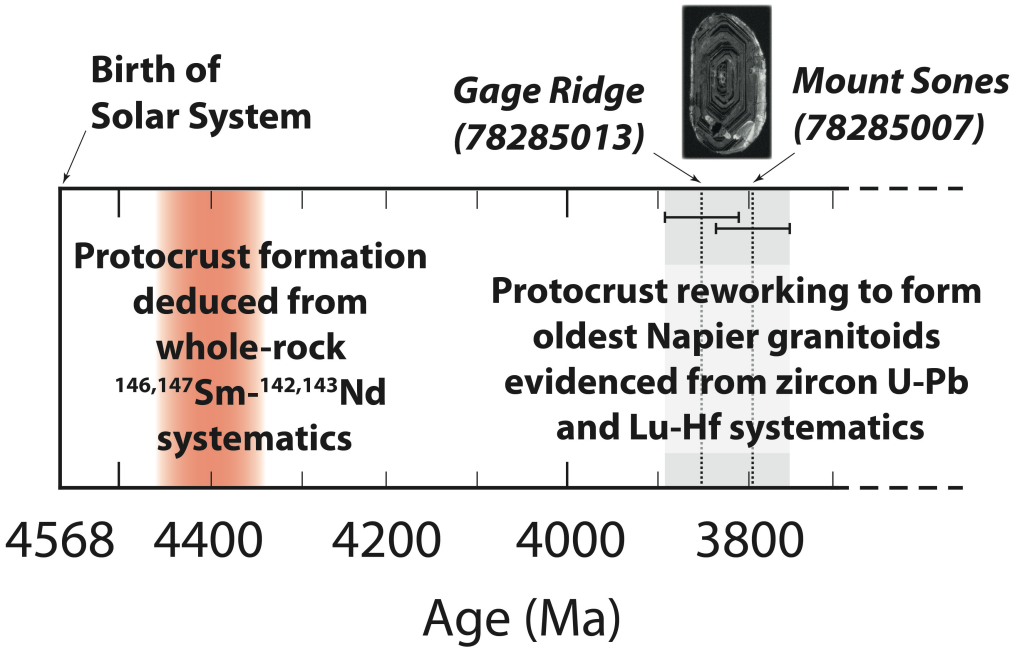
The Hadean origin of the Archean Napier Complex (East Antarctica)



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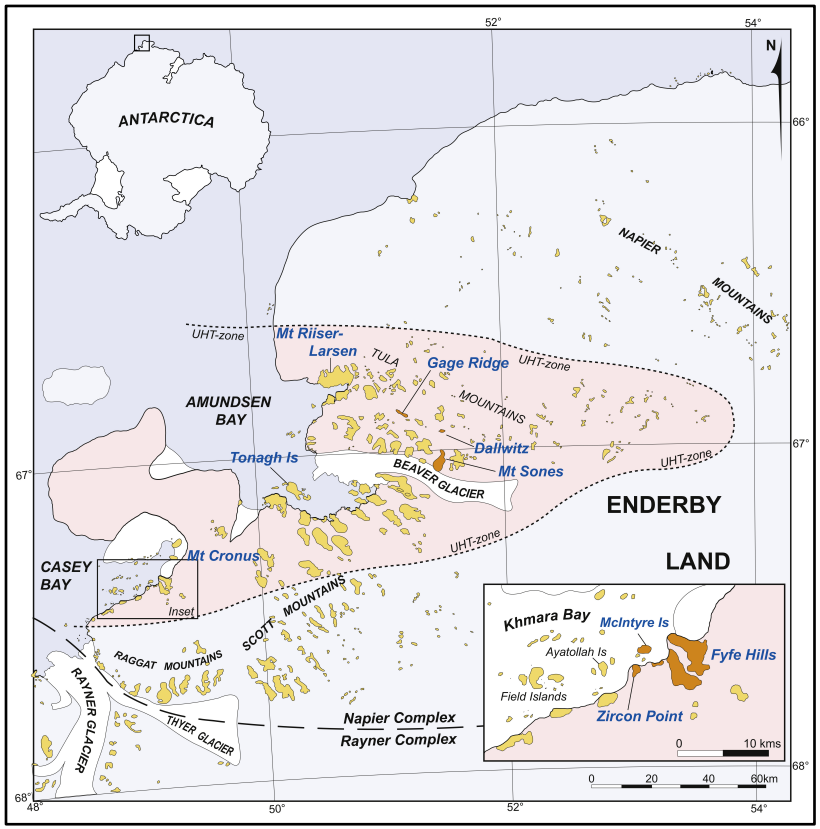
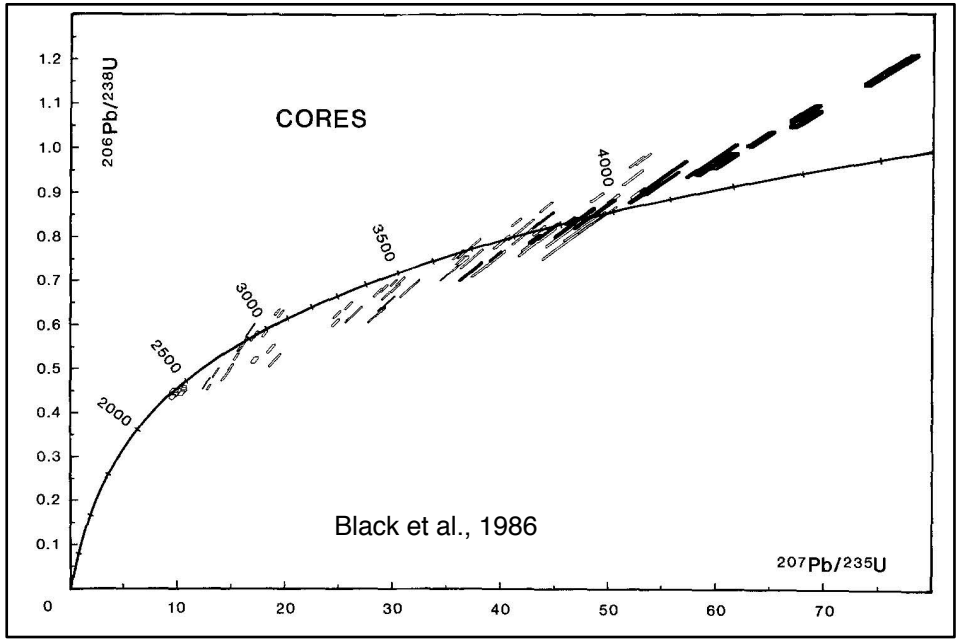


