Deciphering Neoarchean polymetamorphism and crustal melting in the northern Wyoming Province using garnet petrochronology

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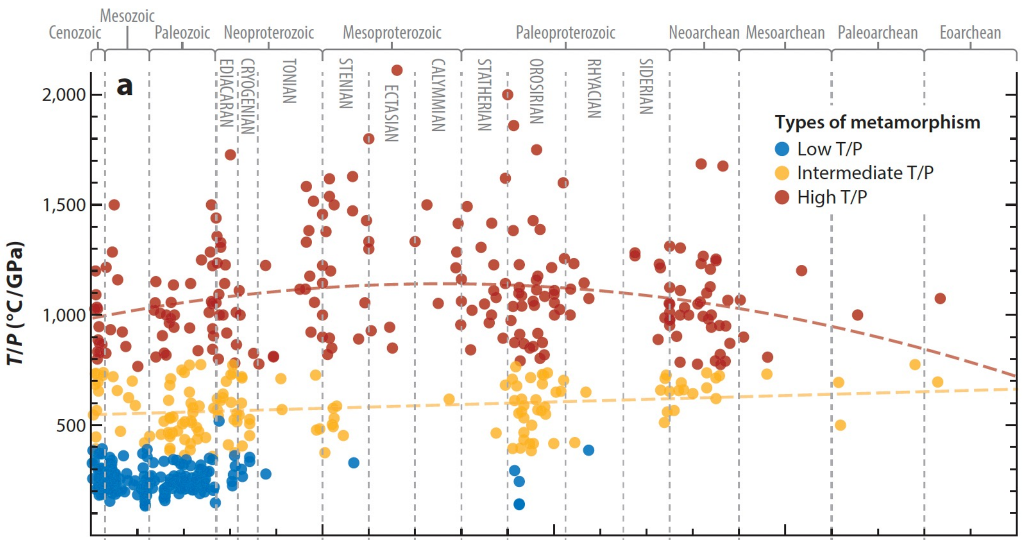
Introduction.

Constraints on depths, temperatures and rates of Archean metamorphism (esp. partial melting of crust)

Archean tectonic modes

Generation of continental crust

Craton stabilization



Brown et al. 2020, Ann. Rev. Earth Planet. Sci.

Archean terranes often polymetamorphic

Unraveling P-T-*t* challenging

Complexities in both petrologic and geochronologic data

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Introduction.

Garnet (and monazite) petrochronology

Thermodynamic modeling

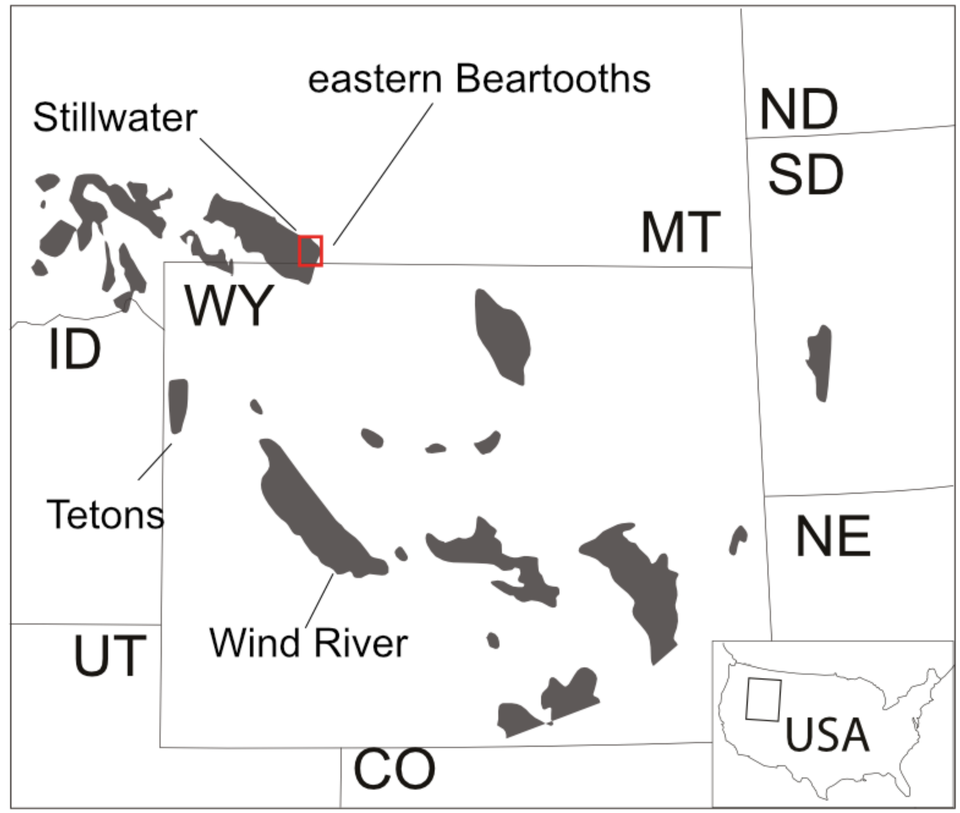
Diffusion "

1-D thermal "

Timing, timescales and mechanisms of HT metamorphism

Eastern Beartooth Mountains of Montana and Wyoming, U.S.A.

***Two phases of HT metamorphism likely driven by magmatic heat advection**



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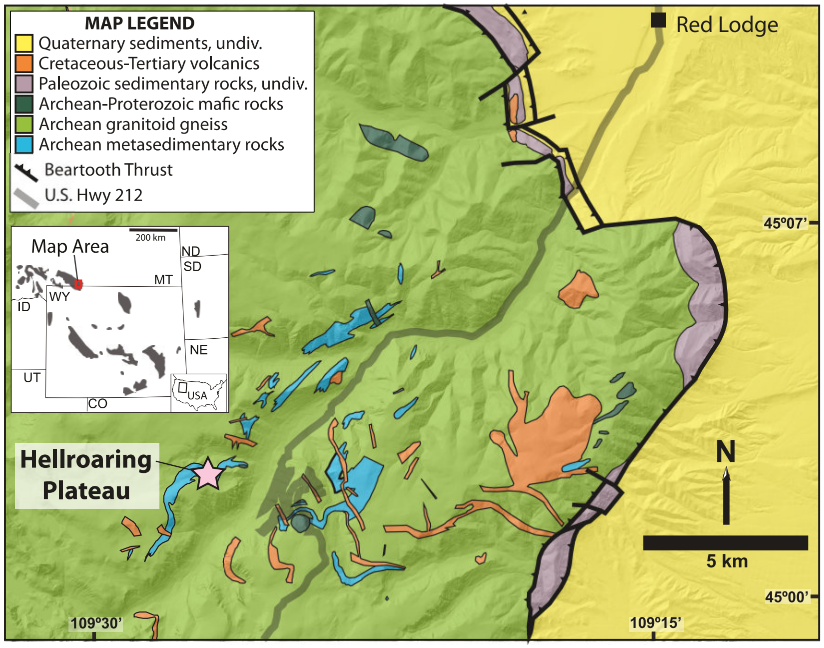
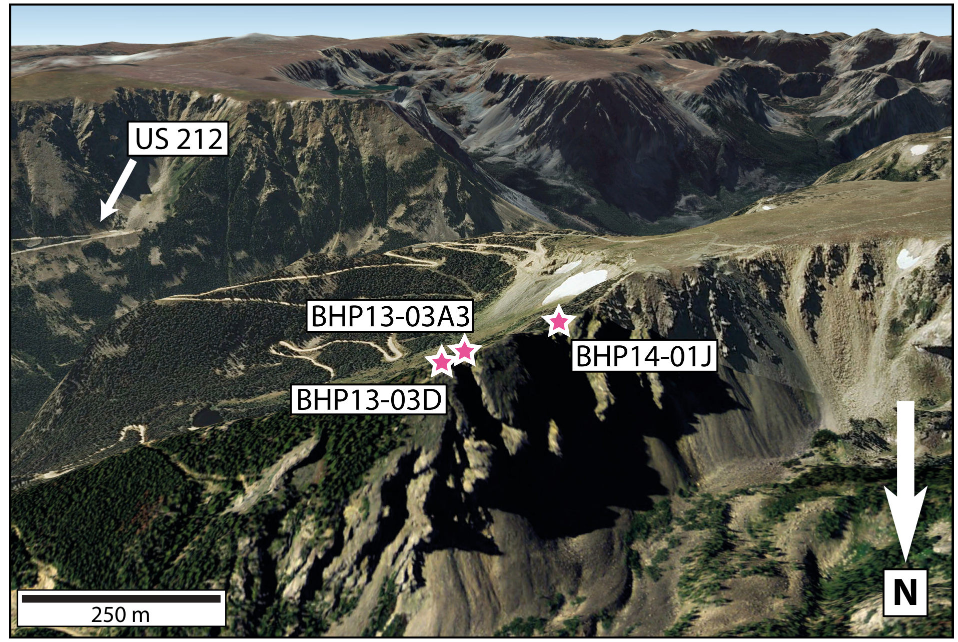
Eastern Beartooth Mountains.





