Goldschmidt 2022 Abstract
https://doi.org/10.46427/gold2022.10897

of Geophysical Research: Solid Earth,
https://doi.org/10.1029/2021JB022080

Experimental evaluation of anisotropic elastic thermobarometry applied to stiff mineral inclusions in soft hosts: First evaluation of zircon inclusions in quartz

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Elastic geothermobarometric models are often applied to mineral host-inclusion systems to estimate P-T when both the host and inclusion have a relatively large difference in thermoelastic properties (i.e. quartz-in-garnet). However, stiff inclusions entrapped in soft hosts have not been widely used for thermobarometry despite the fact that they should also yield thermobarometric constraints. To evaluate the use of stiff inclusions in soft hosts for elastic thermobarometry, we used a recently developed model for fully anisotropic host-inclusion systems [1] to calculate the residual strain state expected for zircon inclusions entrapped in quartz hosts after exhumation from a range of P-T conditions. These theoretical calculations show that zircon inclusions in quartz exhumed from high pressures will be subject to tensile volume strains whereas zircon inclusions exhumed from low pressures will have compressive volume strains. For comparison we synthesized quartz crystals with zircon inclusions using a piston-cylinder apparatus over a range of isothermal P-T conditions (0.8–2.5 GPa at 900°C) and isobaric P-T conditions (700–900°C at 1.5 GPa). Strains for the synthesized inclusions were determined using Raman spectroscopy measurements and the zircon phonon-mode Grüneisen tensor. The strains and Pinc values are significantly different from the theoretical values. Therefore, when the experimental Pinc values are used to recalculate the entrapment conditions, the entrapment pressures are ~0.3 GPa greater than the synthesis conditions of the piston-cylinder apparatus. These discrepancies cannot be attributed to apparatus calibration errors, the relative crystallographic orientation of the host-inclusion system, or strain relaxation. The observed discrepancies may be related to non-elastic behavior of the host-inclusion system during the experiment and therefore the recorded inclusion strains reflect a transition from inelastic to elastic behavior of the quartz during rapid experimental cooling. We show that this behavior of the zircon-in-quartz host-inclusion system may be used to provide P-T constraints on rapid exhumation that occurs over short timescales.

[1] Gonzalez, J. P., Mazzucchelli, M. L., Angel, R. J., & Alvaro, M. (2021). Elastic geobarometry for anisotropic inclusion in anisotropic host minerals: quartz-in-zircon.