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Petrology, Geochemistry, and Geochronology of the Dharma Kimberlites, Northwest Territories, Canada

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Introduction

Situated in Paleoproterozoic sediments west of the Slave Craton (Figure 1A), the Dharma kimberlites were discovered through drilling programs completed by Santana Resources Inc. and Kennecott Canada Exploration Inc. The diatreme blows of the Dharma kimberlite intruded into mudstones and dolomite of the Dismal Lake and Hornby Bay Groups (Gill, 2016). This study reports the first mineral chemistry, geochemistry, geochronology, and indicator mineral data for samples collected from volcaniclastic and hypabyssal kimberlite intersected in diamond drill hole DD007-GH001.

Petrography, Mineral Chemistry, and Phlogopite Rb-Sr Geochronology

The Dharma intrusion comprises poorly-sorted, clast-supported volcaniclastic kimberlite and flow-banded, hypabyssal kimberlite. Volcaniclastic kimberlite contains frame-work clasts of altered olivine ± phlogopite crystals, ash, lapilli, xenocrysts, and crustal xenoliths (Figure 1C). Olivine is the dominant mineral in hypabyssal kimberlite (<35 volume % of grains >100µm diameter; Figure 1D). The hypabyssal kimberlite groundmass (<100µm diameter) consists of carbonate + spinel + serpentine + apatite + ilmenite ± olivine (<71 volume %). Phlogopite from hypabyssal Dharma kimberlite (n=7) exhibits compositions similar to archetypal kimberlite phenocryst cores (Figure 2C). Ilmenite (n=13) from the Dharma kimberlite can be divided into two compositional groups. The first group predominantly displays geikielite to ilmenite (MgTiO3 equivalent to FeTiO3) compositions. Spinel groundmass core compostions (n=22) generally fall along Trend 1 compositions (Kjarsgaard et al., 2022) with 0.26-0.69 Ti apfu/(Ti apfu + Cr apfu + Al apfu) values, 0.25-0.45 Fe^{2+} apfu/(Fe^{2+} apfu + Cr apfu + Al apfu) values, 0.04-0.31 Cr apfu/(Cr apfu + Al apfu). Garnet cores from the hypabyssal Dharma kimberlite (n=276) are dominated by G9A low-Ca lherzolite compositions. Of note, are five low-Ca harzburgite (G10A) analyses which fall between the 47-51 kbar isobar of Grütter et al. (2006). Seven phlogopite aliquots collected from hypabyssal and volcaniclastic kimberlite yielded an isochron age of 220 Ma (error refinement in progress).

Whole Rock Geochemistry of Hypabyssal Kimberlite

Uncontaminated, hypabyssal, Dharma kimberlite analyses (n=9) display SiO_2 (26.03-30.85 wt.%), TiO_2 (0.96-1.5 wt.%), Al_2O_3 (1.17-1.86 wt.%), MgO (22.65-35.49 wt.%), CaO (6.94-19.22 wt.%), and K_2O (0.05-1.24 wt.%) contents within the range of archetypal kimberlite (Pearson et al., 2019). This reasoning is further supported by trace element concentrations (1208-1607 mg/g Ni; 144-219 mg/g Nb; 307-3040 mg/g Ba) and radiogenic isotope (2.2-2.5 $\varepsilon Nd_{initial}$; 1.4-5.6 $\varepsilon Hf_{initial}$; 0.7039-0.7075 $^{87}Sr/^{86}Sr_{initial}$) signatures.