Dominated by 2.83-2.79 Ga TTGs of the Long Lake Magmatic Complex (LLMC)

Roof pendants/xenoliths of supracrustals

> **Metasedimentary granulites** that have been interpreted to form solely from LLMC contact heating

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Petrochronology approach.

1) Zoned (3 samples) and bulk (2 samples) Sm-Nd garnet geochronology*

2) Garnet TE zoning using LA-ICP-MS (spot analyses and mapping)

Elucidates reaction history

Informs microsampling

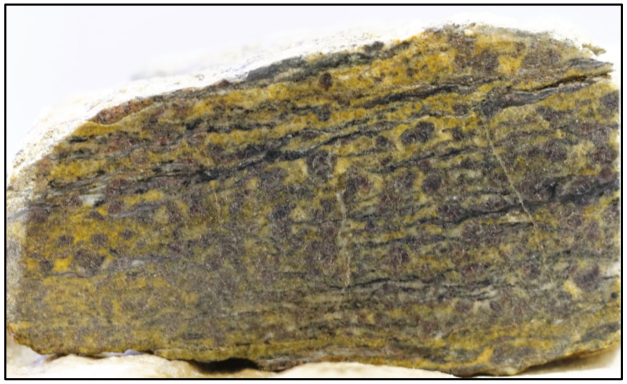
Validates isotope dilution work; highlights deleterious role of inclusions

3) Garnet ME diffusion modeling

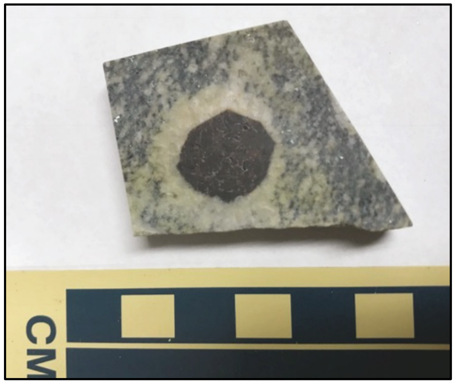
Timescales at peak metamorphic conditions

4) U-Pb monazite petrochronology**

Restitic metapelites



Felsic gneiss



*ID-TIMS analysis performed at UNC-Chapel Hill (IsotopX Phoenix); **LASS performed at UC-Santa Barbara

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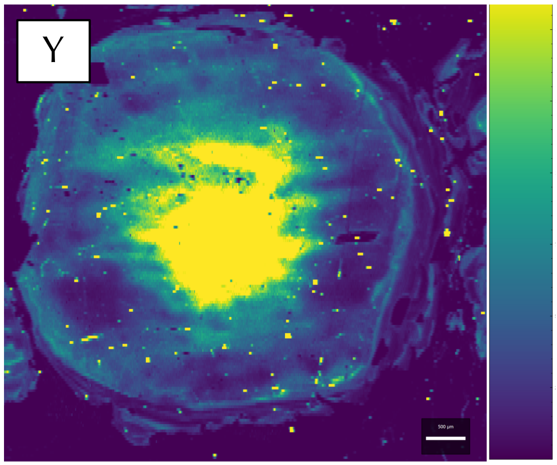
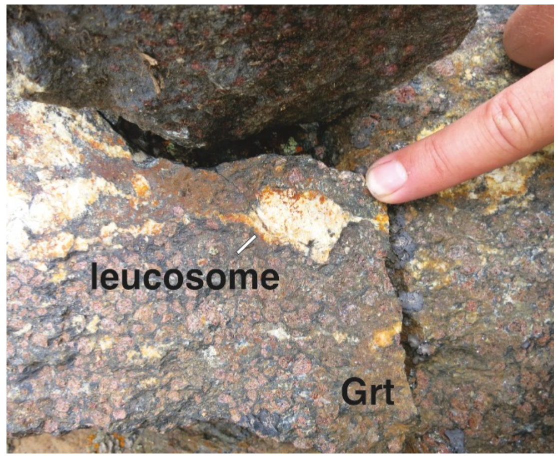
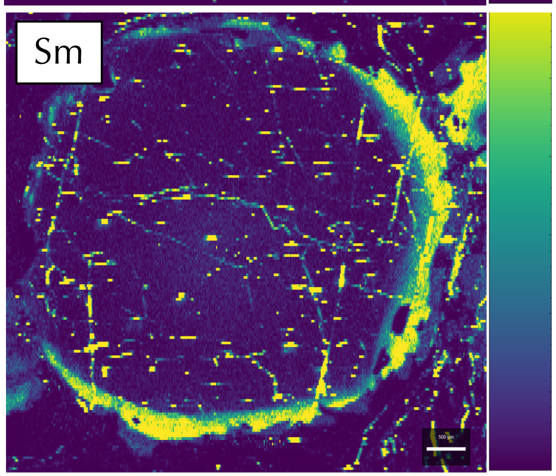
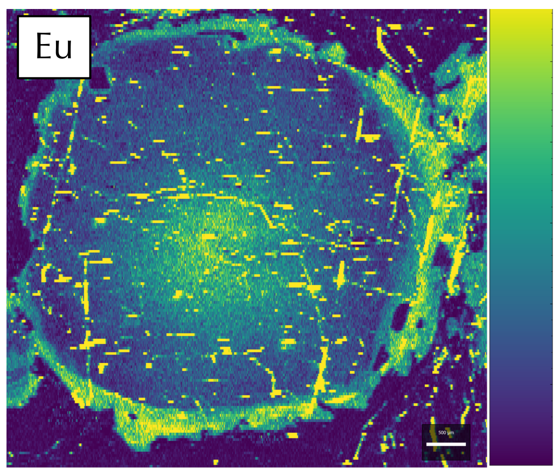
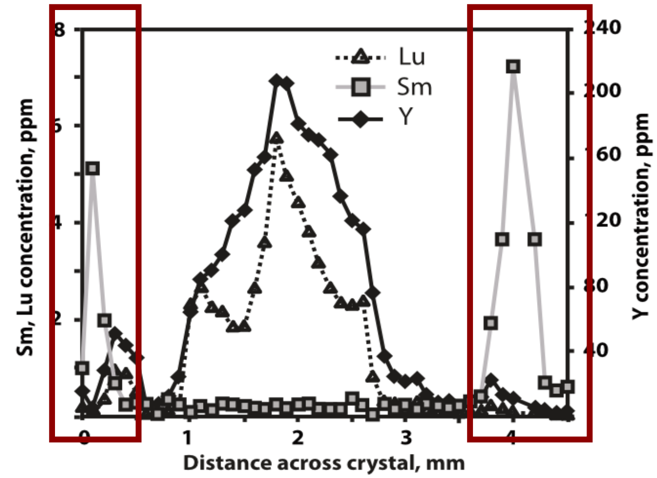
BHP14-01J – restitic metapelite.











