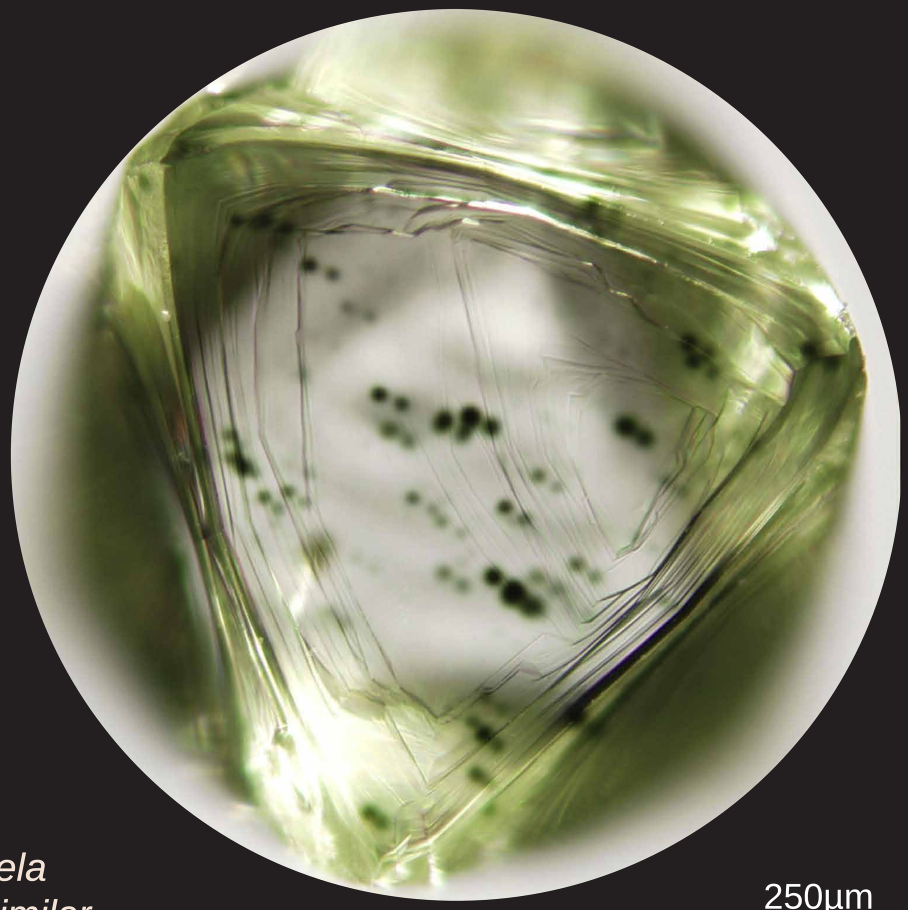
Diamonds trace formation of 3 Ga continental roots



Rory Changleng[1], Andrea Pezzera[2], Richard Stern[2], Thomas Stachel[2], D. Graham Pearson[2], Jesse R. Reimink[1]

[1] Department of Geosciences, Pennsylvania State University, University Park, PA, USA
[2] Department of Earth and Environmental Sciences, University of Alberta, Edmonton, AB, Canada

