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Experimental study of the Fe-Mg exchange between garnet and biotite: Constraints on the mixing behavior and analysis of the cation-exchange mechanisms

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ABSTRACT

New experimental data are presented for the Fe-Mg exchange between garnet and biotite in the temperature range 600–800 °C at 0.2 GPa. The Fe-Mg-Al mixing properties of biotite were evaluated and the garnet-biotite geothermometer was recalibrated. SEM observations and comparative laser granulometry show that solution-precipitation largely controls the cation exchange mechanism, involving about 50% of the mineral volume. Mass balance calculations emphasize the effectiveness of the experimental design: A high Gt/Bio ratio ensures that the garnet composition remains approximately constant and close to equilibrium, even if the entire garnet volume is not involved in the cation exchange. Progressively decreasing partition coefficients with decreasing Fe content of garnet indicate nonideal thermodynamic mixing behavior. The application of various garnet activity models support nearly ideal Fe-Mg mixing in garnet. The remaining nonidealities were attributed to nonideal Fe, Mg, and Al mixing in biotite as the initially binary biotite samples changed toward more aluminous compositions during the experiments. Adopting the standard state properties and the garnet-mixing model of Berman (1988, 1990), least square regressions reveal nearly ideal mixing of Fe and Mg in biotite with $W_{\mathrm{FeMg}} = -2.3 \pm 1.6$ kJ/mol, while the difference between Fe-Al and Mg-Al interactions yield $\Delta W_{\mathrm{Al}} = -17.6 \pm 2.4$ kJ/mol (1 cation). This interaction parameter is strictly valid only for Tschermak-substituted $^{[6]}$Al in biotite according to the operational substitution. Application of the suggested garnet-biotite geothermometer reproduces well the reference temperatures of experimental and natural garnet biotite assemblages.