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Feldspar Raman shift and application as a magmatic thermobarometer

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Abstract

We calibrate the pressure-dependent Raman shift of feldspars by measuring spectra of 9 compositionally diverse plagioclase and alkali feldspars at pressures ranging between 0.1 MPa and 3.6 GPa using a diamond-anvil cell coupled with Raman spectroscopy. We observe up to 12 vibrational modes that are caused by deformation of $Si(Al)O_4$ tetrahedral chains. The most intense modes are v_{22}, v_{24}, and v_{25}, which are produced by stretching and bending of four-membered Si(Al)-O-Si(Al) rings. Because modes are a product of lattice environments, feldspar composition may relate to mode frequency. We find that the frequencies of the v_{25} mode correlates with composition, whereas the other intense bands do not correlate with composition. All feldspar compositions exhibit modes that shift linearly ($r^2 > 0.9$) to higher frequencies with increasing pressure. Modes v_{22}, v_{24}, and v_{25} shift to higher frequencies with slopes that range from 1.7 ± 0.5 to 5.5 ± 1.6 cm^{-1} GPa^{-1}, and provide the best combination of intensity and pressure-sensitivity. For all compositions the v_{22} mode exhibits the most advantageous pressure-dependent (*P*-*T*) frequency shift. We use an elastic model, thermodynamic properties, and shear moduli to establish the pressure-temperature dependent sensitivity of feldspar inclusions hosted by garnet, clinopyroxene, and olivine. Raman shifts for all feldspars are <2 cm^{-1} for crustal and upper lithosphere conditions. Albitic plagioclase inclusions show the least temperature-sensitive inclusion pressures and provide the best barometers, followed by alkali feldspars and anorthitic plagioclase. Our new calibration allows Raman spectroscopy of feldspars to be used to quantify *P*-*T* conditions for crustal magmatic rocks, low- to high-grade metamorphic rocks, and the mantle.

Keywords: Raman, barometry, inclusions, magma storage; Rates and Depths of Magma Ascent on Earth