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Petrology and Geochronology of kimberlites from the Victoria Island field, NU/NT, Canada

Alex A. Müller[1], Chiranjeeb Sarkar[1], Sarah J. Woodland[1], James LeBlanc[1], Bruce A. Kjarsgaard[2], D. Graham Pearson[1]

[1] *Department of Earth and Atmospheric Sciences University of Alberta, Edmonton, Alberta, Canada*
aamuller@ualberta.ca, chiranjeeb.sarkar@ualberta.ca, swoodlan@ualberta.ca, jleblan1@ualberta.ca, gdpearson@ualberta.ca

[2] *Geological Survey of Canada Natural Resources Canada, Ottawa, Ontario, Canada, Bruce.Kjarsgaard@nrcan-rncan.gc.ca*

Introduction

Victoria Island, Nunavut / Northwest Territories is home to four kimberlite clusters: Blue Ice, King Eider, Galaxy, and Snowy Owl (Figure 1). More than 30 kimberlites were discovered in the 1990s and 2000s (The Northern Miner, 2003). Previous age determinations (286 - 256 Ma: Heaman et al., 2003; 2004) indicate Permian kimberlite activity – a rather unusual time period that falls outside the main global emplacement epochs, with few kimberlites of similar age known. Only a few others in North America are of similar age in the Laurentia super-craton. Here, we aim to define the duration of kimberlite magmatism on Victoria Island with new Rb-Sr and U-Pb age determinations, as well as characterize the mineral chemistry and geochemistry of a selection of hypabyssal kimberlites. New tracer isotope data tests the veracity of the global kimberlite temporal trend in source isotopic composition in a key period during the existence of the Pangea supercontinent.

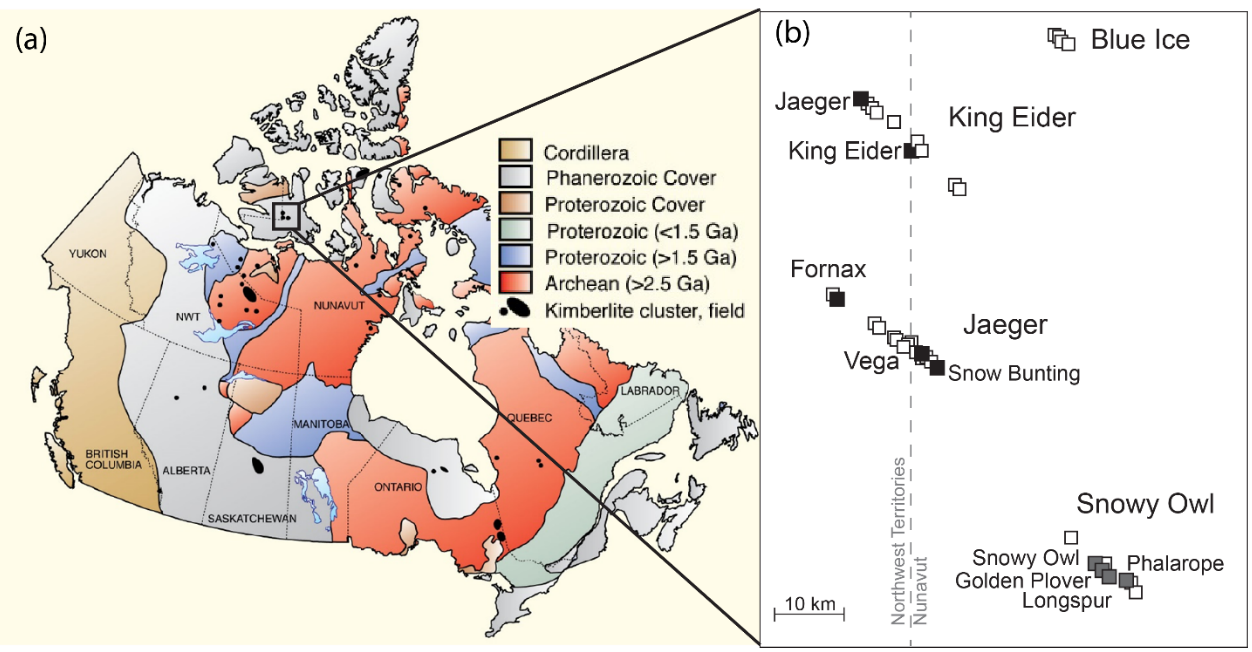

Figure 1: (a) Simplified geological overview of Canada (modified after Kjarsgaard, 2007a). (b) Detailed outline of the Victoria Island kimberlite field. White squares represent the individual kimberlites, black filled squares are part of this study, the gray squares are the ones that have previously been age dated by Heaman et al. (2003; 2004).