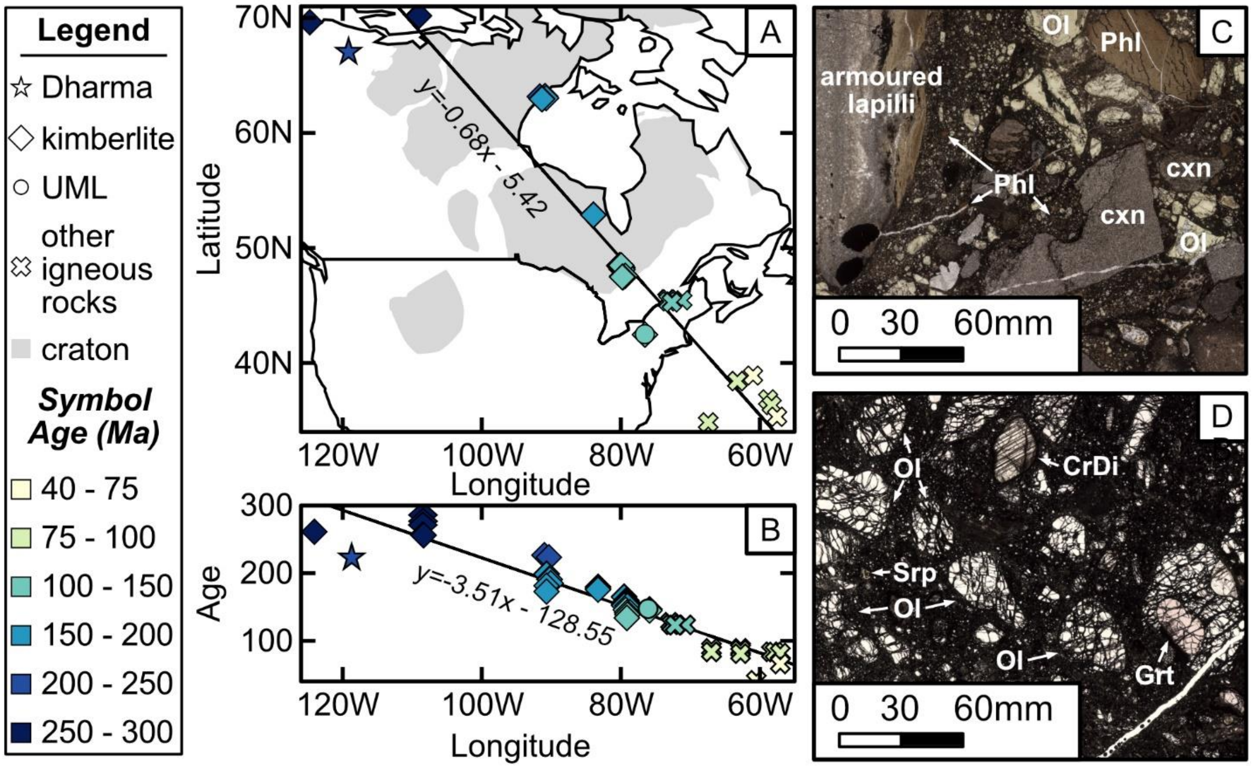

Figure 1: A) Distribution of 300-40 Ma magmatism related to a linear regression model of the Great Meteor Hotspot track (Heaman et al., 2004; Kinney et al., 2021) for North America. B) Age vs. longitude for data in Figure 1A with a linear regression model. Plane-polarized photomicrographs of: C) Volcaniclastic Dharma kimberlite sample D129. D) Hypabyssal Dharma kimberlite sample D86. Labels: CrDi – Cr-rich diopside, Grt – garnet, Ol – olivine, Phl – phlogopite, Srp – serpentine group mineral, cxn – crustal xenolith, UML – ultramafic lamprophyre.

