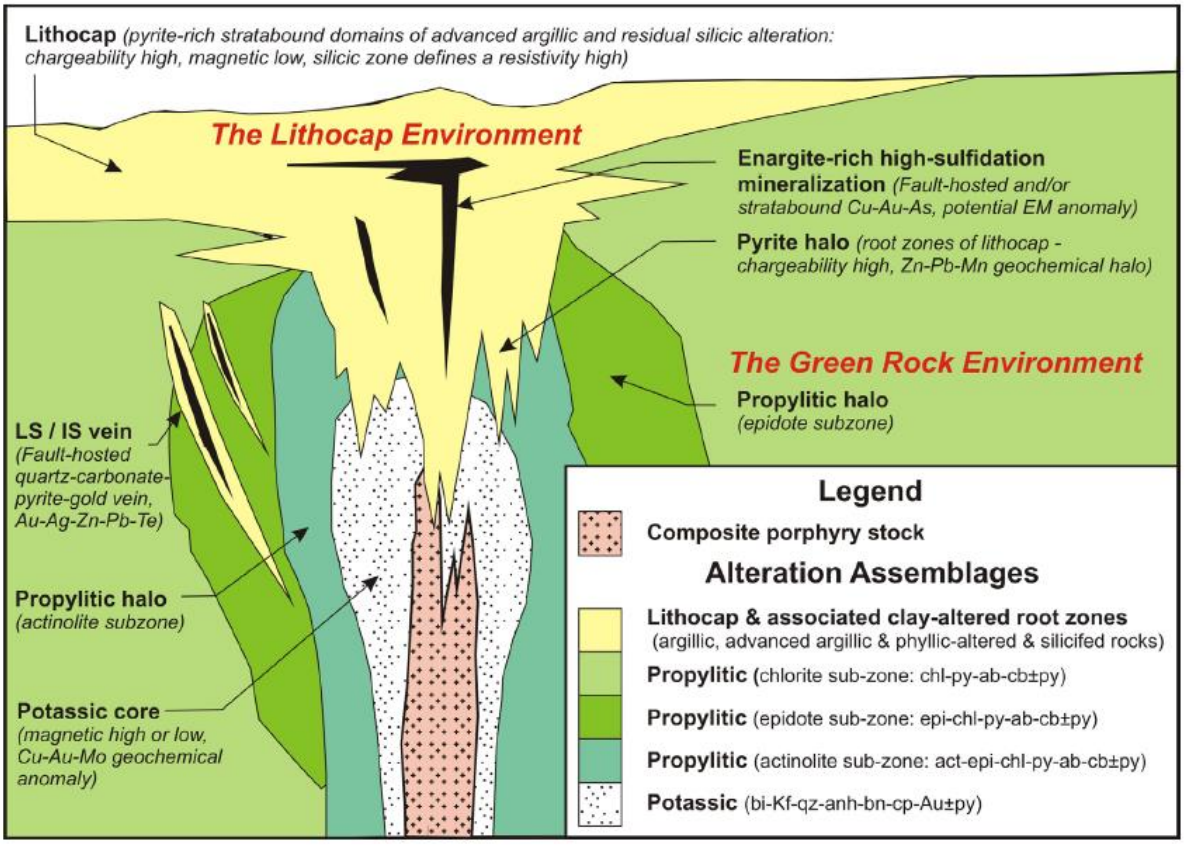
Every hydrothermal metal deposit formed within a chemical gradient. There has to be a change in temperature, pH, fO_2 or aH_2S to precipitate metals from a fluid. The same changes also lead to a zoned silicate mineral distribution along the flow path. Mapping the bulk mineralogy is therefore a guide to exploring a system and planning drill holes.

Once a resource has been discovered and delineated, we need to understand the economics of mining and processing. A good 3D mineralogy model is needed to map variability within the orebody and to predict variability in comminution, complexity of sulfides and how that might impact the required grind size, mass pull (in the flotation stage), components that are deleterious to flotation or quality of the concentrate and abundances and distribution of minerals that need to be considered in waste rock storage.

