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 SiO₂-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 (F₈₃–₉₃), 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 SiO₂ contents, expressed in the lack of melilite and perovskite, high quantities of clinopyroxene, and the presence of olivine with Fo₇₃–₈₈, 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 (Fo₇₃–₈₃) 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 CO₂/(CO₂+H₂O) 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 CO₂/(CO₂+H₂O) 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 H₂O and CO₂ 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 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.