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Elastic geobarometry for ultra high pressure metamorphic (UHPM) rocks

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Conventional thermo-barometric methods can be challenged in UHPM terraines as the temperatures of deep subduction often exceed the closure temperature of geothermobarometers, and they are also afflicted by the effects of further reactions and re-equilibration on exhumation.

Since minerals trapped as inclusions within other host minerals develop residual stresses on exhumation as a result of the differences between the thermo-elastic properties of the host and inclusion phases, their elastic behavior provides an alternative method independent of chemistry and chemical equilibria. The determination of possible entrapment pressures from this residual stress requires the knowledge of the equations of state (EoS) and the mutual elastic relaxation of the host and inclusion phases. So far, even the simplest elastic system of a single inclusion embedded in an isotropic host has not been properly addressed for geological systems. However, this is useful for determining the depths of formation of diamonds, and could also provide constraints on the prograde and retrograde stress-temperature paths of metamorphic assemblages. Previous analyses (i.e. Zhang, 1998) have relied on assumptions that are not physically correct (i.e. linear elasticity and invariant elastic properties of the minerals with P and T, or assume that the host material is completely rigid).

We will present a solution to the single-inclusion problem that incorporates non-linear elasticity and can be applied to determine the stress distribution in the host and inclusion that arises from any change in P and T. Our solution shows that the previous calculations of residual inclusion pressures are incorrect in the relaxation term, which arises from the difference in stress at the host/inclusion interface.

The general form of our solution relies on the concept of the isomeke, a line in P-T space along which the fractional volume changes of the host and inclusion are the same (Angel et al. 2014a). This allows our solution to be used in combination with any form of equation of state and/or thermal expansion, and is not restricted to linear elasticity or just invertible EoS. Calculations can be performed with Eosfit7c (Angel et al. 2014b).

A key result is that non-uniform stress fields are developed within the constrained two-phase system. Such stress fields can give rise to either over- or under-pressure with respect to external lithostatic pressure. This is true for all combinations of host and inclusion minerals and examination of simplified systems can provide some constraints to this problem. Thus, for example, quartz inclusions trapped in the cores of garnet during the prograde path of the Kulet whiteschist (e.g. Parkinson, 2000) experience pressures lower than the external pressure. By peak conditions of $\sim$3.5 GPa and $\sim$780°C, the quartz inclusions are calculated as experiencing a peak pressure of only 1.9 GPa, sufficient to prevent them entering the stability field of coesite.

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