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A first look at diamonds and their inclusions from the Sequoia Kimberlite Complex, Northwest Territories, Canada

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Introduction

The Central Slave Craton hosts numerous diamondiferous kimberlites, some of which were developed into prolific diamond mines, such as Diavik and Ekati. Kimberlites from this region are collectively referred to as Lac de Gras field and erupted in the Upper Cretaceous-Eocene (Sarkar et al. 2015). The Sequoia kimberlite complex (**Fig. 1a**) was first recognized in 2018 by Arctic Star Exploration Corp. Ongoing drilling and geophysics work suggests a trough like structure (~1 x 0.25 km) with 3-4 coalescing eruption centers. Drilled kimberlite ranges from coherent to volcaniclastic. To characterize the diamond substrates beneath the Sequoia kimberlites and the diamond cargo they brought to surface, we studied micro- and macro-diamonds and their inclusions recovered by caustic fusion from seven exploration and delineation drill cores.

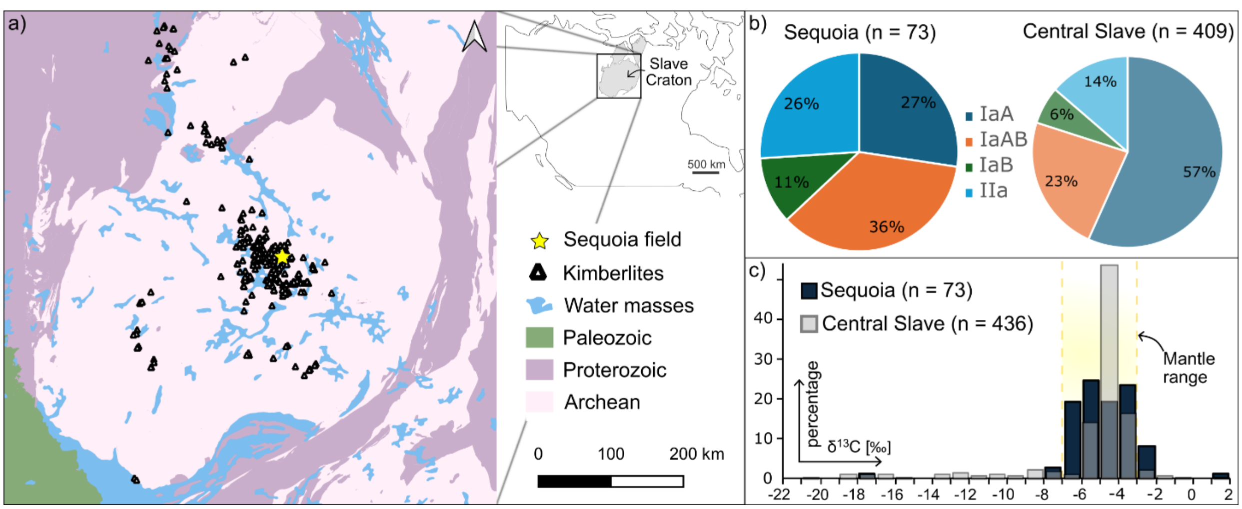

Figure 1: a) Simplified map showing the location of the Sequoia kimberlite complex on the Slave Craton. b) Distribution of macro-diamond types (with Type IaAB = 20 < %B < 80), and (c) average $\delta^{13}C$ values, for diamonds from Sequoia (this study) and Central Slave area (database of Stachel 2021). Histograms (1‰ binning interval) are plotted in front of each other.

Samples

Seventy-three diamonds were selected from caustic fusion samples based on size (>700 µm; n = 51) or the presence of visible mineral inclusions (n = 22). The diamonds were analyzed for their nitrogen content [N] and aggregation state (%B; relative percentage of nitrogen in B-centers) by micro-Fouriertransform infrared spectroscopy (µ-FTIR) and for their C and N isotope compositions and [N] by secondary ion mass spectrometry (SIMS). Mineral inclusions from 24 diamonds were analyzed *in situ* by Raman spectroscopy.

Diamond characteristics

The studied diamonds mainly are fragments (27%), aggregates/twins (26%), octahedra (18%), rounded dodecahedra/resorbed (18%) and macles (11%). Twins and octahedra are overrepresented in the subpopulation selected for the presence of visible mineral inclusions. Six diamonds are fibrous, highly resorbed, and black/dark grey (n = 4), white (n = 1) or yellow (n = 1) in color. The colors of monocrystalline diamonds are mainly white (43%), pale yellow (48%), or brown (9%).

FTIR analyses revealed that 26% of the diamonds are Type IIa (no detectable nitrogen), 11% are Type IaB (>80% of N in B-centers), 27% are IaA (<20% of N in B-centers), and 36% are intermediate Type IaAB. Type IaA and IaAB diamonds have mean N contents of ~395 and 583 at.ppm, respectively, while Type IaB diamonds are N-poor with a mean of ~154 at.ppm. Five of the fibrous diamonds are pure Type IaA (0 %B) with high N contents (290 to 800 at.ppm). The single white fibrous diamond has a very high nitrogen content (1350 at.ppm), with 27 %B (Type IaAB).

Comparing the nitrogen aggregation states in diamonds from Sequoia with other kimberlites from the central Slave (**Fig. 1b**), specifically Diavik, Ekati, DO27-DO18, and Ranch Lake (database of Stachel 2021), Sequoia contains a higher abundance of Types IIa and IaB diamonds, with a much lower proportion of stones with poorly aggregated nitrogen (Types IaA).

