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Coupled elastic and intracrystalline geothermobarometers to constrain PT conditions of lower arc crust granulites

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In metamorphic petrology, element-exchange geothermobarometry allows us to retrieve the pressure and temperature (P–T) conditions of (re-)equilibration of a mineral assemblage. These P–T conditions are not necessarily the conditions at which such mineral assemblage formed, nor where the rock reached its peak P and/or T, but those at which there was the last thermodynamic equilibrium (i.e., when the exchange of chemical components among and within phases of the system was stopped). Beyond this point, the system freezes due to slow diffusion kinetics, thus preserving the chemical composition at the reset conditions of equilibration.

The interpretation of P–T estimates from element exchange geothermobarometer is particularly challenging in (U-)HT rocks due to chemical re-equilibration during cooling (Frost and Chacko, 1989; Spear and Florence, 1992). Here we try to overcome the abovementioned problems of determining the UHT conditions of peak metamorphism or of mineral growth by proposing an alternative and viable method. We present and discuss the estimates of equilibration P–T conditions of a crustal garnet-pyroxenite xenolith from the Granatifera tuff, located in the Mercaderes–Rio Mayo area of the southern Colombian Andes, obtained using multiple geothermobarometric methods. This xenolith formed as a residue after extraction of granitic melt, and consists of garnet, clinopyroxene (X_{Mg} 0.73, Jd_{16}), plagioclase ($Ab_{72}An_{26}Or_3$), minor pargasitic amphibole (X_{Mg} 0.87), and accessory rutile and apatite. Garnet is chemically homogeneous ($Alm_{42-43}Pyr_{38-41}Grs_{16-20}Sps_1$) and often contains inclusions of quartz and zircon within the same crystals, as well as primary melt inclusions. Quartz is present only as inclusion in garnet. The sample has a well-equilibrated granoblastic texture, without evidence of reaction rims pointing to interaction with the host lava during entrapment and magma ascent.

We estimated the pressure and temperature of equilibration using a multi-methodological approach involving intracrystalline geothermometry, elastic geothermobarometry, and classical Fe–Mg exchange between garnet and clinopyroxene. The equilibration temperatures obtained on clinopyroxenes using the intracrystalline geothermometer by Brizi et al. (2000) are around 1150–1250 °C. This estimate is consistent with results of elastic geothermobarometry: the isomekes for quartz- and zircon-in-garnet (Angel et al., 2014; Gilio et al., 2021) indicate

equilibration conditions of 1150–1200 °C and 1.7–2.1 GPa. Instead, geothermometry based on Fe–Mg exchange between garnet and clinopyroxene (Nakamura, 2009) gives lower equilibration temperatures of 950–1000 °C, suggesting a re-equilibration during regional cooling at the roots of the magmatic arc. Our results have important implications for the reliability of element–exchange geothermobarometry in UHT rocks. Elastic geothermobarometry gives reliable and independent P–T estimates and it is virtually unaffected by the diffusion–induced reset during retrogression typical of cation–exchange geothermometry. This new approach solves the long-standing issue of estimating pressure and temperature conditions in HT and UHT rocks and appears to be robust and reliable to temperatures as high as 1200 °C.

References:

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