INTRODUCTION

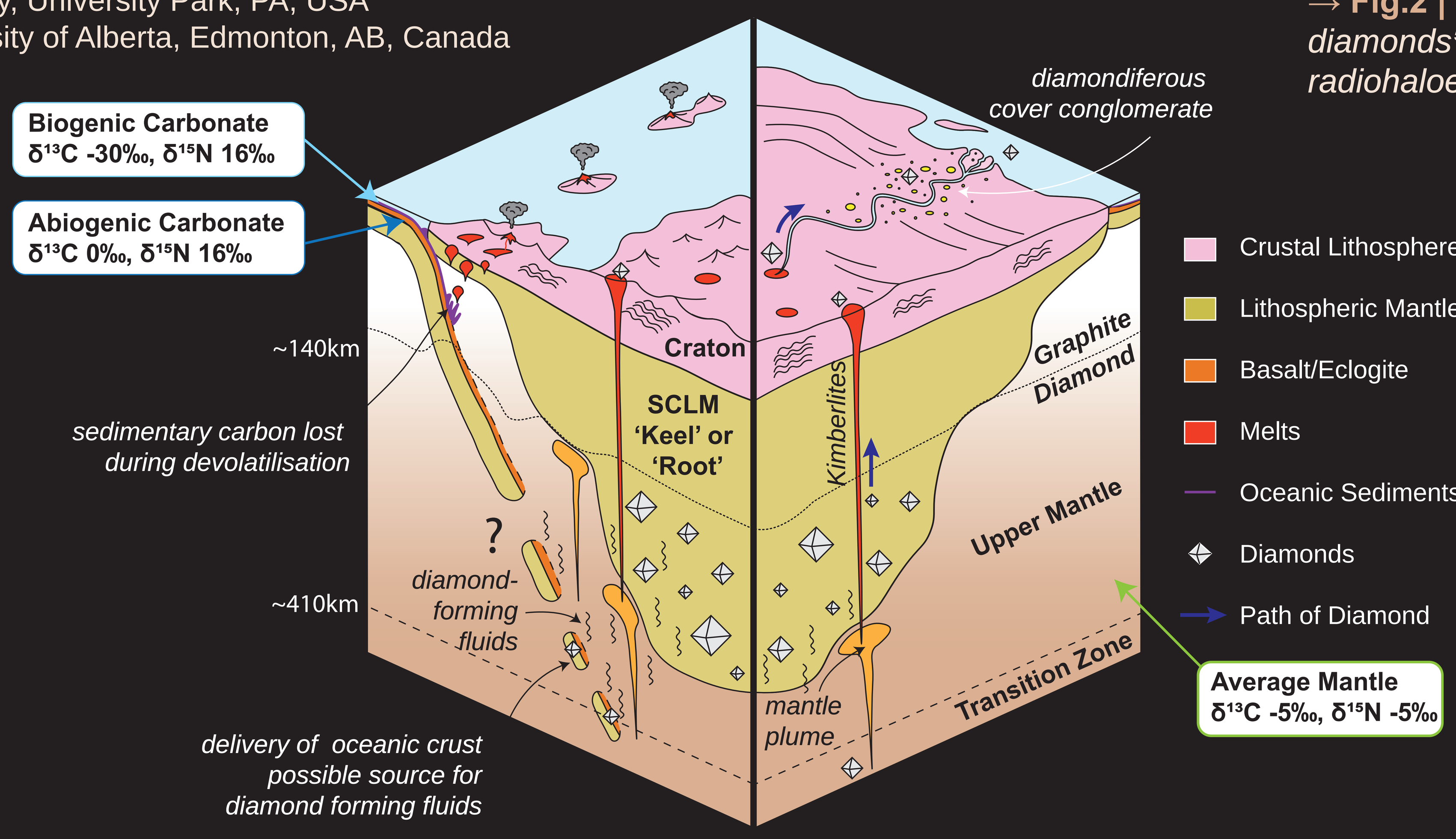
- Diamonds are direct samples of the mantle lithosphere and are used to constrain the processes that formed cratonic roots.

Motivating Questions

1. How and when did Earth's lithospheric mantle roots form beneath cratons?
2. What geodynamic regimes operated 3 billion years ago (Ga) in the Archaean?

