Late-stage Archean continental growth:

New insights from zircon Hf-isotopes of granitoids from the Slave craton (Canada)

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Outstanding Student & PhD candidate Presentation contest

What was the nature of Earth's earliest crust?

Was preserved Archean continental crust formed from the reworking of either:
an ancient (long-lived) continental crust or
a juvenile (short-lived) continental crust?



short-lived continental crust (subduction)

or...

long-lived continental crust (sagduction)

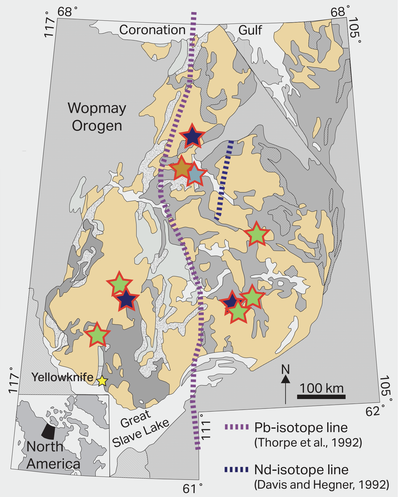
Long crustal growth history in the Slave craton

The Slave craton (NWT, Canada) has an exceptionally long record of Archean crustal growth. Its Central Slave Basement Complex (CSBC) has ages which range ca. 4.02-2.8 Ga, the oldest of which are within the Acasta Gneiss Complex (AGC).

Notably, Neoarchean (ca. 2.62-2.58 Ga) granitoids across the craton have intruded this Mesoarchean basement.

We test for widespread crustal reworking in the late Archean by analyzing these granitoids for zircon U-Pb-Hf-O and comparing with their whole-rock geochemistry

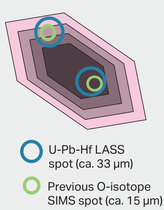
This allows us to evaluate the extent of juvenile vs. ancient crustal reworking.



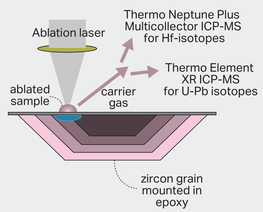
→ **Figure 1.** Map of the Slave craton in the Northwest Territories of Canada. Samples of this study are stars, colored by their rock classification (see Figure 2). Samples were chosen based on their positions relative to both the Pb-isotope boundary (purple dashed line) and the Nd-isotope boundary (dark blue dashed line). The western side of these boundaries define more radiogenic Pb and signatures of ancient crustal precursors from Nd-isotopes, whereas the eastern side is more juvenile. Map modified after Bleeker et al., 1999.

Precise U-Pb-Hf-O zircon analysis

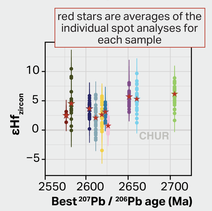
Zircon Spot Selection



Laser Ablation Split-Stream (LASS) ICP-MS



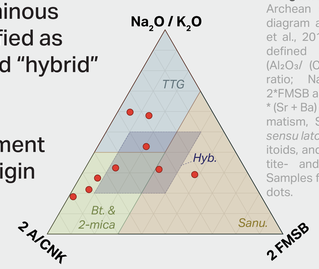
Weighted mean average for best sample εHf



Granitoid evolution: A geochemical and isotopic view

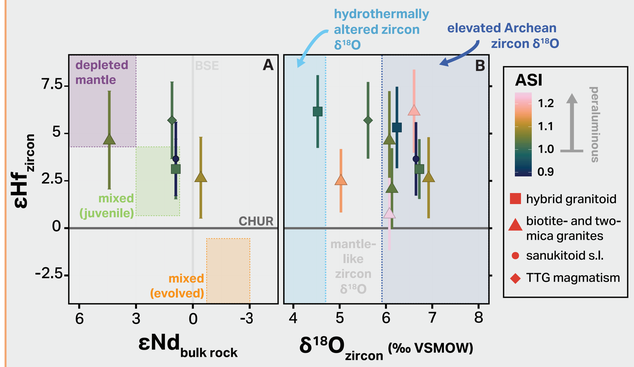
These are predominantly peraluminous granitoids, and are broadly classified as biotite- and two-mica granites and "hybrid" granitoids