Harley et al., 2019

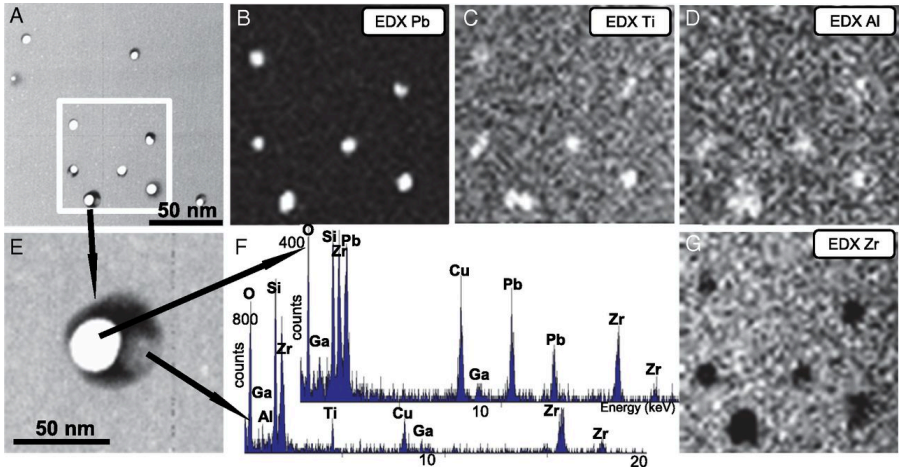
Age (Ma)	Event
>3900	Inherited (?) zircons
3850	**Mount Sones, Gage Ridge orthogneisses**
3550-3500	Inherited zircons, Rippon point
3490-3420	Metamorphism and anatexis, Rippon point
3280-3250	Riiser-Larsen orthogneiss
3190-3160	Thermal resetting Rippon point
3050-2990	Proclamation orthogneiss
2840-2800	**Dallwitz orthogneisss and dominant tonalitic orthogneisses**
2620	Tonagh orthogneiss
2550-2520	**Ultrahigh temperature metamorphism**
2520-2460	Local granitoids, waning metamorphism

After Harley and Kelly, 2007

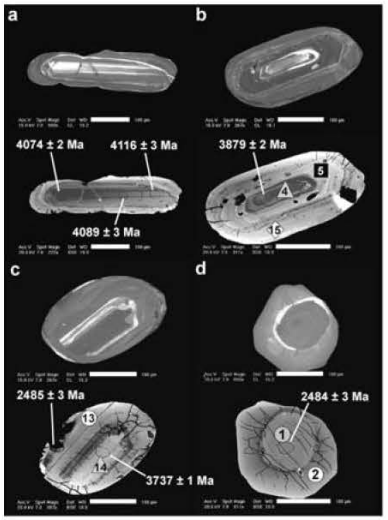
- Due to the scarcity of >3.6 Ga rocks, The Napier Complex represents a precious window into the Eoarchean Earth
- It is composed of typical Archean craton lithologies equilibrated in granulite facies
- The Napier complex recorded a long history (~1500 My) of evolution
- Protoliths of oldest orthogneisses formed ~3900 My ago
- The Napier complex experienced a UHT event at 2500 Ma (>1000°C at 9-10 kbars; e.g., Harley et al., 2019)



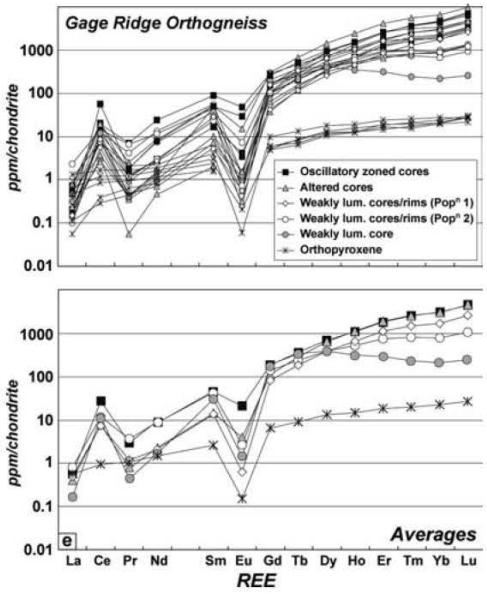
- Complex zircon age distribution
- First example of reversely discordant zircons
- Local effect of Pb nanospheres
- Problem in igneous age establishment
- Multistage evolution also recorded in Napier zircons