The carbon and nitrogen isotope compositions of diamonds from Sequoia are generally within typical diamond mantle ranges (-5 ± 2‰ for $\delta^{13}C$, Cartigny et al. 2014; -3.5 ± 5‰ for $\delta^{15}N$, Stachel et al. 2022), which encompasses around 80% of the measurements (**Fig. 1c**). Published data for the central Slave area are also dominated by typical mantle $\delta^{13}C$ values, with the difference that there is a prominent peak in range -5 to -4‰, while at Sequoia there is a wider distribution throughout the mantle range (-7 to -3‰).

Lithospheric and sublithospheric mantle sources for diamonds of the Sequoia Field

Our Raman study on mineral inclusions from 24 diamonds shows that Sequoia kimberlites tapped both lithospheric and sublithospheric mantle sources of diamonds beneath the Slave Craton, with peridotite being the main diamond substrate. Fourteen diamonds were classified as peridotitic based on the presence of only olivine, five diamonds contained cpx ± ol ± opx and can be assigned to the lherzolitic paragenesis, and another five diamonds belong to the sublithospheric suite based on the presence of ferropericlase ± ol, breyite, or larnite ± ol (**Fig. 2a**).

All diamonds classified as sublithospheric are either Type IaB or IIa. Carbon isotope compositions are slightly ^{13}C depleted in diamonds with larnite or ferropericlase (-5.4 to -7.2‰) but slightly ^{13}C enriched in a diamond with breyite inclusions (internal variation of -3.6 to -1.7‰), suggesting contributions of distinct carbon reservoirs in the formation of sublithospheric diamonds.

Infrared spectra of fibrous diamonds document micro-inclusions of an aqueous fluid with high H_2O/CO_2 (**Fig. 2b**). The presence of IR peaks indicative of olivine and mica micro-inclusions documents derivation from peridotitic substrates.

Conclusions

The diamond population sampled by the Sequoia kimberlites is characterized by the presence of both lithospheric and sublithospheric diamonds. The relatively high abundance of diamonds with inclusions of sublithospheric and lherzolitic origin provides important background for the interpretation of indicator mineral data. An enhanced understanding of the particular characteristics of the diamond substrates tapped by the Sequoia kimberlites will contribute to the evaluation of their economic potential.

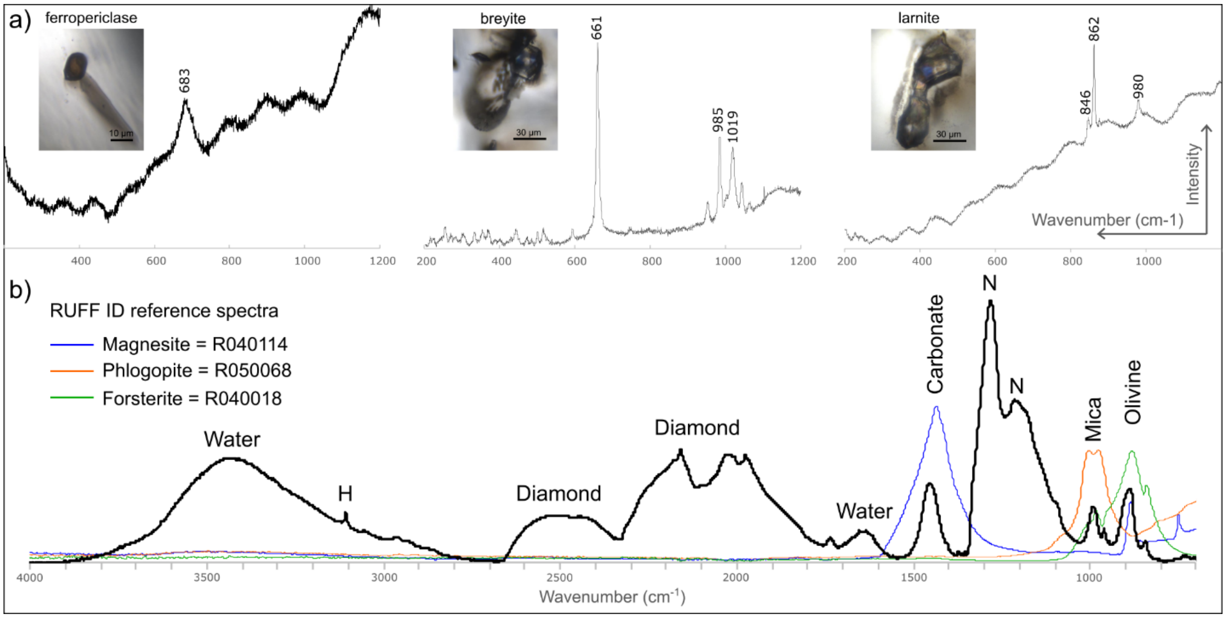

Figure 2: a) *In situ* Raman spectra of mineral inclusions of sublithospheric origin in Sequoia diamonds. The main peaks in each spectrum are indicated by their wavenumber position. (b) FTIR spectrum of a fibrous diamond showing high water to carbonate ratio in the fluid inclusions. Additional peaks in the spectrum are likely related to micro-inclusions of carbonate minerals, mica and olivine. Magnesite, phlogopite and forsterite FTIR spectra from Ruff database are shown for comparison.

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