Two garnet growth stages

2nd stage shows garnet resorption and regrowth accompanied by accessory phase breakdown (?) and partial melting

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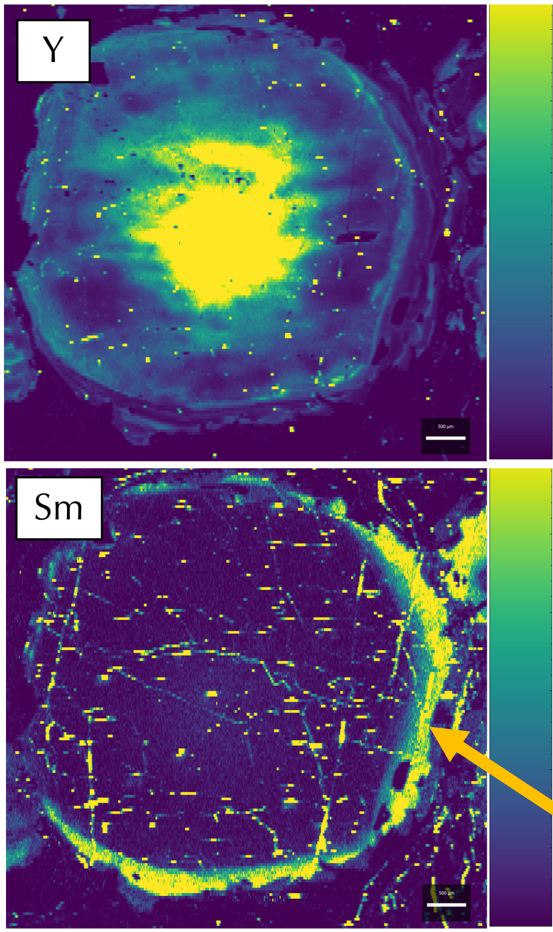
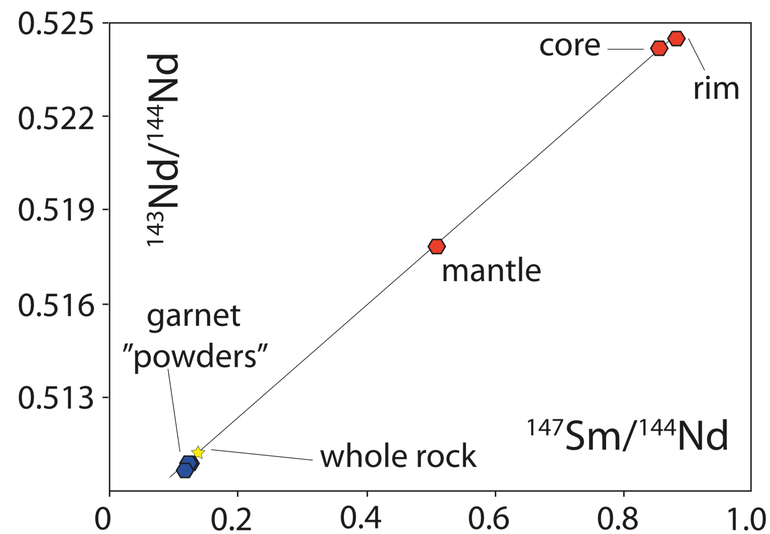
BHP14-01J – restitic metapelite.



Core-WR:
2761.5 ± 5.5 Ma

Mantle-WR:
2735.3 ± 9.6 Ma

Rim-WR:
2726.1 ± 5.6 Ma



Dragovic et al., in prep

Two garnet growth stages

Gt mantle date likely mixing of two stages

Rim likely dates 2nd stage of (granulite-facies) metamorphism

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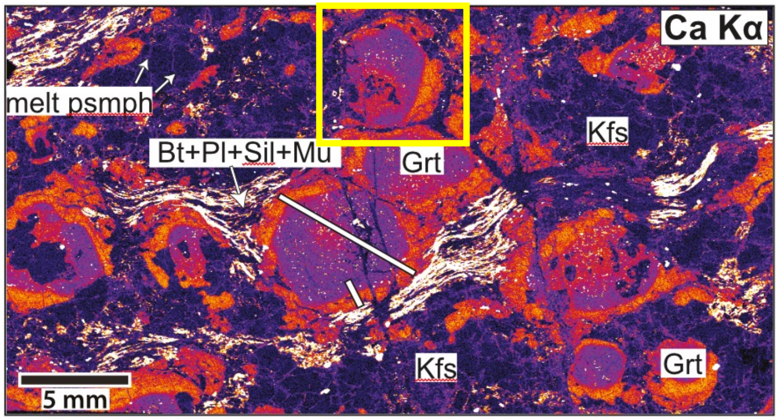
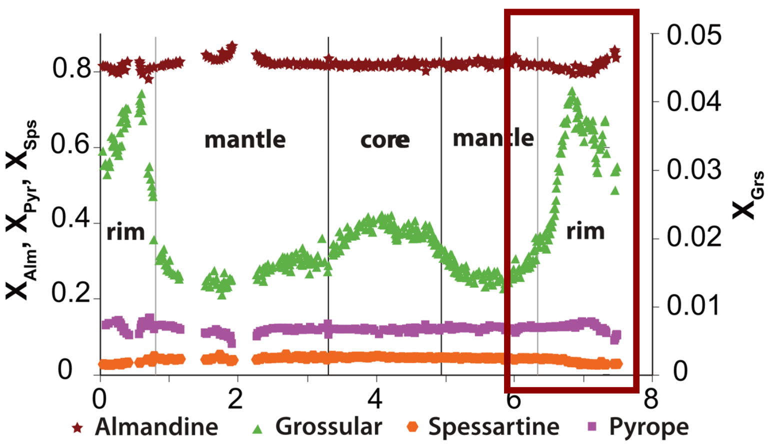
BHP13-03D – restitic metapelite.

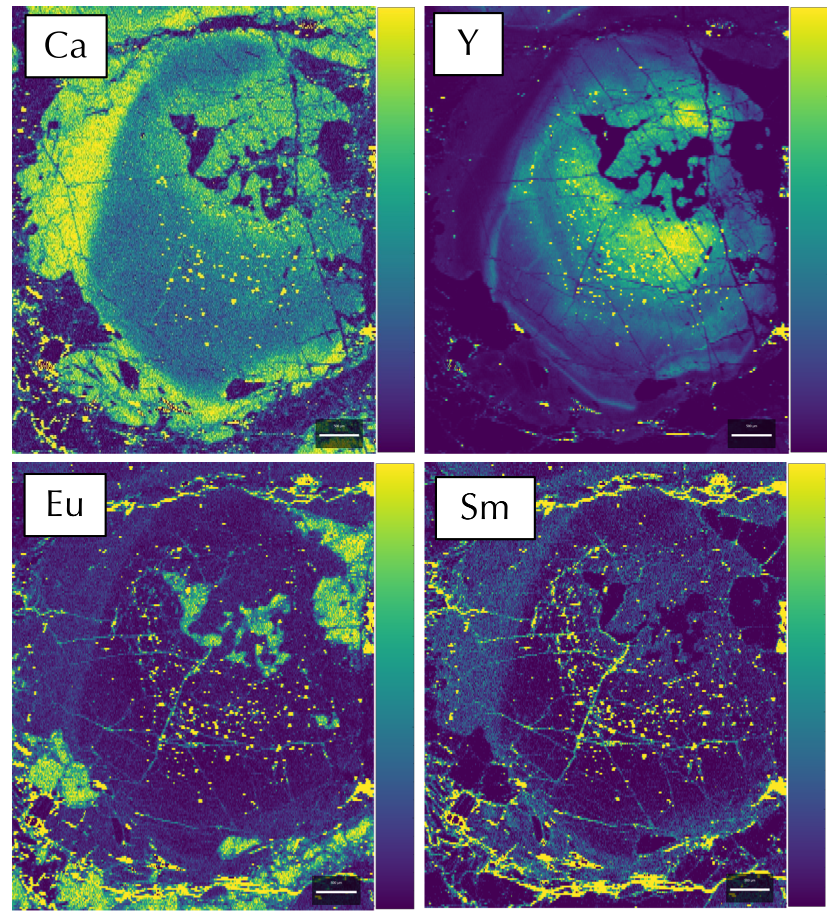




Two garnet growth stages

High Ca rim – biotite breakdown melting

Diffusion modeling of ME suggests duration at near peak T (750-800°C) of < 1 M.y.*



*from Guevara et al. 2017, JMG

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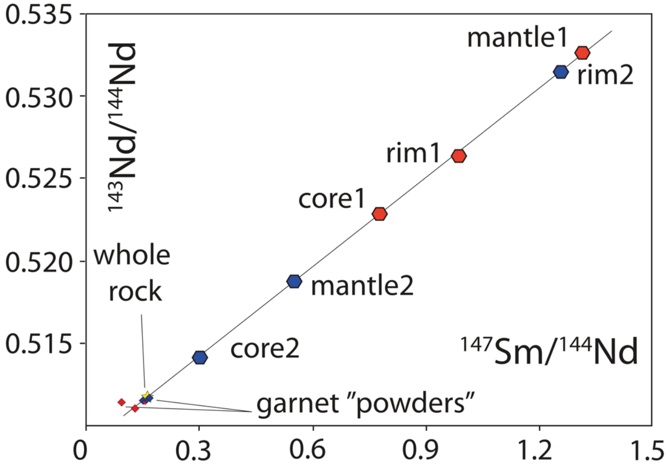
BHP13-03D – restitic metapelite.



