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Mg-Mn-Sr distribution between calcite and apatite: a new geothermometer

MS. ALANA ANDREA MINA AND MICHAEL ANENBURG

Research School of Earth Sciences, Australian National University

Apatite and calcite are valuable tracers of petrogenesis, which makes them ideal candidates for developing thermometric models. This study presents the first thermometric model based on the partitioning of minor elements (Mg, Mn, and Sr) between two coexisting minerals (calcite-apatite, CAp) under controlled experimental conditions. The two minerals were grown from a carbonatite liquid in a piston cylinder apparatus. We find that Mg, Mn, and Sr partitioning correlate with temperature, supporting their use as thermometric indicators. We also find apatite compositional effects on partitioning with T-site deficiency (as a proxy for carbonate contents) and halogen composition as important variables. The negligible volume change associated with these reactions limits the CAp system utility as a barometer. Using our data we are able to derive thermodynamic parameters for these exchange reactions, including ΔH, ΔV, ΔS, ΔG, and W values for reciprocal solid solutions. As a test for the model success in predicting temperatures, we find that the difference between known temperature and modelled temperature at any given pressure for the experimental runs can predict over 80% of runs to within 50 °C. We tested a series of statistical models, incorporating pressure and temperature as initial variables. Finally, we improved the model by considering complex mixing behaviour and additional compositional factors.