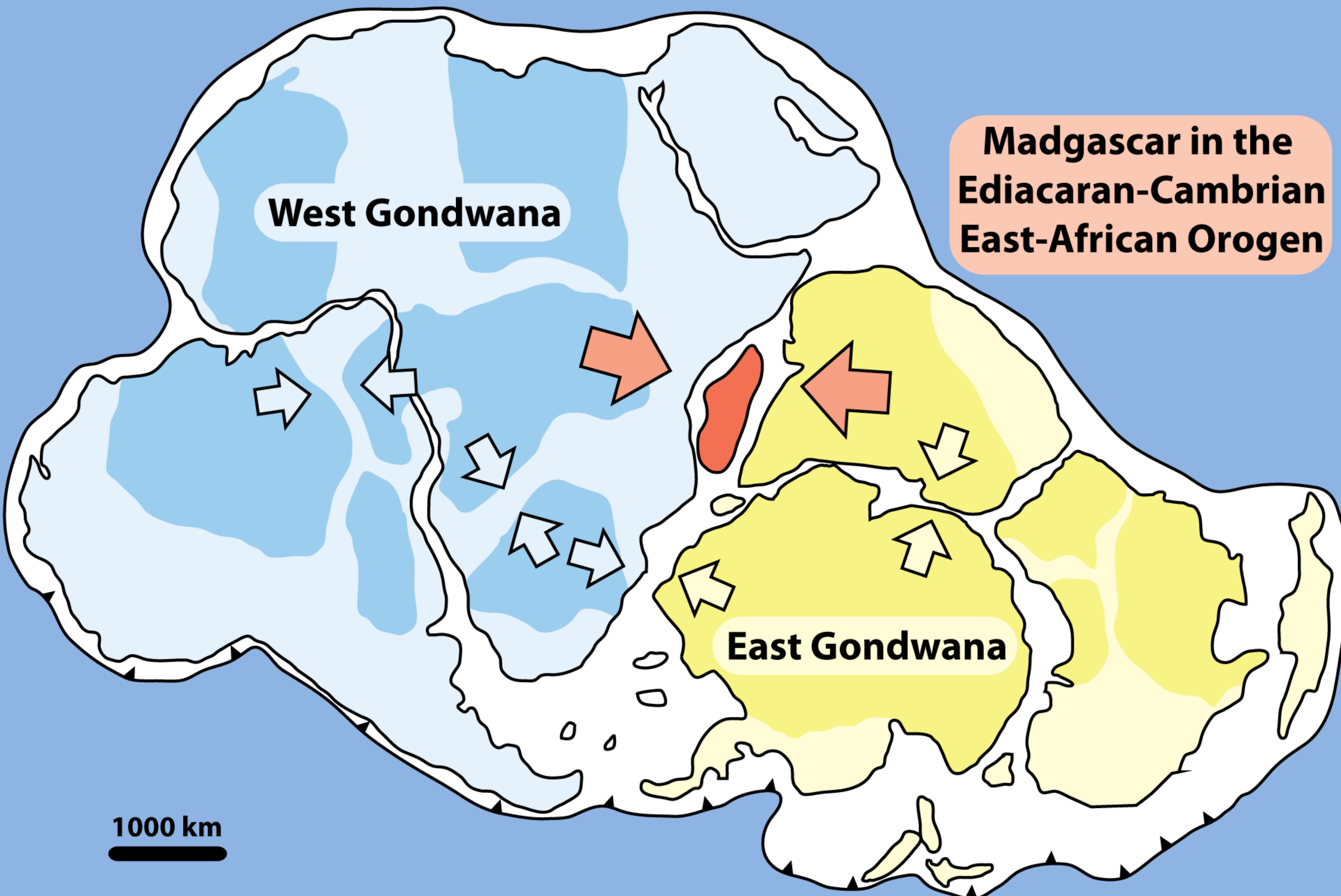
Intracrustal magmatic heat advection in the Ediacaran UHT domain of southern Madagascar

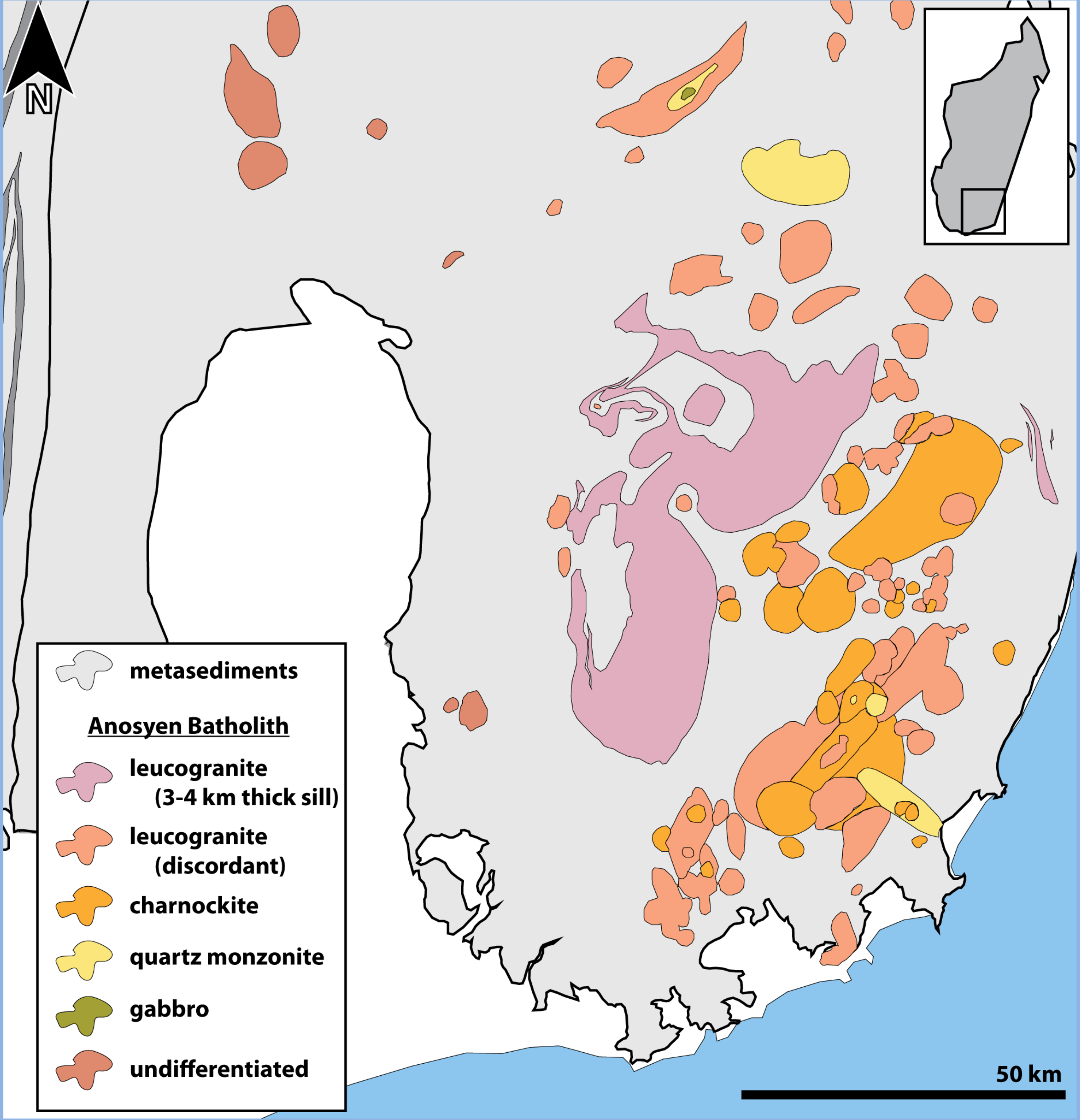
Robert M. Holder

Bradley R. Hacker

University of California, Santa Barbara

Geological setting



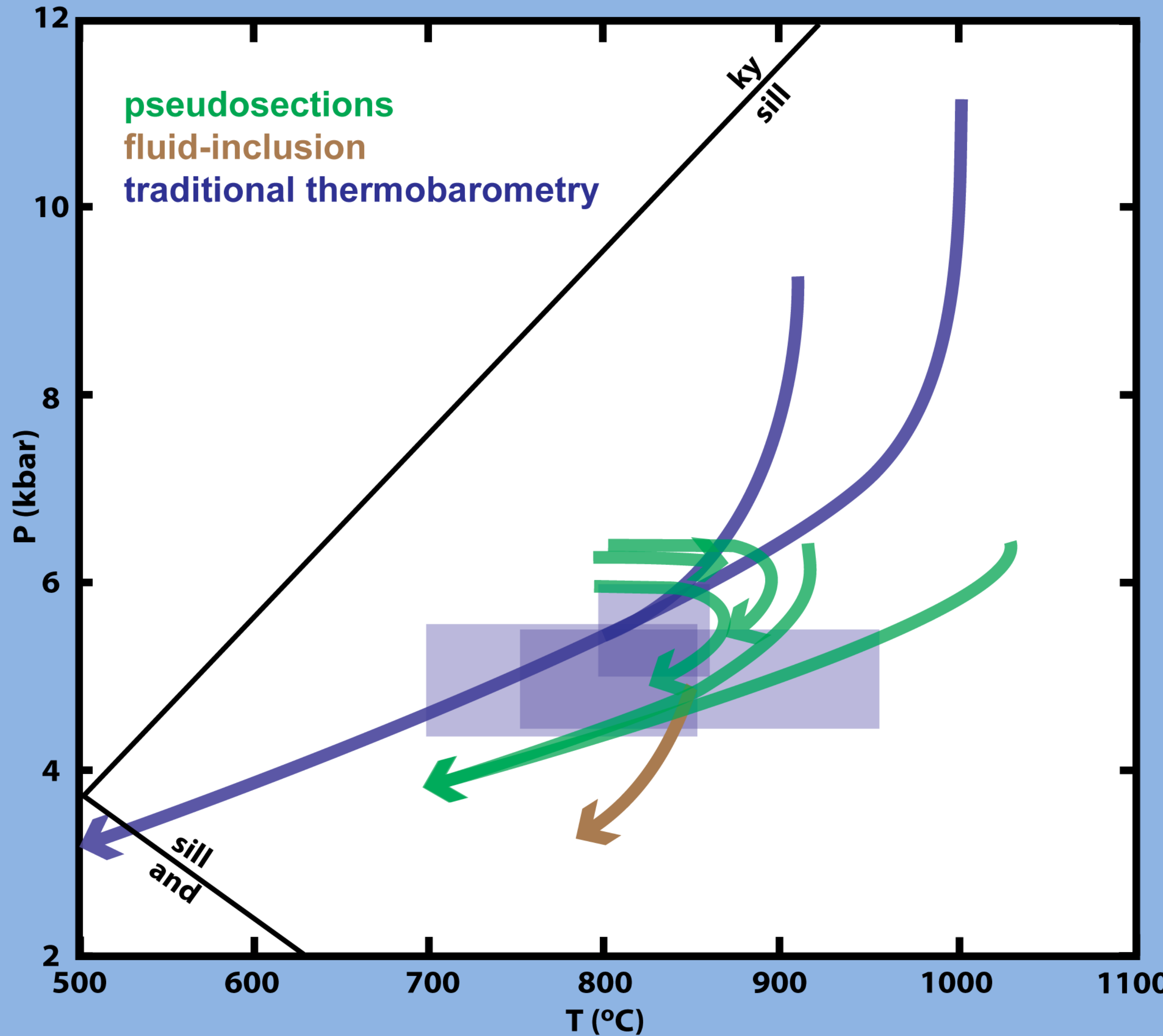

N
metasediments
Anosyen Batholith
leucogranite
(3-4 km thick sill)
leucogranite
(discordant)
charnockite
quartz monzonite
gabbro
undifferentiated
50 km

