

Experimental investigation into the substitution mechanisms and solubility of Ti in garnet

MICHAEL R. ACKERSON^{1,2,*}, E. BRUCE WATSON¹, NICHOLAS D. TAILBY¹, AND FRANK S. SPEAR¹

¹Department of Earth and Environmental Sciences, Rensselaer Polytechnic Institute, Troy, New York 12180, U.S.A.

²Geophysical Laboratory, Carnegie Institution of Washington, Washington, D.C. 20015, U.S.A.

ABSTRACT

Garnet is a common and important mineral in metamorphic systems, but the mechanisms by which it incorporates Ti—one of the major elements in the crust—are not well constrained. This study draws upon garnets synthesized at a range of temperatures and pressures to understand Ti solubility and the substitution mechanisms that govern its incorporation into garnet at eclogite and granulite facies conditions. Garnets from these synthesis experiments can incorporate up to several wt% TiO₂. Comparison of Ti content with deficits in Al and Si in garnet indicates that Ti is incorporated by at least two substitution mechanisms (${}^{\text{VI}}\text{Ti}^{4+} + {}^{\text{VI}}\text{M}^{2+} \leftrightarrow 2{}^{\text{VI}}\text{Al}^{3+}$, and ${}^{\text{VI}}\text{Ti}^{4+} + {}^{\text{IV}}\text{Al}^{3+} \leftrightarrow {}^{\text{VI}}\text{Al}^{3+} + {}^{\text{IV}}\text{Si}^{4+}$). Increasing Ti solubility is correlated with increasing Ca and Fe/Mg ratios in garnet, clinopyroxene and melt. The complexity of the substitution mechanisms involved in Ti solubility in garnet makes practical Ti-in-garnet thermobarometry infeasible at present. However, a model fit to Ti partitioning between garnet and melt can be used to predict melt compositions in high-grade metamorphic systems. Additionally, the solubility and substitution mechanisms described here can help explain the presence of crystallographically aligned rutile needles in high-grade metamorphic systems.

Keywords: Garnet, titanium, UHP, UHT, experimental petrology