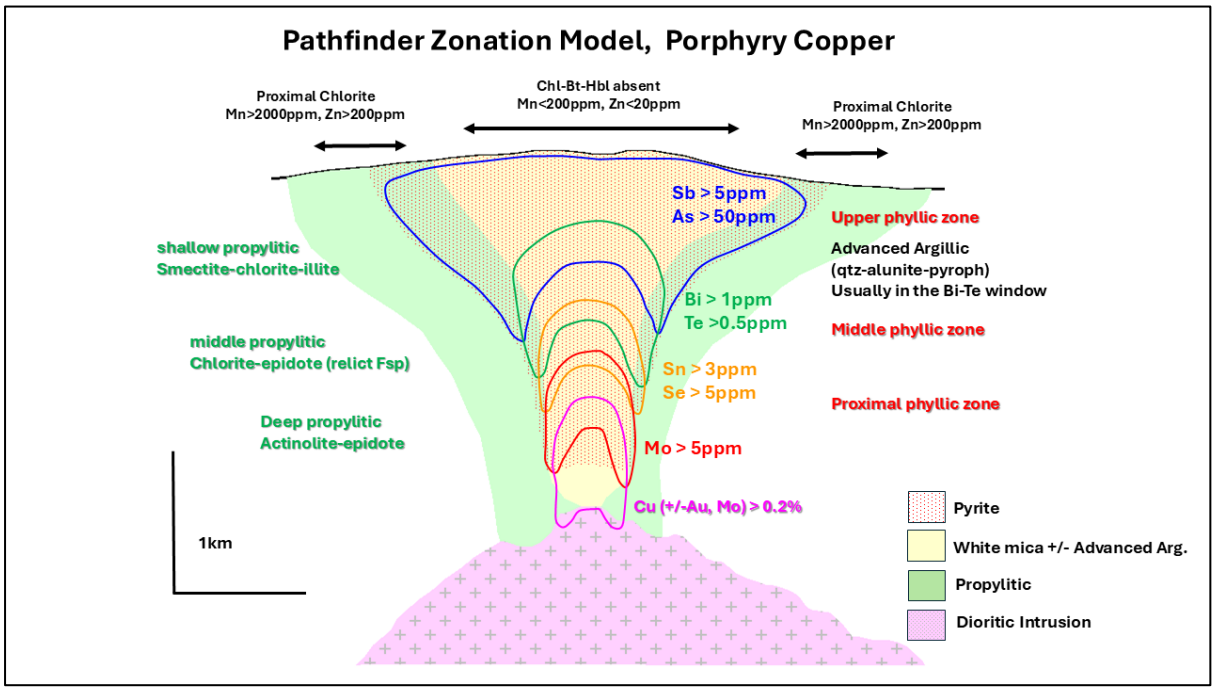
Alteration Mineralogy in Porphyry Copper Deposits

Porphyry copper deposits are the most studied deposit type in the world. Every geologist will understand the basic mineralogy model. We expect to see a zoning pattern from albite-orthoclase-biotite-anhydrite-magnetite in potassic zones, to white mica-quartz-pyrite +/- chlorite in phyllic zones, and perhaps a preserved lithocap with quartz-pyrite-alunite-pyrophyllite-dickite-kaolinite-muscovite at the top of the system. We expect to see a zoning pattern in the sulfide minerals. If bornite is present, it is most

likely in the deep core of the system associated with magnetite. The center of the copper grade shell should be dominated by chalcopyrite with subordinate pyrite. Heading upwards and outwards, the proportion of chalcopyrite will decrease, and pyrite will increase.



Holliday et al., 2007



There should also be a predictable pathfinder element zoning pattern around porphyry systems. The trace element signature of pyrite changes with declining temperature, from Mo, Se, Sn, Bi, Te, As to Sb. Therefore the spatial pattern of the pathfinders in some instances will highlight overprinting events.

All porphyries show some degree of overprinting. This can be evident in the vein paragenesis, in the silicate minerals or in the sulfides. In simple porphyries, this happens just because of cooling with time, but more commonly porphyry systems have multiple intrusions and/or breccias, each with their own hydrothermal event, coalescing in time and space. This is important because it can add (or remove) metal and change the costs of processing and recoveries of metals. We want a 3D mineralogy model that helps to spatially define the extents of these processes.