Limits on our understanding of Madagascar

1: uncertain
PT path

4-11 kbar

700-1050 ^oC



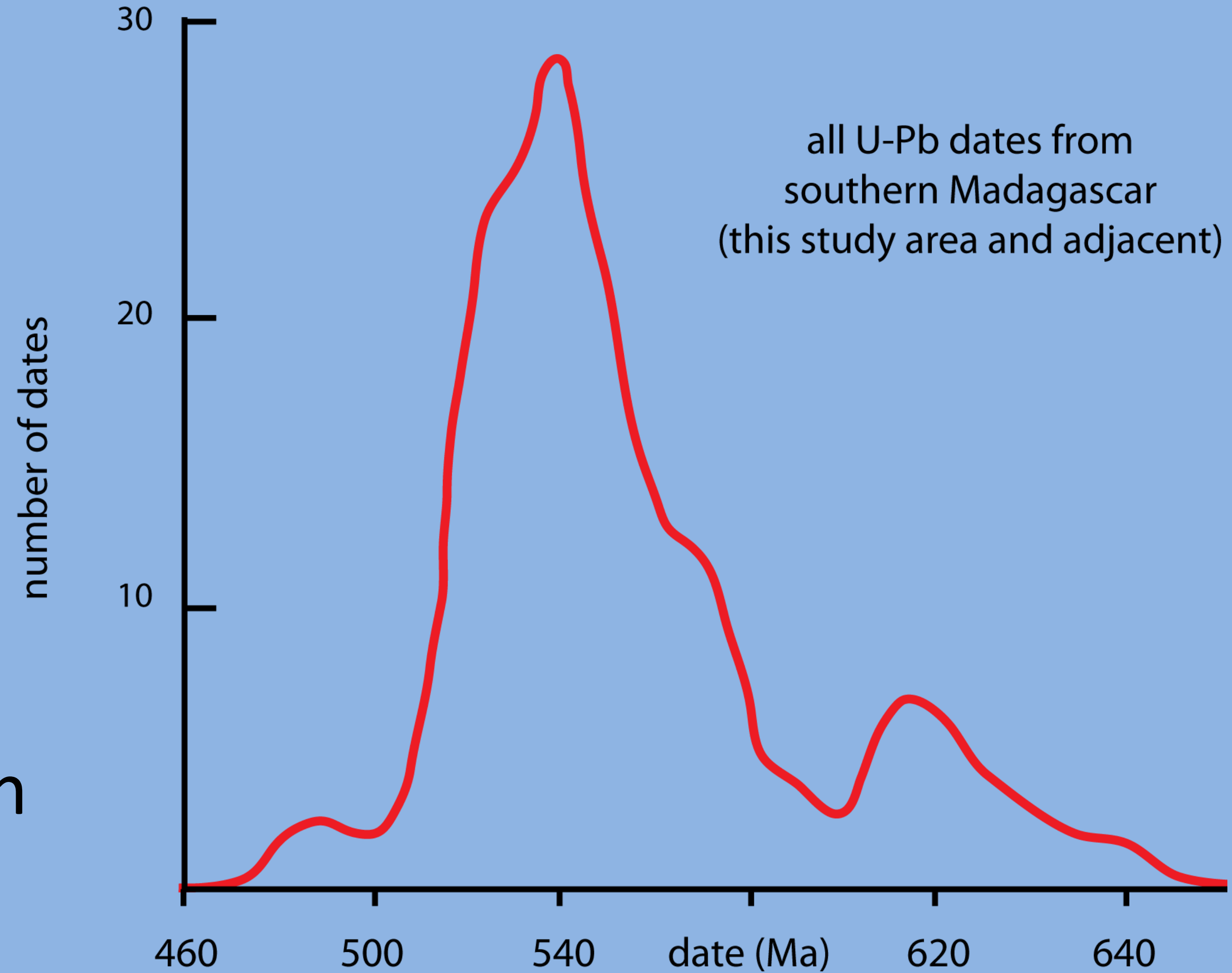
Limits on our understanding of Madagascar

1: uncertain PT path

2: no PT-time data

timing of peak (P)T unknown

(Tucker et al., 2014)



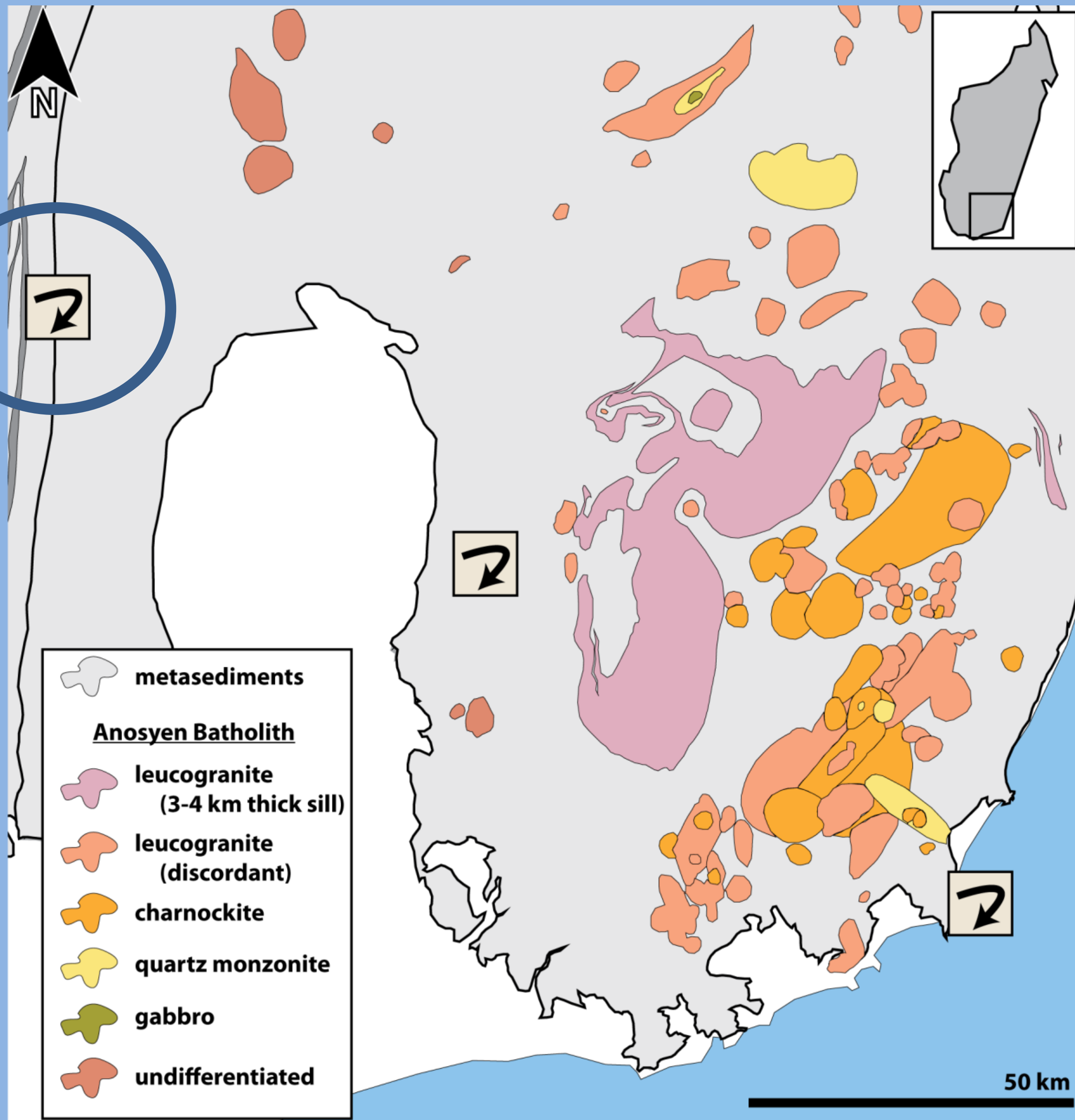
Overview

- test the proposed models for UHTM in Madagascar…
  - radiogenic heat production in thick crust
  - magmatic heat advection
  - increased mantle heat flow following delamination

- … with thermobarometry (pseudosections, Zr in rutile, and ternary feldspars)

