American Mineralogist, Volume 101, pages 2222–2232, 2016

SPECIAL COLLECTION: RATES AND DEPTHS OF MAGMA ASCENT ON EARTH

Error sources in single-clinopyroxene thermobarometry and a mantle geotherm for the Novinka kimberlite, Yakutia

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Abstract

A new suite of 173 clinopyroxene grains from heavy-mineral concentrates of the diamondiferous Novinka kimberlite (Upper Muna field, Yakutia) has been analyzed for major and minor elements with an electron microprobe to perform a thermobarometric study and model the thermal structure of the Archean Upper Muna lithospheric mantle. Scrupulous evaluation of propagation of analytical uncertainties on pressure estimates revealed that (1) the single-clinopyroxene geobarometer can be very sensitive to analytical uncertainties for particular clinopyroxene compositions, and that (2) most clinopyroxenes from Novinka have compositions that are sensitive to analytical uncertainties, notwithstanding their apparent compositional suitability for single-clinopyroxene thermobarometry based on previously proposed application limits. A test on various mantle clinopyroxenes containing different proportions of the sensitive elements Cr, Na, and Al allowed us to identify clinopyroxene compositions that produce unacceptably high propagated errors and to define appropriate analytical conditions (i.e., higher beam currents and longer counting times for specific elements) that allow precise *P-T* estimates to be obtained for sensitive compositions. Based on the results of our analytical test, and taking into account the intrinsic limitations of the single-clinopyroxene thermobarometer, we have designed a new protocol for optimum thermobarometry, which uses partly revised compositional filters. The new protocol permits precise computation of the conductive paleogeotherm at Novinka with the single-clinopyroxene thermobarometer of Nimis and Taylor (2000). Thermal modeling of the resulting *P-T* estimates indicates a ~34 mW/m^2 surface heat flow, a thermal lithosphere thickness of ~225 km, and an over 100 km thick "diamond window" beneath Novinka in the middle Paleozoic (344–361 Ma). We estimate that appropriate analytical conditions may extend the applicability of single-clinopyroxene thermobarometry to over 90% of clinopyroxene-bearing garnet peridotites and pyroxenites and to ~70% of chromian-diopside inclusions in diamonds. In all cases, application to clinopyroxenes with $Cr/(Cr+Al)_{mol} < 0.1$ is not recommended. We confirm the tendency of the single-clinopyroxene barometer to progressively underestimate pressure at $P > 4.5$ GPa.

Keywords: Geobarometry, chromian diopside, lithospheric mantle, palaeogeotherms