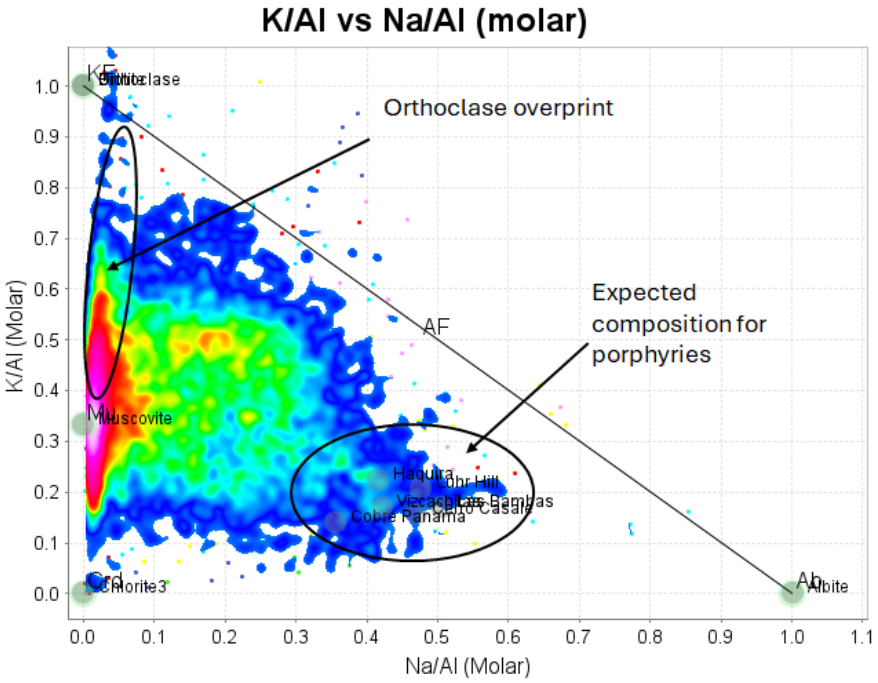
Explore the data

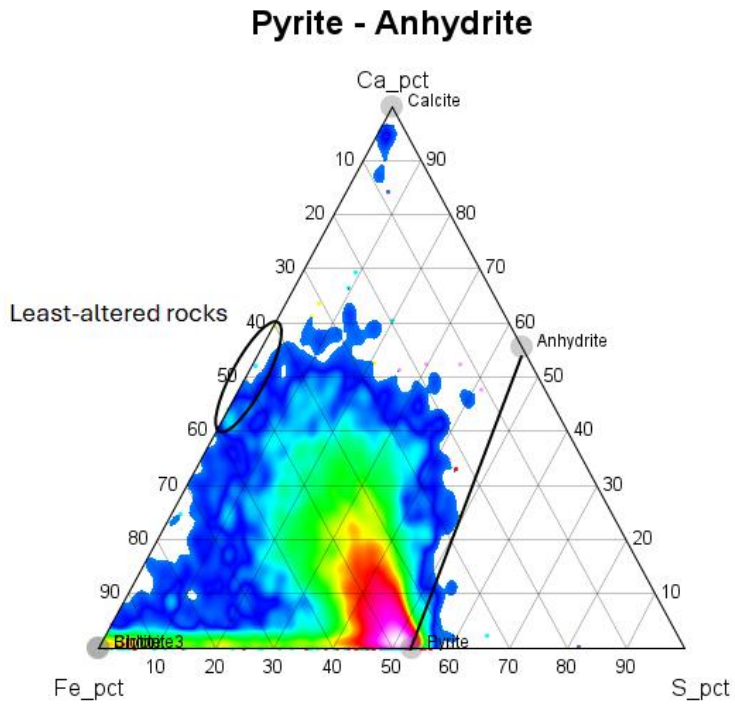
Before running the Comet software to estimate mineral abundances create some mineralogy plots from the major elements in the assay table to see what the mineralogy trends are likely to be.

- K/Al vs Na/Al (molar) to see relative amounts of feldspar versus mica and aluminosilicates.
- Al-K-Mg ternary to see relative amounts of white mica, orthoclase, aluminosilicates and chlorite
- Ca-Fe-S ternary to see relative amounts of pyrite vs anhydrite
- Ca-K-Na ternary to see primary feldspar compositions and to see if Ca is lost or retained (anhydrite, carbonate) as plagioclase is altered.

A characteristic of porphyry Cu magmas is that they do NOT fractionate sodic plagioclase, so the intrusions tend to evolve to relatively sodic compositions. The dominant reaction in potassic zones is plagioclase + SO_2 = albite + anhydrite. Hornblende is replaced by biotite, but the absolute amounts of K and Na in potassic zones don't change much. Almost all the Mocoa rocks show significant Na depletion.

Also note the trend of data from the muscovite node, heading towards the orthoclase node. This is a very distinctive style of low Al white mica and orthoclase that occurs in overprinted systems.





Most igneous rocks have roughly equal amounts of Ca and Fe on a weight percent basis. This shows immediately that there is at least some pyrite everywhere in the system. In a hydrothermal system with a high water to rock ratio, the amount of pyrite that can be formed is limited by the amount of Fe in the rocks, not by the amount of S in the fluid. The host rocks here have a relatively low Fe content.

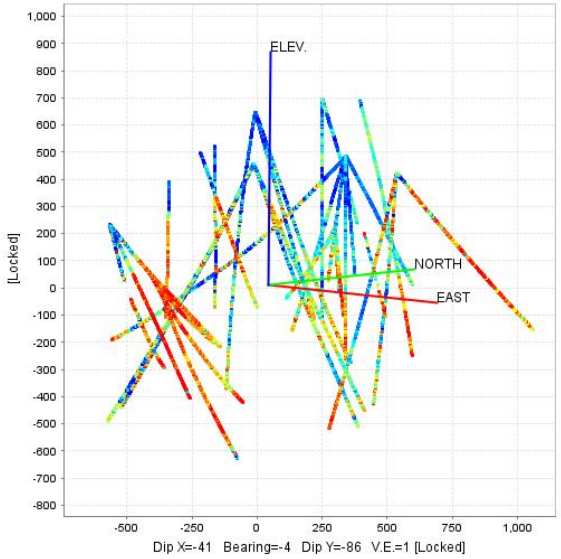
In almost every porphyry system, the data cloud on this figure has a bounding edge that is the tie line between the pyrite node and the anhydrite node. Mocoa is a low anhydrite