  & monazite petrochronology

Garnet-orthopyroxene-cordierite gneiss

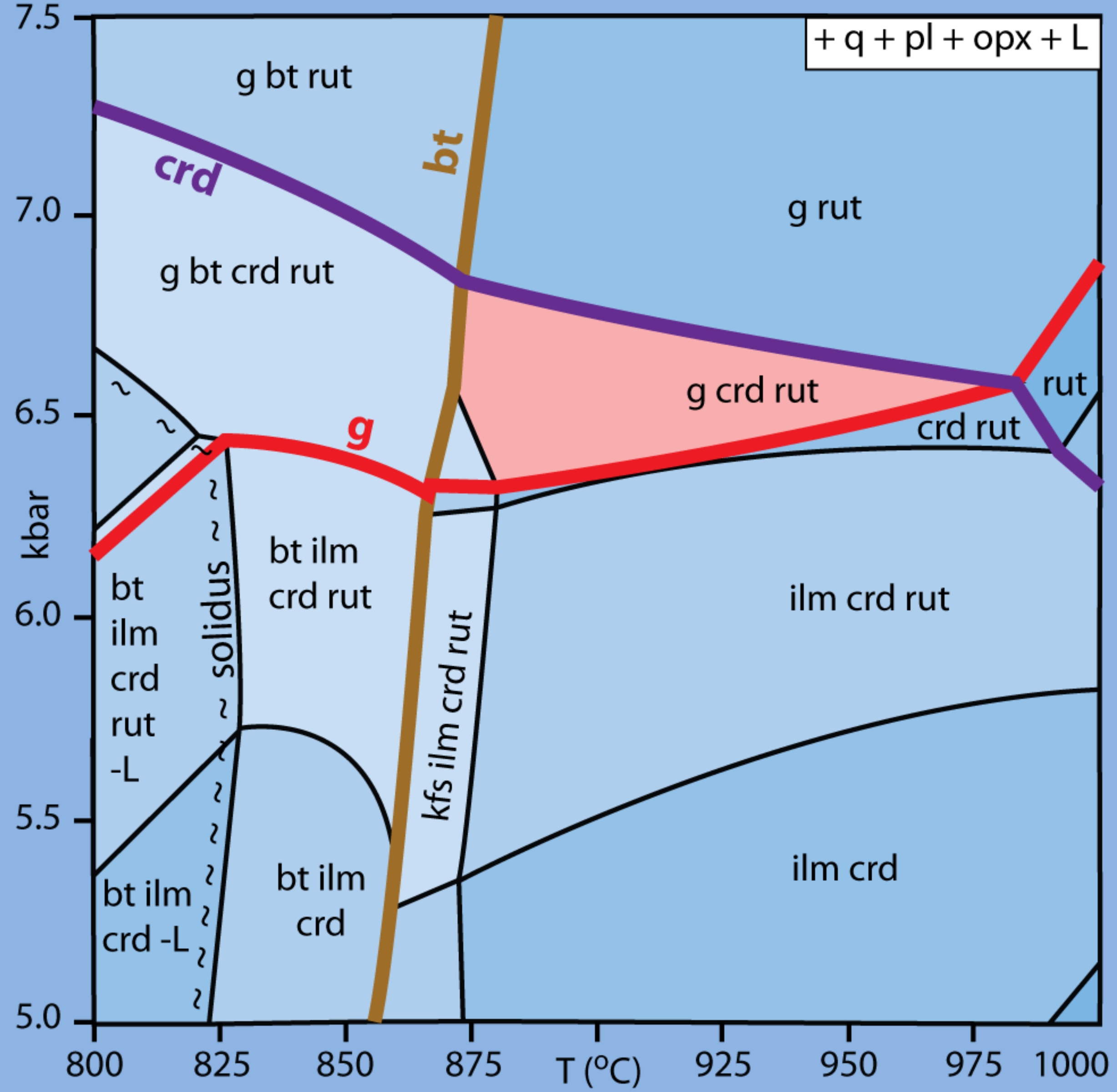


Garnet-orthopyroxene-cordierite gneiss

- equilibrium assemblage

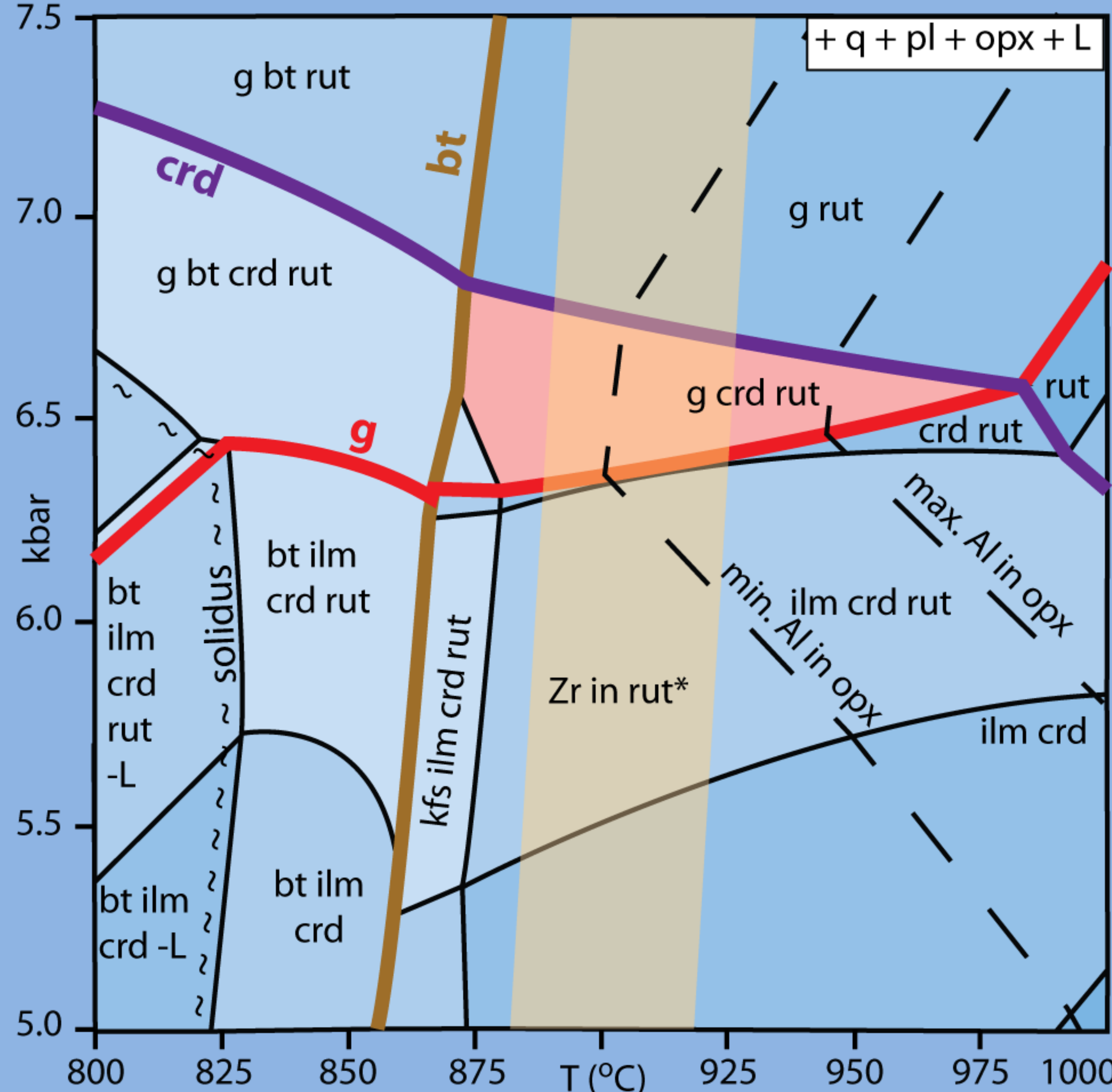
875–975 °C

~6.5 kbar

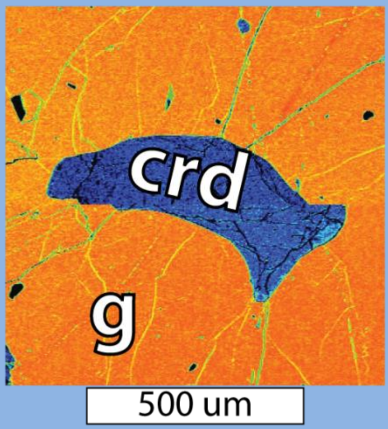


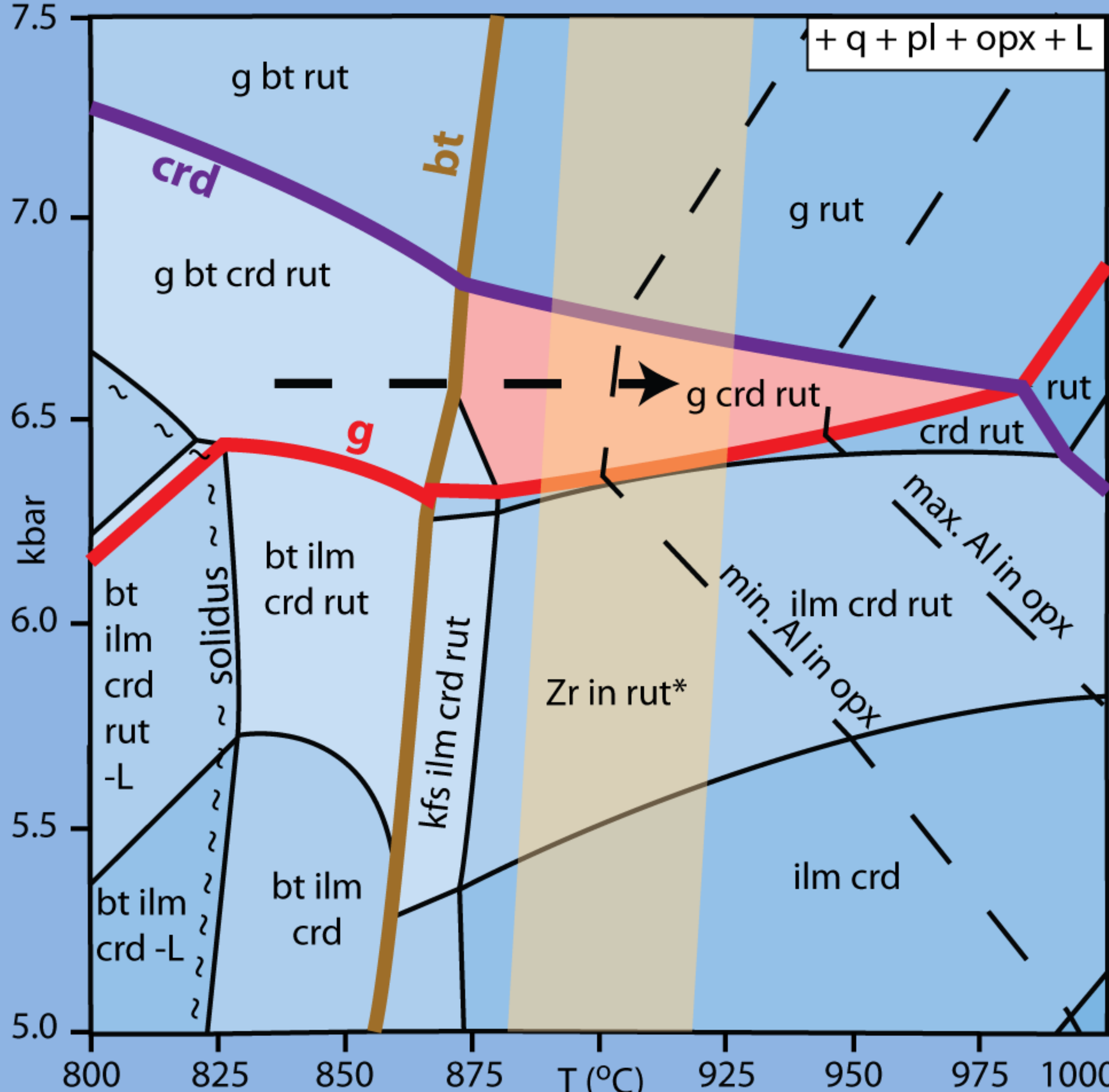
Garnet-orthopyroxene-cordierite gneiss

- equilibrium assemblage
