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The Eastern Alpine metallogenic province: a resource of critical and strategic elements?

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One of the benchmarks of the Critical Raw Materials Act of the European Union requires a minimum of 10% supply from primary sources within the European Union until 2030. In the Eastern Alps, numerous deposits of base (Cu, Pb, Zn) and precious metals (Au, Ag) have been mined in the past, with production terminating in the 1990s. The contents of trace metals in the ores are largely unknown. In order to close this knowledge gap, a LA-ICP-MS study was conducted covering more than 60 polymetallic sulphidic mineralizations in the Eastern Alps. These comprise polymetallic (Cu-Zn-Pb±Ag) stratiform ores, polymorphic ore bodies and vein deposits in Neoproterozoic to Late Paleozoic, low- to medium-grade metamorphic rocks of the Subpenninic and Austroalpine nappe systems, and "Alpine-type" Zn-Pb-(pyrite) ores in Mesozoic carbonate sequences of the Austroalpine and South Alpine. The results indicate a large compositional variability of sphalerite, chalcopyrite, pyrite and pyrrhotite.

Two chemical types of sphalerite are broadly distinguished: (1) sphalerite in Alpine-type mineralizations is low in Fe (<1 %), Mn, Co, Ga, In, Sn, Sb, but may be significantly enriched in Ge (up to >500 ppm), Ga, As, Tl and Pb; (2) sphalerite in stratiform or vein-type ores hosted by low- to medium grade metamorphic rocks is elevated in Fe, Co, Ni, Cu, Ag, In and Sn.

Chalcopyrite carries Zn, Ag, Sn, Se, Pb and Mn as most important trace elements. Median concentrations of Ag and Sn may reach hundreds to thousands of ppm. Median concentrations of In exceed 40 ppm in several deposits. Concentrations of Co, Ge and Ga only exceptionally exceed the 10 ppm level.

Pyrite carries Co, Ni and As as most abundant trace elements, followed by Mn, Pb, Zn and Cu. The maximum concentrations of In, Ge and Ga reach 20 ppm. The most Co and Ni enriched pyrites occur in the Subpenninic unit in association with Ni-rich pyrrhotite, pentlandite and chalcopyrite. In stratiform ores hosted by Paleozoic low- to medium-grade sedimentary and magmatic host rocks, median values for Co are close to 500 ppm, whereas those from many vein and carbonate-hosted ores are much lower. Pyrite from some ores are Ni enriched with respect to Co.

The preferential incorporation of trace elements in Fe-Cu-Zn sulphide assemblages was investigated using polyphase assemblages comprising 2 up to 4 minerals. The elements Mn, Ga, Se and Cd are preferentially incorporated into sphalerite; Co, Ni into pyrite and pyrrhotite; As into pyrite; Ag and Sn into chalcopyrite. Germanium is present in sphalerite, and/or in chalcopyrite (in Cu-rich ores), rarely in pyrite. Likewise, In may be bound to sphalerite and chalcopyrite. Antimony, Tl, Bi, Mo may be present in all sulphide minerals, albeit usually at low concentrations.

The study provides estimates of critical and strategic metal concentrations in sulphides of the Eastern Alpine metallogenic province. Due to the mostly unknown resource of both, primary (in-situ) and secondary materials (dumps, tailings), geological exploration including drilling is needed to provide resource information for these raw materials.

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