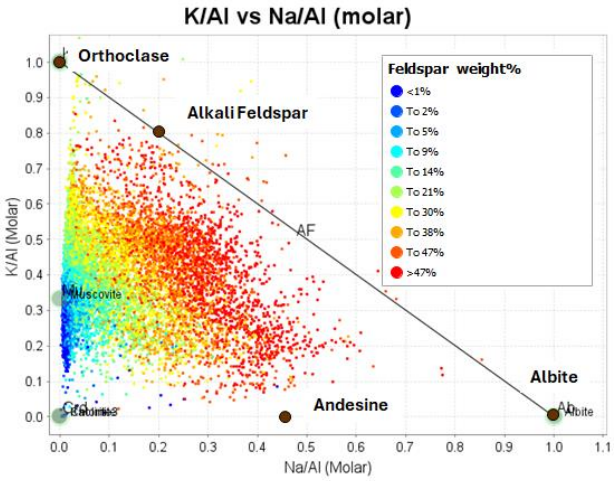
system. A curious feature of anhydrite is that it has retrograde solubility, that is, as the temperature of a fluid decreases, anhydrite becomes more soluble. It is highly likely here that the lack of anhydrite is also a result of overprinting.

Results From Comet

Feldspar.

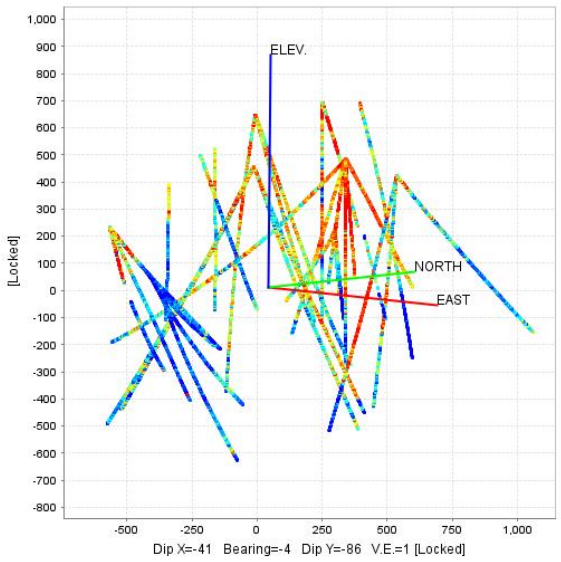
Feldspar was calculated as end members; alkali feldspar, plagioclase, albite, orthoclase and Ba-feldspar. This shows the sum of feldspars. The total should be low from the muscovite node to the origin (kaolinite), and increase outwards towards the orthoclase-albite tie-line.

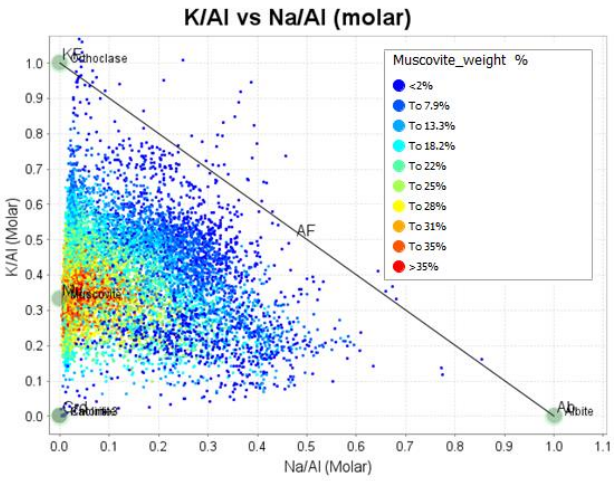




Muscovite

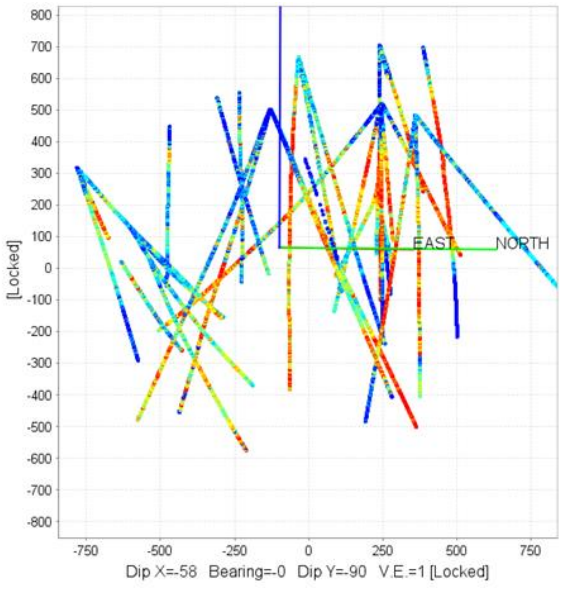
Muscovite abundances cluster around the muscovite node as expected, and it is more or less the inverse of feldspar. Copper grades spread across the transition from potassic to phyllic. This has possible implications for crushing, grinding and mill throughput rates. Note the high mica abundance in some of the deeper holes. Deep phyllic alteration is most likely the result of an overprinting event(s) in this system. This has implications for variations in crushing, grinding, flotation, sulfide textures and recoveries for those ore blocks.

