High-pressure aragonite phenocrysts in carbonatite and carbonated syenite xenoliths within an alkali basalt

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ABSTRACT

We describe the first observation of primary magmatic aragonite in carbonatite and carbonated syenite, occurring as xenoliths in a Pliocene basaltic diatreme located near the Hungary–Slovakia border. The aragonite-hosting matrix consists of disordered P-rich calcite, occasionally associated with trachyte glass. We interpret the aragonite growth as evidence of supra-lithostatic overpressure in the magmatic plumbing system that connected the crustal basaltic reservoir with the partial melting zone of the lithospheric mantle, and the disordered calcite ± trachyte as quenched residual, immiscible melts, generated close to the solidus of the carbonated alkali basalt differentiated in the crustal reservoir. The quenching event was a phreato-magmatic eruption within the stability field of the low-pressure calcite; this was triggered by advective overpressure, caused by expanding gas bubbles in a quasi-incompressible silicate melt system. The high-pressure, pre-eruption origin of aragonite is indicated by enrichment in 13C compared to the associated calcite interpreted as a record of CO2 degassing at \( T > 500 \) °C. The oxygen (\( \delta^{18} \)O ranges of 22.1–24.5‰ V-SMOW in aragonite, 21.6–22.7‰ in calcite) and carbon (\( \delta^{13} \)C ranges of –4.4 to –5.9‰ V-PDB in aragonite, –11.9 to –12.7‰ in calcite) isotope signatures are consistent with a degassed carbonatite melt primarily derived from a subduction zone.

Keywords: Aragonite, carbonatite, syenite, xenolith, alkali basalt, Slovakia

INTRODUCTION

Carbonatites are magmatic rocks, whose mantle origin is widely accepted (e.g., Bailey 1993; Harmer and Gittins 1997; Bell and Simonetti 2010). However, the origin of calcic carbonatites remains controversial, because experimental work (e.g., Lee and Wyllie 1998a, 1998b; Brooker and Kjarsgaard 2011) has ruled out the generation of CaCO3-dominant liquids devoid of silica and alkalis via magmatic fractionation processes in the crust or the mantle. Consequently, natural calcic carbonatites have been interpreted to represent either degraded calcic carbonatites modified by sub-solidus alteration and/or loss of alkaline aqueous fluid (Keller and Zaitsev 2006), or as cumulates of calcite crystals that have settled from parental dolomite carbonatite (Lee and Wyllie 1998a) or silicate melts (Brooker and Kjarsgaard 2011).

Here we describe aragonite phenocrysts that have crystallized from a calcic carbonatite melt. We document variations in the structural ordering, major element partitioning, and isotope composition of calcite and aragonite, thus corroborating the existence of calcic carbonatite liquids in nature. We propose, however, that the magmatic aragonite need not be related to ultrahigh-pressure (\( P > 3 \) GPa) conditions in the mantle, as proposed by Humpreys et al. (2010), but may reflect episodic supra-lithostatic overpressure in the magmatic plumbing system and the overlying crustal reservoir.

FIELD EVIDENCE, PETROGRAPHY, AND MINERALOGY

Carbonatite and carbonated syenite xenoliths with aragonite occur in a diatreme exposed in the center of Hajnáčka village (48°13’5.25”N, 19°57’18.59”E, southern Slovakia). The diatreme, towering about 75 m above the surrounding river terrace, represents a feeder conduit of a basaltic maar removed by erosion. The diatreme is composed of palagonitized tuffaceous breccia and scoria breccia, and is intersected by a 2.7 ± 0.5 Ma old basalt dike (Vass et al. 2007).

The Hajnáčka diatreme is one of numerous monogenetic volcanic centers of the Late Miocene–Late Pleistocene alkali basalt province in the northern part of the intra-Carpathian back-arc basin (Pannonian Basin). The volcanism was triggered by rifting in the orogenic hinterland superimposed on Middle Miocene gravity-driven subduction, which was compensated by diapiric rise and decompression melting of the asthenosphere (Nemcok et al. 1998; Konečný et al. 2002). The northern Pannonian Basin has been characterized as having high (80–90 mWm-2) heat flow, moderate (26–28 km) crustal thickness and a 70–90 km thick lithospheric mantle (Dérerová et al. 2006; Tašárová et al. 2009).

Direct evidence for carbonatitic melts in, and carbonate metasomatism of, the lithospheric mantle beneath Pannonian Basin has been provided by the occurrence of calcite blebs in silicate veins within mantle xenoliths (Chalot-Prat and Arnold 1999; Bali et al. 2002; Demény et al. 2004, 2010), calcite inclusions and carbonate veins in mafic cumulate xenoliths...