Dragovic et al., in prep

Gt1 core:
2759.3 ± 6.4 Ma

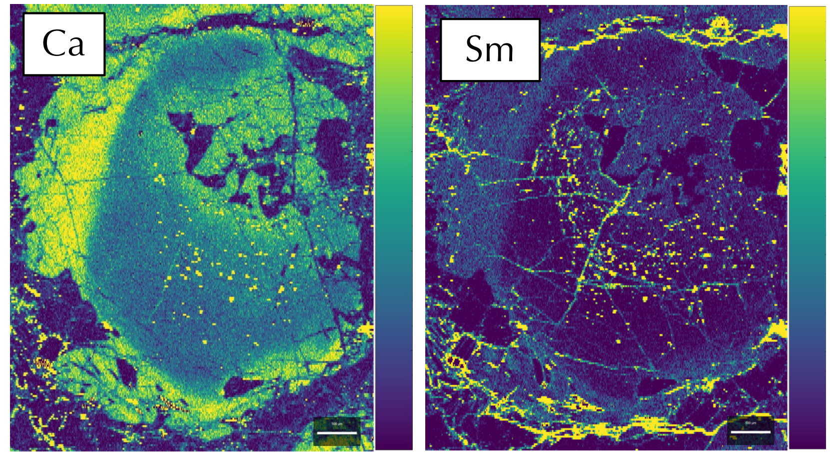
Gt1 mantle:
2750.1 ± 4.3 Ma

Gt1 rim:
2709.2 ± 5.1 Ma

Gt2 core:
2664.4 ± 24.8 Ma

Gt2 mantle:
2700.0 ± 9.2 Ma

Gt2 rim:
2715.1 ± 4.3 Ma



Two garnet growth stages

***Gt2 core and mantle – likely affected by remnant monazite inclusions – confirmed by modeling the effects of inclusion contamination**

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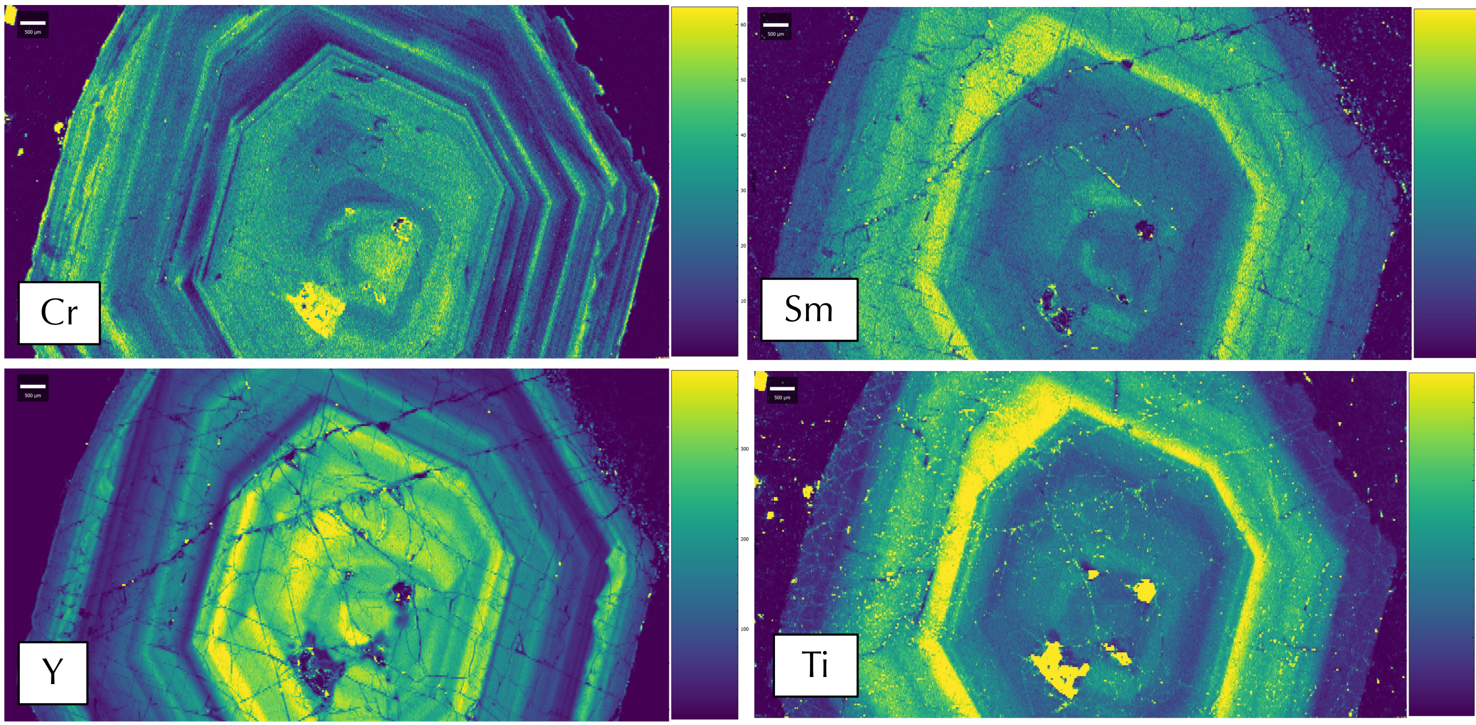
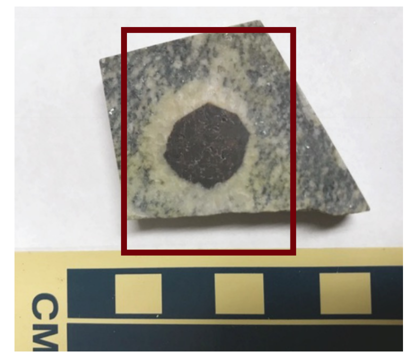
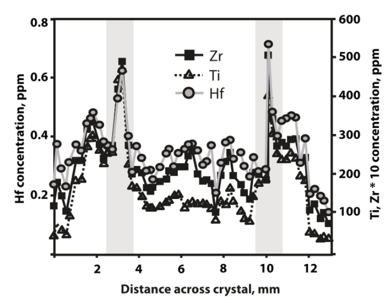
BHP13-03A3 – felsic gneiss.





Trace element zoning elucidates a complex growth history (3 zones were microdrilled)

Evidence for mineral breakdown (amphibole + accessory phase?) likely during partial melting



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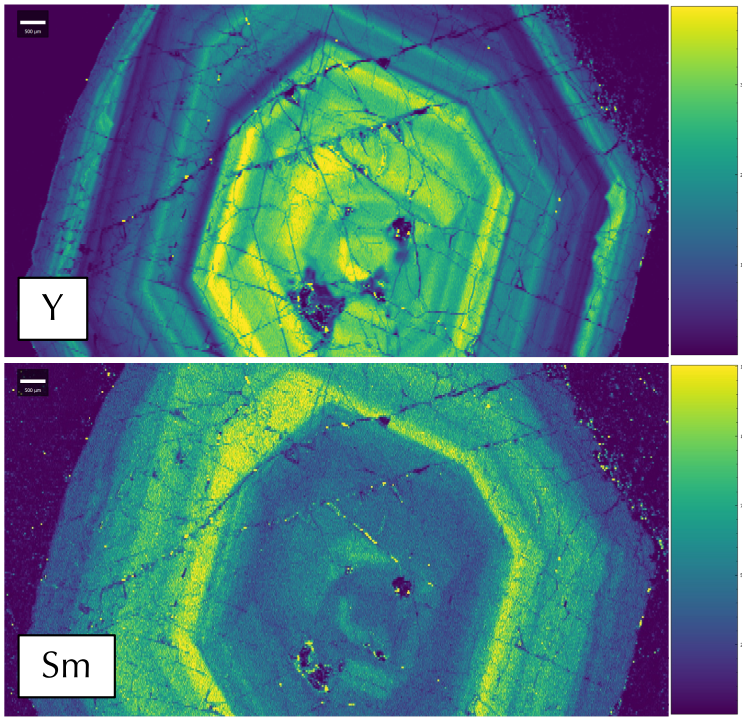
BHP13-03A3 – felsic gneiss.