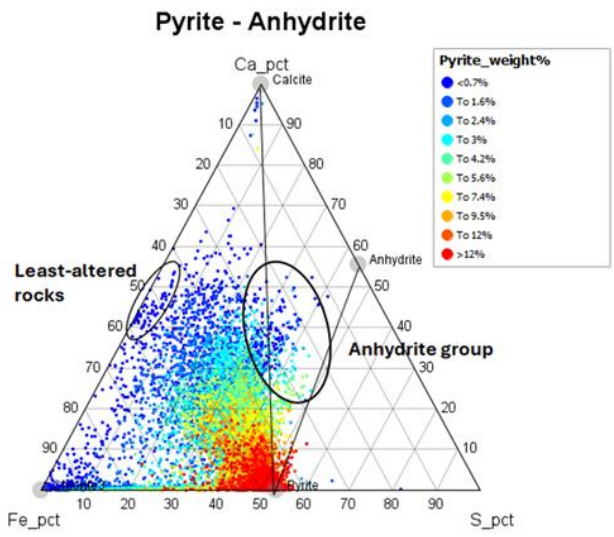




Pyrite

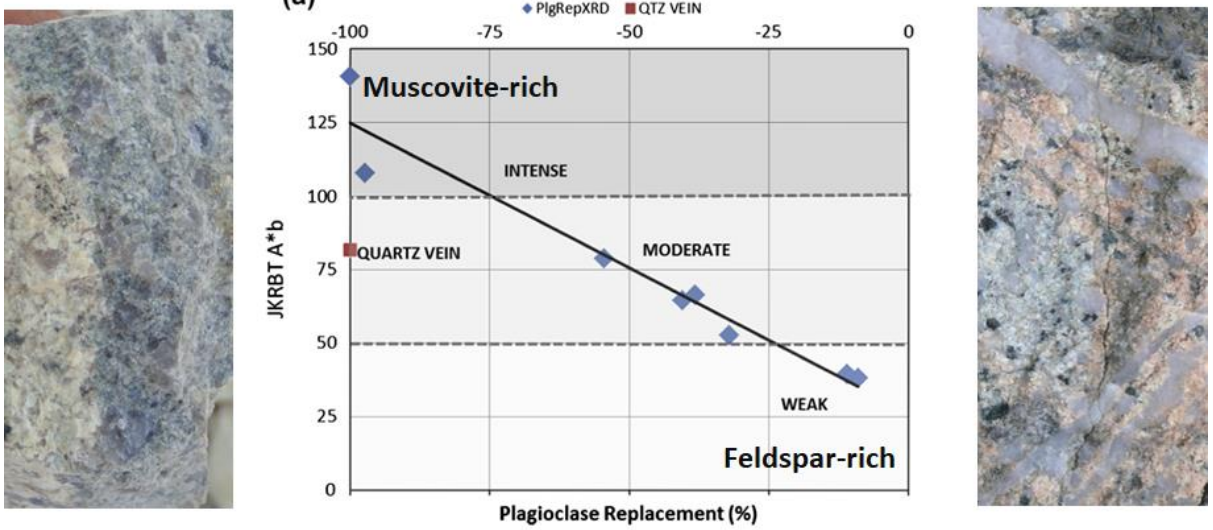
Pyrite forms a distinct shell around the system, especially around the northern copper zone. However, it is significant to note the abundance of pyrite in the deep holes where we would expect Chalcopyrite>>Pyrite. This is another likely indication of overprinting. The marked decrease in pyrite at the top of the holes is also obvious, and this marks the base of oxidation. We know this is related to pyrite dissolution rather than gypsum, because the Ca depletion front is significantly deeper. With gypsum dissolution in groundwater, Ca and S depletion are coupled. If it is carbonate dissolution, the Ca depletion front is deeper than the S dissolution front. I interpret carbonate is part of the overprinting event.