This suggests significant involvement of a crustal component in their origin (such as a meta-sedimentary or mixed source)



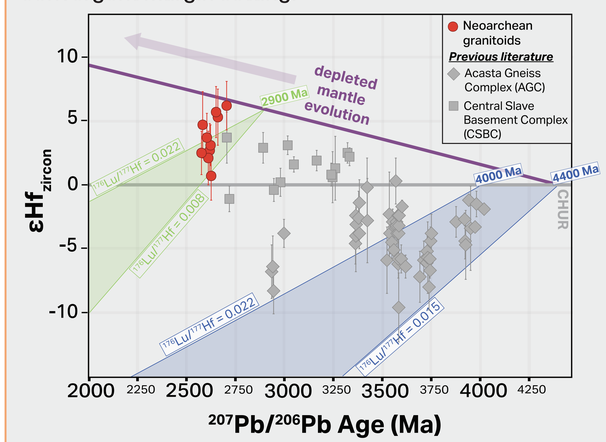
↙ **Figure 2.** Synthetic late-stage Archean classification ternary diagram adapted from Laurent et al., 2014. End members are defined as molar 2*A/CNK (Al_2O_3/ (Ca_2O + Na_2O + K_2O)) ratio; Na_2O/K_2O ratio; and 2*FMSB as 2*(FeOt + MgO) wt% * (Sr + Ba) wt%. TTG is TTG magmatism, Sanu. are sanukitoids *sensu lato*, Hyb. are hybrid granitoids, and Bt. & 2-mica are biotite- and two-mica granites. Samples from this study are red dots.

Combined εHf and εNd also indicates a mixed source including a juvenile supracrustal input. Zircon $\delta^{18}O$ values are elevated from typical mantle-like values suggesting there was a significant supracrustal input.



↙ **Figure 3.** Data is colored by ASI (Alumina Saturation Index; molar Al_2O_3/(CaO – 1.67*P_2O_5 + Na_2O + K_2O) after Bucholz et al., 2018) and shaped as their granitoid classification (See Figure 2). ASI > 1.0 is considered "peraluminous" and is often correlated with increased supracrustal input.
Panel A is whole-rock εNd ($^{143}Nd/^{144}Nd$ normalized to bulk silicate Earth) versus zircon εHf ($^{176}Hf/^{177}Hf$ normalized to CHUR). Both systems have similar magmatic behavior, and together they show a mixed source.
Panel B is zircon $\delta^{18}O$ (normalized to Vienna Standard Mean Ocean Water) and corresponding zircon εHf, majority of these samples are elevated from mantle-like zircon. Indicating a notable supracrustal input at the time of zircon crystallization.

εHf signatures are very juvenile, suggesting derivation from a short-lived crustal reservoir. This is consistent with the whole-rock εNd results of these samples and previous interpretations these granitoids formed in a convergent margin setting.



← **Figure 4.** Weighted means of zircon εHf ($^{176}Hf/^{177}Hf$ normalized to CHUR) for Slave craton samples plotted against their corresponding zircon $^{207}Pb/^{206}Pb$ ages. Error bars are 2SE. Grey line at 0 εHf represents the Chondritic Uniform Reservoir (CHUR). Depleted mantle evolution curve begins at the chondritic value at 4.4 Ga and ends at the typical modern MORB (+17 εHf). Lu/Hf model evolutions for felsic ($^{176}Lu/^{177}Hf$ = 0.009) to mafic ($^{176}Lu/^{177}Hf$ = 0.022) crust derived from a depleted mantle at 2.9 Ga shown in green, representing the evolution of a potential short-lived continental crust; evolution for mafic ($^{176}Lu/^{177}Hf$ = 0.022 at 4.0 Ga) and intermediate ($^{176}Lu/^{177}Hf$ = 0.015 at 4.4 Ga) crust derived from bulk silicate Earth in dark blue, representing the recycling of a Hadean mafic crust. Previous Acasta and Central Slave gneiss data from Reimink et al., 2019; Amelin et al., 2000; Iizuka et al., 2009; Bauer et al., 2017; Reimink et al., 2016.

