

## **Petrological, geochemical and isotopic investigations on a carbonate-dyke and enclosed pyroxenite xenoliths from Val Mastallone (Ivrea-Verbano Zone): evidence of a cumulate carbonatite in the lower crust?**

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The Ivrea-Verbano Zone (Italy/Switzerland) represents one of the best exposed mantle-crust sections worldwide. Its geological evolution has been governed by the Permian underplating of mantle-derived basic magmas („Mafic Complex“) into the high-grade basement of the Southern Alps.

In the Ivrea-Verbano Zone, marbles occur as concordant bodies or partly discordant carbonate-dykes. Generally, these dykes are constituted of calcite, diopside, scapolite, contain enclave of the host rocks and display sharp contacts to the host lithologies without evidences of alteration zones. In Val Mastallone, an up to 40 m thick carbonate-dyke with different characteristics occurs within mafic granulites. This dyke is composed of calcite, clinopyroxene and subordinate allanite and zircon. No scapolite is observed. The contacts to the host granulites are characterized by alteration zones composed of actinolite, chlorite, clinozoisite, plagioclase and calcite.

The carbonate-dyke bears enclave of phlogopite-amphibole-apatite-rutile-ilmenite  $\pm$  garnet or spinel clinopyroxenites. These rock type is not outcropping elsewhere in the proximity of the dyke, suggesting a significant transport. Host mafic granulite enclave are found exclusively at the margin of the dyke. Calcite dykelets rich in zircon, baddeleyite and other Ba, U, Th, REE-rich phases cut across the enclave.

The carbonate-dyke shows an enrichment of LREE over HREE ((La/Yb)<sub>N</sub> = 14), with a  $\Sigma$  REE = 338 and Y/Ho = 27. On the chondrite-normalized REE abundances diagram, no Eu anomaly is observed. Mantle-normalized pattern shows strong negative anomalies at Cs, Rb, K, Pb, P, Zr, Hf, Ti and positive Ba, Th, Sr, Nd anomalies, similarly to the “world average carbonatites”. Measured absolute trace element concentrations are lower than average carbonatites but significantly higher than typical limestones and similar to cumulate carbonatites found elsewhere in the world (e.g. India, China, Brazil).

Grt-bearing clinopyroxenite enclave have a XMg of 0.5, K<sub>2</sub>O + Na<sub>2</sub>O of 1.01 wt% and are rich in TiO<sub>2</sub> (3.40 wt%) and P<sub>2</sub>O<sub>5</sub> (0.93 wt%). Grt-free clinopyroxenites show higher XMg values of 0.61-0.73 and are alkali, TiO<sub>2</sub> and P<sub>2</sub>O<sub>5</sub> poorer (K<sub>2</sub>O + Na<sub>2</sub>O of 0.21-0.59 wt%, TiO<sub>2</sub> of 1.16-2.72 wt% and P<sub>2</sub>O<sub>5</sub> < 0.20 wt%). On the mantle-normalized trace element diagram, the enclave display positive anomalies at Cs, Rb, U, Pb, Zr, Hf, Ti and negative anomalies at Ba, Th, Sr, Nd.

Preliminary Sr and Nd isotopic investigations on the carbonate-dyke yielded <sup>87</sup>Sr/<sup>86</sup>Sr of 0.708 and <sup>143</sup>Nd/<sup>144</sup>Nd of 0.51228, similarly to the isotopic characteristics of the host Mafic Complex and some UM cumulates of the Ivrea Zone.

Field observations including cross cutting relationships, metasomatic contacts, fluidal texture and occurrence of clinopyroxenite enclave, together with the geochemical and isotopic features explained above, indicate that the carbonate-dyke from Val Mastallone may be a cumulate carbonatite. The antithetic trace element patterns of the carbonate-dyke and clinopyroxenite enclave may suggest a genetic relationship between the two rocks. This carbonatitic magmatism is probably related to the Triassic CO<sub>2</sub>-bearing alkaline magmatism occurring during the early stage of the opening of the Thetyan ocean.