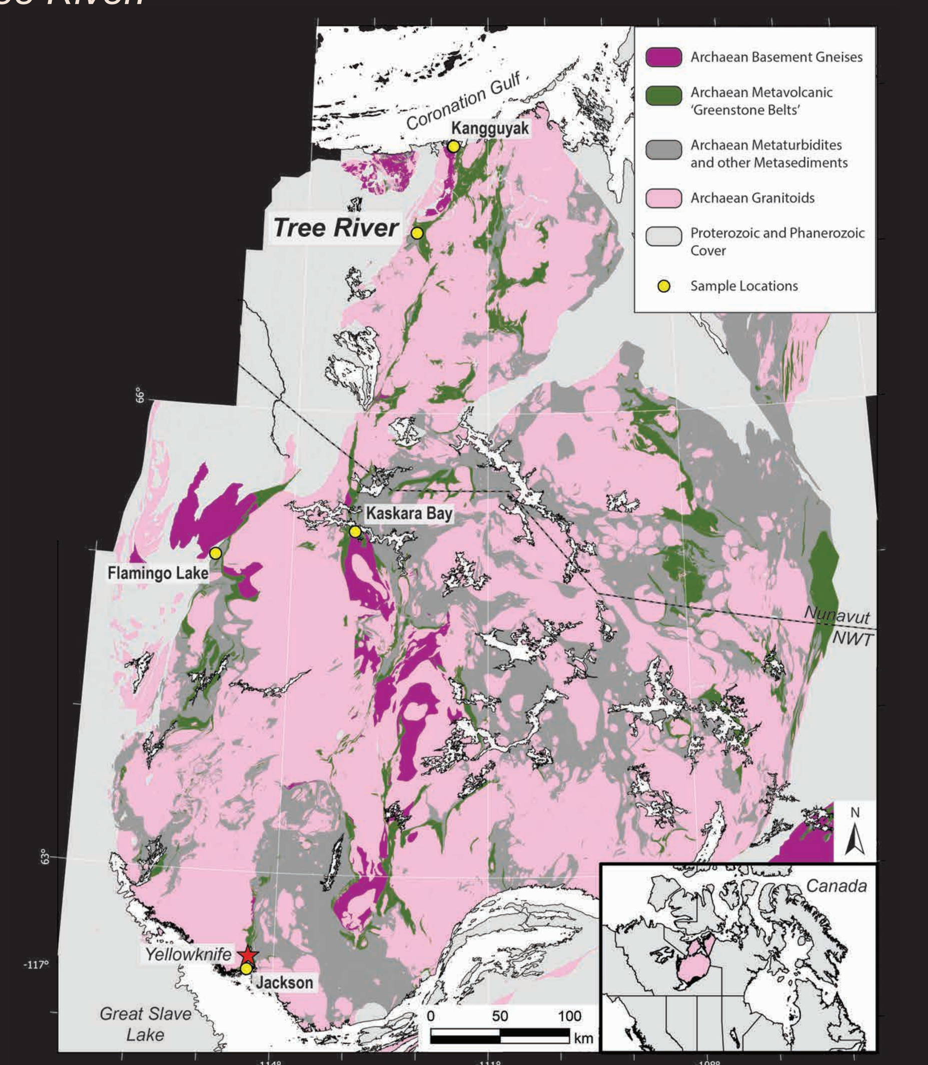
Aims

- Recover diamonds from Mesoarchaean-aged (2.6 - 3.2 Ga) sediments from the Slave Craton, NW Canada.
- Measure isotopes to trace diamond-forming fluid sources and test tectonic models for cratonic keel formation.
- Expand on the 3 diamonds previously recovered[1] and test the proposed model of cratonic root formation via slab-stacking.

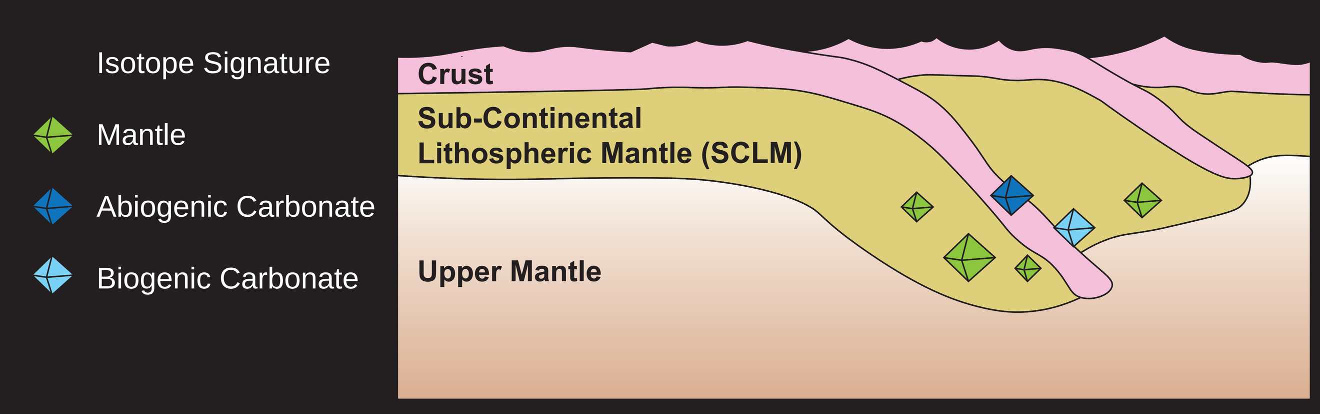


↑ **Fig.1** | *Schematic of an Archaean craton with carbon and nitrogen isotope reservoirs and processes associated with diamond formation highlighted. Modified from [2] and [3].*