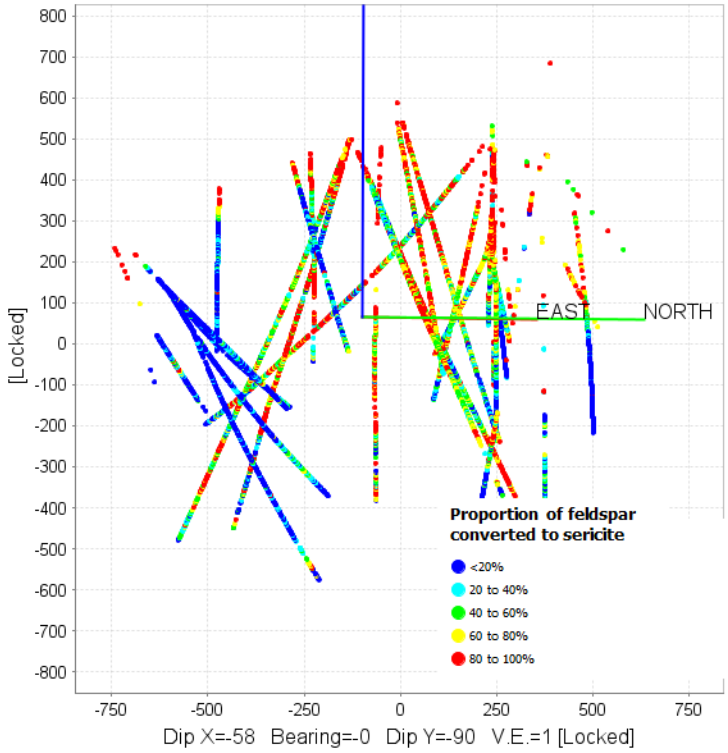


Proxy for Grindability

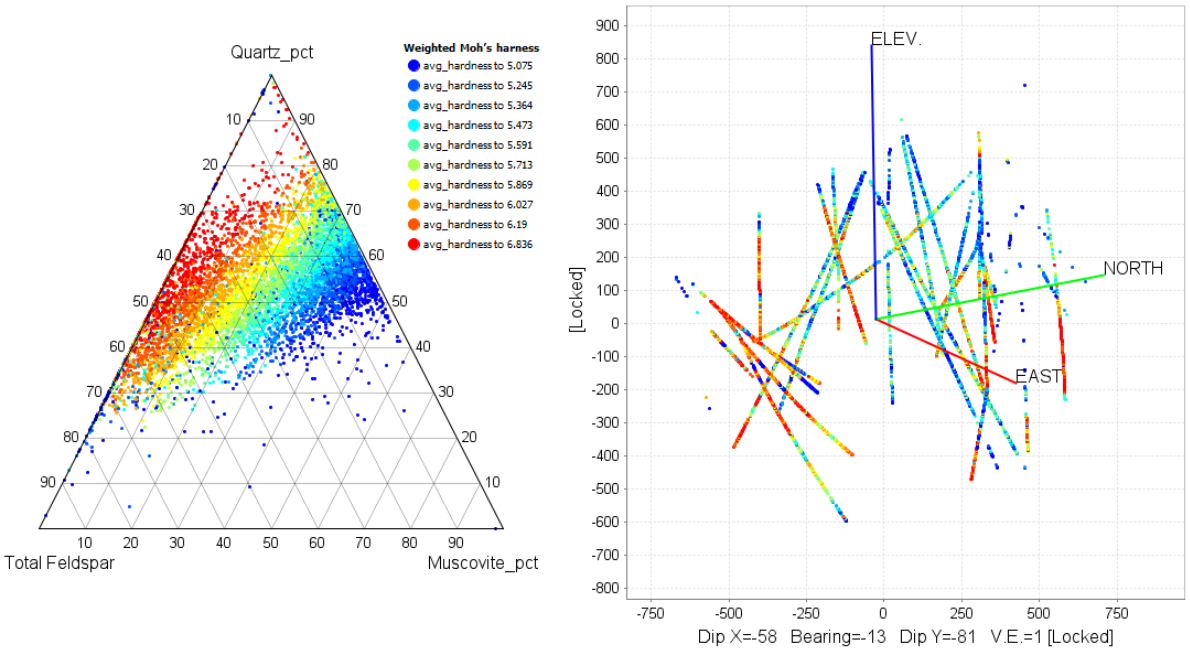
There are few published case studies that compare measured quantitative mineralogy with some kind of grinding index. One of the more detailed studies is by Yildirim et al, (2014). In this study, the authors selected a suite of Highland Valley samples from feldspar-rich to sericite-rich. They quantified the mineralogy using qXRD and calculated a “Plagioclase Replacement Index”. Each sample was subjected to the JK Rotary Breakage Test. This allowed a comparison between bulk mineralogy and comminution. In this study there were just 8 data points.



Something we can do with the results from Comet is calculate an index that is analogous to Yildirim’s Plagioclase Replacement Index. Take a subset of samples with Cu>0.2%. From the Comet results, calculate Muscovite wt%/(Muscovite% + Feldspar%).



Some studies, eg Schmitt (2021) demonstrated a reasonable correlation between a weighted Mohs hardness from the sum of the component minerals and a grindability index. The Comet output includes a weighted Mohs hardness.



