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CR-DIOPSIDE AND CR-PYROPE XENOCRYST THERMOBAROMETRY REVISITED: APPLICATIONS TO LITHOSPHERE STUDIES AND DIAMOND EXPLORATION

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We utilize well-characterized suites of mantle peridotite xenoliths and complimentary mantle xenocrysts from the same localities, to revisit the application of pressure temperature (P-T) determinations on single grain xenocryst datasets to lithosphere studies and diamond exploration. The applicable thermometers and barometers utilized include the Nimis and Taylor (2000) pyroxene thermobarometer (NT00), and Cr-pyrope garnet thermometers (T_{Ni} e.g., publications by Griffin et al., 1989; Kjarsgaard, 1992; Canil, 1994; T_{Mn} of Creighton, 2009) and barometers (P_{Cr} of Ryan et al., 1996; P_{38} of Grütter et al., 2006).

We observe that pyroxene grains from equilibrated lherzolite xenoliths, that have NT00 temperatures above ~1125-1150 °C may record NT00 P-T conditions that deviate (and in some cases significantly) from the P-T conditions determined by conventional lherzolite thermobarometry i.e., TA98 thermometer of Taylor (1998), and NG85 barometer of Nickel and Green (1985). These deviations can artificially produce 'cooler' and/or 'kinked' paleogeotherms that are not useful representations of lithospheric mantle thickness or heatflow. An important additional issue with application of NT00 thermobarometry are uncertainties related to electron microprobe (EMP) analysis, which is especially relevant to lower P-T pyroxene grains, with potentially inherent errors of ± 75 °C and ± 0.4 GPa, that are greater than those of the calibration errors of the thermometer or barometer. To address this issue we provide analytical guidelines for EMP analysis of Cr-diopside to be used for NT00 thermobarometry, based on test using EDS and WDS analyses at varying analytical conditions. The calibration of the Ni in Cr-pyrope garnet has been contentious; here we present a new, robust calibration based on trace Ni analysis by LA-ICP-MS and PIXE utilizing our well-characterized mantle peridotite xenolith suites. The pressure conditions determined by Cr barometry of pyrope garnet provides a minimum base to the depth of the depleted lithosphere, but does not provide a depth to the actual base of the lithosphere. The random sampling of the mantle by kimberlite is an additional complication i.e., the deepest, most depleted peridotites may not be sampled. Furthermore, arrays of P-T points determined by either pyroxene or garnet thermobarometry are used to define paleogeotherms that are qualitatively fitted to Pollack and Chapman (1977; PC77) mantle geotherms (e.g., a 38-mW/m^2 geotherm). Notably, many xenocryst derived paleogeotherms cut across multiple PC77 geotherms, which is impossible, unless there have been thermal perturbations in the mantle.

For academic studies of the mantle lithosphere, and applied studies of interest to diamond explorers, the uncertainties and issues noted above make it problematic to utilize single grain thermobarometry to accurately determine mantle heat flow (the paleogeotherm), the base of the lithosphere, and hence the thickness of the 'diamond window'. However, by using the FITPLOT method (McKenzie & Bickle, 1988; Mather et al., 2011), we are able to input a subset of the xenocryst P-T data, along with crustal heat flow and mantle isentrope data, to quantitatively determine the paleogeotherm and base of the lithosphere. For pyroxene thermobarometry, higher P-T grains are not utilized as input; for garnet thermobarometry, only the highest P at a given T are utilized as input.

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