→ **Fig.2** | *Venezuela diamonds[5] have similar radiohaloes to Tree River.*

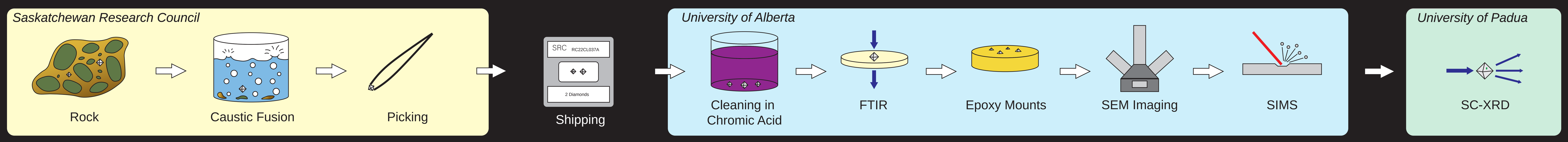


↑ **Fig.3** | *Map of Samples collected during Summer 2022 from the Slave Craton, NW Canada. Diamonds were only recovered from Tree River. Modified from [4].*



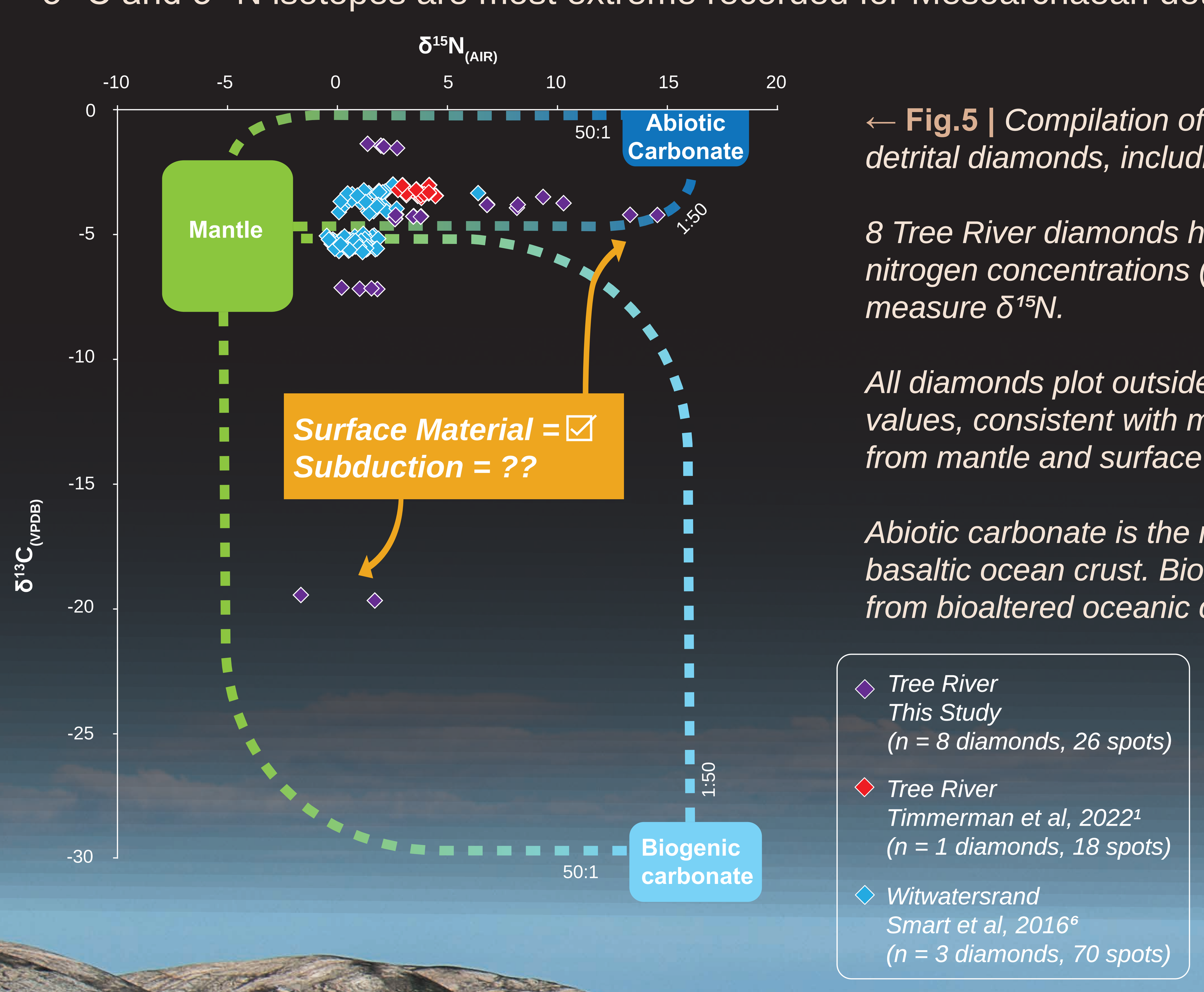
← **Fig.4** | *Schematic of Slab-Stacking[1]. Slabs of crust and the attached underlying lithospheric mantle are imbricated and stacked, generating cold cratonic roots capable of stabilising diamonds. This may deliver surface carbonate into the cratonic root.*

METHODS



RESULTS

- 25 new detrital diamonds recovered from the >2.83 Ga Tree River conglomerate.
- Nitrogen aggregation measured with FTIR indicates mantle residence at 1110-1190°C.
- $\delta^{13}C$ and $\delta^{15}N$ isotopes are most extreme recorded for Mesoarchaean detrital diamonds.

