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Sodic-Calcic Alteration in Porphyry Cu Systems: Definitions, Footprints, and Origins

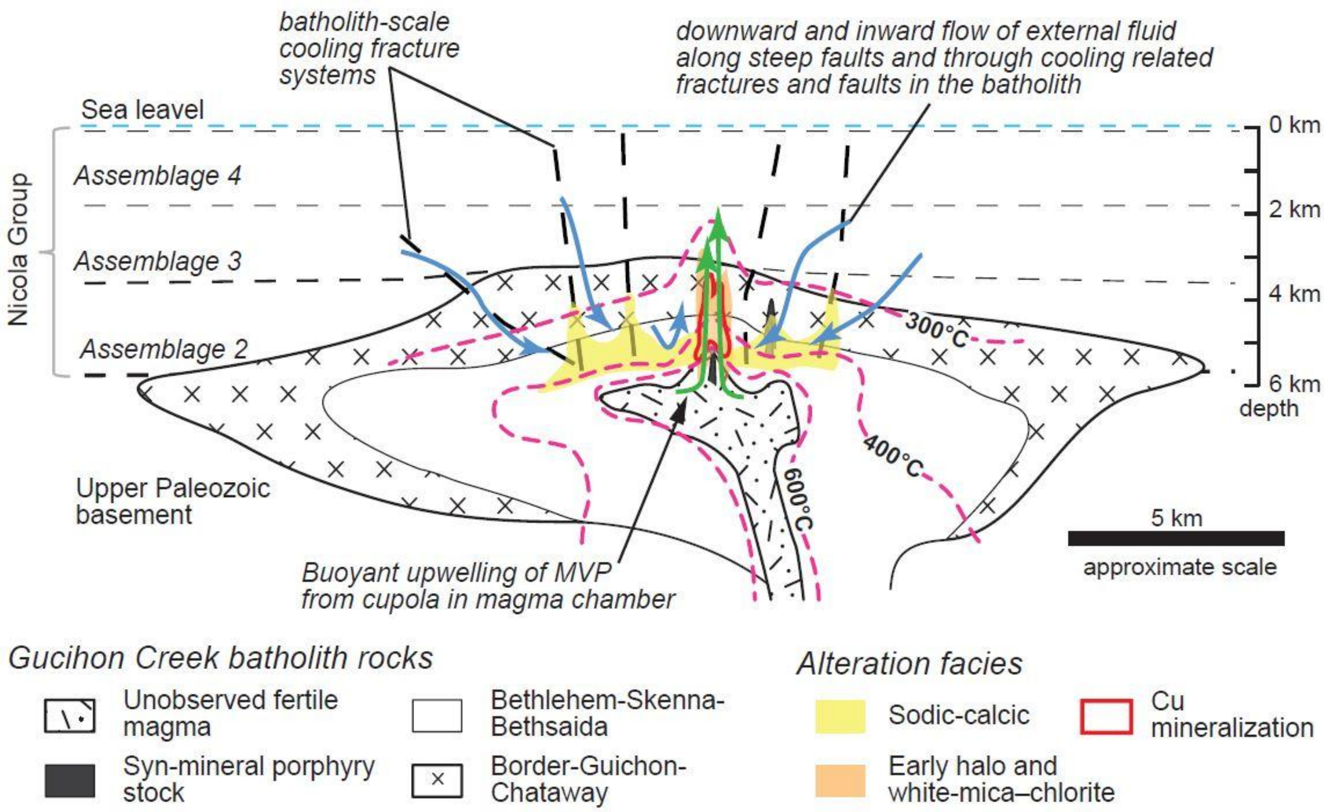
Kevin Byrne
Teck Resources Limited, Vancouver, BC, Canada

The Highland Valley Copper (HVC) porphyry Cu (±Mo) district is hosted in the Late Triassic Guichon Creek batholith (GCB) in the Mesozoic Quesnel island arc of the Canadian Cordillera. Fracture-controlled sodic-calcic alteration is important because it forms a large footprint (34 km^2) outside of the porphyry Cu centers. This alteration consists of epidote ± actinolite ± tourmaline veins with halos of K-feldspar-destructive albite (1–20 X_{An}) ± fine-grained white mica ± epidote. Sodic-calcic-altered rocks exhibit depletion in K, Fe, and Cu and are generally enriched in Na, Ca, and H_2O.

Calculated $\delta^{18}O_{fluid}$ and δD_{fluid} values of mineral pairs in isotopic equilibrium from the sodic-calcic veins and alteration range from 4 to 8‰ and -20 to -9‰, respectively, which contrasts with the whole-rock values for least-altered magmatic host rocks ($\delta^{18}O$ = 6.4 to 9.4‰ and δD = -99 to -75‰). The whole-rock values are suggested to reflect residual magma values after D loss by magma degassing, while the range of hydrothermal minerals requires a mixed-fluid origin with a contribution of magmatic water and an external water source. Supporting evidence for a seawater-derived fluid entrained in the porphyry Cu systems comes from boron isotope data. The calculated tourmaline $\delta^{11}B_{fluid}$ values from the sodic-calcic domains reach 18.3‰, which is consistent with a seawater-derived fluid source.

Sodic-calcic and sodic alteration is also recognized in several Laramide-age porphyry Cu systems in the SW US. Where Na-Ca alteration is present in these systems, it is best developed at relatively deep levels of porphyry systems. The calculated δD isotopic compositions of fluids in equilibrium with associated alteration minerals span a broad range (–46 to –1‰) and are consistently less negative than magmatic fluids. The isotopic compositions of minerals and the geologic alteration zoning patterns have led other researchers to conclude that sodic and sodic-calcic facies in and around the porphyry Cu systems formed by incursion of saline external fluids.

The studies at HVC and in the SW US imply that sodic-calcic facies can form in different geologic environments from a variety of external fluids. At HVC the presence of Na-Ca alteration in the GCB demonstrates that seawater-derived fluids can infiltrate batholiths and porphyry systems at deep levels (4–5 km) in the crust and highlights that complex paleohydrology and nonmagmatic fluid sources result in atypical porphyry Cu alteration zones. Key factors for generating widespread sodic-calcic assemblages, K-depleted rocks, and local leaching of Fe and Cu are the presence of permeability and conditions such that the external saline fluid is heated on ingress to the porphyry system.



batholith-scale cooling fracture systems
downward and inward flow of external fluid along steep faults and through cooling related fractures and faults in the batholith
Sea leavel
Nicola Group
Assemblage 4
Assemblage 3
Assemblage 2
0 km
2 km
4 km
6 km
depth
300°C
400°C
600°C
Upper Paleozoic basement
5 km
approximate scale
Buoyant upwelling of MVP from cupola in magma chamber
Gucihon Creek batholith rocks
Unobserved fertile magma
Syn-mineral porphyry stock
Bethlehem-Skenna-Bethsaida
Border-Guichon-Chataway
Alteration facies
Sodic-calcic
Early halo and white-mica–chlorite
Cu mineralization