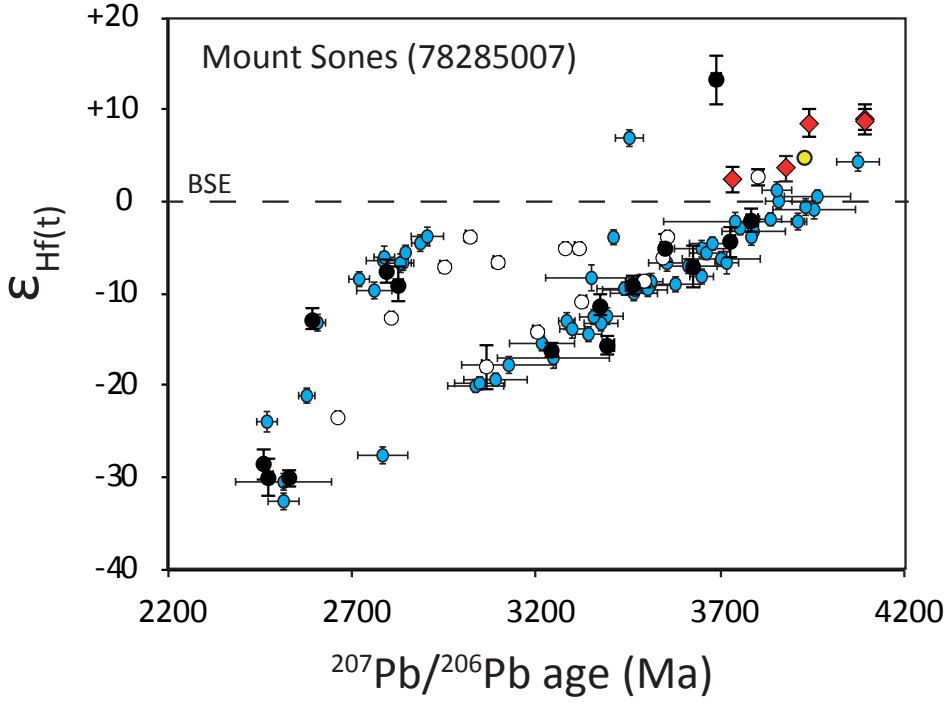


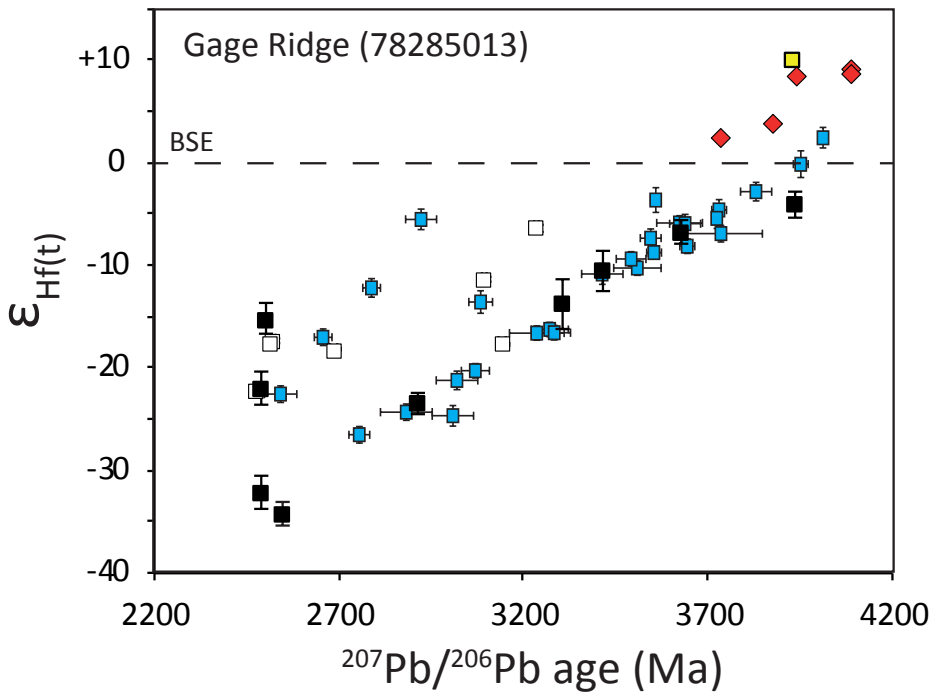
Kusiak et al., 2015



Kelly and Harley, 2005

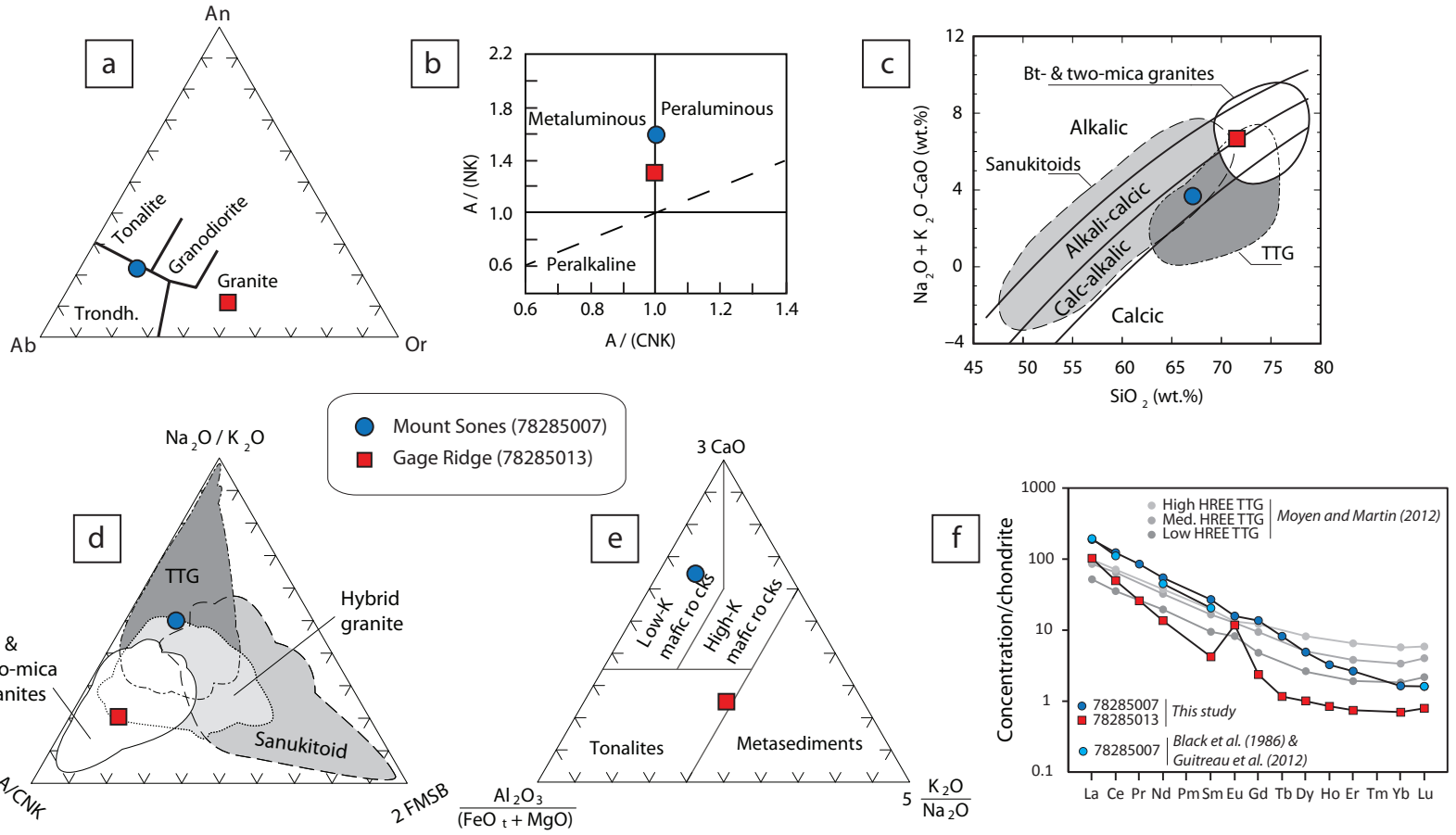






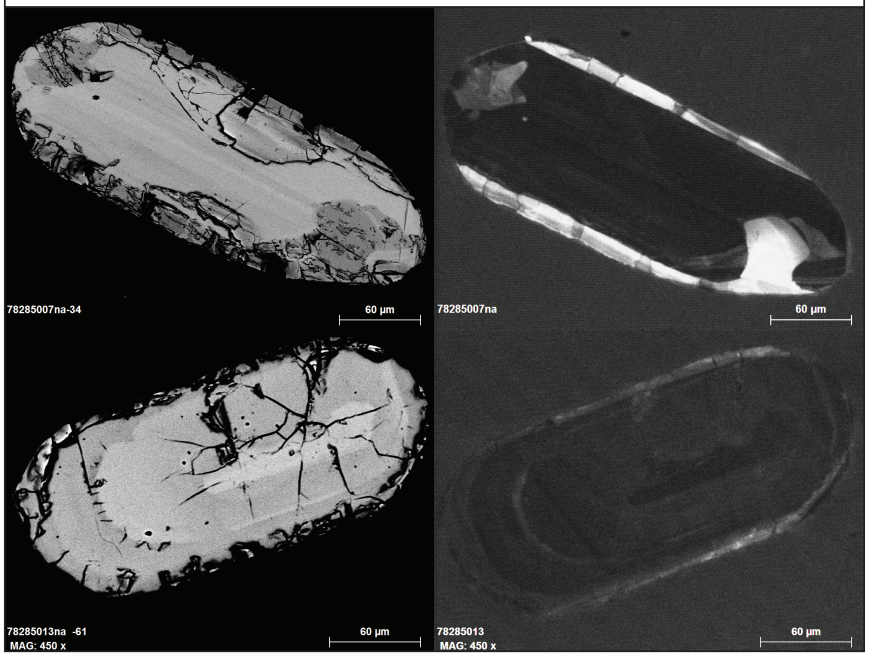
- Zircon (Hf by solution and age by SHRIMP) from Choi et al. (2006)
- Whole-rock from Guitreau et al. (2012)
- Zircon (Hf and age by solution) from Guitreau et al. (2012)
- Zircon (Hf and age by laser-ablation) from Guitreau et al. (2012)
- Zircon (Hf by laser-ablation and age by SHRIMP) from Hiess and Bennett (2016)

