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Propagation of analytical errors in single-clinopyroxene geobarometry and implications on estimated mantle palaeogeotherms

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Single-clinopyroxene barometry [1] has become a popular tool for estimating pressure (P) of equilibration of garnet-bearing ultramafic rocks. It is well known that high-quality electron microprobe (EMP) analysis is necessary for reliable thermobarometry. Notwithstanding, the EMP analytical conditions employed by many mantle workers using the Cr-in-Cpx barometer are often not optimized. Moreover, no quantitative evaluation of the propagation of analytical errors on the calculate P has ever been made for this barometer. When compared to the orthopyroxene–garnet barometer ([2] as modified by [3]), the Cr-in-Cpx method shows decreased precision for clinopyroxenes with low a_{Cr} (i.e., Cr – 0.81·Na·Cr#), with discrepancies up to 3.0 GPa for a_{Cr} <0.002 atoms per formula unit (apfu). Multiple electron microprobe analyses on compositionally diverse clinopyroxenes using different analytical conditions demonstrate that such discrepancies are mostly related to propagation of analytical errors on the calculated Cr-in-Cpx P. The results of the analytical tests were used to calculate model analytical errors and propagated P uncertainties for a large set of published analyses of mantle xenolith-borne clinopyroxenes (database of [4]). The resulting P uncertainties are negatively correlated with the a_{Cr} parameter and positively correlated with the Cr/(Cr + Al) ratio (Cr#). The a_{Cr}/Cr# parameter can thus be used to discriminate clinopyroxenes for which analytical errors alone will propagate unacceptable P uncertainties (i.e., higher than $\pm$0.25 GPa) for several combinations of analytical conditions. Using appropriate analytical conditions, the barometer can be applied to at least 90% of clinopyroxene-bearing garnet peridotites and pyroxenites (database of [4]), 80% of clinopyroxene inclusions in lherzolitic diamonds, and 23% of clinopyroxene inclusions in websteritic diamonds (database of [5]). Application of the barometer to clinopyroxenes with Cr# < 0.1 remains unwarranted in all cases, owing to limitations in the barometer calibration. Evaluation of P uncertainties for clinopyroxenes included in diamonds from the Premier kimberlite [6] shows that propagation of analytical errors produces biased $P - -T$ distributions. If only low-uncertainty P estimates are selected, the $P - -T$ distribution is essentially compatible with that of mantle xenoliths from the same kimberlite, indicating that (i) diamond formation occurred when the lithospheric mantle had already attained a thermal state comparable with that extant at the time of kimberlite eruption, and (ii) the majority of Premier lherzolitic diamonds most likely formed in the cratonic lithosphere under virtually unperturbed thermal conditions.

[1] Nimis et al. (2009) Lithos 112, 397–412. [2] Nickel & Green (1985) Earth Planet Sci Lett 73,158–170. [3] Carswell (1991) Mineral Mag 55, 19–31. [4] Nimis & Grütter (2010) Contrib Mineral Petrol 159, 411–427. [5] Stachel & Harris (2008) Ore Geol Rev 34, 5–32. [6] Richardson et al. (1993) Nature 366, 256–258.