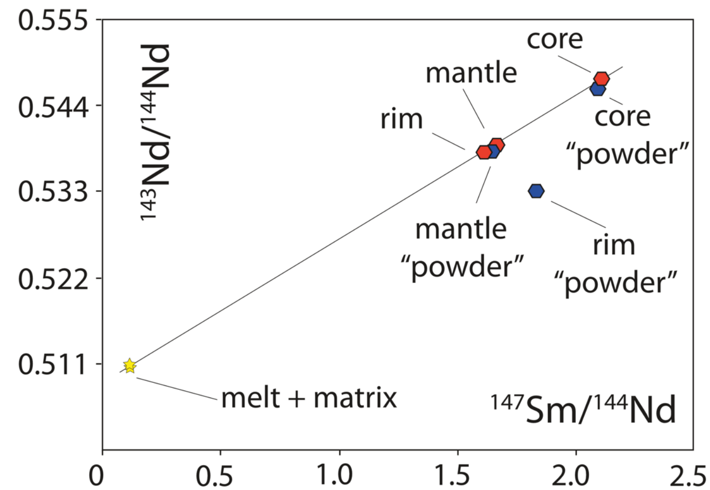


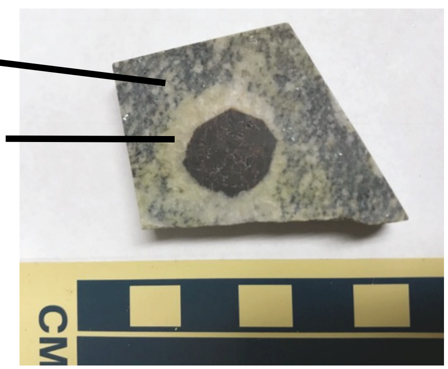
Core-matrix:
2784.8 ± 3.4 Ma

Mantle-matrix:
2753.6 ± 3.6 Ma*

Rim-matrix:
2780.6 ± 3.7 Ma

Rim-"melt":
2777.9 ± 3.7 Ma





Trace element zoning elucidates a complex growth history

***Evidence for accessory phase breakdown and temporary isotopic disequilibrium (?) between garnet and surroundings during mantle growth**

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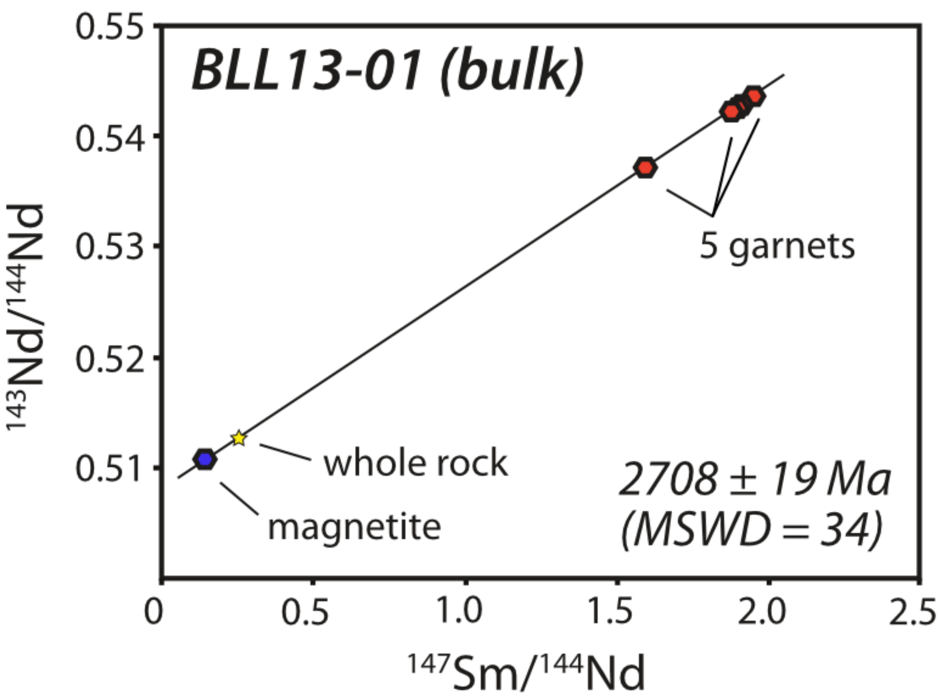
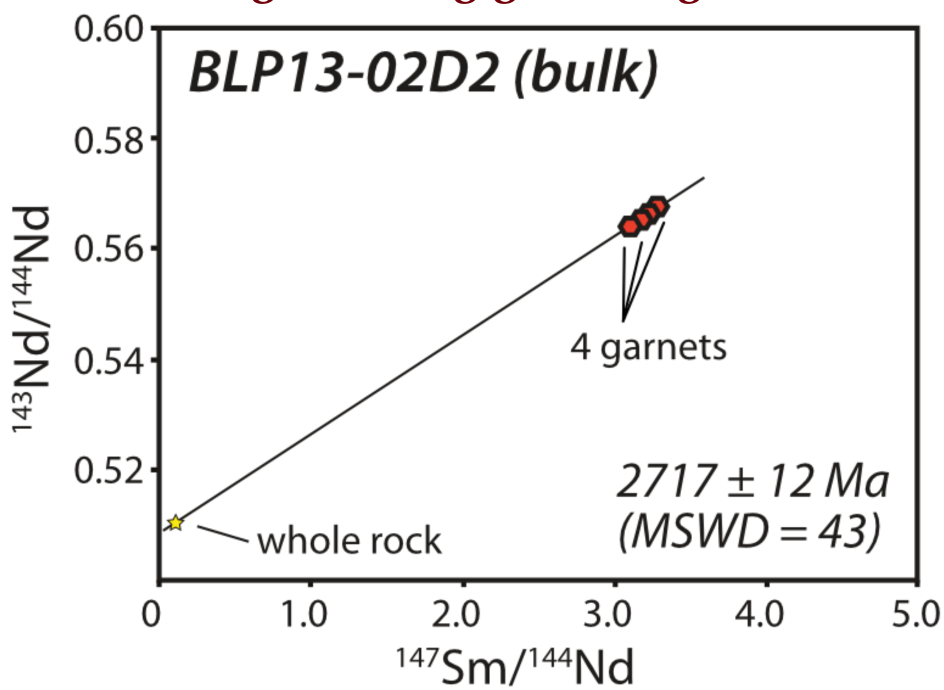
Additional bulk garnet Sm-Nd.

meta-banded iron formation



gt-bearing granitic gneiss



Dragovic et al., in prep

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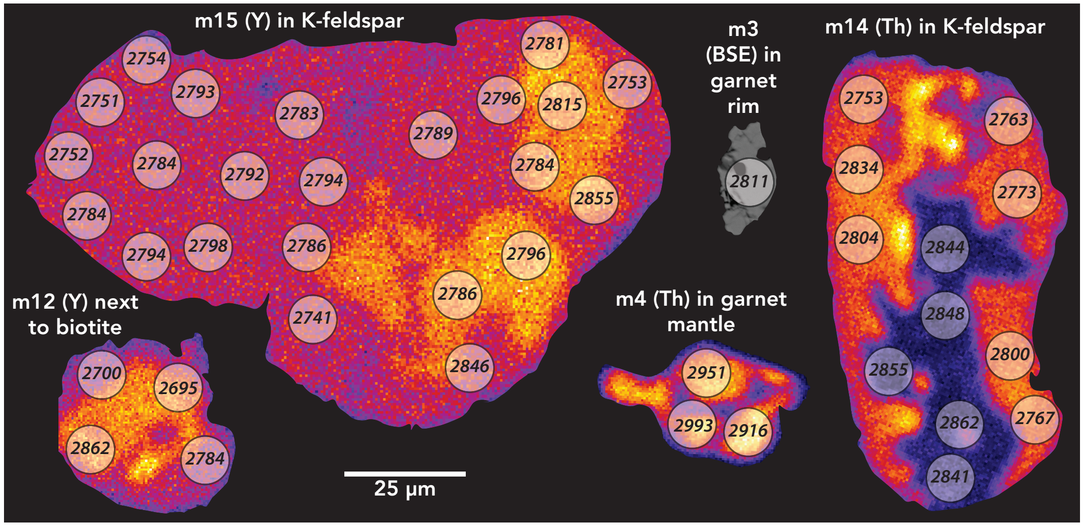
U-Pb monazite.