- Zr in rut
  - Horton et al. (2016)
- Al in opx



Garnet-orthopyroxene-cordierite gneiss

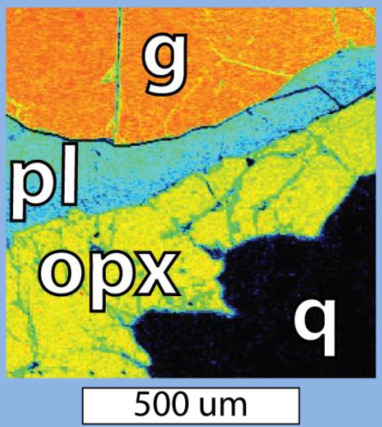




cordierite + biotite in garnet

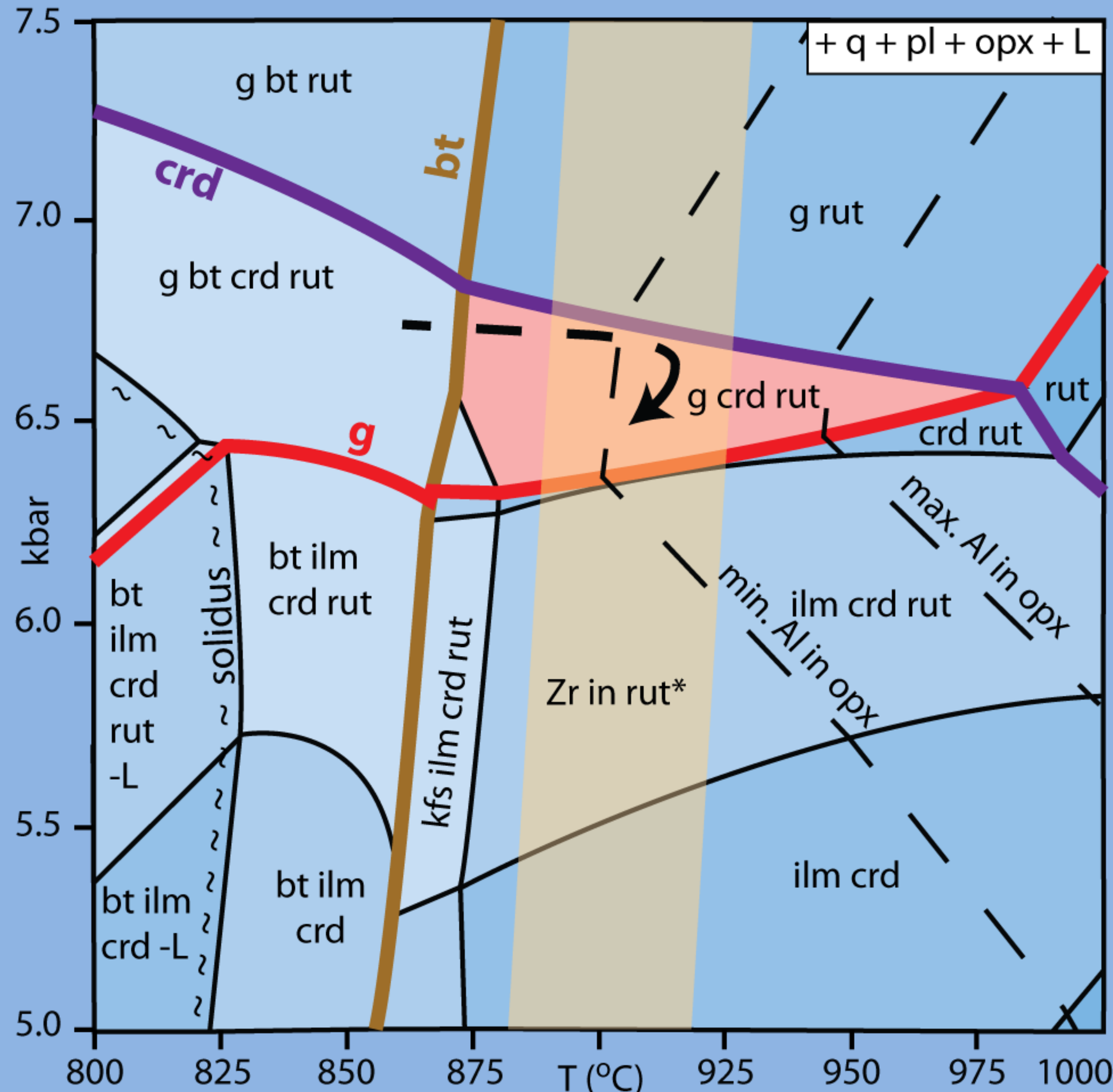
low-pressure prograde path

Garnet-orthopyroxene-cordierite gneiss

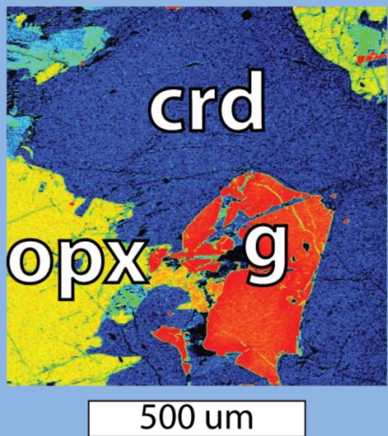


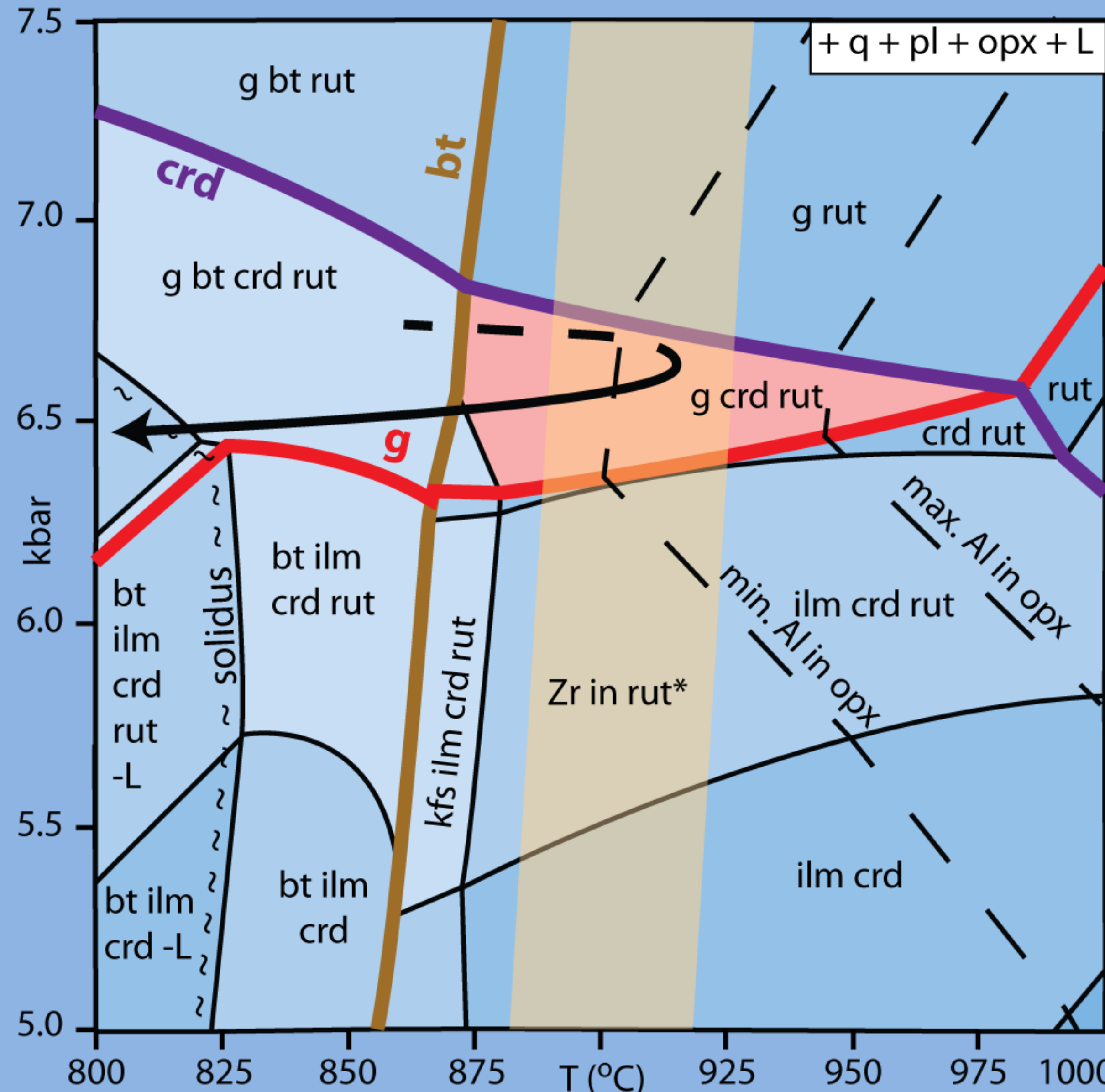
decompression reactions:

g + q = pl + opx



Garnet-orthopyroxene-cordierite gneiss



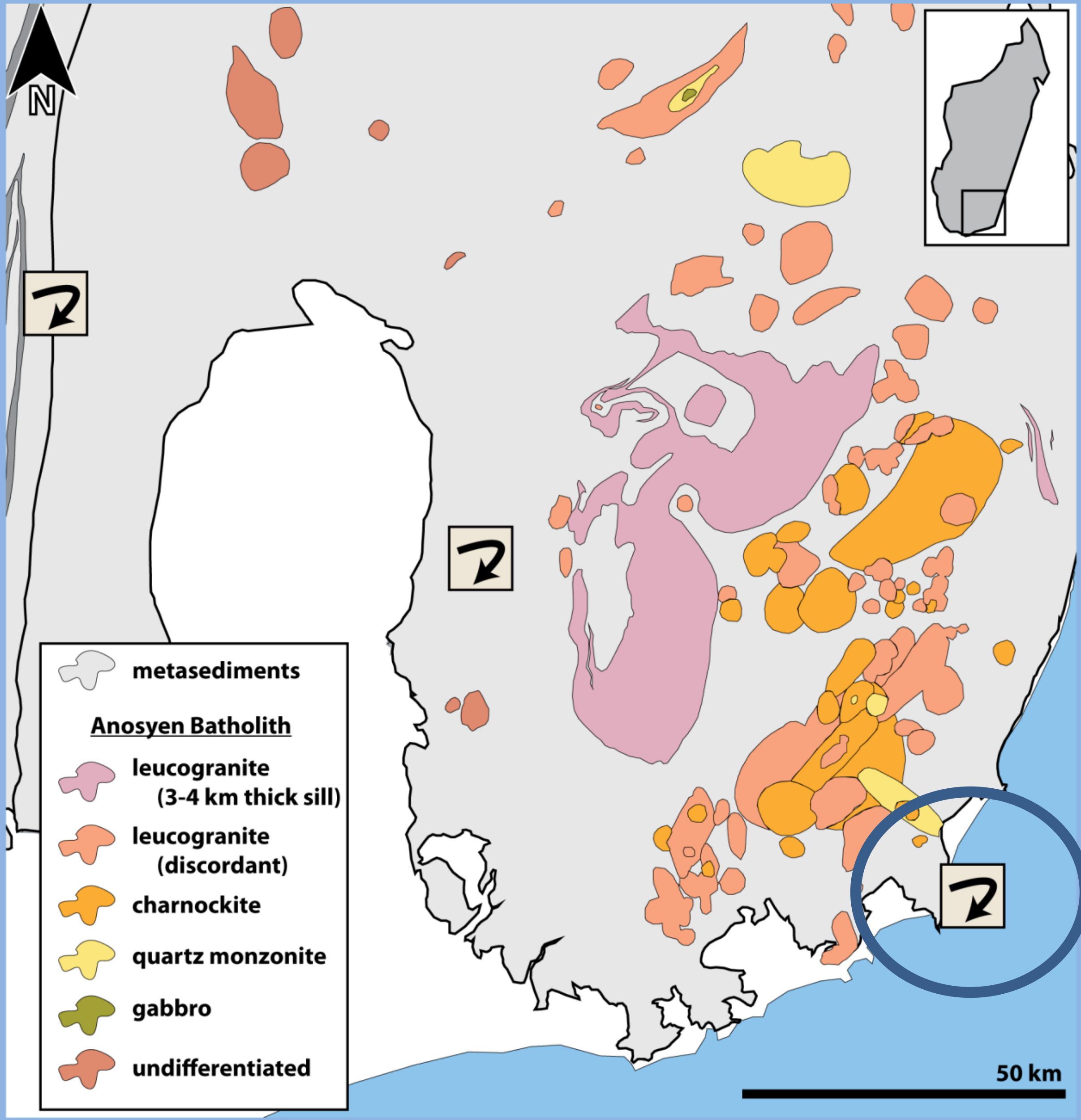


preservation of peak cordierite & garnet

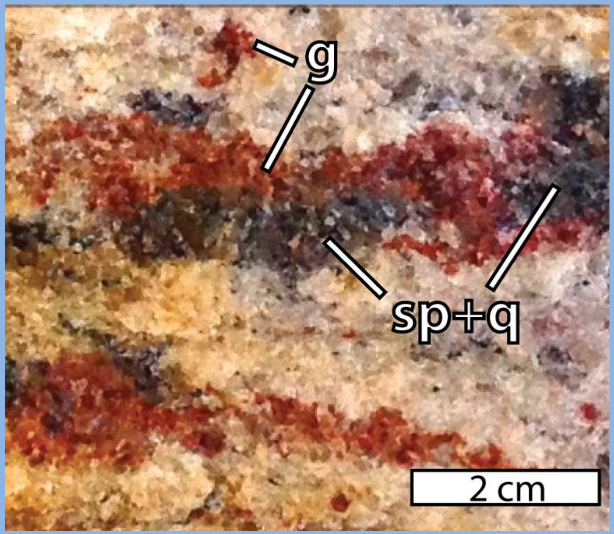
both minerals stable at solidus

~isobaric cooling

Spinel-garnet leucogneiss



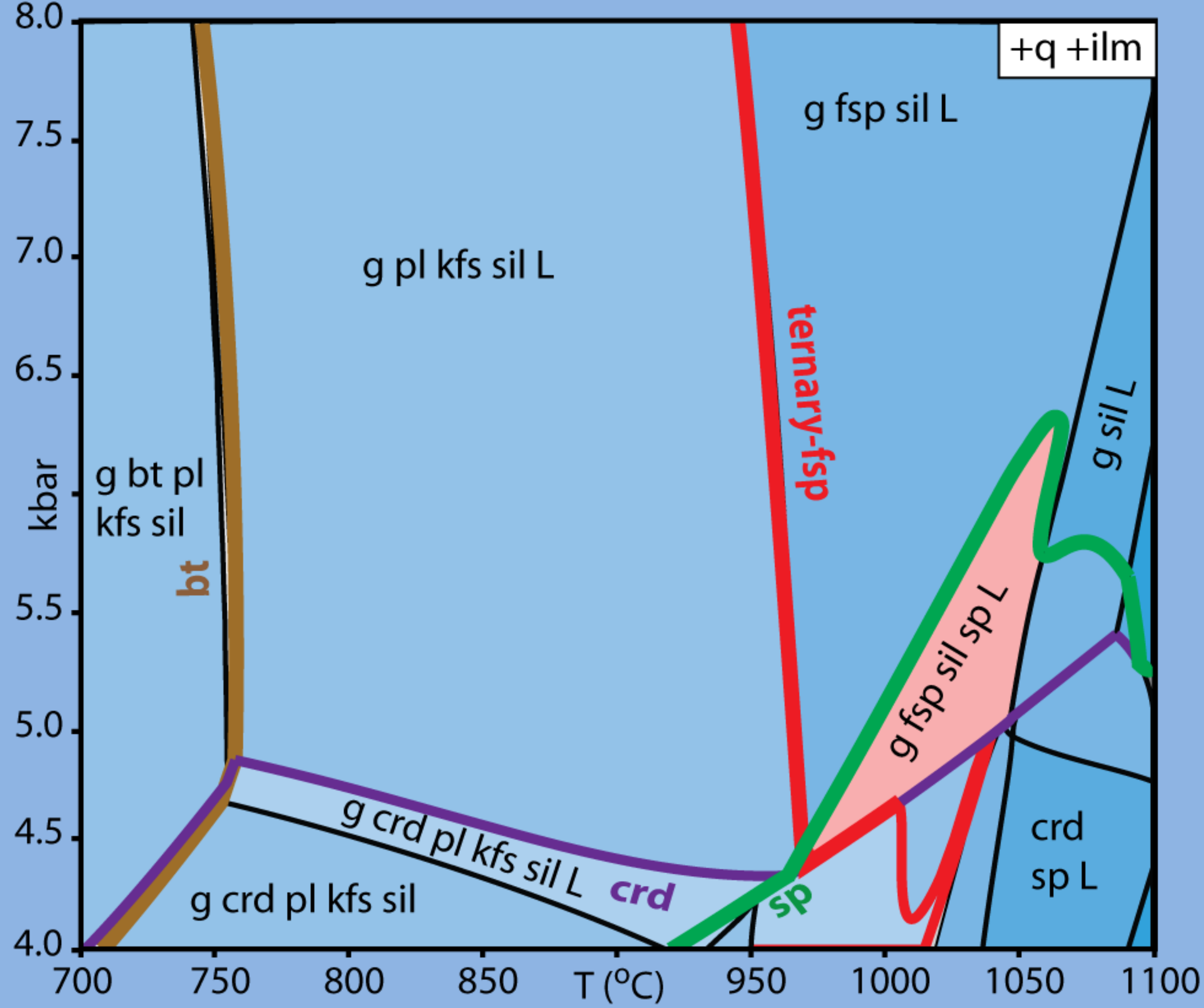
Spinel-garnet leucogneiss



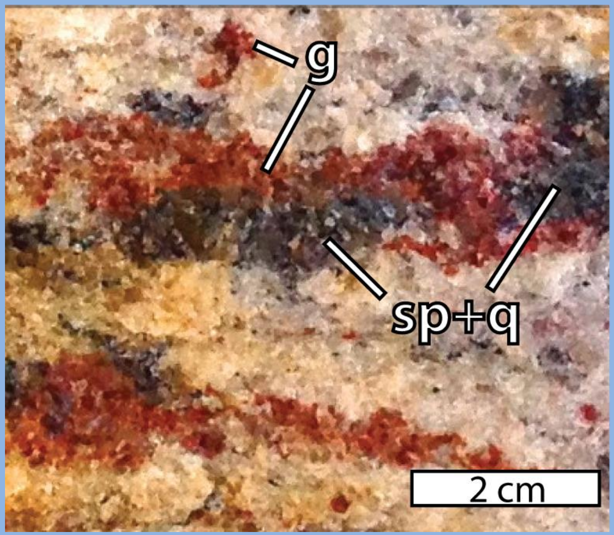
equilibrium assemblage

960–1050 °C

4.5–6.5 kbar

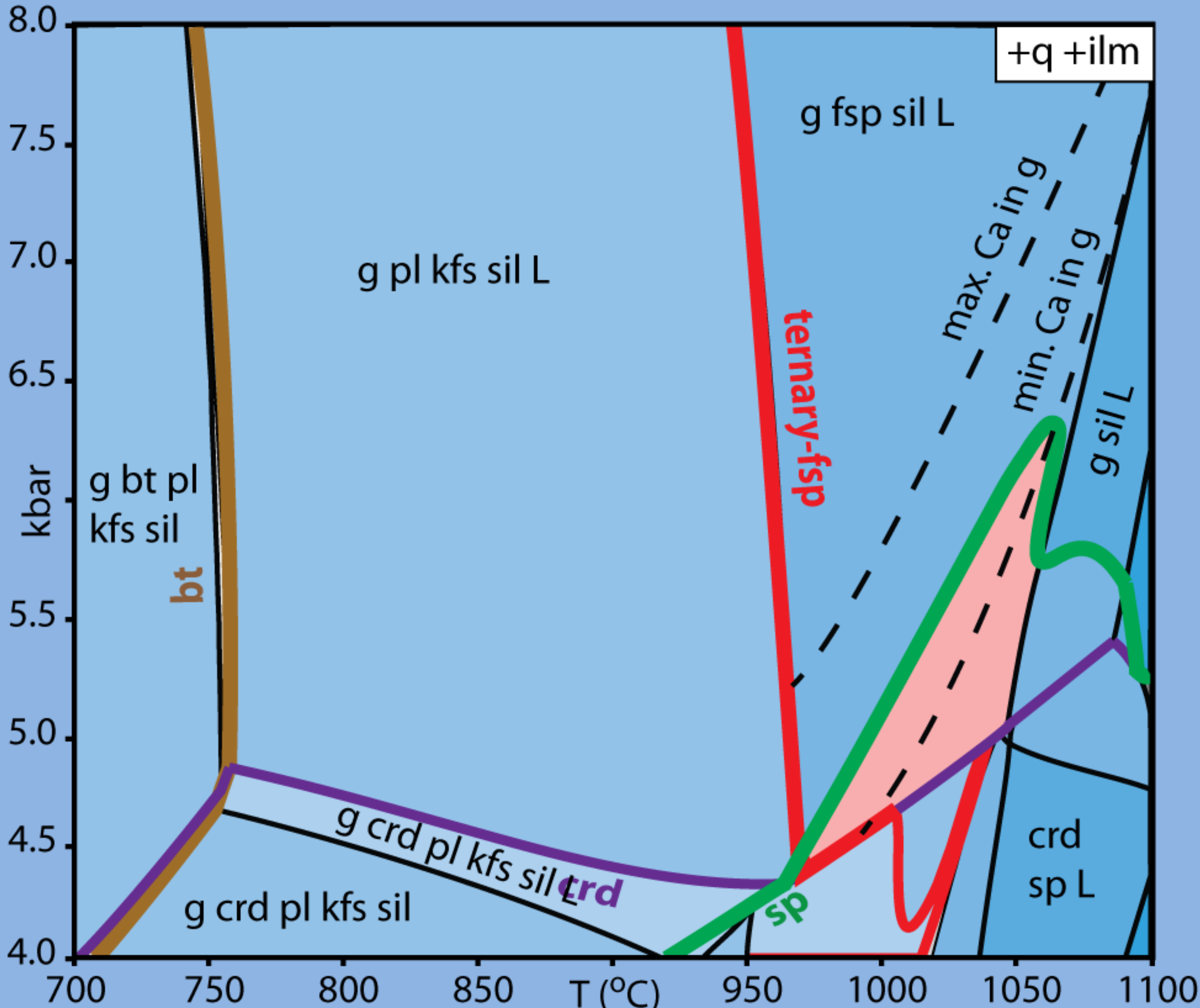


Garnet leucogneiss

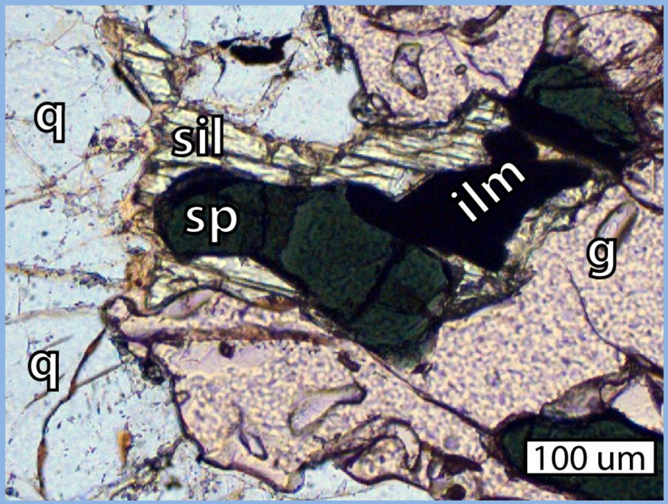


equilibrium
assemblage

consistent with
Ca in garnet (GASP)