Petrography and Mineralogy

Forty new whole rock hypabyssal kimberlite samples were analyzed for this study, comprising samples from two dyke and pipe complexes of the King Eider cluster (Jaeger and King Eider) and three dyke and pipe complexes of the Galaxy cluster (Fornax, Snow Bunting, and Vega). Five whole rock samples were chosen for Sr, Nd, and Hf tracer isotope analysis in order to constrain the isotopic characteristics of the mantle source. The kimberlites consist of macrocrystic olivine ± phlogopite ± ilmenite as well as groundmass olivine, spinel, mica, calcite, ilmenite, apatite, and scarce perovskite. Compositional zonation is visible for olivine, mica, and spinel. The mineral chemistry of phlogopite (phlogopite-eastonite trend) (Figure 2a) and of spinel (dominantly Trend 1) (Figure 2b) from Victoria Island kimberlites are consistent with a classification as kimberlite. The spinel textures, using the terminology of Mitchell et al. (2019), are atoll textures and are typically zoned from Mg-chromite to Mg-ulvöspinel to Ti-magnetite.

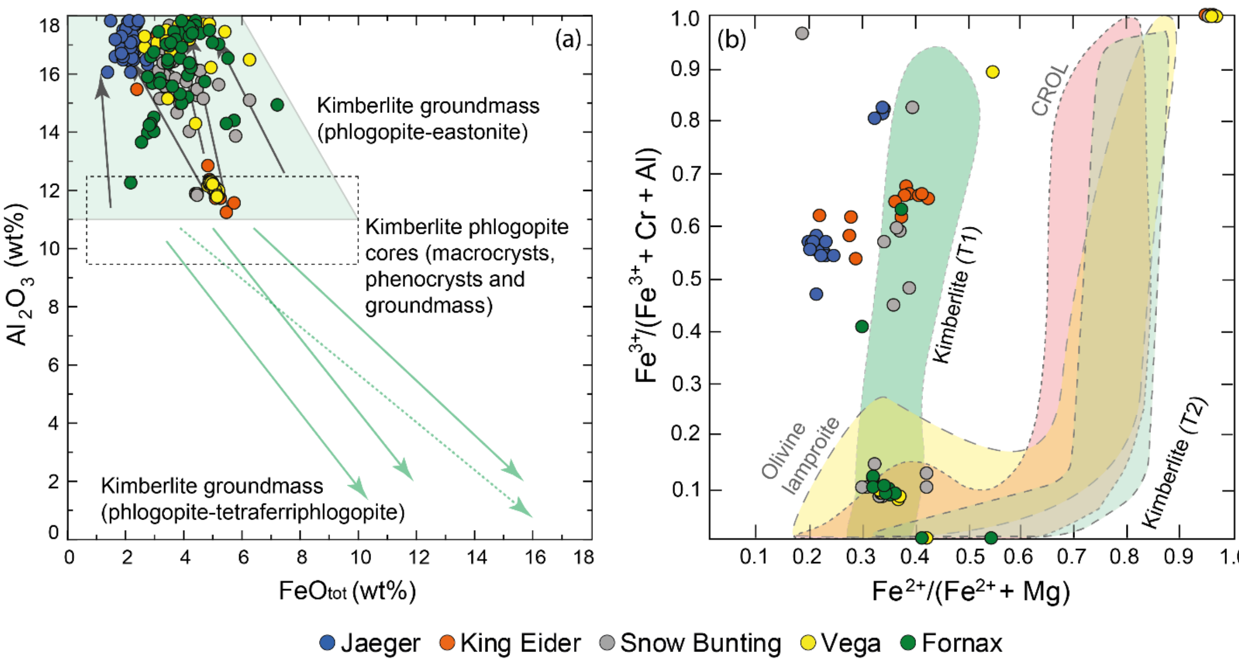

Figure 2: Bivariat mineral chemistry plots for Victoria Island kimberlites. (a) Phlogopite mica of Al_2O_3 (wt%) versus FeO_{tot} (wt%), showing the kimberlite field and the compositional trends for phlogopite-eastonite and phlogopite-tetraferriphlogopite. (b) Oxidized spinel of $Fe^{3+}/(Fe^{3+}+Cr+Al)$ versus $Fe^{2+}/(Fe^{2+}+Mg)$, with fields and compositional trends for kimberlite (Trend 1 and Trend 2), carbonate-rich olivine lamproite (CROL), and olivine lamproite. Compositional fields after Kjarsgaard et al. (2022).

Results and Discussion