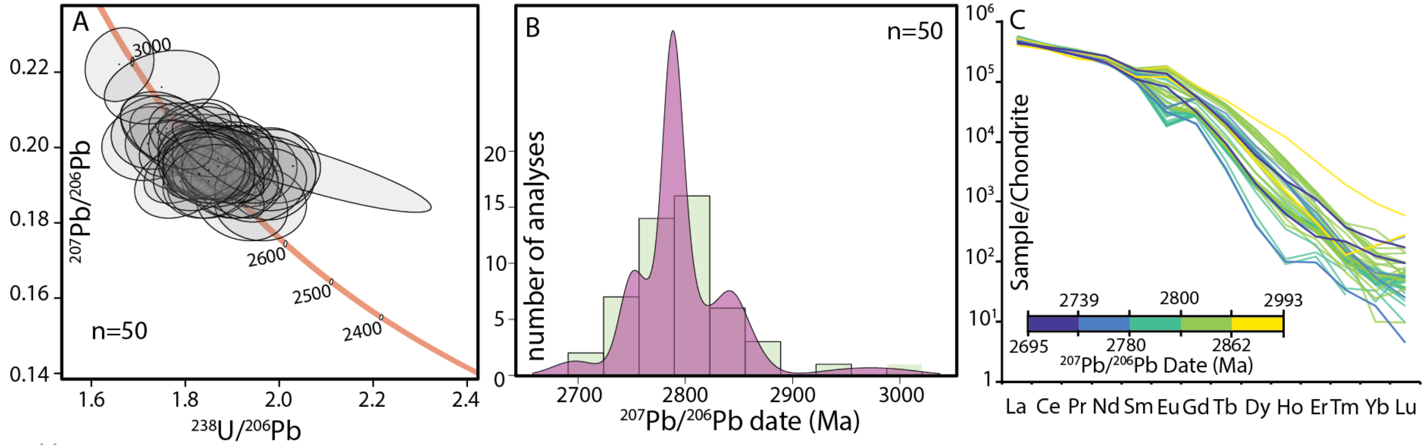
Dominant population @ ~2780 Ma

TE shows growth in the presence of garnet

Minor population @ ~2700 Ma

Relative enrichment in HREE suggests growth during gt breakdown





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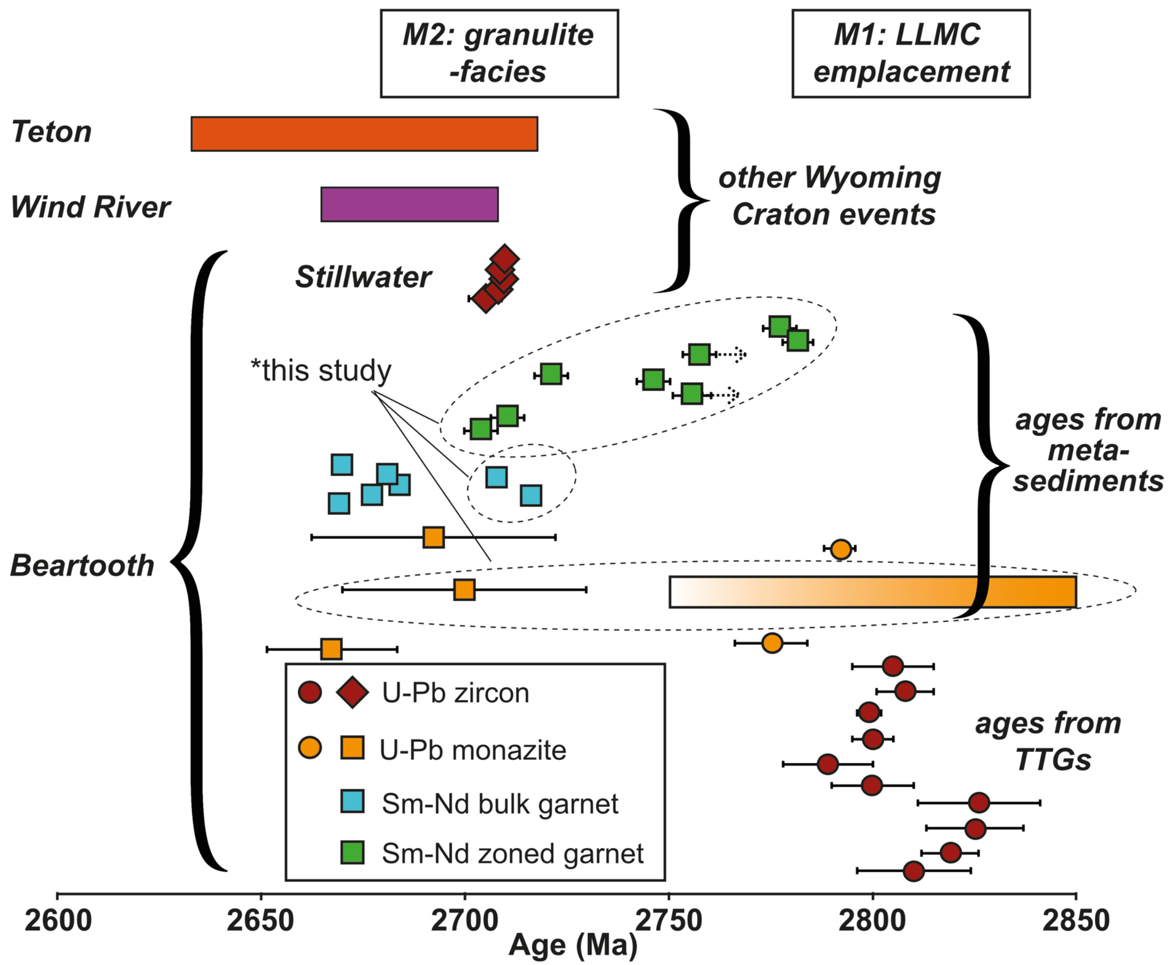
Age summary.



Gt and mnz show correspondence to two stages of HT metamorphism

1. LLMC emplacement

2. 2nd metamorphic, related to biotite breakdown melting, 70 Myrs later….

But what could have driven heating of the crust at this time?

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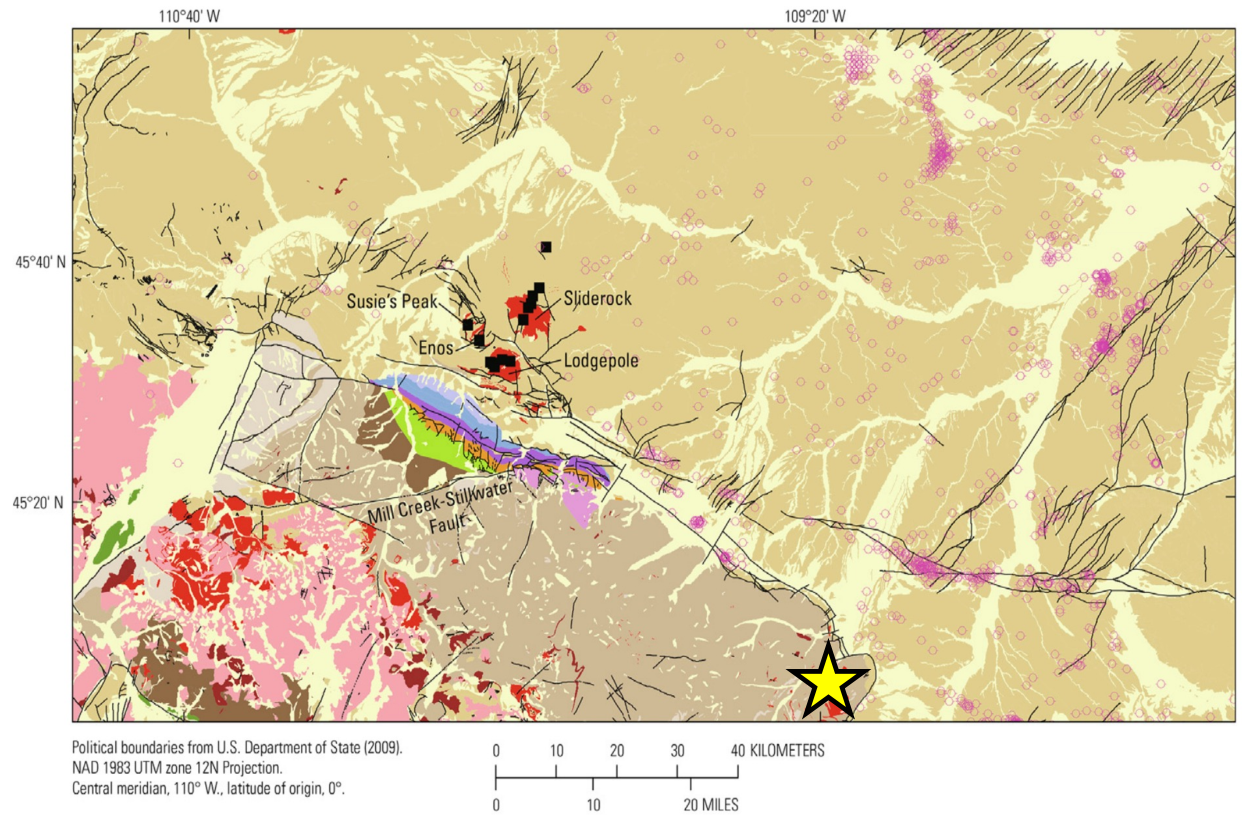
Stillwater Complex?

