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Rheo-speedometer: constraining the exhumation rate using inclusion-host system with visco-elastic rheology

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Constraining the time scale of rock exhumation is of great interest in geology. Geochronology and diffusion chronometry have been applied to obtain the exhumation duration by using the radioactive isotope decay and the diffusion kinetics of the major/minor elements, respectively. Here, we present an approach based on visco-elastic mechanical solutions applied to inclusion-host systems, e.g. quartz-in-garnet. During cooling and decompression, the difference in the thermal-elastic moduli between the inclusion and host forms a "pressure-vessel" that can generate a gigapascal level pressure jump at the inclusion-host interface as confirmed with the laser Raman spectroscopy (Enami et al., 2007; Sobolev et al., 2000). In order to main the mechanical equilibrium, a differential stress in the host is applied that results in viscous creep and pressure relaxation. The relaxed inclusion pressure can be quantitatively linked to the exhumation rate using the experimentally calibrated viscous flow law of the host mineral. The newly developed, so called, "rheo-speedometer" thus allows to constrain the exhumation rate by measuring the residual pressure with Raman spectroscopy. The rheo-speedometer is applied to four geological case studies of the Stak eclogite (Pakistan), Kokchetav mica schist (Kazakhstan), Udachnaya Kimberlite (Russia), and Sifnos blueschist (Greece). We demonstrate that: 1) the exhumation rate can be quantitatively constrained with certain confidence interval; 2) rocks undergoing either rapid magmatic ascent or slower metamorphic exhumation can be qualitatively distinguished; 3) the elastic limit can be reached for a quartz-in-garnet system below ∼550°C.

References

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