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## The Role of Volatiles in the Metal Budget of Magmatic Sulfide Deposits: Insights from the Lower Crustal Valmaggia Ultramafic Pipe, Ivrea Zone, Italy

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A large body of literature has argued for a long time that "dry" magmas can produce the wide range of mineralised bodies observed in nature. The pieces of evidence for the presence of volatile-bearing phases have been largely relegated to the occurrence of secondary processes related to hydration and carbonation during alteration and metamorphism. However, the development of analytical and experimental techniques has recently allowed us to document the near-ubiquitous presence of high-temperature volatile-rich phases (e.g., mica, amphibole, and carbonate) associated with magmatic sulfides, as well as the preservation of melt-vapor and fluid inclusions in high-temperature phases, together with the widespread occurrence of pegmatoids in mineralized mafic-ultramafic intrusions. Moreover, scientists have recently documented the spatio-temporal relationship between magmatic sulfides and platinum group minerals together with mineral phases enriched in CO<sub>2</sub>, H<sub>2</sub>O, Cl, F, and P (e.g., carbonate, apatite, amphibole, biotite). This common association has questioned the role of volatiles in the genesis of magmatic ore systems, more specifically in the formation of magmatic sulfide and reef-type platinum group element (PGE) deposits.

This study was dedicated to the close investigation of the interaction of high-temperature volatile-rich phases with base metal sulfides in the lower crustal Valmaggia ultramafic pipe, Italy. The analysis of polished thin sections using the Maia Mapper helped to establish the textural and morphological relationship of coexisting metal- and volatile-rich phases (Fig. 1). This work was complemented by the thorough examination of fluid and melt inclusions in high-temperature minerals, such as olivine and plagioclase. Using the Australian Synchrotron XFM technique, the focus was laid on the spatial distribution of nanonuggets of PGE along the margins of sulfide globules with carbonate phases. Furthermore, to unveil the source of carbon we conducted in situ carbon isotope measurements of the carbonates associated with the sulfide globules using the IMS1280 ion probe. Results are used to test the hypothesis that the observed magmatic calcite embracing sulfide globules does not only represent the frozen product of a CO<sub>2</sub> supercritical liquid that physically entrained dense sulfide liquid upwards across the lithosphere, but also evidence of a fractionation process that partitioned precious metals between sulfide liquid and exsolving volatiles. In this scenario, it is proposed that the exsolution of a CO<sub>2</sub>-bearing fluid in the middle-lower crust may promote metal fractionation and priming of ascending hydrothermal fluids in precious elements including Au and PGE.

Fig. 1. Maia Mapper image of the peridotite from the Valmaggia ultramafic pipes representing the intimate spatial association of sulfides with calcite. Cal – calcite, Pn – pentlandite, Po – pyrrhotite.