Recent geophysical modelling by Finn et al. (2020) shows that subsurface extent of Stillwater Complex is ~10 times greater than is exposed, dipping ~25-30° to the north.

If Stillwater extended south with the same geometry, it would have been ~15 km above the current exposure of the eastern Beartooth granulites.



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1-D thermal modeling.

Does a model for heat advection from the Stillwater recreate P-T-t estimates?

Stillwater thickness estimates range from 7-12 km

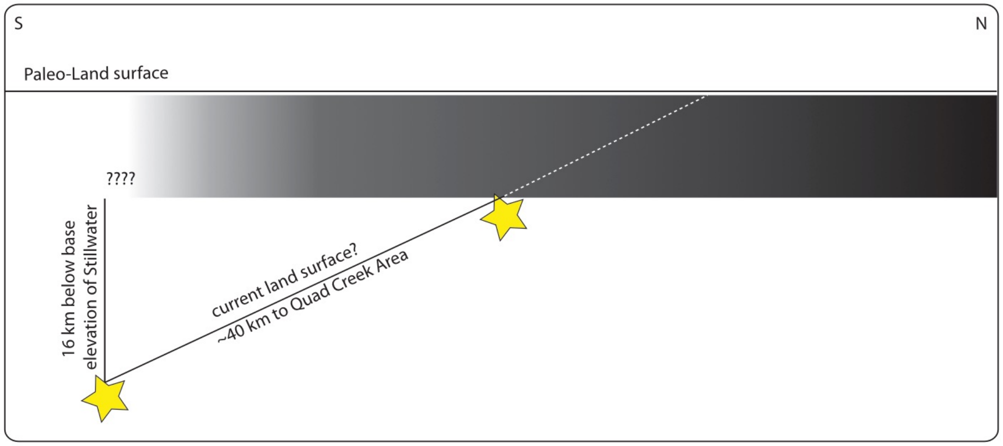
Model: **10 km**

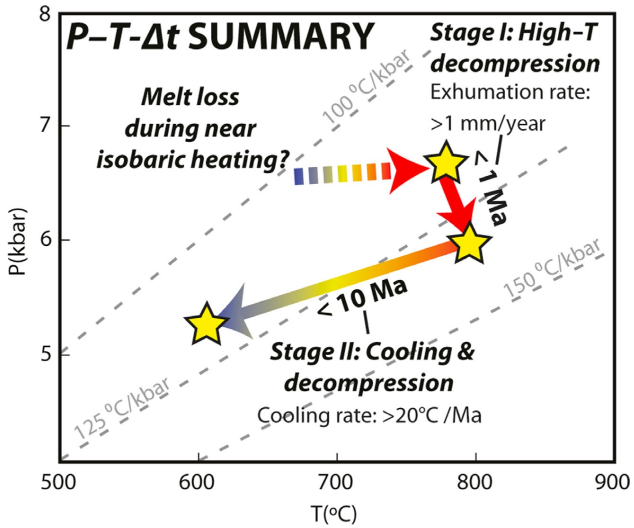
Depth of the base of Stillwater, based on thermobarometry of aureole (Thomson, 2008) – **10 km**

Stillwater T – **1250°C**

Radiogenic heat production: **Q_{rad} = 2 μW/m³**

*based from Guevara et al. 2017, JMG





Granulite-facies *P-T* path (thermodynamic modeling, mineral chemistry and petrographic observations)

+

Timescales at peak *T* and during the initial stage of cooling (diffusion modeling)

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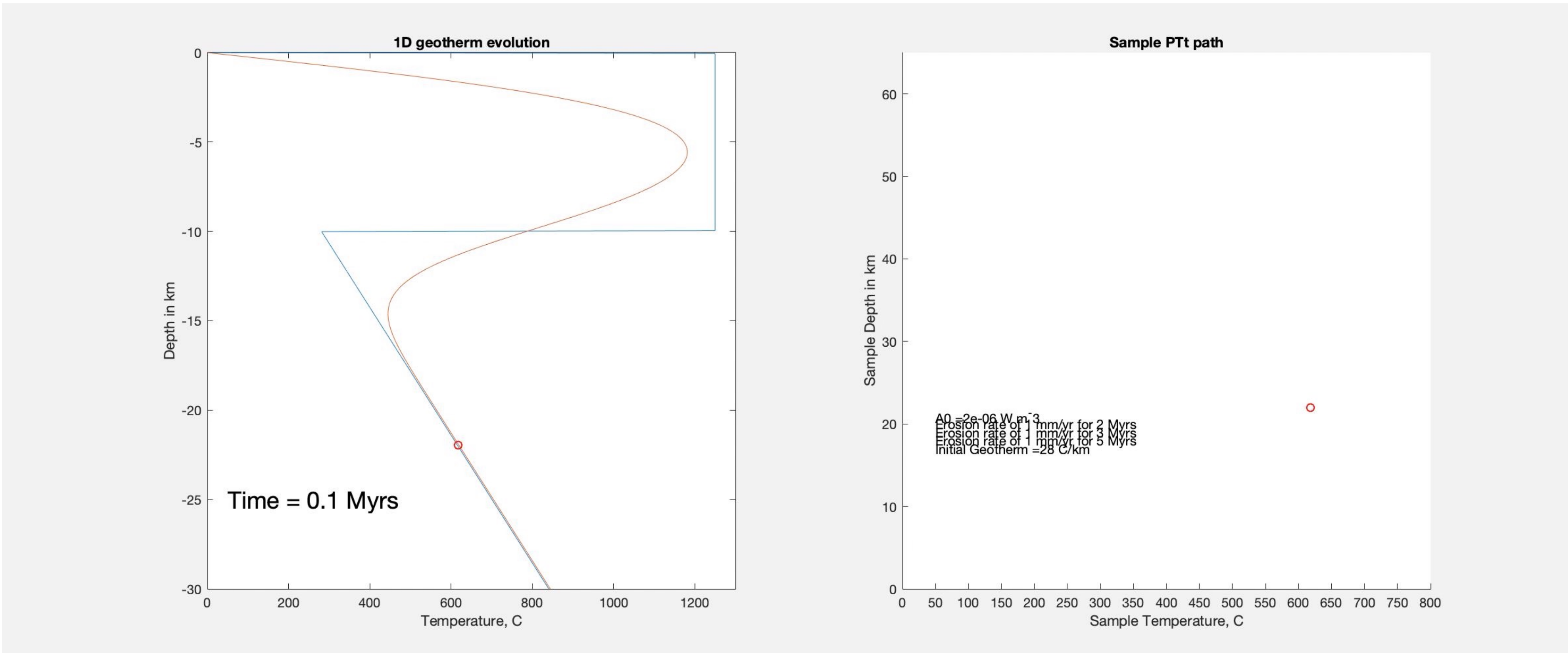
28°C/km; 1 mm/yr exhumation.



