Evidence for Fluid- and Gas-Driven Magmatic Ni-Fe-Cu-PGE–Rich Sulfide Ore Deposition Associated with Mantle Metasomatism in the Valmaggia Ultramafic Pipe, Ivrea-Verbano, Italy

Marilena Moroni,[1,*] Marco Fiorentini,[2] Stefano Caruso,[2] Maria Luce Frezzotti,[3] and Gianluca Sessa[1]

[1]Earth Sciences Dept., Università degli Studi di Milano, Italy
[2]CET/CCFS, University of Western Australia, Perth, WA, Australia
[3]Environmental and Earth Sciences Dept., Università degli Studi di Milano Bicocca, Italy

*E-mail, marilena.moroni@unimi.it

Fluid/gas-mediated ore-forming processes in magmatic contexts are not confined to porphyry systems but are also important in mafic-ultramafic systems, as suggested, for example, by the PGE- and sulfide-rich pegmatoidal reefs in the Bushveld and Stillwater complexes. Mechanisms of fluid-governed sulfide deposition are expressed to a notable intensity in the Ni-Cu-PGE-sulfide deposit at Valmaggia, Western Alps, Italy. The Valmaggia deposit is hosted in one of the sulfide-bearing ultramafic pipe-like intrusions emplaced within the Main Gabbro of the Ivrea-Verbano basic-ultrabasic complex. The ultramafic intrusion consists of an olivine+ enstatite + diopside + hercynite spinel assemblage extensively overprinted by the growth of metasomatic pargasitic amphibole and phologopite oikocrysts. Apatite and dolomite are common accessory phases interstitial to the ultramafic silicate-oxide assemblage. Sulfide enrichment along the margins of the pipe derives from solidification of an immiscible metal-rich sulfidic liquid. Fe-Ni sulfide droplets and blebs are included in and interstitial to magmatic silicates and spinels, whereas Cu-rich veinlets outline dislocation and cleavage planes of main silicates. The main ore facies is represented by an irregular distribution of coarse massive to dendritic nodules closely associated with amphibole over a few meters near the contact of the ultramafic body with the enclosing gabbro domain. The coarse sulfide blebs may be up to several centimeters across and consist of a wide mono- to coarsely polycrystalline core of FeS (troilite and pyrrhotite) with pentlandite and rare chalcopyrite. The FeS core is surrounded by a marginal intergrowth of fine-grained pyrrhotite, pentlandite, chalcopyrite, and magnetite. Accessory PGE-bearing tellurides are disseminated within the nodules, although recent and current analyses show that the main sulfides (pyrrhotite s.l. and pentlandite) contain remarkable concentrations of PGE (ΣPGE up to 1% wt). The coarse sulfide aggregates are associated with carbonates with variable composition: Mn-rich siderite blebs trapped within the sulfide cores and Fe-rich dolomite or calcite in more or less continuous, coarse-grained rims at the contact between sulfides and nearby olivine/enstatite and amphibole, respectively. Carbonate rims locally exhibit remarkable comb-like textures with bladed crystals intimately intergrown with the magmatic sulfides and, locally, with magnetite along the marginal portions of the nodules. Such features are a coarse equivalent of what was recently observed by Boudreau and coworkers in the footwall levels of the J-M Reef and Merensky Reef. The enrichment of sulfides in close association with metasomatic pargasite in the pipe is accompanied by a general increase of interstitial carbonate and by an impressive increase of fluid (and melt) inclusions in olivine and amphibole compared to sulfide-poor portions of the intrusion. Preliminary optical inspection revealed several populations of fluid inclusions pre- to post-amphibole crystallization, suggesting the presence of hypersaline aqueous solutions (brines) associated with carbonic gases. A hypersaline character of the fluids could be consistent with the PGE-rich nature of the sulfide aggregates, whereas the (immiscible) carbonic gases would contribute to create some sort of pneumatic cushions (carbonate rims) around coarse pockets of fluid-drenched sulfide melt, allowing flotation of dense metallic magma, defying gravity.