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Laser Raman microspectrometry of metamorphic quartz: A simple method for comparison of metamorphic pressures—Corrigendum

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Abstract

A minor error in calculation of geobarometric estimates from laser Raman microspectrometry of quartz inclusions in garnet appears in Enami et al. (2007). Correction of this error eliminates anomalous results for grossular-rich garnet, inspiring greater confidence in the validity and applicability of this geobarometric technique.

Keywords: Geobarometry, Raman spectrometry, quartz, garnet, elastic model

Background

Enami et al. (2007) presented a novel and promising technique for estimation and comparison of metamorphic pressures based upon measurements of Raman spectra of quartz inclusions in garnet. Frequency shifts in the Raman spectrum of quartz are quantitative indicators of residual pressure on the inclusion imposed by the enclosing garnet. For quartz grains completely enclosed in garnet and not affected by fracturing or other modes of stress release, the residual pressure on the inclusion can be related to the original pressure of entrapment by means of elastic models that account for partial relaxation in response to cooling from the temperature of entrapment. The elastic model of Van der Molen (1981) is employed; it calculates normal stresses on a spherical isotropic inclusion in an infinite isotropic medium subjected to an external stress applied at infinite distance from the inclusion. Using this model, the relationship between the residual pressure P_{Qtz} and the entrapment pressure P_{Grt} is given by the following equation, which appears (unnumbered) on p. 1311 of Enami et al. (2007):

$$P_{Qtz} = \frac{\kappa_{Qtz}}{\kappa_{Grt}\left(3\kappa_{Qtz} + 4\mu_{Grt}\right)} \quad \left\{P_{Grt}\left(3\kappa_{Grt} + 4\mu_{Grt}\right) - 4\kappa_{Grt}\,\mu_{Grt}\,\Delta T\,\Delta A\right\}. \tag{1}$$

In this expression, κ is bulk modulus (GPa), μ is shear modulus (GPa), ΔT is the difference between the temperature T_M at which the Raman spectrum is measured and the temperature T_E of entrapment (K), and ΔA is the difference in volumetric thermal-expansion coefficients between garnet and quartz (K^{-1}), which is defined by $\Delta A \equiv A_{Grt} - A_{Qtz}$. In discussions among the authors, an ambiguity in the definition of ΔT came to light that we wish to clarify here: when Equation 1 is applied to Raman barometry of quartz inclusions in garnet, ΔT is correctly computed as $T_M - T_E$, and thus both ΔA and ΔT are negative quantities.

Discussion

Enami et al. (2007, their Table 3, p. 1312) compared observed residual pressures to those calculated, on the basis of the elastic model embodied in Equation 1, for five samples for which pressures and temperatures of entrapment were constrained independently within small ranges. For each sample, expected residual pressures were computed for two limiting entrapment pressures at each of two limiting entrapment temperatures, using in each case four different sets of elastic parameters and thermal-expansion coefficients, corresponding to values for each of the four principal garnet end-members, namely almandine, pyrope, grossular, and spessartine.

In Table 3 of Enami et al. (2007), residual pressures computed for the grossular end-member stand out as anomalous: they are roughly half of the values computed for other end-members, despite much less pronounced differences between grossular and other end-members for values of elastic and thermal-expansion parameters. This was found to be the result of a minor error in the calculations, in which the factor of 3 that appears in the term "$P_{Grt}\,(3\,\kappa_{Grt} + 4\,\mu_{Grt})$" was omitted. Recalculated values are shown here in Table 1; they demonstrate that the laser Raman geobarometric technique is significantly less sensitive to the composition of the garnet host than previously thought. Previously, a large effect had been ascribed to composition: in analysis of results for the epidote-amphibolite-facies metapelite and metabasite,

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Table 1. Recalculation of residual pressures appearing in Table 3 of Enami et al. (2007); only values "in Grs" are changed

Sanbagawa	Qtz-rich eclogite				Qtz-poor eclogite			
T_{peak} (°C)	665		710		660		690	
ΔT (°C)	–640		–685		–635		–665	
P_{peak} (GPa)	2.4	2.5	2.4	2.5	2.1	2.2	2.1	2.2
P_{Qtz} (GPa)								
in Alm	0.81	0.85	0.80	0.84	0.69	0.73	0.68	0.72
in Prp	0.90	0.95	0.90	0.94	0.78	0.82	0.78	0.82
in Grs	0.82	0.86	0.81	0.85	0.70	0.74	0.69	0.73
in Sps	0.84	0.88	0.83	0.87	0.72	0.76	0.71	0.75
Sanbagawa epidote-amphibolite facies rocks								
	Olig-biotite zone				Ab-biotite zone			
T_{peak} (°C)	585		635		470		590	
ΔT (°C)	–560		–610		–445		–565	
P_{peak} (GPa)	0.9	1.1	0.9	1.1	0.8	1.0	0.8	1.0
P_{Qtz} (GPa)								
in Alm	0.23	0.31	0.22	0.30	0.22	0.30	0.19	0.27
in Prp	0.30	0.38	0.30	0.38	0.27	0.36	0.26	0.34
in Grs	0.24	0.32	0.23	0.31	0.22	0.30	0.20	0.28
in Sps	0.25	0.33	0.24	0.32	0.23	0.31	0.21	0.29
Altai amphibolite facies rocks								
T_{peak} (°C)	470		570					
ΔT (°C)	–445		–545					
P_{peak} (GPa)	0.3	0.55	0.3	0.55				
P_{Qtz} (GPa)								
in Alm	0.02	0.12	–0.01	0.09				
in Prp	0.07	0.17	0.06	0.16				
in Grs	0.02	0.12	0.00	0.10				
in Sps	0.03	0.13	0.01	0.11				

Notes: T_{peak} and P_{peak} = deduced peak metamorphic conditions; P_{Qtz} = estimated internal pressure at standard condition; Alm = almandine; Prp = pyrope; Grs = grossular; Sps = spessartine; Olig = oligoclase; Ab = albite.

Enami et al. (2007, p. 1312) stated that "incorporation of the grossular component will decrease the [computed] internal pressure drastically," and for all rocks, interpretations of computed pressures (p. 1311–1312) were influenced by allowances for large potential imprecision due to the grossular content of host garnets. Recalculation shows that compositional effects are actually relatively minor in comparison to other factors affecting the precision of geobarometric estimates by this technique, which should encourage its application across the full range of garnet compositions.

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