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Elastic geobarometry: uncertainties arising from the geometry of the host-inclusion system

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Ultra-high-pressure metamorphic (UHPM) rocks are the only rocks that can provide insights into the detailed processes of deep and ultra-deep subduction. The application of conventional geobarometry to these rocks can be extremely challenging. Elastic geobarometry is an alternative and complementary method independent of chemistry and chemical equilibria. Minerals trapped as inclusions within other host minerals develop residual pressure (Pinc) on exhumation as a result of the differences between the thermo-elastic properties of the host and the inclusion. If correctly interpreted, measurement of the Pinc allows for a good estimate of the entrapment pressure. The solution for isotropic non-linear elasticity has been recently incorporated into the classic host-inclusion model [1; 2] and is now available in the EoSFit7c software [3]. However, this solution assumes a simple geometry for the host inclusion system with a small spherical inclusion located at the center of an infinite host.

To verify the results of the analytical solution and to extend the analysis beyond the existing geometrical assumptions we performed numerical calculations using Finite Element Modelling (FEM). This approach has allowed us to evaluate the deviation from the pressure calculated with the isotropic solution if applied to real host-inclusion systems where the geometry is far from ideal, for example when the inclusion is not small, not at the center of the host and not spherical. In order to determine the effects of shape alone, we performed calculations with isotropic elasticity.

Our results show that the deviations from the analytical solution arising from the geometry of the system are smaller than 1% if a spherical inclusion has a radius smaller than 1/4 of that of the host and is located at more than two inclusion radii from the external surface of the host. Deviations produced by changes in the shape of the inclusions include two contributions. First, the effect of edges and corners is small and introduces deviations of less than 2%. Second, the aspect ratio of the inclusion gives rise to large deviations in Pinc with shifts in the calculated pressures of more than 10% for platy inclusions (i.e. aspect ratio 1:5:5). The exact effect on Pinc is a complex function of both the values of the bulk and shear moduli of both host and inclusion, and the contrast in these values. For a soft quartz-like inclusion, the influence of the aspect ratio and of the presence of edges and corners becomes greater as the host is made softer and approaches the bulk modulus of the inclusion, provided a contrast in shear moduli remains. These deviations from the analytical solution induced by the shape are smaller than 1% only when inclusions are approximately spherical (i.e. ellipsoids with aspect ratios of less than 1:2:2) and the host is significantly stiffer than the inclusion.

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