- The zircon complexity is also evident in the Lu-Hf isotope system!
- Ancient and recent Pb-loss issues
- Concurrent sampling of unrelated domains during U-Pb and Lu-Hf analyses



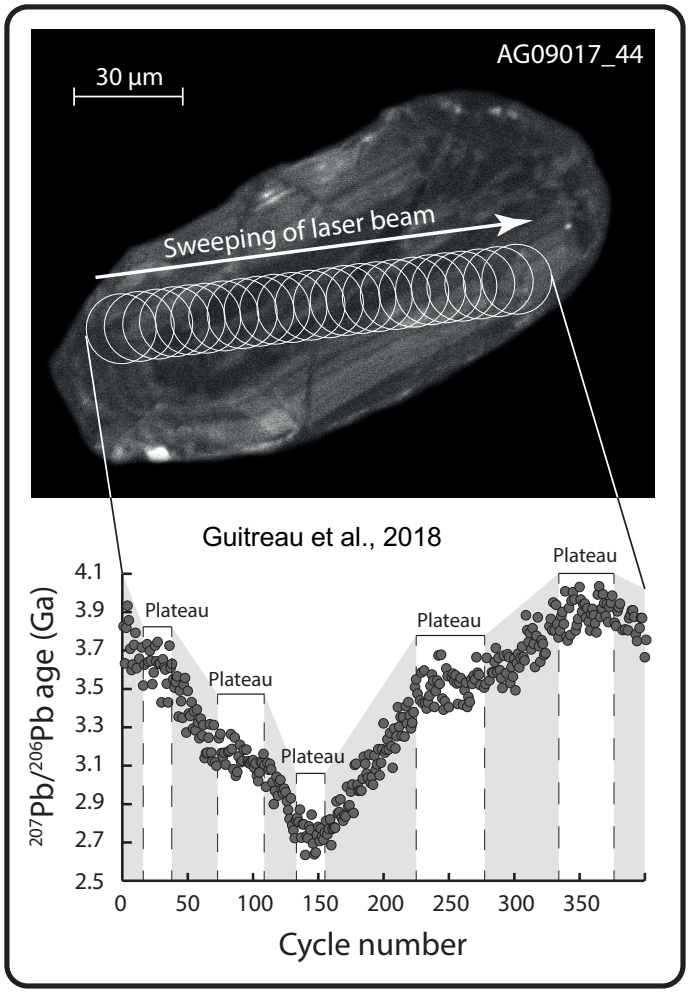
- We studied two of the oldest known orthogneisses (Mount Sones and Gage Ridge; Harley and Black, 1999)
- One is of typical TTG affinity and the other is granitic, though with REE pattern that suggests it is a cumulate from a TTG-like melt.

