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Carbonatites and alkaline rocks from the Ivrea Zone (Southern Alps) related to Pangea break-up

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The association of carbonatites, sodic alkaline rocks and amphibole-peridotites is a common feature of magma-poor passive continental margins. In the Ivrea Zone (Southern Alps), several intrusive carbonates related to amphibole-rich mantle peridotites occur as pipe-like bodies and dykes accompanied by small-scale alkaline intrusions, ranging from hornblendites and clinopyroxenites to alkali gabbros and diorites, to nepheline-syenites and corundum-bearing plagioclasites. Intrusive carbonates display sharp magmatic contacts to the host rocks, are mostly composed of calcite, with minor clinopyroxene, amphibole, apatite, sphene, allanite, zircon, and contain polymict xenoliths and enclaves.

Compositions of intrusive carbonates are characterized by 2.7-13.0 wt% SiO_2, 0.01-0.94 wt% Na2O+K2O, 278-4368 ppm Sr and Σ REE of 83-211 ppm. Chondrite-normalized REE patterns are LREE enriched and show almost no Eu anomalies. Primitive mantle-normalized trace element patterns display negative anomalies for Rb, K, Ta, Nb, P, Hf, Zr and Ti and positive ones for Ba, Th, U and Sr, as commonly observed in carbonatites. Associated alkaline rocks are sodic (on average Na2O/K2O $\sim$ 5). Hornblendites and pyroxenites are TiO_2-rich (up to 3.8 wt%), whereas more evolved syenites and plagioclasites are TiO_2-poor (< 0.5 wt%) and $Al2O_3$-rich (> 20 wt%). All alkaline rocks display steep LREE but flat HREE patterns, variable Th-U, and generally one order of magnitude less enrichment than typical for OIB series.

Zircons separated from two intrusive carbonates are rounded to slightly elongated, 50-150 μm long, homogeneous to faint-zoned in cathodoluminescence and contain calcite inclusions. Zircons have low REE, U, Th, Y, and high Th/U and Zr/Hf. Chondrite normalized REE show no Eu and almost no Ce anomalies, and HREE only slightly fractionated over LREE. Such characteristics are typical for zircons of carbonatites. LA-ICP-MS U-Pb zircon dating yielded concordant intrusion ages of 187 $\pm$ 2 Ma and 195 $\pm$ 1 Ma, coeval with sodic alkaline magmatism in the Ivrea Zone.
Field relations, bulk rock geochemistry, zircon morphology, age and composition indicate that the studied intrusive carbonates are carbonatites, the first ones reported in the Alps. In the TAS diagram, hornblendite, alkali gabbros, diorites, plagioclasite and syenite follow the two trends of differentiation that lead through alkali- and CO_2-enrichment to immiscibility with carbonatite melts. We hence propose that during the Early Jurassic Pangea break-up, partial melting of amphibole-bearing mantle beneath the passive distal margin of the Adriatic continent produced small-scale sodic alkaline magmas, whose fractionation led to carbonatite-silicate melt immiscibility. Similar occurrences in many rifts suggest that small scale, sodic and CO_2-rich alkaline magmatism is a common result of extension and decompression of amphibole-bearing lithospheric mantle during passive continental break-up and magma-poor rift evolution. This contrasts an extension and break-up driven by large-scale mantle convection which would result in larger and more deeply rooted volumes of strongly enriched alkaline magmas.