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Using mineral equilibria to estimate H_2O activities in peridotites from the Western Gneiss Region of Norway

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Abstract

The Earth's mantle is an important reservoir of H_2O, and even a small amount of H_2O has a significant influence on the physical properties of mantle rocks. Estimating the amount of H_2O in rocks from the Earth's mantle would, therefore, provide some insights into the physical properties of this volumetrically dominant portion of the Earth. The goal of this study is to use mineral equilibria to determine the activities of H_2O (a_{H_2O}) in orogenic mantle peridotites from the Western Gneiss Region of Norway. An amphibole dehydration reaction yielded values of a_{H_2O} ranging from 0.1 to 0.4 for these samples. Values of f_{O_2} of approximately 1 to 2 log units below the FMQ oxygen buffer were estimated from a f_{O_2}-buffering reaction between olivine, orthopyroxene, and spinel for these same samples. These results demonstrate that the presence of amphibole in the mantle does not require elevated values of a_{H_2O} (i.e., $a_{H_2O} \approx 1$) nor relatively oxidizing values of f_{O_2} (i.e., >FMQ).

It is possible to estimate a minimum value of a_{H_2O} by characterizing fluid speciation in C-O-H system for a given value of oxygen fugacity (f_{O_2}). Our results show that the estimates of a_{H_2O} obtained from the amphibole dehydration equilibrium are significantly lower than values of a_{H_2O} estimated from this combination of f_{O_2} and C-O-H calculations. This suggests that fluid pressure (P_{fluid}) is less than lithostatic pressure (P_{lith}) and, for metamorphic rocks, implies the absence of a free fluid phase.

Fluid absent condition could be generated by amphibole growth during exhumation. If small amounts of H_2O were added to these rocks, the formation of amphibole could yield low values of a_{H_2O} by consuming all available H_2O. On the other hand, if the nominally anhydrous minerals (NAMs) contained significant H_2O at conditions outside of the stability field of amphibole they might have served as a reservoir of H_2O. In this case, NAMs could supply the OH necessary for amphibole growth once retrograde *P-T* conditions were consistent with amphibole stability. Thus, amphibole growth may effectively dehydrate coexisting NAMs and enhance the strength of rocks as long as the NAMs controlled the rheology of the rock.

Keywords: Amphibole equilibria, C-O-H fluid equilibria, H solubility, nominally anhydrous minerals, mantle fluid, peridotite