Whole rock major element geochemistry (average compositions, n=27: 28.8% SiO_2; 2.1% TiO_2; 1.7% Al_2O_3; 32% MgO; 0.03% Na_2O; 0.27% K_2O; 0.3% P_2O_5) align well with global kimberlite compositions, with Clement's CI of <1 and Yb <0.5 ppm in most of the samples revealing minimal crustal contamination, typically rare limestone clasts. Mildly depleted εHf_i (+4.7 to +8.4) and εNd_i (+1.4 to +2.6) conform well to the Pre-Mesozoic temporal trend for kimberlite sources (Figure 3). $^{87}Sr/^{86}Sr_i$ ranges from 0.7045 to 0.7055 for the whole rock samples and the weighted average ratio on the perovskite grains is 0.7039.

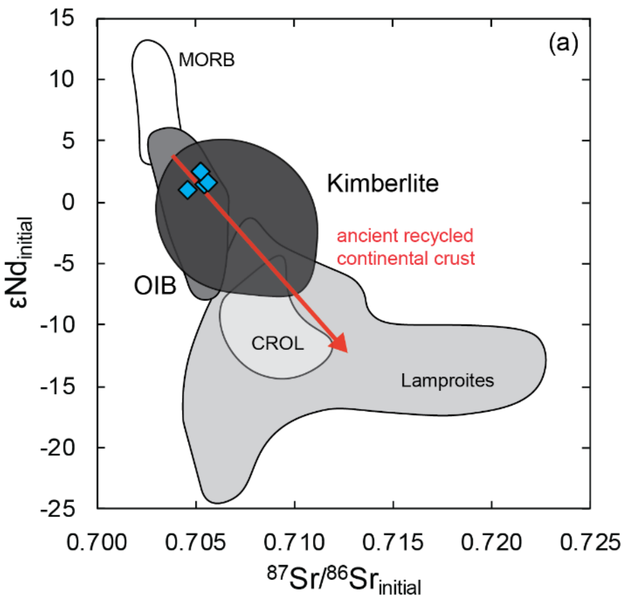

Figure 3: Whole rock tracer isotope data of (a) εNd_i versus $^{87}Sr/^{86}Sr_i$ and (b) εHf_i versus εNd_i for Victoria Island kimberlites (blue). Fields for global kimberlites, lamproites, carbonate-rich olivine lamproite (CROLs), ocean island basalts (OIB), and mid-ocean ridge basalts (MORB) with a vector for incorporation of ancient recycled continental crust (after Pearson et al., 2019).

Given the relatively high percentage of radiogenic Pb in the analyzed perovskites (~ 49% $^{206}Pb_r$) and the large spread in Rb/Sr on the isochrons, with $^{87}Rb/^{86}Sr$ values > 500 in some fractions resulted in age precisions on individual mineral fractions of <1% uncertainties. Our new U-Pb perovskite and Rb-Sr mica ages range from 270-241 Ma and extend the overall range of Victoria Island kimberlite magmatism to over 40 Myr, with each kimberlite cluster containing bodies ranging in age > 20 Myr. New U-Pb perovskite and Rb-Sr mica ages considerably extend the range of emplacement ages in Victoria Island kimberlites into Middle Triassic times.

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