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Pressure relaxation of mineral inclusion: when inclusion pressure can be used for Raman-barometry?

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To infer a pressure and temperature (P-T) path is a fundamental goal in metamorphic petrology and serves as a crucial ingredient in the reconstruction of tectonic history. Among numerous studies in metamorphic petrology, mineral inclusions were extensively analyzed after they have experienced a complex P-T path after being entrapped into the host. Therefore, the system of mineral inclusion and host possesses important mechanical properties in virtue of the different thermoelastic parameters. During exhumation accompanied with changes of confining pressure and temperature, differential expansion/contraction between inclusion and host occurs and pressure variations are developed. The inclusion pressure can be measured with Raman spectroscopy given experimental calibrations for some minerals, e.g. quartz (Schmidt and Ziemann, 2000). Owing to the relation between the amounts of P-T changes after entrapment and preserved inclusion pressure, the measurements of inclusion pressure can be used for barometry purposes. Ideally, the constrained metamorphic history should be consistent with the results of other barometers based on the chemical equilibrium between inclusion and host. However, in many cases, inclusion pressure shows significant relaxation that invalidates its usage for Raman-barometry. To better understand this problem, we systematically investigate the relaxation of inclusion pressure due to three following mechanisms: 1) viscous relaxation of host; 2) plastic yield of host; 3) pressure release due to the proximity of inclusion to thin-section surface. For the first two mechanisms, we develop a 1D visco-elasto-plastic model in a radially symmetric coordinate frame to study both viscous relaxation and plastic yield. For the third mechanism, we apply the analytical solution from Mindlin and Cheng, (1950) to show the pressure field of an inclusion close to a free surface. Three dimensionless numbers are presented after non-dimensionalization to quantify the amount of pressure relaxation due to these three mechanisms, respectively. These three dimensionless numbers are: 1) Deborah number defined as the ratio between Maxwell viscoelastic relaxation time and exhumation time; 2) cohesion number defined as the ratio between plastic cohesion and inclusion over (under)-pressure; 3) proximity number defined as the ratio between surface-to-inclusion distance and inclusion radius. If Deborah number and cohesion number are lower than $\sim$1, significant pressure relaxation occurs that will lead to an underestimate of the entrapment pressure based on Raman-barometer. If proximity number is lower than $\sim$0.5, inclusion pressure becomes very heterogeneous and care must be taken when performing Raman-barometry.

References:
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