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A systematic assessment of the diamond trap method for measuring fluid compositions in high-pressure experiments

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Abstract

A variety of experimental techniques have been proposed to measure the composition of aqueous fluids in high-pressure experiments. In particular, the "diamond trap method," where the fluid is sampled in the pore space of diamond powder and analyzed by laser-ablation ICP-MS after the experiment, has become a popular tool. Here, we carried out several tests to assess the reliability of this method. (1) We prepared several capsules loaded with fluid of known composition and analyzed the fluid by laser-ablation ICP-MS, either (a) after drying the diamond trap at ambient condition; (b) after freezing and subsequent freeze-drying; and (c) after freezing and by analyzing a frozen state. Of these methods, the analysis in the frozen state (c) was most accurate, while the results from the other two methods were poorly reproducible, and the averages sometimes deviated from the expected composition by more than a factor of 2. (2) We tested the reliability of the diamond trap method by using it to measure mineral solubilities in some well-studied systems at high pressure and high temperature in piston-cylinder runs. In the systems quartz-H_2O, forsterite-enstatite-H_2O, and albite-H_2O, the results from analyzing the diamond trap in a frozen state by laser-ablation ICP-MS generally agreed well with the expected compositions according to literature data. However, in the systems corundum-H_2O and rutile-H_2O, the data from the analysis of the diamond trap were poorly reproducible and appeared to indicate much higher solubilities than expected. We attribute this not to some unreliability of the analytical method, but instead to the fact that in these systems, minor temperature gradients along the capsule may induce the dissolution and re-precipitation of material during the run, which causes a contamination of the diamond trap by solid phases. (3) We carried out several tests on the reliability of the diamond trap to measure fluid compositions and trace element partition coefficients in the eclogite-fluid system at 4 GPa and 800 °C using piston-cylinder experiments. The good agreement between "forward" and "reversed" experiments—with trace elements initially either doped in the solid starting material or the fluid—as well as the independence of partition coefficients on bulk concentrations suggests that the data obtained are reliable in most cases. We also show that the rate of quenching/cooling has little effect on the analytical results, that temperature oscillations during the run can be used to enhance grain growth, and that well-equilibrated samples can be obtained in conventional piston-cylinder runs. Overall, our results suggest that the diamond trap method combined with laser-ablation ICP-MS in frozen state yields reliable results accurate within a factor of two in most cases; however, the precipitation of accessory minerals in the diamond trap during the run may severely affect the data in some systems and may lead to a gross overestimation of fluid concentrations.

Keywords: Fluids, diamond trap, high-pressure experiments, laser-ablation ICP-MS, solubility, fluid/mineral partitioning