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Systematics of hydrothermal alteration at the volcanic-hosted Falun Zn-Pb-Cu-(Au-Ag) deposit – implications for ore genesis, structure and exploration in a 1.9 Ga ore district, Fennoscandian Shield, Sweden

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The Palaeoproterozoic, volcanic-hosted Falun Zn-Pb-Cu-(Au-Ag) sulphide deposit was mined for base and precious metals during several centuries, until its closure in 1992. The deposit is located in a 1.9 Ga ore district in the Bergslagen lithotectonic unit, Fennoscandian Shield, south-central Sweden. Both the ores and their host rock underwent polyphase ductile deformation, and metamorphism under amphibolite facies and later retrograde conditions at 1.9–1.8 Ga (Svecokarelian orogenic system).

This study has the following aims: (i) Classify styles and intensities of alteration in the hydrothermally altered zone at Falun; (ii) identify precursor rocks to hydrothermally altered rocks and their spatial distribution at the deposit; (iii) evaluate the chemical changes resulting from hydrothermal alteration using mass change calculations; and (iv) assess the pre-metamorphic alteration assemblages accounting for the observed metamorphic mineral associations in the altered rocks at Falun. Results will have implications for both the ore-genetic and structural understanding of the deposit, as well as for local and regional exploration.

Metamorphic mineral associations in the altered rocks include biotite-quartz-cordierite-(anthophyllite) and, more proximally, quartz-anthophyllite-(biotite-cordierite/almandine), biotite-cordierite-(anthophyllite) and biotite-almandine-(anthophyllite). The proximal hydrothermally altered zone corresponds to intense chlorite-style alteration. Subordinate dolomite or calcite marble, as well as calc-silicate (tremolite, diopside) rocks are also present at the deposit. Metavolcanic rocks around the deposit are unaltered, weakly sericitized or sodic-altered. Immobile-element (e.g. Zr, TiO_2, $Al2O_3$, REE) systematics of the silicate-rich samples at and around the deposit suggest that the precursors to the hydrothermally altered rocks at Falun were predominantly rhyolitic in composition, dacitic rocks being subordinate and mafic-intermediate rocks strongly subordinate.

Pre-metamorphic alteration in the proximal hydrothermally altered zone is characterized by general depletion in Na and Ca, and a strong enrichment in Mg and Fe. Pre-metamorphic alteration assemblages of Mg- or Fe-chlorite, sericite and talc can account for the observed mineral associations in the altered rocks. During metamorphism, strongly Mg-enriched altered rocks yielded Mg-rich biotite and cordierite porphyroblasts, whereas Fe-enriched altered rocks typically have Fe-rich biotite and garnet porphyroblasts dominated by the cations Fe and Mn. The less aluminous quartz-anthophyllite rocks could have formed from rocks enriched in talc.

The nature of the precursor, style of hydrothermal alteration and mineralogy at Falun are characteristic of a metamorphosed volcanogenic massive sulphide (VMS) deposit. The zone of intense chlorite-style alteration of rhyolitic precursor rocks envelops the formerly mined sulphide ore bodies on all sides of the deposit. These spatial relationships are consistent with a previously suggested structural model, wherein the mineralization is hosted by a steeply plunging, D2 sheath fold with no preserved stratigraphic hanging wall in the core of the structure. The parts of other sulphide deposits in the 1.9 Ga ore district lacking good stratigraphic control and previously considered as barren hanging-wall rocks may have a higher exploration potential for base metals than previously thought.