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Sulfide-rich crust-mantle transition zone of Balmuccia orogenic massif: new insights from Fe-S isotope system in sulfides

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Combined Fe-S isotope studies are useful in understanding ore formation processes [1]. This study aims to provide new knowledge on the origin of sulfides using the Fe-S isotope systems at the transition between the subcontinental mantle peridotites of the Balmuccia massif and lower crustal gabbronorites of the Mafic Complex (Ivrea-Verbano Zone, NW Italy).

We investigated a transect from mantle peridotites (avg. 0.12 vol.‰ sulfides; mostly pentlandite-rich) through an 80-m-thick zone composed of interlayered pyroxenites and gabbronorites (Contact Series; up to 10.2 vol.‰, mostly Fe-rich sulfides) to the lower crustal gabbronorites (avg. 0.002 vol.‰ of Fe-rich sulfides). The Contact Series hosts two sulfide assemblages: (1) predominant magmatic pyrrhotite-chalcopyrite-pentlandite (Fig. 1A) especially in the proximity of the mantle peridotites, and (2) pyrite-chalcopyrite-pyrrhotite replacing the magmatic assemblage in the proximity of the crust. The pyrrhotite relicts in pyrite-dominated sulfides indicate replacement of primary magmatic assemblages (Fig. 1B–C).

The whole-rock $\delta^{34}S$ range from –1.6 to +2.0‰ indicating that the entire S within the Contact Series is of mantle origin. The *in situ* $\delta^{56}Fe$ values of pyrrhotite from the magmatic assemblages range from –0.8‰ to 0.0‰, and the adjacent chalcopyrite exhibits values varying from +1.3 to +1.7‰. Such Fe isotope variations between magmatic sulfide phases indicate an important role of diffusion-driven fractionation during sulfide cooling. Mass balance calculations of bulk $\delta^{56}Fe$ of magmatic polyphase sulfide grains ranges from –0.2 to –0.1‰ indicating that Fe, similar to S, originates from the mantle. The pyrrhotite relicts within pyrites display a $\delta^{56}Fe$ value of –0.8‰, similar to pyrrhotites from the magmatic assemblages. This supports our view that the primary magmatic pyrrhotite in the proximity of the crust was replaced by pyrite due to post-magmatic re-equilibration with late magmatic fluids [2].

The Fe-S isotope signatures in sulfides reflect the petrographic observations indicating that the enrichment in sulfides in the Contact Series was magmatic. This could have been caused by mantle-derived melts stagnated at the crust-mantle transition zone.

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References:

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Fig.1 **(a)** Typical magmatic assemblages of sulfides comprising of pyrrhotite (Po) with massive chalcopyrite (Ccp) at the rims and pentlandite (Pn). **(b)** Polyphase sulfide grain comprising of pyrite (Py) replacing preexisting pyrrhotite accompanied by chalcopyrite blebs. **(c)** Primary pyrrhotite grain partially replaced by pyrite with massive chaclopyrite at the rim.