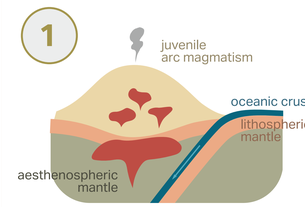
Forming granitoids from juvenile sediments ↘

1 - Arc magmatism forming thick, young volcanics/plutonics

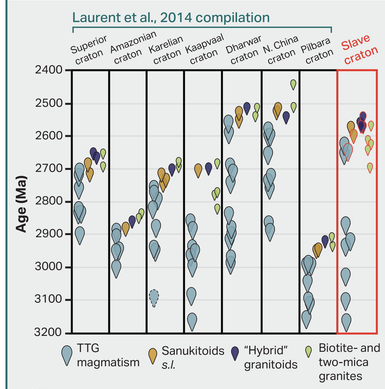
2 - Thickening of the continental crust over time while rapid erosion (ca. 5-20 Myr) of young crust resulted in juvenile sediment and deposition

3 - Heating, from radiogenic heat and possibly mafic underplating, partially melted the buried juvenile sediments

4 - Granites were emplaced following the end of subduction (potentially due to micro-continental collision) and the continental crust is stabilized



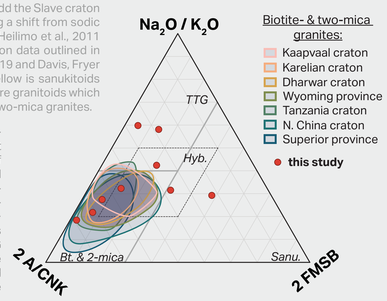
Global comparsion



The Slave Craton follows the same trajectory as other cratons globally, with a magmatic transition from sodic TTG magmatism to K-rich granitic magmatism in the late Archean.

Evolved granites (biotite- and two-mica granites) fall within range of every reported craton.

↑ **Figure 5.** Adapted from Laurent et al., 2014, to add the Slave craton onto their compilation of global cratons exhibiting a shift from sodic TTG magmatism to K-rich granitoids. Data from Heilimo et al., 2011 and Laurent et al., 2014 compilations; Slave craton data outlined in red is this study, other data from: Reimink et al., 2019 and Davis, Fryer and King,1994. Light blue is TTG magmatism; yellow is sanukitoids *sensu lato*; dark blue is "hybrid" granitoids which are granitoids which overlap in chemistry/origin; green is biotite- and two-mica granites.



→ **Figure 6.** Synthetic late-Archean granitoid classification ternary diagram adapted from Laurent et al., 2014. Outlined fields represent the bounds of biotite- and two-mica granite data from individual cratons, shaded interiors are to visualize the density of overlapping regions. End members are defined as molar 2*A/CNK (Al_2O_3/(Ca_2O + Na_2O + K_2O)) ratio; Na_2O/K_2O ratio; and 2*FMSB as 2*(FeOt + MgO) wt% * (Sr + Ba) wt%. TTG is TTG magmatism, Sanu. are sanukitoids *s.l.*, Hyb. are hybrid granitoids, and Bt. & 2-mica are biotite- and two-mica granites. Samples from this study are red dots.

Summary

- The final stage of Archean terrane accretion in the Slave craton indicates partial melting of juvenile metasediments
  - Consistent with the reworking of short-lived continental crust
- There is no significant geospatial trend in the εHf values reported in this study
  - No new evidence from these samples towards significant/widespread ancient crustal reworking, meanwhile previous whole-rock εNd results for western granitoids do show derivation from ancient precursors (Davis and Hegner, 1992)
- The Slave craton exhibits the same transition in its late-Archean magmatism as seen in other cratons globally

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