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Age, petrology and geochemistry of carbonate-dykes and related clinopyroxenite xenoliths from the Ivrea-Verbano Zone (Italy/Switzerland): evidence of Jurassic carbonatite formation by liquid immiscibility

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In the Ivrea-Verbano Zone (IVZ, Italy/Switzerland) the deepest portion of the continental crust is exposed. Its geological evolution has been largely controlled by both Permian underplating of mantle-derived basic magmas and Mesozoic alkaline intrusions into the high-grade basement of the Southern Alps.

Widespread in the IVZ, up to 40 m thick, zircon-bearing carbonate-dykes occur. The dykes are mostly composed of calcite with subordinate clinopyroxene and amphibole, show sharp intrusive contacts to the host rocks and typically contain rounded or angular, up to 2 meter large phlogopite-amphibole-apatite-rutile-ilmenite $\pm$ garnet, corundum or spinel clinopyroxenite xenoliths.

Carbonate-dykes shows an enrichment of LREE over HREE ((La/Yb)N = 14), with a Σ REE = 95-115 ppm and Y/Ho = 26-33. 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 and Ti and positive Ba, Th, Sr, Nd anomalies, similarly to the "world average carbonatite" composition. Measured absolute trace element concentrations are lower than average carbonatites but significantly higher than limestones and similar to typical cumulate carbonatites.

Grt-bearing clinopyroxenite enclave have a XMg of 0.50, K2O + Na2O of 1.01 and are rich in TiO_2 (3.40 wt%) and P2O5 (0.93 wt%). Grt-free clinopyroxenites show higher XMg values of 0.61-0.73 and are alkali, TiO_2 and P2O5 poorer (K2O + Na2O of 0.21-0.59 wt%, TiO_2 of 1.16-2.72 wt% and P2O5 < 0.20 wt%). On the mantle-normalized trace element diagram, the enclave display a nearly antithetic pattern in respect to the enclosing carbonates, with positive anomalies at Cs, Rb, U, Pb, Zr, Hf, Ti and negative anomalies at Ba, Th, Sr and Nd. Melt composition calculated from carbonate composition using partitioning coefficients between carbonatite and silicate melts reproduces the trace element patterns displayed by the pyroxenite xenoliths. This suggests that carbonate-dykes and enclosed clinopyroxenites may originated by liquid immiscibility, probably from a parental K-rich, ultramafic melt, similar to alkaline ultramafic intrusions occurring in the IVZ.

Zircons separated from carbonate-dykes are faint-zoned, present low REE and U concentrations and display a Th/U ranging between 0.35 and 1.37. On the chondrite-normalized REE diagram, no Eu and Ce anomalies are observable. Zircon U-Pb dating by laser ablation yielded an age of 186.7 $\pm$ 2 Ma, which is interpreted as the age of intrusion of the dykes.

This carbonatitic magmatism is probably related to the Jurassic, CO_2-bearing alkaline magmatism occurring during the early stage of the opening of the Thetyan ocean.