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Application of new experimental and garnet Margules data to the garnet-biotite geothermometer

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ABSTRACT

Garnet-biotite experiments now exist from Ferry and Spear (1978, FS), Perchuk and Lavrent'eva (1983, PL), and Gessmann et al. (1997, GE). Recent garnet Margules parameters exist from Berman and Aranovich (1996, BA), Ganguly et al. (1996, GA), and Mukhopadhyay et al. (1997, MU). A comparison of ΔG_{mix} plots for garnet binaries shows similarity among models with some significant differences. In all, 20 garnet-biotite geothermometers were retrieved from the various data using a modified form of the approach of Holdaway et al. (1997, HO) such that experimental vs. calculated values of T, in °C, were regressed stepwise to a line with intercept of zero and slope of one, maximizing r^2. All tests assumed the GA model for garnet MnMg and the HO Fe^{3+} correction and ΔW_{Ti}^{Bio}. The experimental combinations (sets) were: (1) GE + FS with GE values of $^{VI}Al^{Bio}$ in FS; (2) PL + FS with GE $^{VI}Al^{Bio}$ in FS; (3) PL + FS with GE $^{VI}Al^{Bio}$ in FS, increasing W_{MnMg}^{Gr} by 5 kJ; (4) PL + FS with no $^{VI}Al^{Bio}$ in FS, increasing W_{MnMg}^{Gr} by 5 kJ; (5) PL + FS with 0.10 $^{VI}Al^{Bio}$ in FS, increasing W_{MnMg}^{Gr} by 5 kJ; (6) PL + FS + GE with 0.10 $^{VI}Al^{Bio}$ in FS, increasing W_{MnMg}^{Gr} by 5 kJ. Models are designated by a number for the experimental set and letters to designate the above garnet model, e.g., 5BA.

Experimental sets vary in maximum r^2 as follows: (1) 0.892–0.896; (2) 0.943–0.956; (3) 0.943–0.955; (4) 0.980–0.982; (5) 0.980–0.983; and (6) 0.939–0.944. Application to the HO Maine biotite-garnet data gives the following sequence of increasing quality from experimental sets: $1 < 2 < 3 < 6 < 4 \cong 5$. The various garnet models show only small differences in r^2 and in quality with the Maine data base. For all 20 models, average T (°C) for the Maine M3 staurolite zone varies between 554(15) and 588(13). The best models appear to be 5BA, 5GA, and 5MU, which allow for 0.10 ^{VI}Al in FS biotite. A model based on an average of the three garnet Margules models, 5AV, has some justification and provides a slight improvement. Model 5AV gives (in J) $\Delta G_{ex} = 40198 - 7.80T$; $W_{FeMg}^{Bio} = 22998 - 17.40T$; $\Delta W_{Al}^{Bio} = 245559 - 280.31T$, and Maine M3 average staurolite zone $T = 571(12)$ °C. The high quality of sets based mainly on PL experiments (2–5 above) results in part from their experimental P of 6 kbar. The results suggest that FS biotite contained only minor ^{VI}Al. The wide ranges of derived exchange and biotite Margules parameters, which provide reasonable calibrations, indicate that while accuracy in parameters is important, consistency is even more important. These geothermometers (5BA, 5GA, 5MU, 5AV) are available on PC disk. I recommend geothermometer 5AV.