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Geochemical response of magmas to Neogene–Quaternary continental collision in the Carpathian–Pannonian region: A review

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Abstract

The Carpathian–Pannonian Region contains Neogene to Quaternary magmatic rocks of highly diverse composition (calc-alkaline, shoshonitic and mafic alkalic) that were generated in response to complex microplate tectonics including subduction followed by roll-back, collision, subducted slab break-off, rotations and extension. Major element, trace element and isotopic geochemical data of representative parental lavas and mantle xenoliths suggests that subduction components were preserved in the mantle following the cessation of subduction, and were reactivated by asthenosphere uprise via subduction roll-back, slab detachment, slab-break-off or slab-tearing. Changes in the composition of the mantle through time are evident in the geochemistry, supporting established geodynamic models.

Magmatism occurred in a back-arc setting in the Western Carpathians and Pannonian Basin (Western Segment), producing felsic volcaniclastic rocks between 21 to 18 Ma ago, followed by younger felsic and intermediate calc-alkaline lavas (18–8 Ma) and finished with alkalic-mafic basaltic volcanism (10–0.1 Ma). Volcanic rocks become younger in this segment towards the north. Geochemical data for the felsic and calc-alkaline rocks suggest a decrease in the subduction component through time and a change in source from a crustal one, through a mixed crustal/mantle source to a mantle source. Block rotation, subducted roll-back and continental collision triggered partial melting by either delamination and/or asthenosphere upwelling that also generated the younger alkalic-mafic magmatism.

In the westernmost East Carpathians (Central Segment) calc-alkaline volcanism was simultaneously spread across ca. 100 km in several lineaments, parallel or perpendicular to the plane of continental collision, from 15 to 9 Ma. Geochemical studies indicate a heterogeneous mantle toward the back-arc with a larger degree of fluid-induced metasomatism, source enrichment and assimilation on moving north-eastward toward the presumed trench. Subduction-related roll-back may have triggered melting, although there may have been a role for back-arc extension and asthenosphere uprise related to slab break-off.

Calc-alkaline and adakite-like magmas were erupted in the Apuseni Mountains volcanic area (Interior Segment) from15–9 Ma, without any apparent relationship with the coeval roll-back processes in the front of the orogen. Magmatic activity ended with OIB-like alkali basaltic (2.5 Ma) and shoshonitic magmatism (1.6 Ma). Lithosphere breakup may have been an important process during extreme block rotations (~60°) between 14 and 12 Ma, leading to decompressional melting of the lithospheric and asthenospheric sources. Eruption of alkali basalts suggests decompressional melting of an OIB-source asthenosphere. Mixing of asthenospheric

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melts with melts from the metasomatized lithosphere along an east–west reactivated fault-system could be responsible for the generation of shoshonitic magmas during transtension and attenuation of the lithosphere.

Voluminous calc-alkaline magmatism occurred in the Cãlimani-Gurghiu-Harghita volcanic area (South-eastern Segment) between 10 and 3.5 Ma. Activity continued south-eastwards into the South Harghita area, in which activity started (ca. 3.0–0.03 Ma, with contemporaneous eruption of calc-alkaline (some with adakite-like characteristics), shoshonitic and alkali basaltic magmas from 2 to 0.3 Ma. Along arc magma generation was related to progressive break-off of the subducted slab and asthenosphere uprise. For South Harghita, decompressional melting of an OIB-like asthenospheric mantle (producing alkali basalt magmas) coupled with fluid-dominated melting close to the subducted slab (generating adakite-like magmas) and mixing between slab-derived melts and asthenospheric melts (generating shoshonites) is suggested. Break-off and tearing of the subducted slab at shallow levels required explaining this situation.

Keywords: Carpathian–Pannonian region; Geodynamic processes; Calc-alkaline magmas; Adakite-like magmas; Alkalic-basaltic magmas; Neogene–Quaternary

1. Introduction

This paper reviews the geochemical characteristics of Neogene–Quaternary magmatic rocks generated in both collisional and post-collisional settings in the Carpathian–Pannonian Region (CPR) of Eastern and Central Europe (Fig. 1). We discuss the various source-reservoirs responsible for the geochemical signature of the erupted magmas and attempt to connect them with the presumed geodynamic history via a temporal evolution study using well-established, internally consistent age determinations (e.g.. Pécskay et al., 1995a,b, 2000; Roşu et al., 1997; Pécskay, unpublished data). Our work is based on a large database of published whole rock and mineral geochemical and isotopic data, much of it produced in the same laboratories making comparisons highly reliable (Salters et al., 1988; Szabó et al., 1992; Embey-Isztin et al., 1993; Dobosi et al., 1995; Embey-Isztin and Dobosi, 1995; Downes et al., 1995a,b; Harangi et al., 1995, 2001, submitted for publication; Mason et al., 1996; Dobosi and Jenner, 1999; Harangi, 2001a,b; Roşu et al., 2001, 2005; Seghedi et al., 2001, 2004a).

We use the recently defined segmentation of the magmatic activity (Seghedi et al., 2004a) based on spatial distribution and timing: *Western Segment* (magmatism occurring in the central part of Alcapa block), *Central Segment* (magmatism occurring in front of the eastern part of Alcapa and western Tisia blocks), *Interior Segment* (magmatism occurring inside the Tisia block) and *South-Eastern Segment* (magmatism occurring at the eastern margin of the Tisia block) (Fig. 1). The study aims to determine variations in magma geochemistry in response to changes in tectonic setting, using the combination of isotopic and trace element data. Furthermore, we try to unravel the contributions of various mantle or crustal sources to the magmas, which have been sampled at the surface, in order to interpret the role of different tectonic processes in the region.

2. Geodynamic history

Tectonic reconstructions of the CPR have been given by numerous authors, e.g. Balla (1987), Ratschbacher et al. (1991), Csontos et al. (1992), Horvath (1993), Royden (1993), Csontos (1995), Nemčok et al. (1998), Fodor et al. (1999), Huismans et al. (2001), Sperner et al. (2002). The following is a short summary of their findings.

The Carpathians are an arcuate orogen in Central and Eastern Europe between the Eastern Alps and the Balkans. They were formed during Tertiary times, as a result of subduction of a land-locked basin and convergence of two continental fragments (here named Alcapa and Tisia) with the European foreland. (Note that the term "Tisia" is a simplified name; it was defined as "Tisza-Dacia" by Csontos et al., 1992, Csontos, 1995, and as "Tisia-Getia" by Seghedi et al., 1998). The age of deformation of the external Carpathian nappes (accretionary wedge), which involved thrust-loading of the foreland and coincided with the end of the collision event, is Karpatian (~17Ma) at the edges of the *Western Segment,* Badenian-Sarmatian (16.5–12 Ma) in the *Central Segment* and Sarmatian (13–11 Ma) in the *South-Eastern Segment* (e.g. Royden et al., 1982; Sãndulescu, 1988). An eastward progression of deformation along the thrust system is suggested (e.g. Royden et al., 1982; Csontos et al., 1992; Meulenkamp et al., 1996).

From the Eocene to Early Miocene (~33–24 Ma) an important NNE–SSW compression with ESE–WNW extension occurred. At this stage the blocks comprising the Intracarpathian area were already assembled. (Huismans et al., 2001; Sperner et al., 2002).