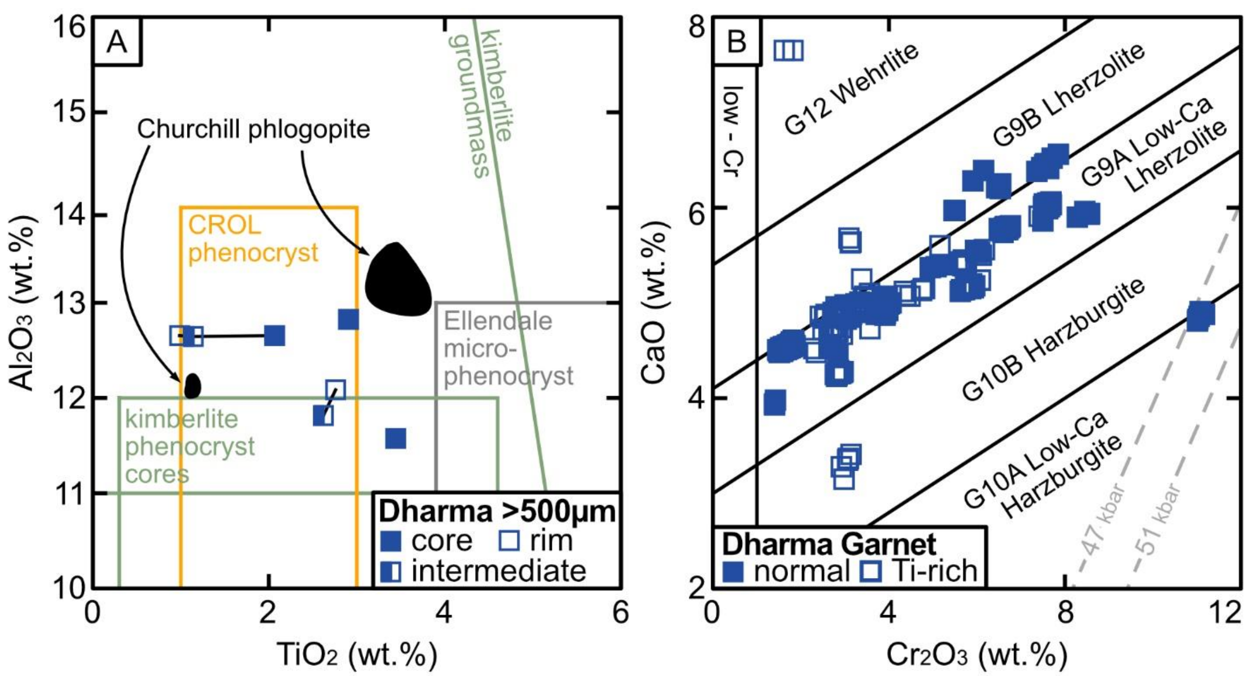

Figure 2: A) Al_2O_3 vs. TiO_2 composition of >500 µm phlogopite from Dharma kimberlite compared to phlogopite from the Churchill kimberlite field (Zurevenski et al., 2008; Kjarsgaard et al., 2022). B) CaO vs. Cr_2O_3 composition of the garnet plot after Grütter et al. (2006) and Snyder et al. (2021). Labels: CROL – carbon-rich olivine lamproite.

Discussion

The Dharma intrusions are classified as kimberlites. Phlogopite grains plot within or adjacent to kimberlite phenocryst core compositions, include a zonation trend of Ti-depletion at constant Al and increasing Fe (Kjarsgaard et al., 2022), and plot between phlogopite populations of similarly-aged Churchill kimberlites (Zurevinski et al., 2008). Alongside whole rock major and trace element contents, radiogenic isotope results from the Dharma intrusions align with archetypal kimberlite signatures (Pearson et al., 2019) and fall within the range of kimberlite compositions from the Churchill kimberlite field (Zurevinski et al., 2008). The Triassic Dharma kimberlite shares its age with a few other Canadian kimberlites. Permian kimberlites occur at Darnley Bay (Brin et al., 2016) and Victoria Island (Heaman et al., 2004). Triassic kimberlites of nearly identical age occur in the Churchill kimberlite field (Zurevinski et al., 2008). These kimberlites fit along a geographic and temporal succession of volcanism from Darnley Bay to the New England Seamounts (Figure 1A and B). Modeling of hotspot tracks and North American plate motion has identified the Great Meteor Hotspot track as a possible source for this distribution (Heman et al., 2004; Zurevinski et al., 2008).

The chemistry of G10A harzburgite garnet from Dharma indicates mantle sampling from up to 47-51 kbar, and the variety in garnet compositions suggests the presence of a heterogenous, lithospheric mantle beneath the Interior Platform. This supports previous findings which include the presence of G10 garnet kimberlite indicator minerals in the region (Pokhilenko et al., 2012) and regional magnetic, Bouguer gravity, and seismic velocity anomalies (Estève et al., 2020).

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