Zircons not annealed



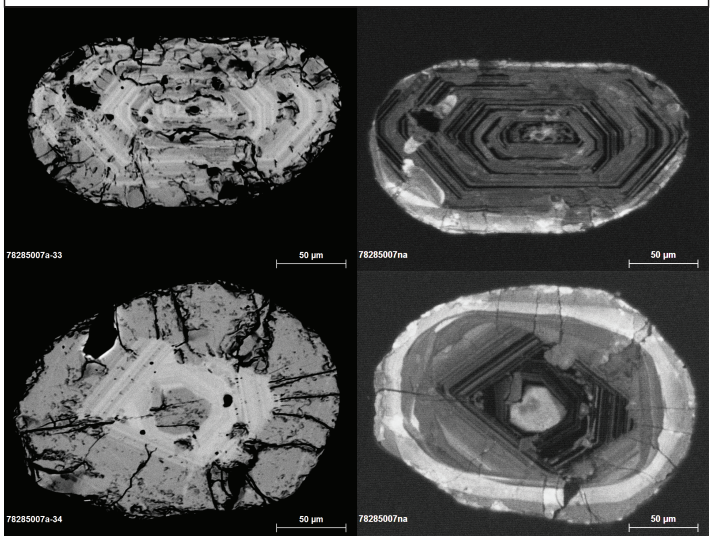
Back-scattered electron images (BSE)

Cathodoluminescence images (CL)



- We performed annealing to cure zircon lattice, enhance CL signal, and in turn, reveal crystal internal textures
- We dated zircons by U-Pb and using LA-ICP-MS traverses (Guitreau et al., 2018)
- We analyzed Lu-Hf isotopes by LA-MC-ICP-MS as spots on zones with coherent U-Pb systematics

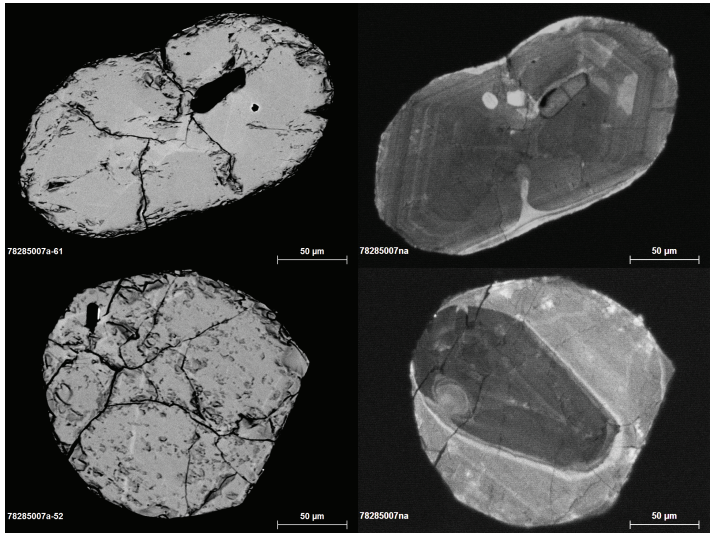
Zircons annealed (850°C for 48h)



Group 1

Back-scattered electron images (BSE)

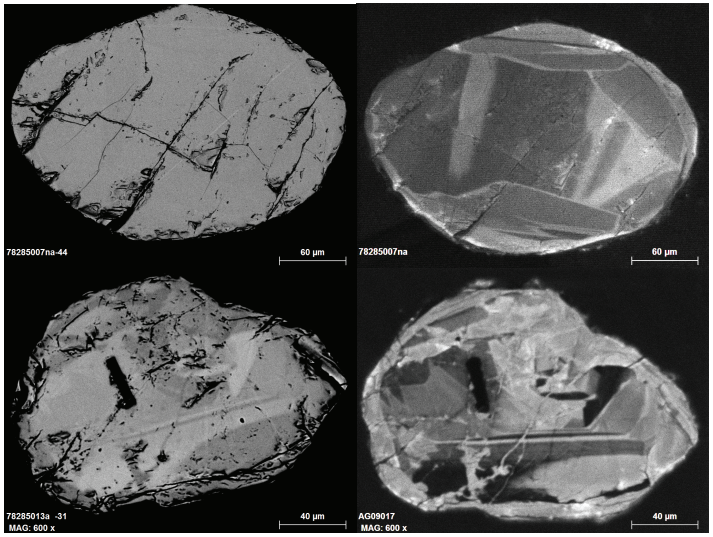
Cathodoluminescence images (CL)



Group 2

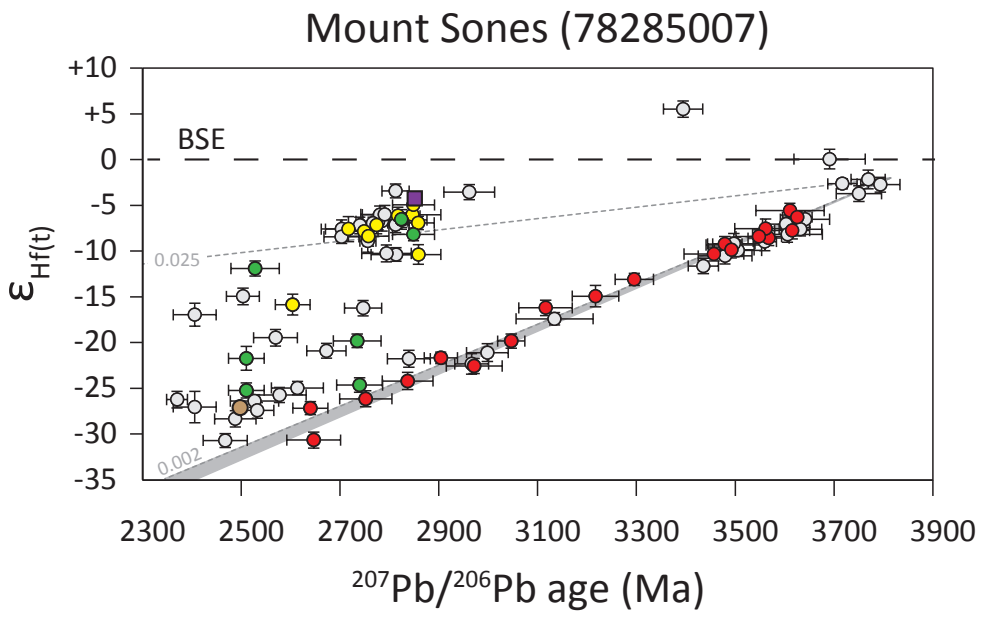
Back-scattered electron images (BSE)

