Experimental investigation of trace element partitioning between amphibole and alkali basaltic melt: Toward a more general partitioning model with implications for amphibole fractionation at deep crustal levels

BARBARA BONECHI1,2,*, ALESSANDRO FABBRIZIO3, CRISTINA PERINELLI1,4,†, MARIO GAETA1, and MAURIZIO PETRELLI5,‡

1Dipartimento di Scienze della Terra, Sapienza Università di Roma, P.le Aldo Moro 5, 00185, Rome, Italy
2Department of Earth and Environmental Sciences, University of Manchester, Williamson Building, Oxford Road, Manchester M13 9PL, U.K.
3Institute of Petrology and Structural Geology, Faculty of Science, Charles University, Albertov 6, 12843 Prague, Czech Republic
4Consiglio Nazionale delle Ricerche, Istituto di Geologia Ambientale e Geoingegneria, Sede Secondaria di Roma, c/o Dipartimento di Scienze della Terra, Sapienza Università di Roma, P.le A. Moro 5, Rome, Italy
5Department of Physics and Geology, University of Perugia, Piazza Università, Perugia 06100, Italy

ABSTRACT

Time-series experiments were carried out in a piston-cylinder apparatus at 0.8 GPa and 1030–1080 °C using a hydrous K-basalt melt as the starting material to determine the element partition coefficients between amphibole and silicate glass. Major, minor, and trace element compositions of amphibole and glass were determined with a combination of electron microprobe and laser ablation inductively coupled plasma mass spectrometry. Results show that the main mineral phase is calcic amphibole, and the coexisting glass compositions range from basaltic trachyandesite to andesite. We estimated the ideal radius, the maximum partition coefficient and the apparent Young’s modulus of the A, M1-M2-M3, and M4-M4′ sites of amphibole. The influence of melt and amphibole composition, temperature, and pressure on the partition coefficients between amphiboles and glasses has also been investigated by comparing our data with a literature data set spanning a wide range of pressures (0.6–2.5 GPa), temperatures (780–1100 °C), and compositions (from basanite to rhyolite). Finally, we modeled a deep fractional crystallization process using the amphibole-melt partition coefficients determined in this study, observing that significant amounts of amphibole crystallization (>30 wt%) well reproduce the composition of an andesitic melt similar to that of the calc-alkaline volcanic products found in Parete and Castelvolturno boreholes (NW of Campi Flegrei, Italy).

Keywords: Amphibole, trace element partition coefficient, lattice strain model, Campi Flegrei

INTRODUCTION

The occurrence of amphibole in rocks encompassing the entire range of silica activities in terrestrial igneous suites, coupled with its capacity to incorporate significant concentrations of geochemically important trace elements, underscores the likely importance of this phase in the chemical evolution of both mantle- and crustal-derived magmas (Brenan et al. 1995; Tiepolo et al. 2007). During the last decades, the behavior of trace element partitioning between calcic amphiboles and silicate melts has been investigated at different pressures (0.2–2.7 GPa), temperatures (750–1150 °C), and system compositions (e.g., Nicholls and Harris 1980; Adam et al. 1993; Adam and Green 1994, 2003; Sisson 1993; LaTourrette et al. 1995; Brenan et al. 1995, 1998; Klein et al. 1997; Tiepolo et al. 1999, 2000a, 2000b, 2007; Hilyard et al. 2000; Zhang et al. 2019). It is widely accepted that the resulting partition coefficients depend on the chemical compositions of mineral and melt phases, pressure, temperature, and H2O-content of the melt, as well as the redox conditions (Blundy and Wood 2003; Adam and Green 2006; Aigner-Torres et al. 2007; Severs et al. 2009; van Kan Parker et al. 2010; Hill et al. 2011; Fabbrizio et al. 2021). Moreover, Blundy and Wood (1994) provided a theoretical framework based on the lattice strain model (Brice 1975) for the interpretation of trace element partitioning. So far, it has been applied successfully to trace element partitioning between pyroxene (e.g., Wood and Blundy 1997; Schmidt et al. 1999; Adam and Green 2006; Sun and Liang 2012, 2013; Mollo et al. 2018; Bonechi et al. 2021; Fabbrizio et al. 2021), olivine (e.g., Zanetti et al. 2004; Sun and Liang 2013), garnet (e.g., Draper and van Westrenen 2007; van Westrenen and Draper 2007; Sun and Liang 2013), amphibole (e.g., LaTourrette et al. 1995; Adam and Green 2006; Tiepolo et al. 2007; Wan et al. 2009; Nandedkar et al. 2016; Shimizu et al. 2017; Zhang et al. 2019; Cannào et al. 2022), phlogopite (e.g., LaTourrette et al. 1995; Schmidt et al. 1999; Fabbrizio et al. 2010), leucite (e.g., Schmidt et al. 1999; Fabbrizio et al. 2008), feldspars (e.g., Icenhower and London 1996; Fabbrizio et al. 2009) and their coexisting melts. Despite numerous investigations on the partition between crystals and melt, there are still some mineral phases, including amphibole, for which data are limited or missing. In this study, we provide new data on partition coefficients of amphibole major, minor, and trace elements derived from crystallization experiments on...