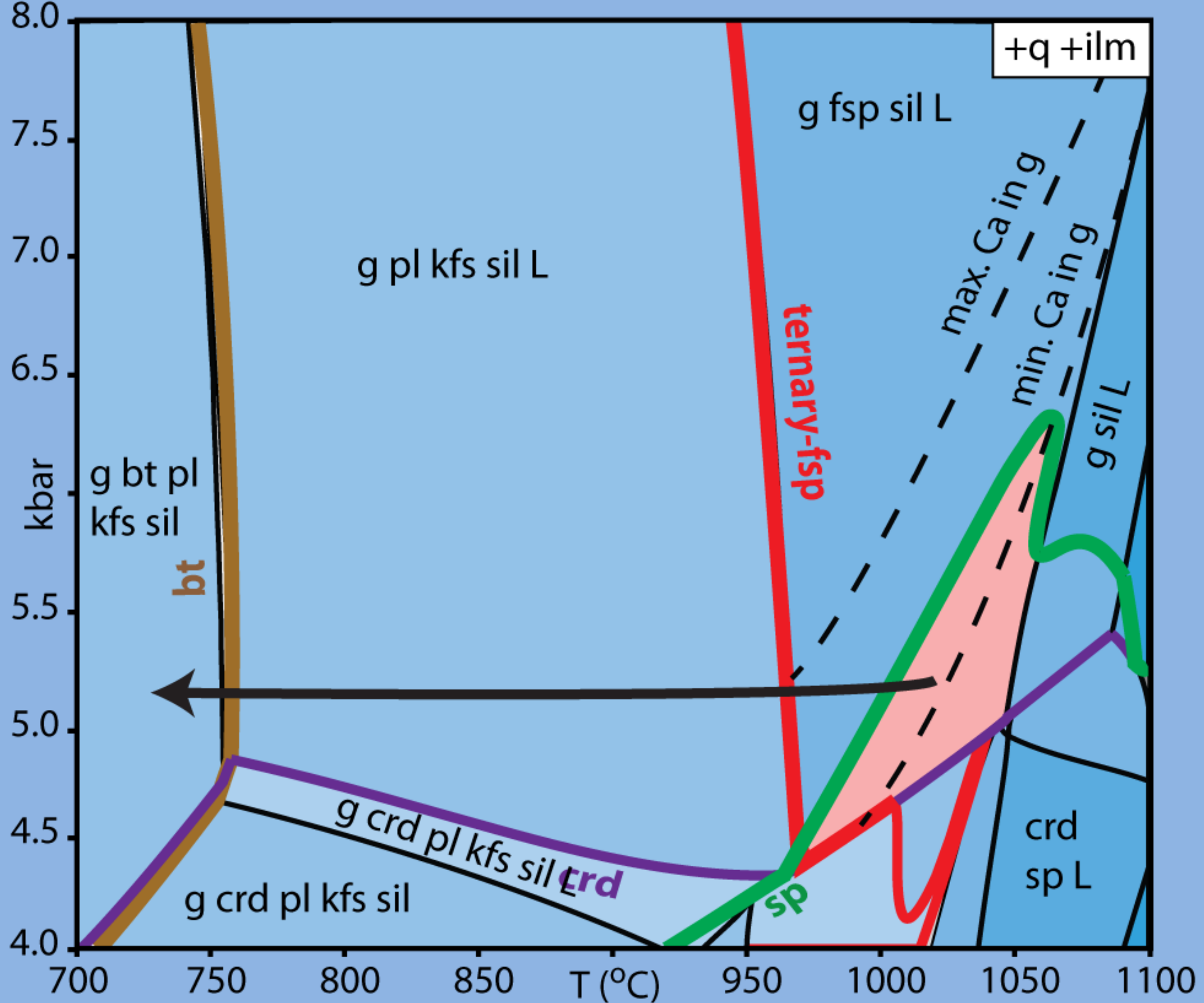
Garnet leucogneiss



spinel + quartz
= sillimanite + garnet

retrograde biotite
no cordierite

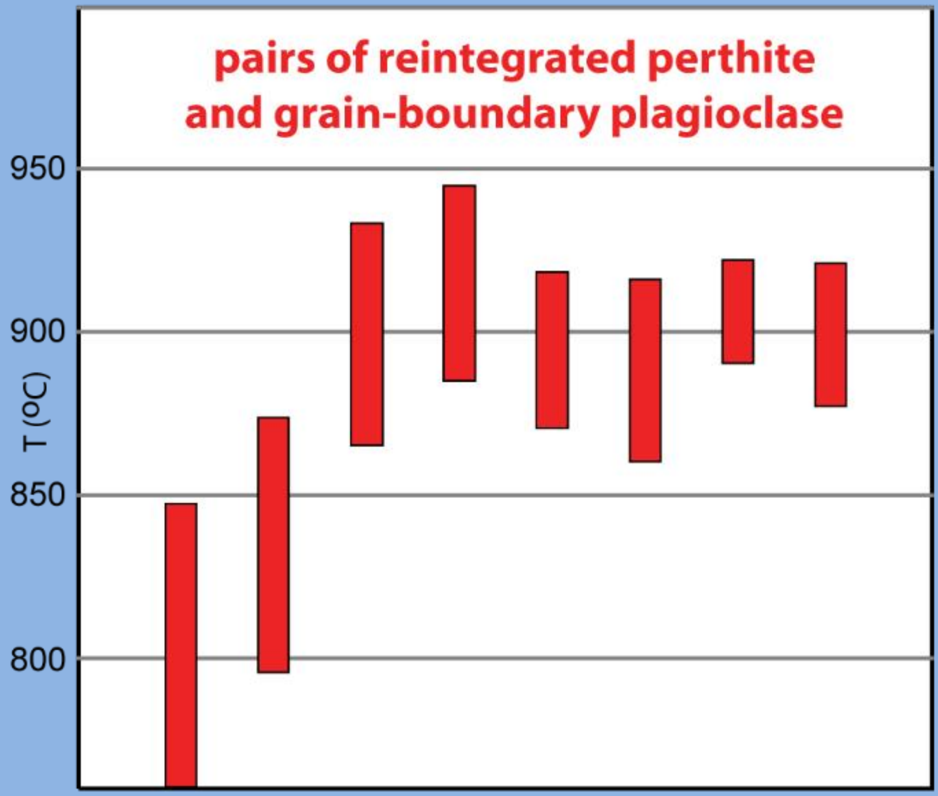
~isobaric cooling

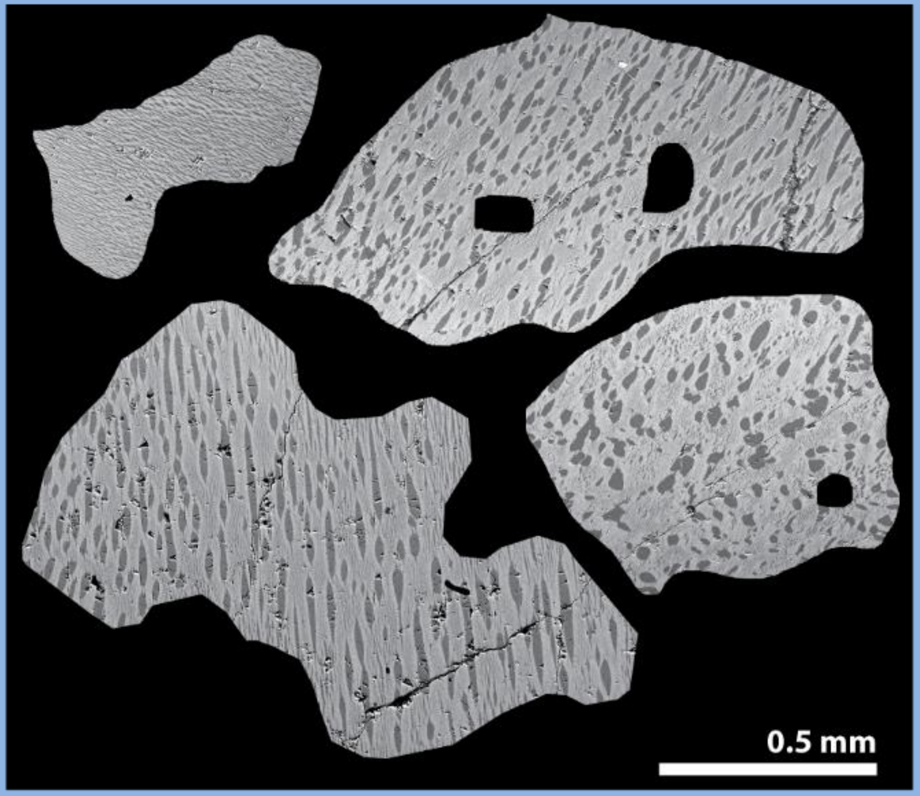


Garnet leucogneiss

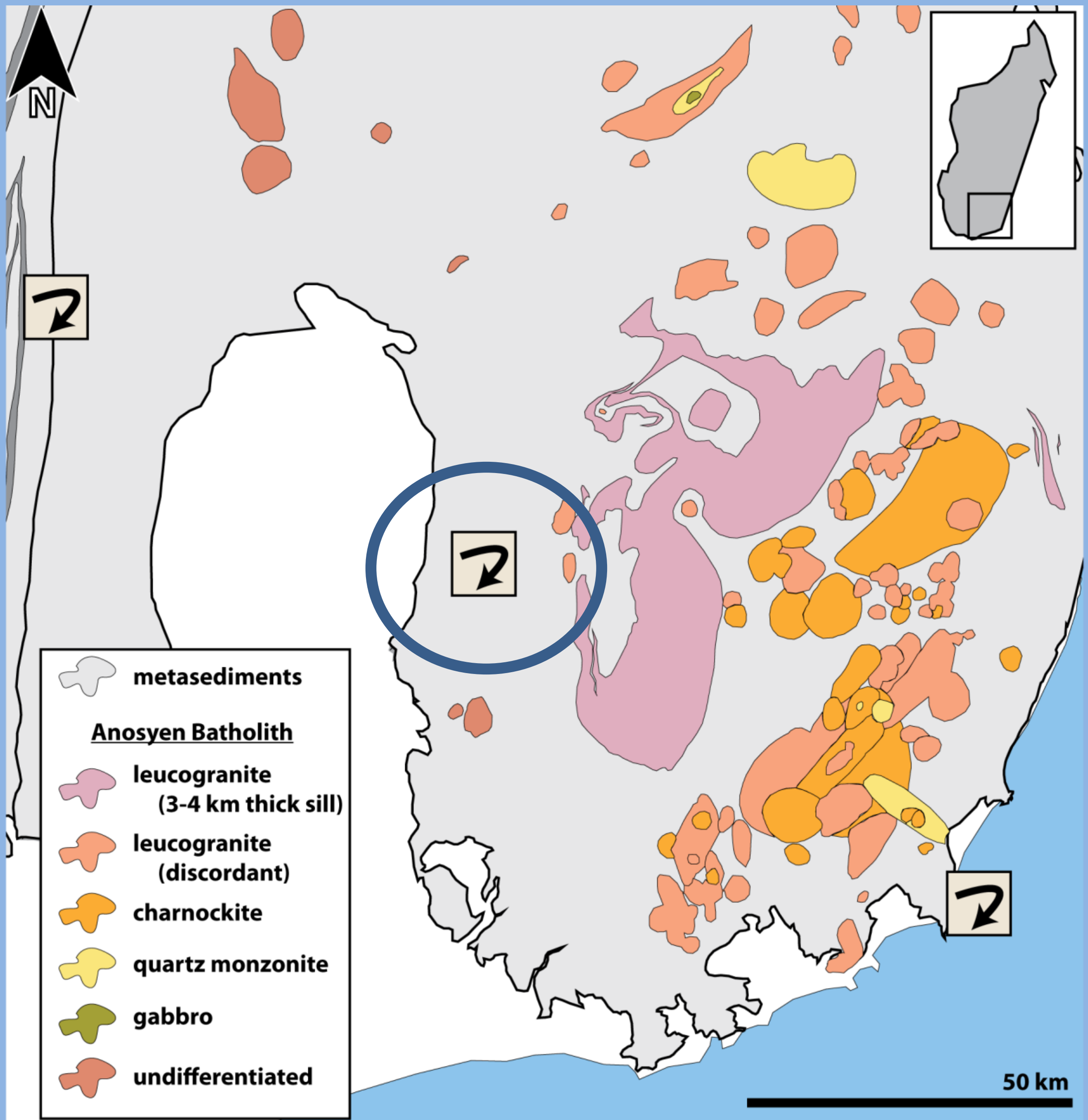
two-feldspar min. temperatures: > 915 ± 30 °C

solution model & method of Benisek et al. (2010)

