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Application of mineral equilibria to estimate fugacities of H_2O, H_2, and O_2 in mantle xenoliths from the southwestern U.S.A.

Lindsey E. Hunt[1] and William M. Lamb[2,*,†]

[1]Electron Microprobe Laboratory, Office of the Vice President for Research, University of Oklahoma, Norman, Oklahoma 73069, U.S.A.
[2]Department of Geology & Geophysics, Texas A&M University, College Station, Texas 77843, U.S.A.

Abstract

Small amounts of H_2O, on the order of tens to hundreds of parts per million, can significantly influence the physical properties of mantle rocks. Determining the H_2O contents of nominally anhydrous minerals (NAMs) is one relatively common technique that has been applied to estimate mantle H_2O contents. However, for many mantle NAMs, the relation between H_2O activity and H_2O content is not well known. Furthermore, certain mantle minerals may be prone to H_2O loss during emplacement on Earth's surface. The goal of this study is to apply mineral equilibria to estimate values of a_{H_2O} in rocks that originated below the Moho.

The chemical compositions of olivine + orthopyroxene + clinopyroxene + amphibole + spinel ± garnet were used to estimate values of temperature (T), pressure (P), a_{H_2O}, hydrogen fugacity (f_{H_2}), and oxygen fugacity (f_{O_2}) in 11 amphibole-bearing mantle xenoliths from the southwestern U.S.A. Application of amphibole dehydration equilibria yields values of a_{H_2O} ranging from 0.05 to 0.26 for these 11 samples and the compositions of coexisting spinel + olivine + orthopyroxene yield $\Delta \log f_{O_2}$ (FMQ) of –1 to +0.6. For nine of the samples, values of f_{H_2} were estimated using amphibole dehydrogenation equilibria, and these values of f_{H_2} ranged from 6 to 91 bars. Values of f_{H_2} and f_{O_2} were combined, using the relation $2H_2O = 2H_2 + O_2$, to estimate a second value of a_{H_2O} that ranged from 0.01 to 0.57 for these nine samples. Values of a_{H_2O}, estimated using these two methods on the same sample, generally agree to within 0.05. This agreement indicates that the amphibole in these samples has experienced little or no retrograde H-loss and that amphibole equilibria yields robust estimates of a_{H_2O} that, in these xenoliths, are generally <0.3, and are often 0.1 or less.

Keywords: Amphibole, fluids, mantle, xenoliths, mineral equilibria; Isotopes, Minerals, and Petrology: Honoring John Valley