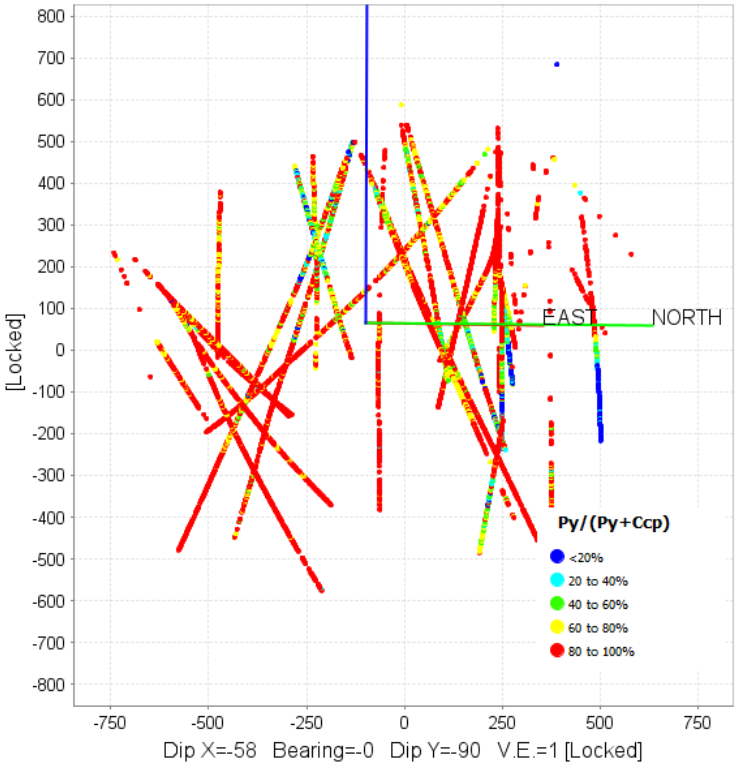
Weighted Mohs Hardness as a Quartz-Feldspar-Muscovite ternary, and in 3D view.

The three most abundant gangue minerals are quartz, feldspar and white mica. Consider the ternary plot below. If you were to select a suite of samples based on this plot that covered the range of quartz:feldspar:mica and send them to a lab for comminution tests, could a calibration between mineralogy and grindability be

established, analogous to that presented in Yildirim (2014)? If so, the results from Comet could be used to populate the entire resource block model with a predicted measure of comminution.

Proxy for Flotation

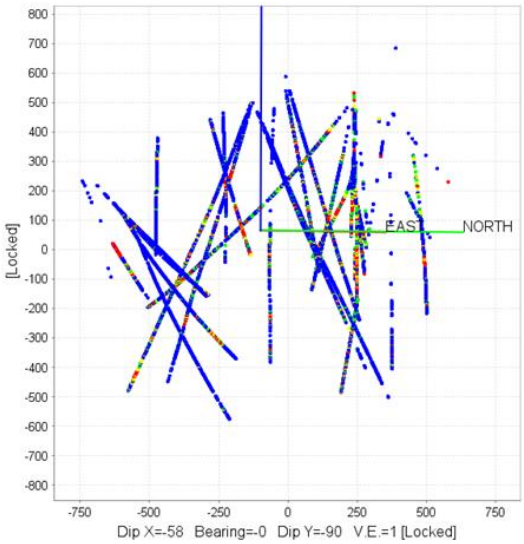
The other obvious consideration from the Comet mineralogy calculations with regards to geometallurgy is to consider the impact of mass pull on flotation. We can calculate the ratio of pyrite to pyrite+chalcopyrite. This is easy to calculate in systems that have no anhydrite, but where anhydrite is present this becomes a non-trivial calculation. We can't calculate the amount of anhydrite without working out how Ca is distributed between plagioclase and Ca sulfate. We can't work out the amount of plagioclase without solving for white mica. We can't calculate white mica accurately without considering the solid solution compositions of mica on a sample by sample basis. Comet does a reasonable job of this. It might therefore be possible to start quantifying variations in mass pull across a porphyry system.

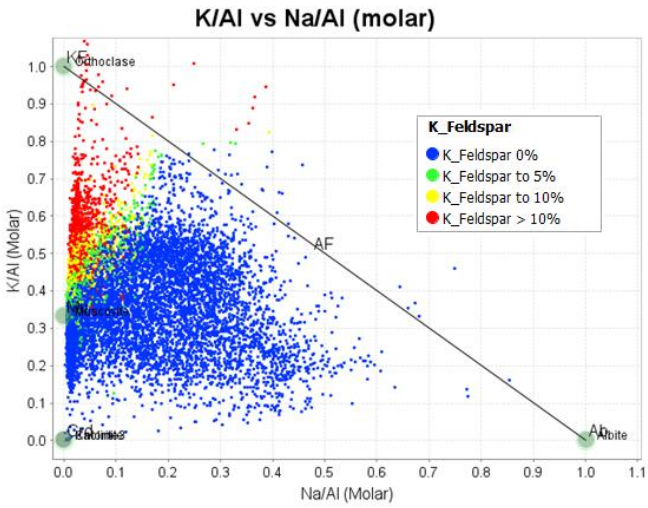


Overprinting and sulfide complexity

There are features of Mocoa that indicate there is extensive hydrothermal overprinting of the initial porphyry system. These include the occurrence of pyrite and muscovite deep in the system where the potassic core might have been expected, the apparent