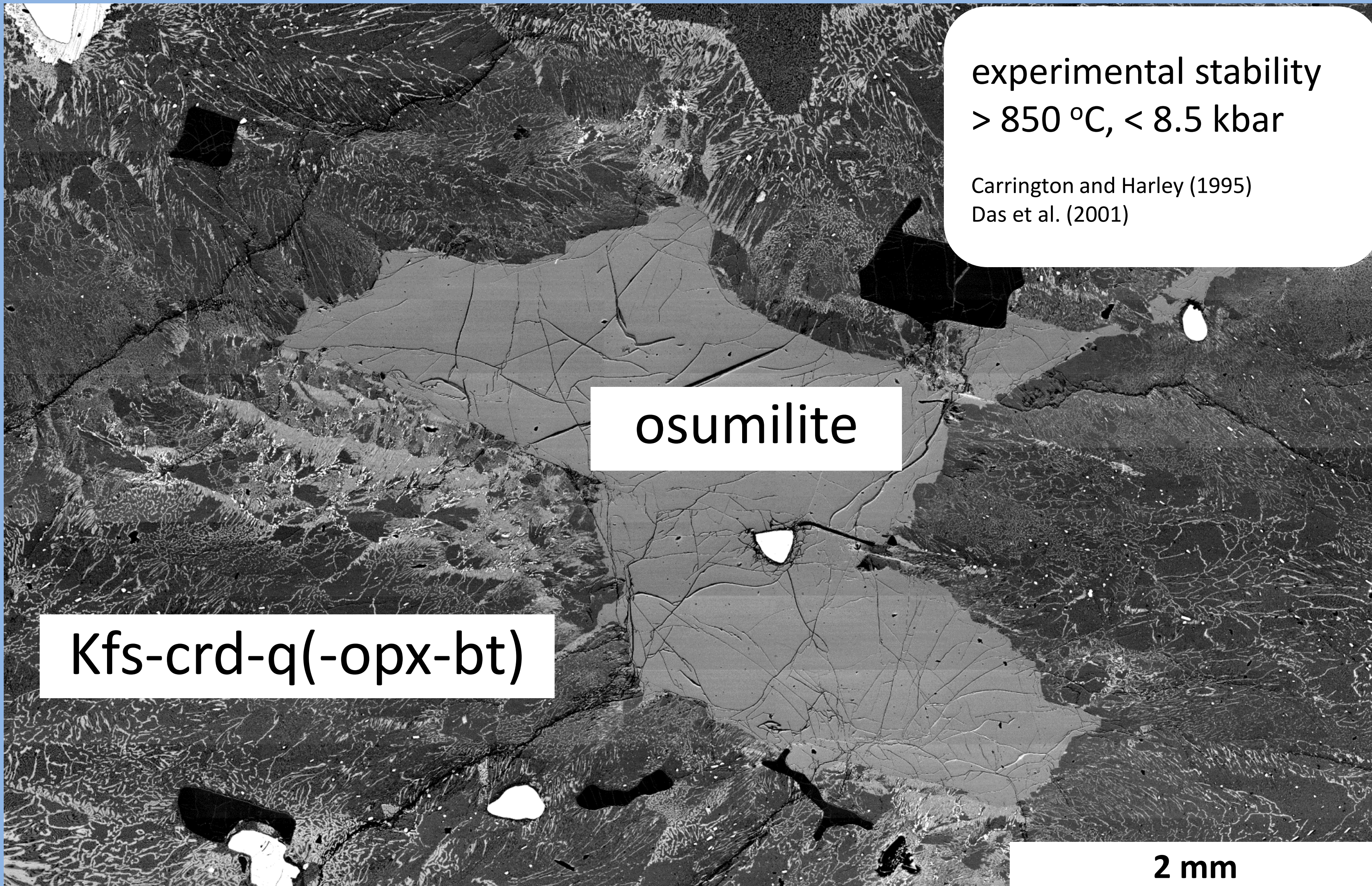




Osumilite gneiss



Osumilite $KMg_2Al_5Si_{10}O_{30}$

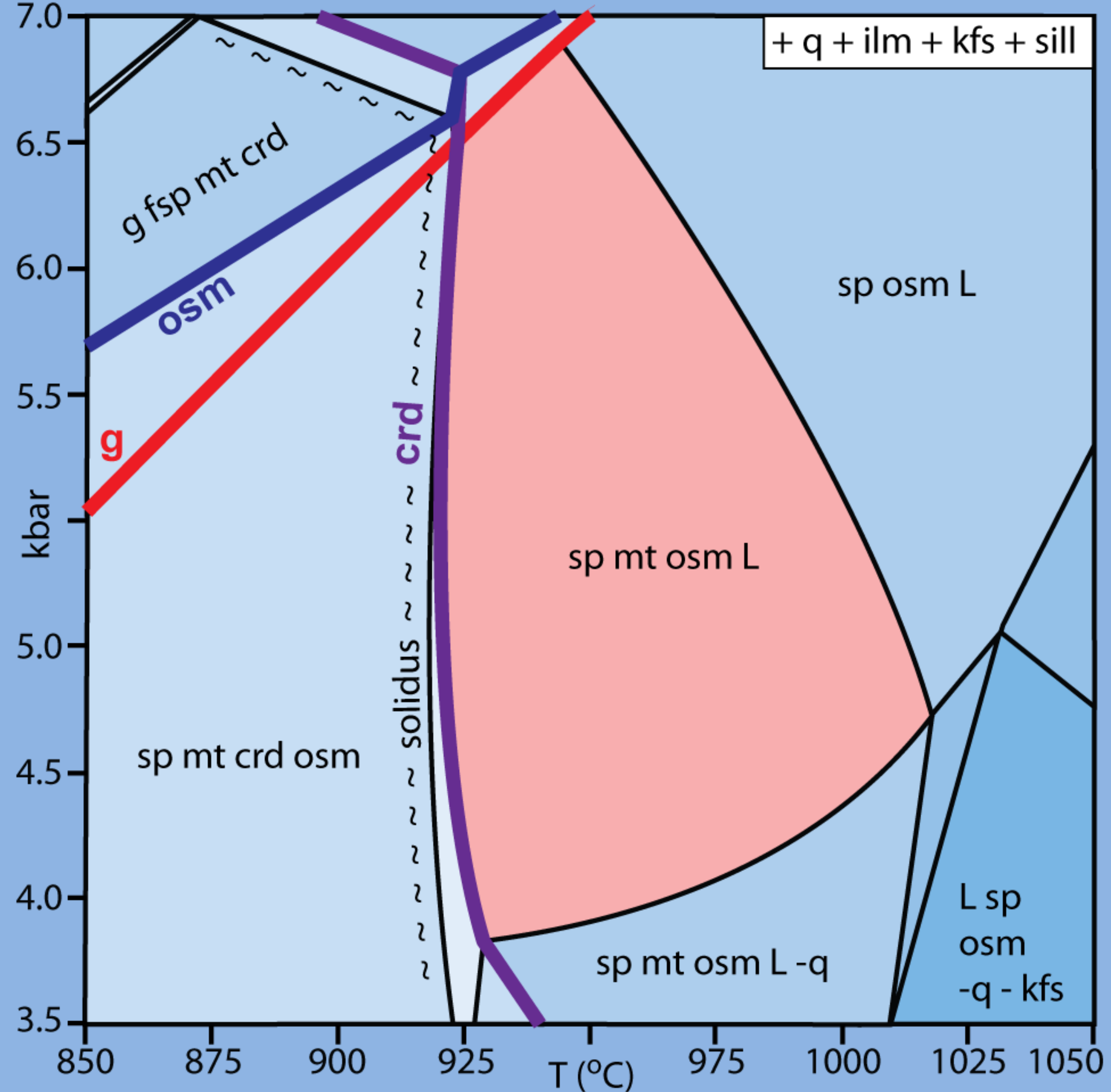


Osumilite gneiss

equilibrium assemblage

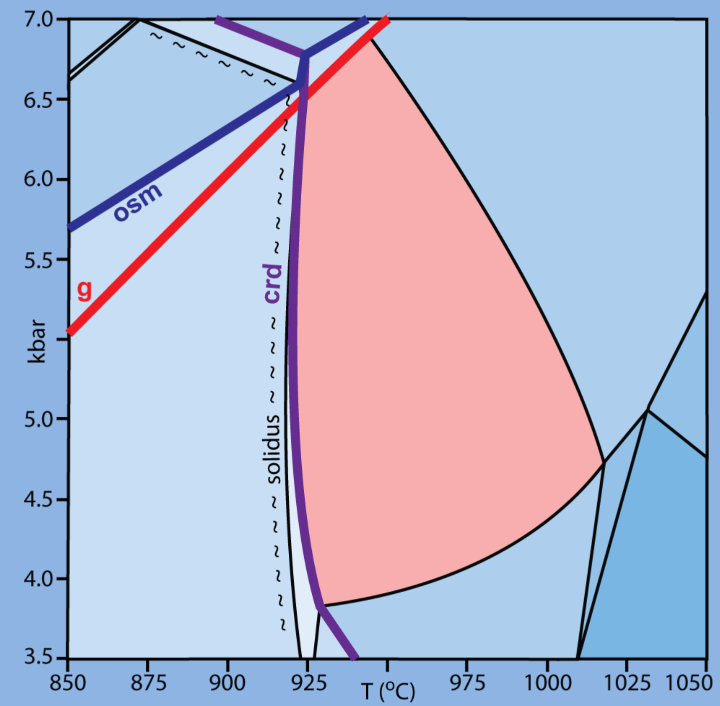
925–1010 °C

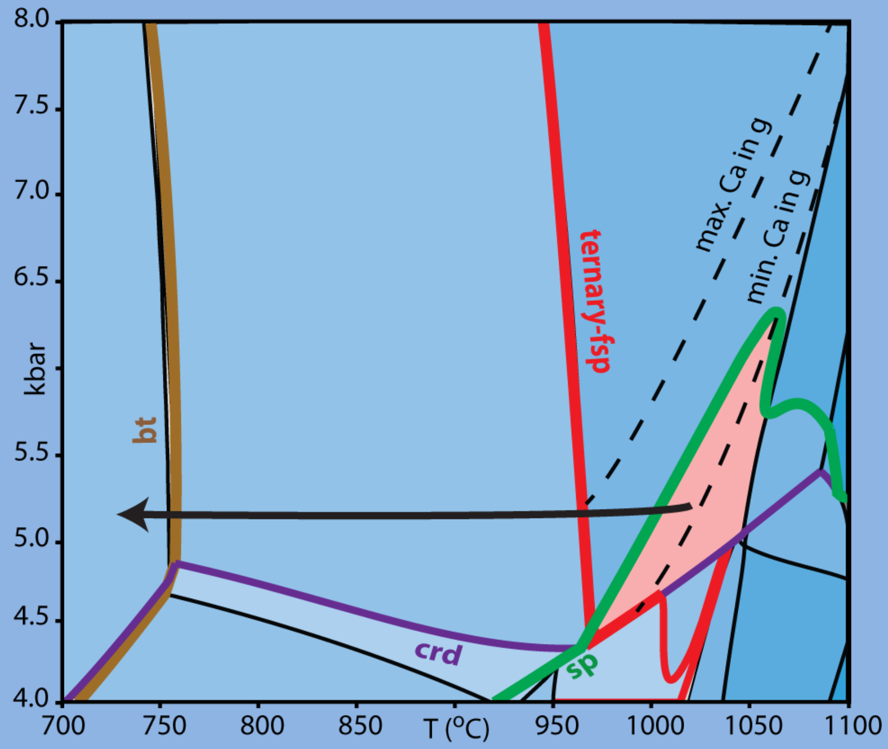
4.0–6.5 kbar

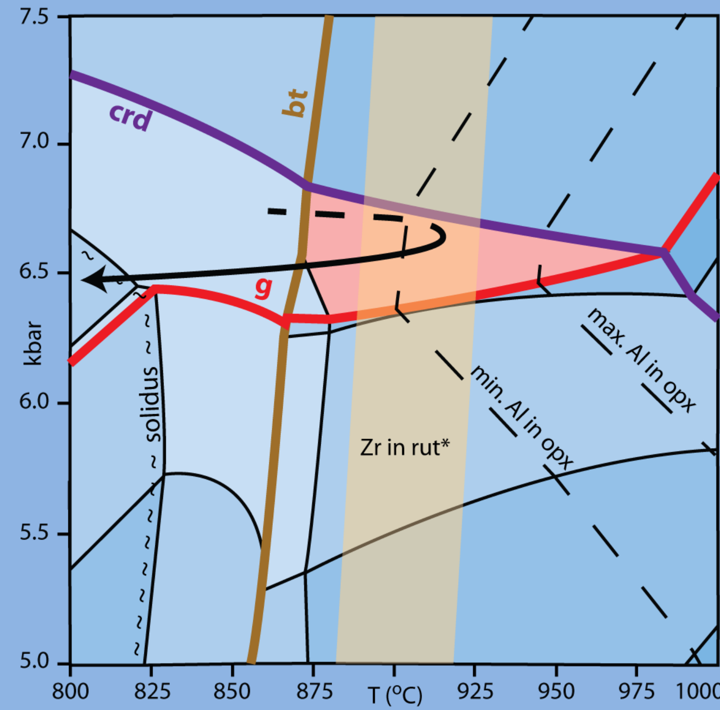


New thermobarometry

- 900-1050 °C, 4.5-6.5 kbar
  - low-pressure prograde path
  - ~isobaric cooling

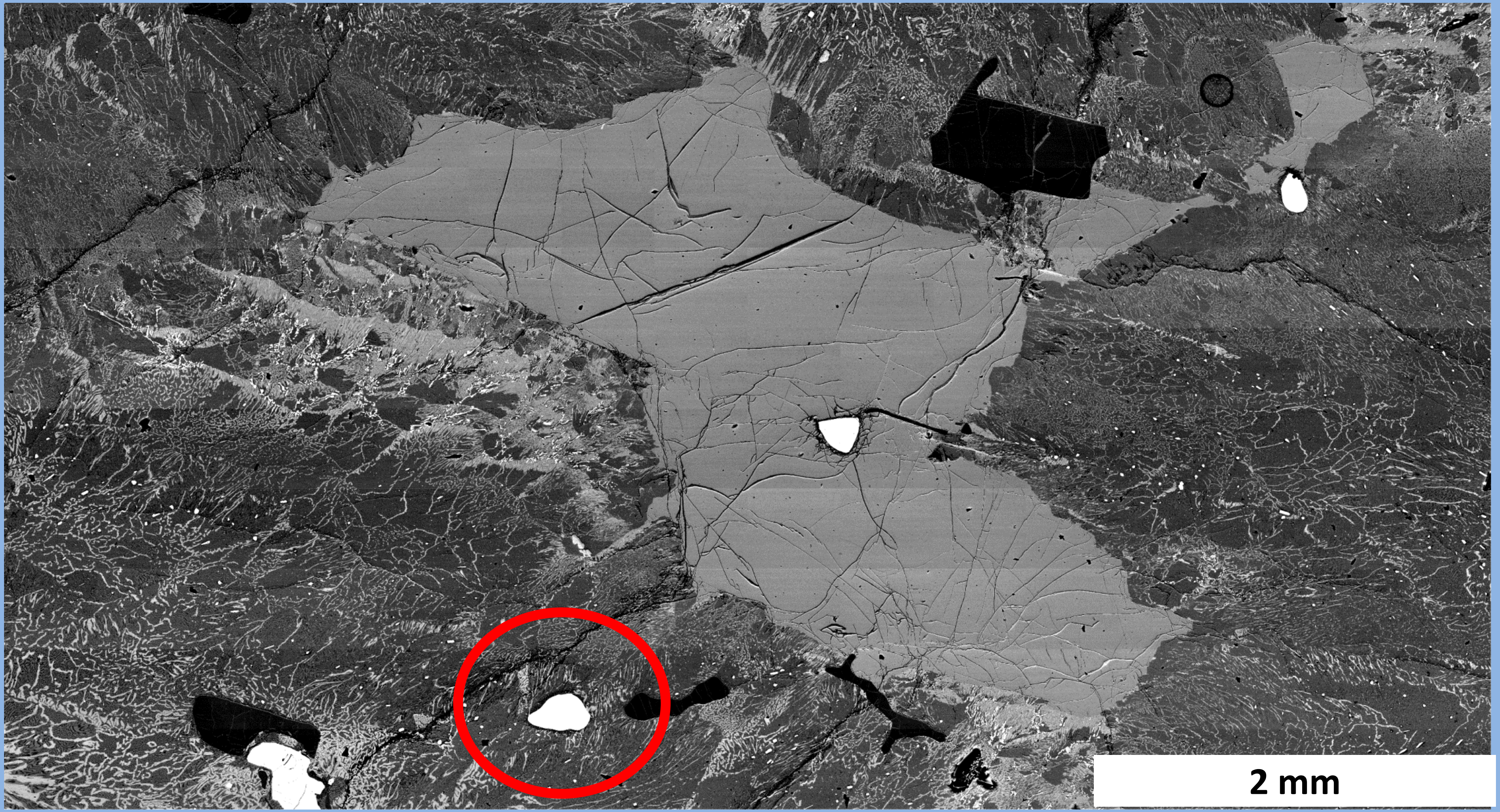