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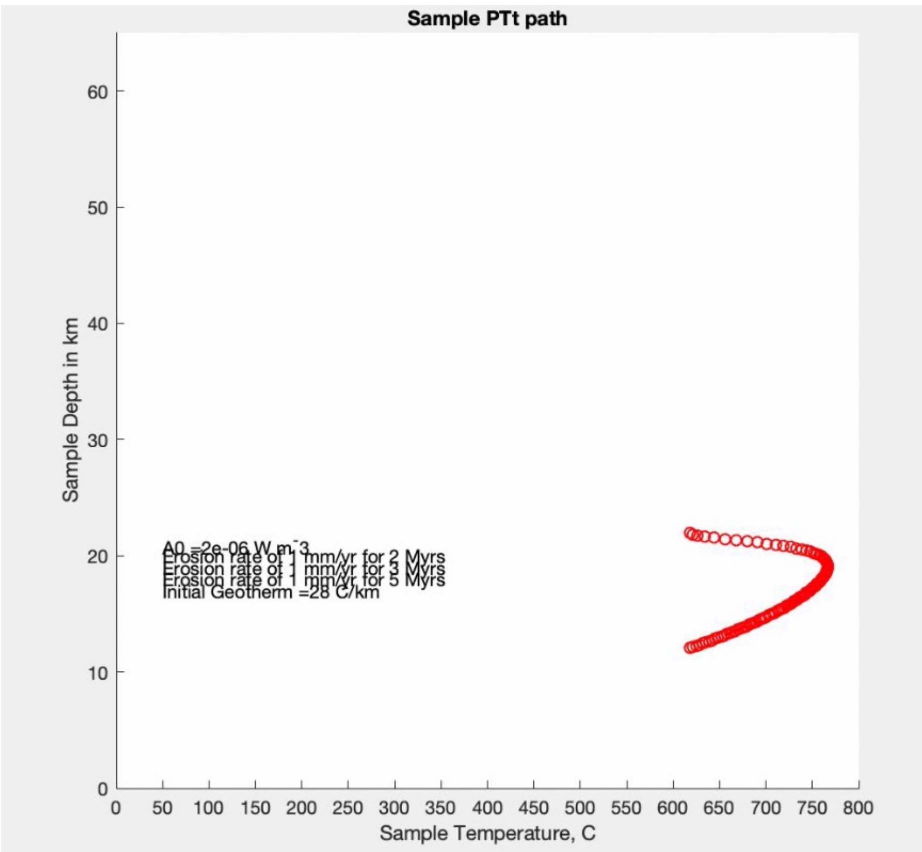
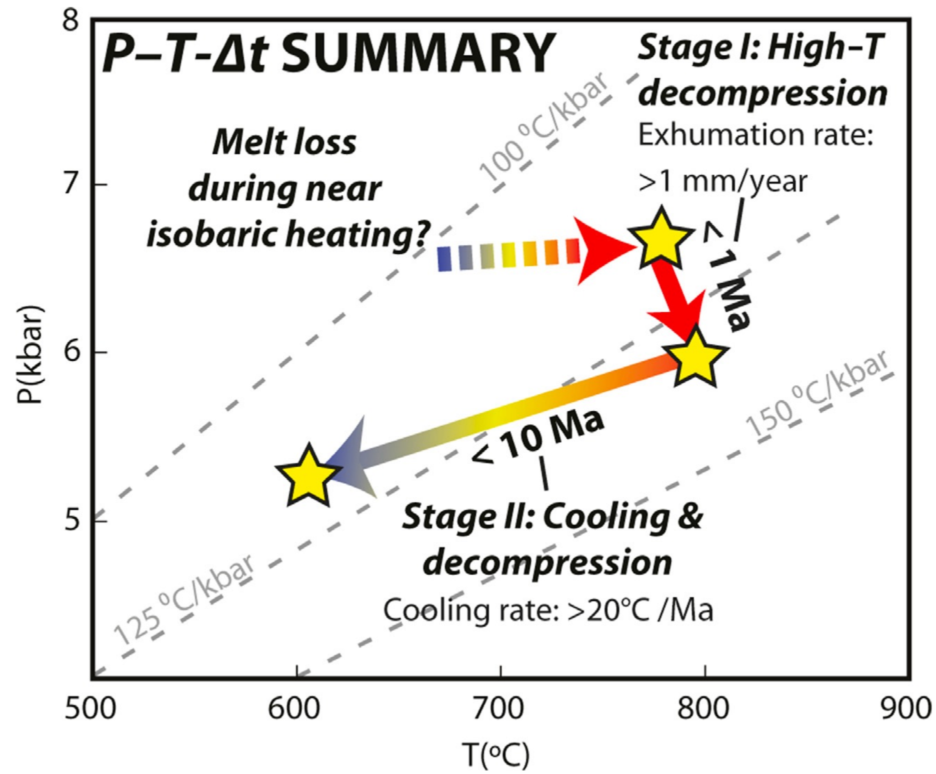
28°C/km; 1 mm/yr exhumation.

Comparison to petrologic constraints





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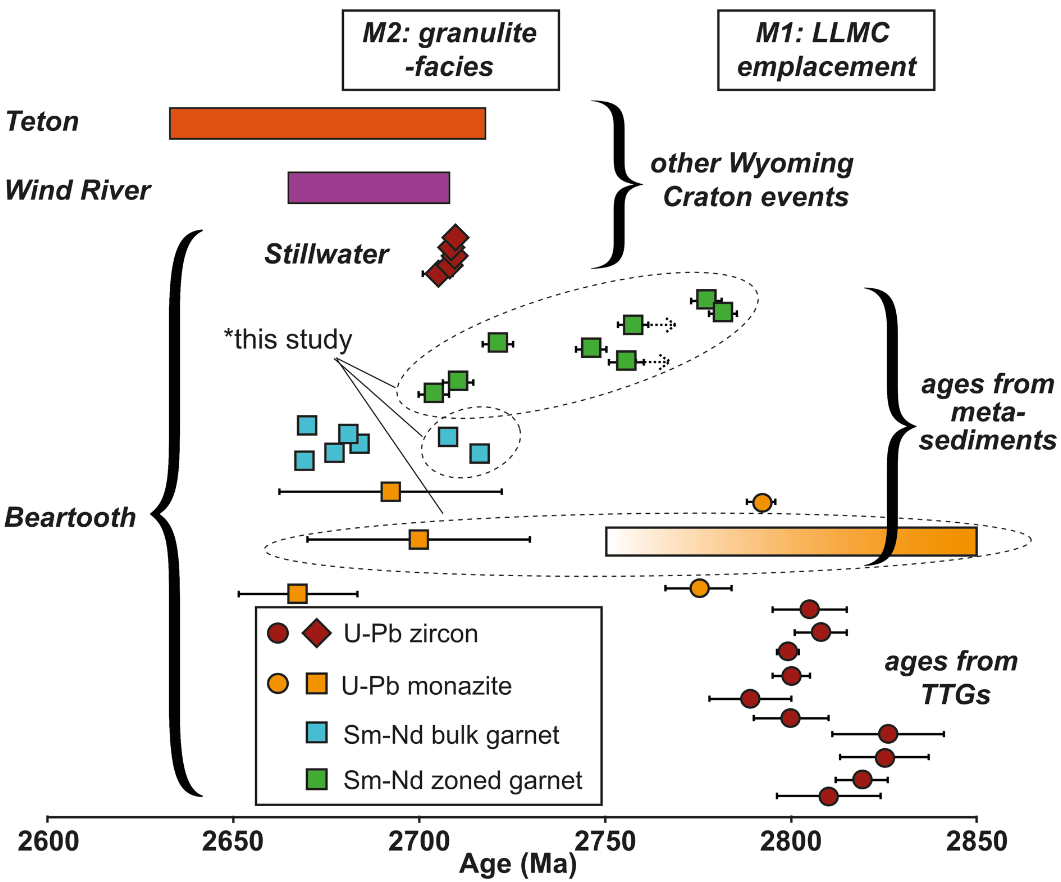
Conclusions.



Two stages of metamorphism, though cryptic or absent in some lithologies

The extent and significance of this second event for craton assembly and stabilization thus remain unclear, despite its synchronicity with metamorphism and magmatism in other portions of the Wyoming Province.

High-temperature metamorphic terranes still remain our clearest window into the tectonic mechanisms operating in the Archean.

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Thank you!

Questions?

Acknowledgments:
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Ryan Mills (UNC-Chapel Hill)

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