American Mineralogist, Volume 101, pages 2199–2209, 2016

FLUIDS IN THE CRUST

A new experimental approach to study fluid–rock equilibria at the slab-mantle interface based on the synthetic fluid inclusion technique

Alexandra Tsay[1,2,*], Zoltan Zajacz[1], Peter Ulmer[2], Markus Waelle[2], and Carmen Sanchez-Valle[3]

[1]Department of Earth Sciences, University of Toronto, 22 Russell Street, M5S 3B1, Toronto, Canada
[2]Institute of Geochemistry and Petrology, ETH Zurich, Clausiusstr. 25, 8092 Zurich, Switzerland
[3]Institut für Mineralogie, Universität Münster, Corrensstrasse 24, 48149 Münster, Germany

Abstract

The role of high-pressure aqueous fluids in mass transfer processes during slab dehydration has been recognized for a long time. However, the quantitative assessment of their material transport capacity in complex natural systems remains poorly understood, mainly as a consequence of their unquenchable nature and current experimental limitations. A new experimental approach has been developed to investigate complex fluid–rock equilibria at high-pressure and -temperature conditions relevant for slab dehydration processes. Aqueous fluids pre-equilibrated with high-pressure mineral assemblages were sampled at run conditions in the form of synthetic fluid inclusions (SFI) in quartz and subsequently analyzed by laser-ablation ICPMS (LA-ICP-MS). The main innovation introduced in the experiments is that the quartz crystal was fractured in situ during the run only after chemical equilibrium between phases has been achieved, thus allowing the entrapment of fluid inclusions that sample true equilibrium compositions. An efficient fracturing of quartz at high-pressure and temperature conditions was achieved by crossing the α-quartz–coesite reaction boundary, which occurs at pressures of the sub-arc slab-mantle interface. An experimental methodology has been developed to implement this strategy and experiments in the eclogite–water system were conducted to demonstrate the feasibility and advantage of the method. The results demonstrate that secondary fluid inclusions formed early in pre-fractured quartz are systematically diluted compared to secondary inclusions formed after in situ fracturing of quartz, particularly for elements such as Sr, Zr, Nb, Ti, and Mg. These observations demonstrate that early entrapment of fluids in pre-fractured quartz do not represent equilibrium fluids at high-pressure-temperature conditions.

Keywords: Subduction zone, magma, slab dehydration, high-pressure fluids, synthetic fluid inclusions