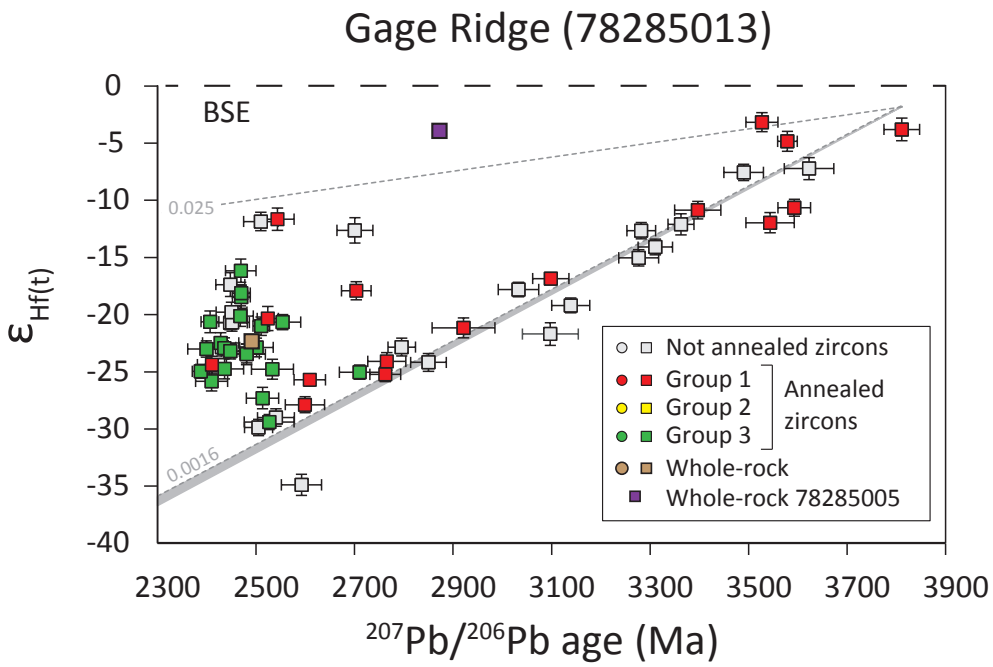
Cathodoluminescence images (CL)



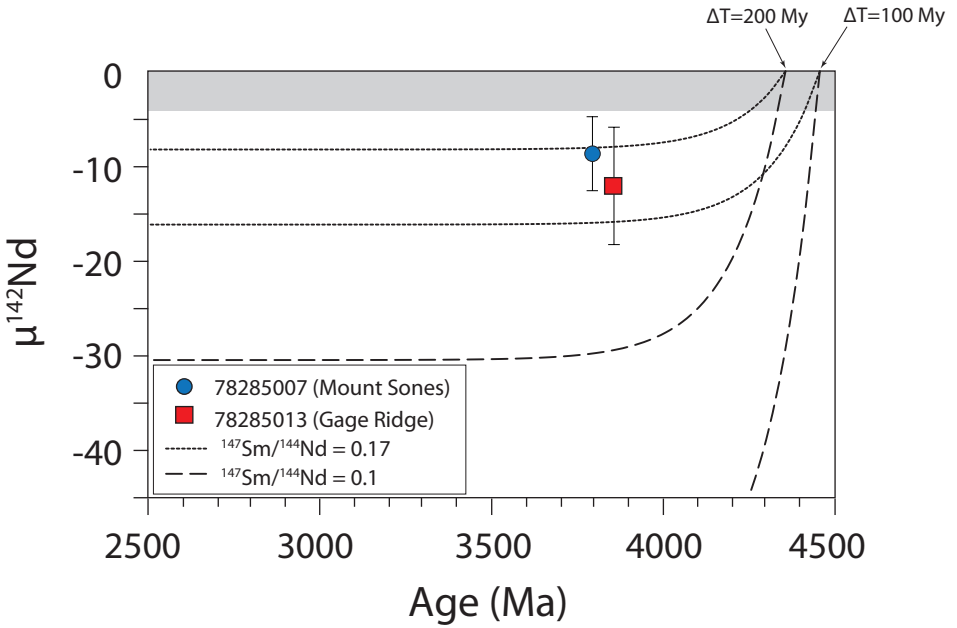
Group 3

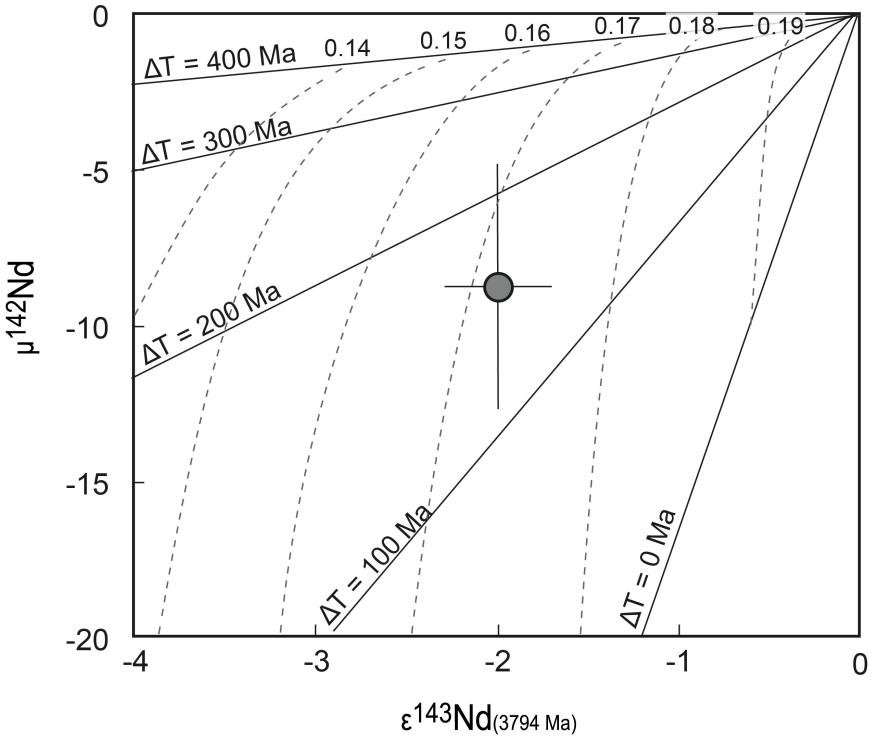
- Three textural groups revealed
- Group 1 is magmatic (commonly with metamorphic overgrowths)
- Group 2 is also magmatic (commonly with metamorphic overgrowth)
- Group 3 is metamorphic





