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Volcanic activity and magmatic evolution in the southern Central European Volcanic Province reveal mantle heterogeneities and two geochemically distinct melt sources

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Petrology, geochemistry, and geochronology on primitive alkaline SiO_2-undersaturated intraplate volcanic rocks in the southern Central European Volcanic Province (SW Germany, E France) display two distinct rock series that derive from different mantle sources. Oligocene–Miocene (27-9 Ma) olivine melilitites and melilite-bearing olivine nephelinites exhibit high MgO, CaO, Ni, Co, Cr, Nb, Ba, and volatile contents, as reflected in olivine ($F_{83–93}$), melilite, perovskite, Cr-bearing spinel, F- and Ba-rich mica, and fluorapatite. In contrast, Upper Cretaceous–Eocene (73−47 Ma) olivine nephelinites, basanitic nephelinites, and nepheline basanites are characterized by lower concentrations for the abovementioned elements at slightly higher SiO_2 contents, expressed in the lack of melilite and perovskite, high quantities of clinopyroxene, and the presence of olivine with $Fo_{73–88}$, K-dominated oxy- and hydroxy-mica, and hydroxyapatite. Phonolitic haüynites/noseanites and haüyne nephelinites (68−62 Ma) with abundant sulfate-, Sr-, and Cl-rich fluorapatite, Zr-bearing aegirine, and Mn−rich olivine ($Fo_{73–83}$) represent differentiated products of the older rock group.

The melilite-bearing rocks derive from an amphibole±phlogopite-bearing garnet wehrlite in the uppermost asthenosphere (<3% partial melting) affected by subduction-related metasomatism with a high $CO_2/(CO_2+H_2O)$ ratio. Instead, the melilite-free nephelinitic–basanitic rocks rooted in an amphibole-bearing garnet-spinel lherzolite (<6% partial melting) in the thermal boundary layer at the base of the lithosphere. Their melt source experienced previous metasomatism involving melts or fluids with a lower $CO_2/(CO_2+H_2O)$ ratio. Further, the occurrence of Fe-rich resorbed olivine cores in the younger rocks and green-core pyroxenes in the older ones, as well as diverging crystallization trends, indicate varying but limited degrees of wall-rock interaction and magma mixing at the Moho and/or in the upper mantle, and different rates and timing of volatile enrichment, retention, and loss (including H_2O and CO_2 saturation, exsolution, degassing).

Since both volcanic episodes correspond to topographic uplift and erosion, asthenospheric doming driven by uplift of the lithosphere-asthenosphere boundary likely initiated magma formation and ascent by providing increased heat flux and perturbation in the metasomatized domains. However, mobilization, infiltration, and emplacement of carbonatitic and/or carbonate-rich melts/fluids probably occurred long before the onset of volcanism and rifting through continuous dehydration, decarbonization, and slab melting (recycling) of oceanic lithosphere during/after Variscan subduction processes.