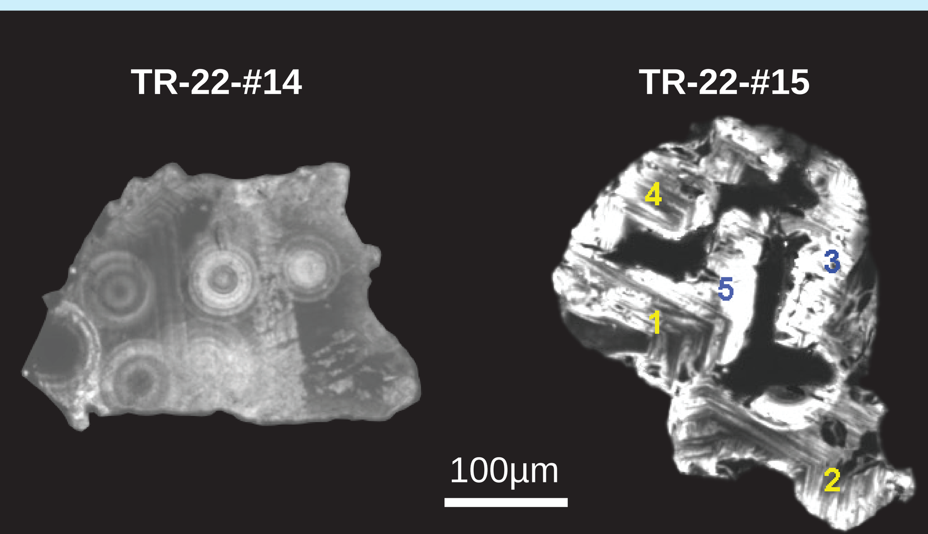


← **Fig.5** | *Compilation of all Mesoarchaean detrital diamonds, including this study.*

8 Tree River diamonds had sufficient nitrogen concentrations (>50ppm) to measure $\delta^{15}N$.

All diamonds plot outside typical mantle values, consistent with mixing of C and N from mantle and surface carbonate[3].

Abiotic carbonate is the normal altered basaltic ocean crust. Biogenic carbonate is from bioaltered oceanic crust.



← **Fig.6** | *SEM (CL) images of radiohalos in two Tree River diamonds. 10-13 of the 23 imaged diamonds contained this radiation damage. TR-22-#15 contains a garnet, clinopyroxene, and magnesite inclusion.*

CONCLUSIONS

- Radiation damage demonstrate these are not contamination from modern diamonds.
- Wide range in $\delta^{13}C$ and $\delta^{15}N$ values outside typical mantle range (~-5‰) indicates surface material mixed with the diamond-forming fluids in the lithospheric mantle root.
- Extremely low (~-19.5‰) $\delta^{13}C$ values may be a signature of biogenic carbonate.
- Slab-stacking best model to account for both the addition of surface material to diamond-forming fluids and the rapid generation of cold mantle roots capable of stabilising diamonds.

PennState College of Earth and Mineral Sciences
UNIVERSITY OF ALBERTA

NSF Grant Number: 500000017281
Archaean Roots Base

References:
1. Timmerman, S., et al. 2022. "Mesoarchean Diamonds Formed in Thickened Lithosphere, Caused by Slab-Stacking." EPSL.
2. Shirey, Steven B., et al. 2013. "Diamonds and the Geology of Mantle Carbon." Rev Min and Geochem.
3. Li et al, 2019 "Diamond isotope compositions indicate altered igneous oceanic crust dominates deep carbon recycling". EPSL.
4. Stubley M P, Irwin D. 2019. "Bedrock Geology of the Slave Craton, Northwest Territories and Nunavut." NTGS.
5. Schulze et al, 2016 "Unusual paired pattern of radiohalos on a diamond crystal from Guaniamo (Venezuela)" Lithos
6. Smart et al, 2016 "Early archaean tectonics and mantle redox recorded in Witswatersrand diamonds" Nature Geosciences