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Contrasting Origins of Neogene Calc-Alkaline Volcanic Suites in the Carpathian-Pannonian Region, Eastern-Central Europe

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Tertiary history of the Carpathian-Pannonian Region was characterised by complex geodynamic and magmatic events. Different micro-plates underwent major block rotations and translations during the Early Miocene. Southward to westward subduction of a possibly oceanic lithosphere beneath these micro-plates started in the Palaeogene and terminated gradually from west (Middle Miocene) to east (Quaternary) as continental lithosphere entered the subduction zone.

Neogene calc-alkaline volcanic rocks are found roughly parallel with the arcuate orogenic belt of the Carpathians. However, several differences can be observed between the western (Western Carpathians Volcanic Field: WCVF) and eastern (Eastern Carpathians Volcanic Field: ECVF) segments of the volcanic arc. The volcanic complexes of the WCVF are underlain by thin lithosphere (<80km), while those of the ECVF are situated over thicker lithosphere (80-120km). Seismic data and gravity modelling indicate that there is no crustal root beneath the Western Carpathians in contrast to the deep structure of the Eastern Carpathians. There are also differences in the temporal and spatial distribution of the calc-alkaline volcanic rocks. The volcanic activity of the WCVF shows no temporal variation from west to east, whereas a gradual younging of the volcanism can be observed in the ECVF from north to south. In the WCVF, the volcanic complexes occur roughly perpendicular to the Carpathian arc, whereas those of the ECVF are situated parallel with the orogenic belt. The calc-alkaline volcanism in both segments postdates the major period of the subduction process.

A striking feature of the volcanic suites of the WCVF is the relative abundance of garnet-bearing volcanic rocks (andesite to rhyodacite), whereas they are subordinate in the ECVF. These garnet-bearing volcanic products were formed at the early stage of the volcanic activities and are situated along major tectonic lines.

Geochemical characteristics of the calc-alkaline volcanic products both in the WCVF and ECVF are typical of subduction-related magmas and suggest an input of fluids from a dehydrating subducted slab into their mantle source region. However, temporal variation of fluid addition is different at the two segments of the volcanic arc. In the WCVF, a decrease of Ba/La ratio is observed towards the younger volcanic rocks, whereas there is an opposite trend in the ECVF volcanics. Furthermore, a good correlation can be recognized between the age and isotopic and trace element characteristics of the volcanic rocks from the WCVF. The younger volcanic products show more depleted isotopic compositions and are more enriched in HFSE than the initial volcanic products. In contrast, calc-alkaline volcanic rocks of the ECVF show a wider geochemical variation and a more complex temporal relationship.

Based on these characteristics, we propose contrasting origins for the Neogene calc-alkaline volcanic suites of the western and eastern segment of the Carpathian arc. In the WCVF, flat subduction characterised the Palaeogene-Early Miocene period due to the fast convergence rate. It resulted in compressional stress field in the overlying plate, thus preventing eruption of magmas. From the Early Miocene, the slowing plate convergence caused slab roll-back and extension in the WCVF. This is also the main period of the overall extension of the Pannonian Basin. Calc-alkaline magmas were generated by partial melting of fluid-metasomatised lithospheric mantle as a response of lithospheric thinning. In the Late Miocene, when the buoyant continental lithosphere entered the subduction zone, the denser oceanic lithospheric slab detached. The slab roll-back and slab break-off process enhanced the rapid upwelling of OIB-like asthenospheric mantle. During the Pliocene to Quaternary, alkaline mafic magmatism took place from an asthenospheric mantle region similar to the European Asthenospheric Reservoir (Cebriá & Wilson, 1995). Slab roll back and slab detachment were also important processes in the ECVF, however, they were not accompanied with significant extension in the overlying plate. The slab detachment occurred at progressively shallower level causing discrete age progression of the volcanism from north to south (Mason et al., 1998). Calc-alkaline magmas generated in the depleted or slightly enriched asthenospheric mantle wedge metasomatised by slab-derived hydrous fluids. Contemporaneous eruption of minor alkaline mafic and shoshonitic magmas at the southern part of the ECVF can be explained by enriched asthenospheric mantle upwelling into the gap of the broken slab and the increased dehydration of the remnant slab due to the higher thermal regime (Mason et al., 1998).

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