The Thermochemical Conditions of the Diavik Lower Crust: A Kimberlite-Hosted Xenolith Study

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Thermal variables such as lower crustal heat production and the ambient temperature of the lower crust in cratonic regimes are poorly constrained due to the lack of modern geochemical analyses and the relative difficultly of properly sampling the lower crust. These variables are highly important for modelling geochemical and geodynamic processes in cratonic regimes while also potentially interfering on the diamond prospectively of the subcontinental lithospheric mantle sampled via kimberlite. In an attempt to resolve these issues, this study focuses on fifteen (15) lower crustal xenoliths entrained in the Diavik A-154N kimberlite.

In order to constrain the temperatures of the lower crust, we estimated the ambient temperature of the lower crust at the time of kimberlite eruption utilizing geothermometry on touching or included mineral pairings of ferromagnesian phases. Compositions of touching garnet-biotite pairs indicate the ambient temperature of the lower crust to be a maximum of ~500 °C at the time of kimberlite eruption. The amphibole-garnet thermometer yields a somewhat higher maximum temperature estimate of ~525°C whereas the clinopyroxene-garnet thermometer yields much higher maximum temperature of ~ 600°C and this is interpreted as a closure temperature of Fe-Mg exchange between garnet and clinopyroxene.

In conjunction with these measurements, heat-producing element concentrations are quantified utilizing a reconstructed bulk-rock method. This method utilizes in-situ measurements on mineral phases in conjunction with mineral modes in an attempt to remove the contamination due to infiltration of kimberlite magma, which would give spuriously high HPE concentrations. The xenolith average heat production value is 0.16 ± 0.08 $\mu W/m^3$. To remedy the high uncertainty in heat production due to the mineral modes, a range of lower crustal heat production is presented utilizing crusts of fixed mineral modes. This method creates a lower crust comprising only metasedimentary rock (0.37 ± 0.06 $\mu W/m^3$), a crust comprising only mafic granulite (0.08 ± 0.01$\mu W/m^3$), and a hybrid mixture of metasedimentary and mafic granulite in proportions similar to what is observed in the Diavik A-154N kimberlite lower crustal xenolith suite (0.14 ± 0.02 $\mu W/m^3$). In conjunction with these measurements and other variables such as surface heat flux (Mareschal et al., 2004), crustal thickness (Krauss et al., 2007), and thermal conductivity (Merriman et al., 2014), we calculate the modern-day Moho temperature beneath the Diavik mine to be between ~450°C and 480°C, consistent with the constraints provided by mineral-pair geothermometry. These estimates are tested with the geotherm modeling program FITPLOT (Mather et al., 2011) using mantle xenolith-derived P-T constraints for the Lac de Gras (Grutter & Moore, 2003). The modeling results indicate that a range of lower crustal heat production values does not propagate to a large change in the estimated thickness of the lithosphere or the size of the "diamond window".

Works Cited

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