- The three textural groups have distinct coupled U-Pb and Lu-Hf systematics
- Group 1 is the original igneous zircon population and it underwent significant ancient U-Pb disturbances, in line with previous work, which result in positive correlations in ε_{Hf} versus age diagrams
- Oldest zircons are 3794 ± 40 Ma for Mount Sones and 3857 ± 39 Ma for Gage Ridge.
- Initial Hf isotope signatures are sub-chondritic ($\varepsilon_{Hf} < 0$). Mount Sones ε_{Hf} at 3794 is -2.6 and Gage Ridge ε_{Hf} at 3857 is -3.6.
- Old enriched (crustal) reservoir was involved or reworked during the formation of protoliths to the oldest Napier orthogneisses

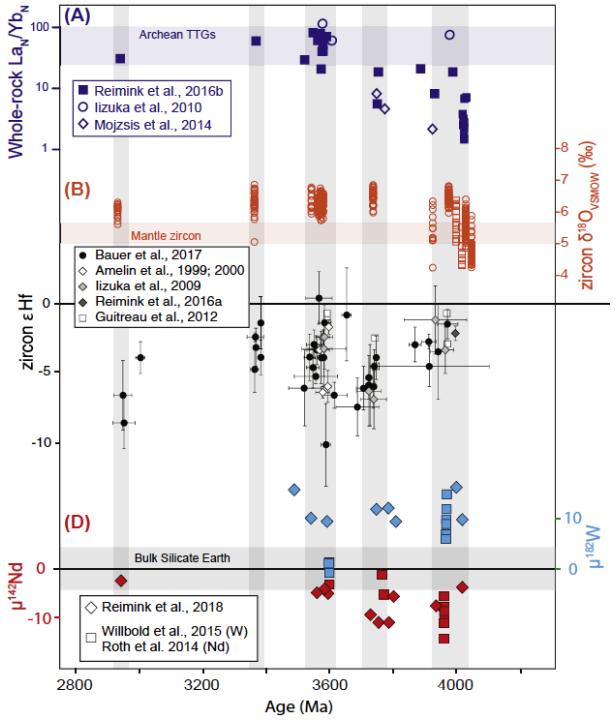




- Both Napier samples exhibit negative ^{142}Nd anomalies indicating their carry the memory of Hadean silicate differentiation
- $^{146,147}Sm$-$^{142,143}Nd$ isotopes in Mount Sones indicate that this differentiation occurred between 100 and 200 My after Solar System formation
- These coupled systematics further indicate that the source of Mount Sones is mafic ($^{147}Sm/^{143}Nd$ =0.17), in line with major and trace element geochemistry

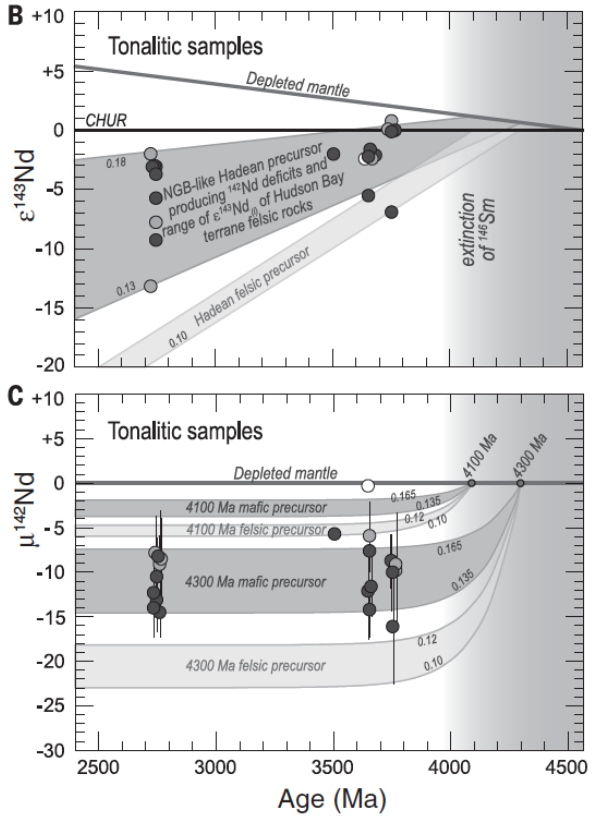
The Napier Complex originally formed by reworking of a mafic Hadean protocrust between 3.8-3.86 Ga

