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Large strain formulations for host-inclusion systems and their applications to mineral elastic geobarometry

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The recent improvement in spectroscopic methods has allowed the detailed characterization of minerals with very high spatial resolution. Such methods allow the accurate estimation of residual pressures in mineral inclusions from exhumed metamorphic rocks. The residual inclusion pressures can be used to recast the pressure conditions during metamorphic recrystallization (e.g. Moulas et al., 2020). The most common assumptions in the aforementioned models are that 1) the rheology of the host-inclusion system is elastic, 2) the pressure was the same in the host and the inclusion phase at the time of recrystallization and, 3) the host and the inclusion can be treated as elastically isotropic phases.

In this work we focus on isotropic host-inclusion systems. Such solutions appear to be sufficient even for anisotropic minerals such as the Quartz-in-Garnet system (Bonazzi et al., 2019; Moulas et al., 2020; Thomas and Spear, 2018). In addition, numerous experimental studies show that mineral Equations-of-State (EoS) are non-linear and, therefore, mechanical solutions which consider linear-elastic host-inclusion systems may be inadequate. We present two analytical solutions for the host-inclusion problem which can be applied in systems under large strain. In the first approach we consider that the volumetric deformation of minerals is non-linear and the deviatoric stresses can be approximated by linear elasticity. The resulting solution is:

$$\Delta P = 4G^h\left[1-\left(\frac{V^h_{fin}}{V^h_{ini}}\cdot\frac{V^i_{ini}}{V^i_{fin}}\right)^{\frac{1}{3}}\right] \quad \text{(Eq. 1)}$$

where ΔP is the residual pressure difference, G is the shear modulus, V are the mineral volumes, superscripts h,i indicate host/inclusion and, “ini”/”fin” indicate initial and final P-T conditions respectively. This result is similar but not identical with a previously published solution (Guiraud

and Powell, 2006). However, we demonstrate that Guiraud and Powell's (2006) solution is a linearization of this formulation and its accuracy decreases with increasing pressure range. Finally, we discuss our results in the framework of a newly-derived, fully-non-linear elastic solution that considers the effects of large finite strain in Neo-Hookean materials (Levin et al., 2020). We conclude that, for common mineral barometry applications, the effects of geometrical non linearity are minor and the application of Eq. 1 is sufficient.

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