dissolution of anhydrite, and the presence of a distinct low temperature K feldspar. If there is a generation of sericite-pyrite overprinting potassic or earlier sericite-pyrite, it can be difficult to consistently recognize and log visually. In a simple porphyry system, most of the copper sulfide minerals precipitate before most of the pyrite. Pyrite has a strong crystal habit, so it nucleates and grows independently. Where there is an overprinting event that introduces more copper or reworks existing copper sulfides, those later copper minerals typically overgrow existing pyrite grains. This makes copper separation from pyrite more difficult. These observations need to be tested with microscopy and/or MLA work to observe the textures and timing of the sulfides and to determine the grinding size required to effective copper sulfide liberation.

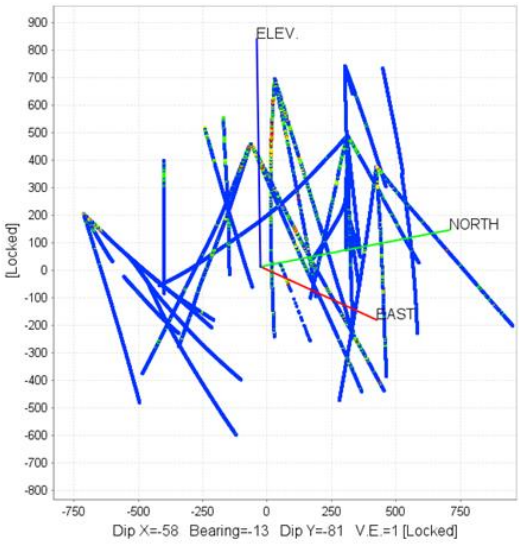


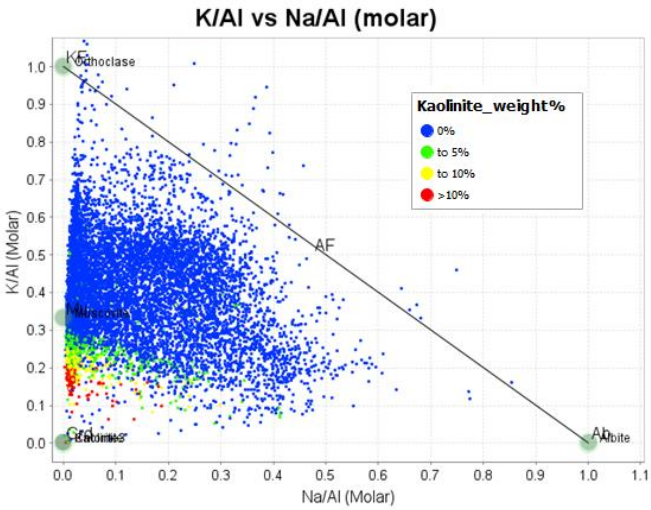


Clay Minerals

It is often discussed that some clay minerals can interfere with flotation, primarily by increasing the viscosity of the slurry and preventing froth formation. How often has this been quantified? Try another online search. See if you can find a published case study where the type and abundance of clay has been modelled in 3D? If we don't make quantitative model of deleterious components of mineral systems, then we don't have a proactive means of handling them during the mining process.

At Mocoa, there is a small amount of kaolinite, mostly near the top of a few holes. Montmorillonite is more likely to be an issue with flotation. It is very likely that SWIR would report a dusting of illite-smectite-kaolinite in the relict feldspars. It could have a broad distribution, but it is not significant on a weight% basis. The predicted clay zones should be compared with RQD measurements to see if they are fault related.





Summary

It is impossible to make consistent and quantitative interpretations of alteration mineralogy from visual logging. Almost every exploration company runs multi-element ICP-MS by default, and very few get the most out of it. Comet produces a quantitative estimate of mineralogy without the need for new sampling and can be run retroactively over years of legacy assays.

SWIR methods from either point sampling or scanning techniques are used by most companies. Comet is significantly cheaper than any of the SWIR methods (point measurements, or scanning), but the methods are complementary rather than competing. The strength of the spectral methods is the identification of the clay minerals and mapping the mica compositions. The strength of Comet is quantifying the major rock-forming minerals in a hydrothermal system; quartz-feldspar-mica-chlorite-pyrite-anhydrite.

There are no cheap and quick methods to determine quantitative mineral abundances, so there are very limited options for creating the types of models that can be generated with Comet.

Comet provides a starting point for creating a 3D mineralogy model that can be used by every discipline in resource estimation, financial modelling, plant design, and mineral processing chain.

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