Acasta Gneiss Complex



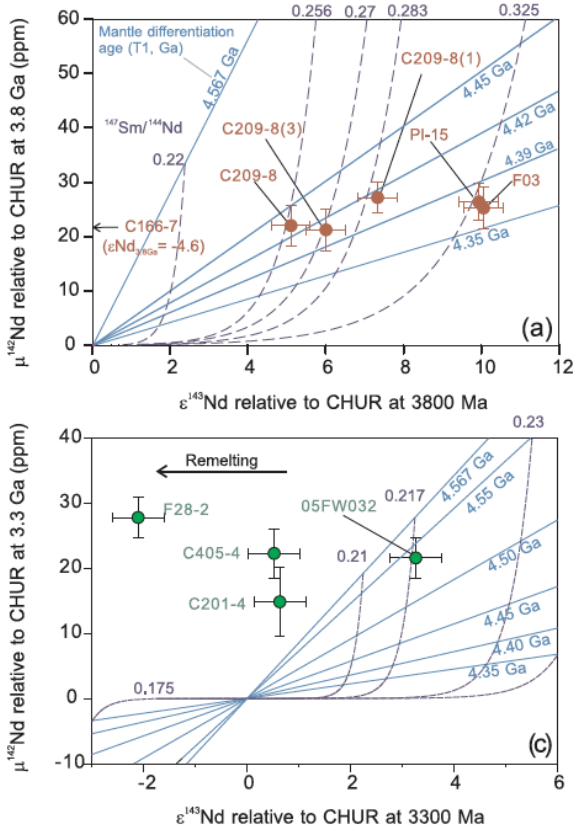
Reimink et al., 2018

Nuvvuagittuq



O'Neil and Carlson, 2017

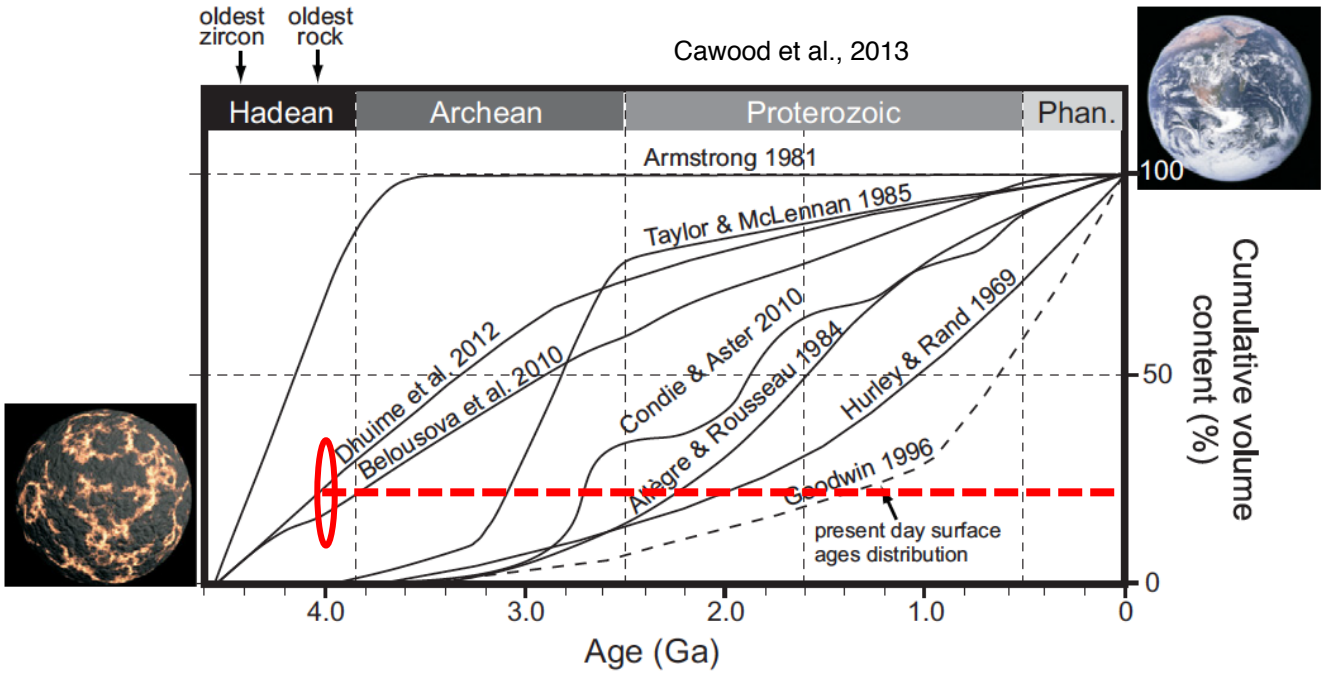
North China craton



Li et al., 2017

- The Napier Complex originally formed by reworking of a mafic Hadean protocrust in the Eoarchean
- Similar observations and/or conclusions were reached from studies of different >3.6 Ga Archean rocks.
- This is notably the case for the Acasta Gneiss Complex, the Nuvvuagittuq supracrustal belt, and the North China craton

- We propose that Hadean protocrust(s) were massively reworked at the beginning of the Archean Eon
- Most recent crustal growth models based on large detrital zircon datasets suggest that up to ~25% of present-day continental crust volume formed by the end of the Hadean
- Our proposed model would account for its absence in the rock record



Conclusions

- Napier orthogneisses contain different zircon groups identified by internal textures
- Each group has its own age-Hf pattern
- Mount Sones orthogneiss contains three zircon populations: an original magmatic group (1), a second magmatic group formed at ~2850 Ma (2), and a metamorphic group formed as a response to the UHT granulite event at 2500 Ma
- Gage Ridge orthogneiss contains two zircon populations: an original magmatic group and a metamorphic one that originated from the 2500 Ma granulite event
- Our best estimate for the age of the protoliths to Mount Sones and Gage Ridge orthogneisses are 3794 ± 40 and 3857 ± 39 Ma, respectively
- Hf isotope signatures in oldest Napier zircons are sub-chondritic which reveal that both granitoids formed by reworking of, or interaction with, an ancient enriched reservoir
- Coupled $^{146,147}Sm$-$^{142,143}Nd$ systematics indicate that this enriched crustal reservoir formed within ~150 My of Solar System formation and that it corresponds to a mafic protocrust.
- The Napier Complex, therefore, originally formed in the Eoarchean by reworking of Hadean mafic protocrust(s)
- Similar scenario have been suggested for other Eoarchean terranes
- Consequently, we suggest that Hadean mafic protocrusts were massively reworked at the beginning of the Archean, thereby accounting by their general absence in the rock record.

Thank you for reading!

Further information can be found in the published version of this contribution

Geochemical Perspectives Letters

Hadean protocrust reworking at the origin of the Archean Napier Complex (Antarctica)

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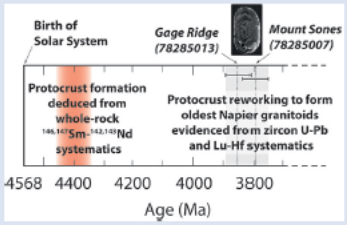
Abstract



The origin of the first continents is still poorly constrained due to the great scarcity of >3.7 Ga rocks. The Napier Complex (East Antarctica) hosts such rocks but the extreme metamorphic conditions it experienced have compromised most isotopic systematics. Here we have studied Mount Sones and Gage Ridge orthogneisses from the Napier complex using microbeam (LA-MC-ICP-MS) U-Pb and Lu-Hf isotope measurements in zircon, together with ^{146,147}Sm-^{143,142}Nd isotope systematics in the corresponding whole rocks to uncover primary information about their origin. Our U-Pb results reveal that these orthogneisses formed at 3794 ± 40 and 3857 ± 39 Ma, respectively, by reworking of 4456-4356 Ma mafic protocrust, as testified to by ^{176}Lu-^{176}Hf and ^{147,146}Sm-^{143,142}Nd systematics. Other Eoarchean terranes in Greenland, Canada, and China also show involvement of Hadean crust(s) in their formation which suggests that protocrusts were massively reworked to form new continents around the Hadean-Eoarchean boundary. Such a mechanism would account for the absence of early-formed protocrust from the geological record despite recent models proposing rapid crustal growth in the Hadean (~25 % of present day volume or surface).

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