Timing of peak metamorphism

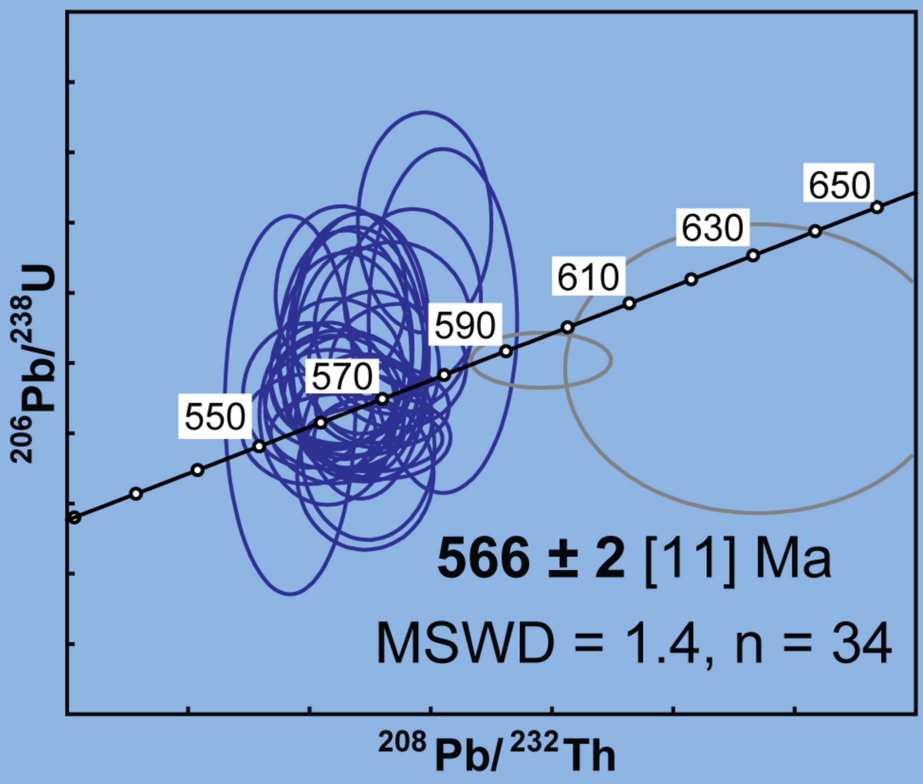
monazite inclusions in osumilite pseudomorphs



Timing of peak metamorphism

monazite inclusions in osumilite pseudomorphs

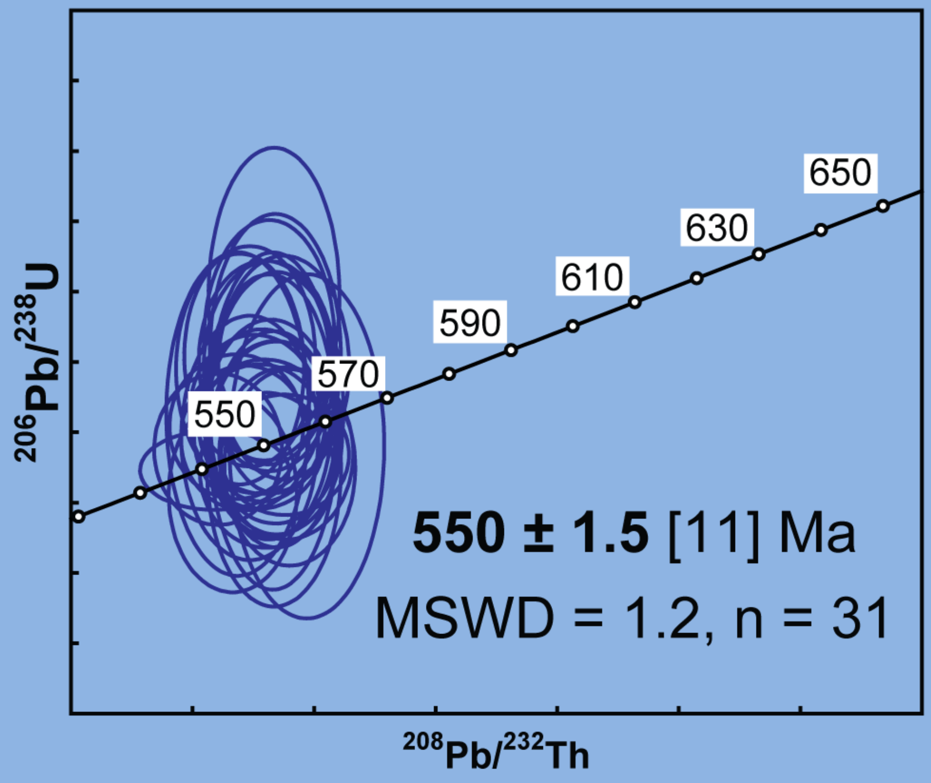
-max. date for osm growth (T ≥ 850 ^{o}C)



Timing of peak metamorphism

monazite in leucosomes at osumilite outcrop

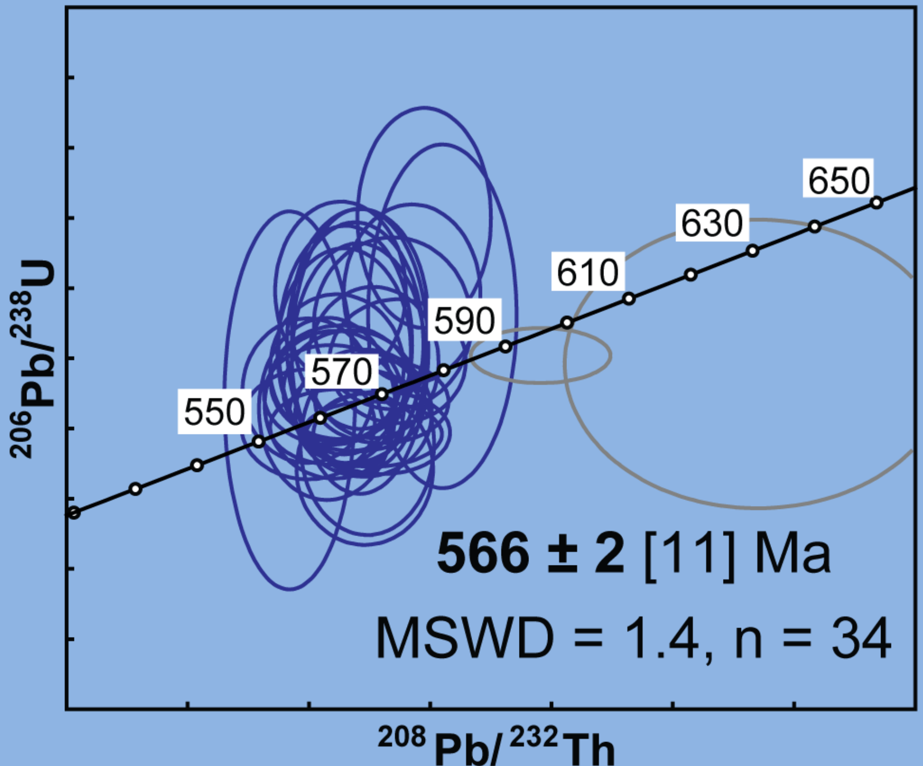
-date of leucosome crystallization (T ≤ 925 °C)



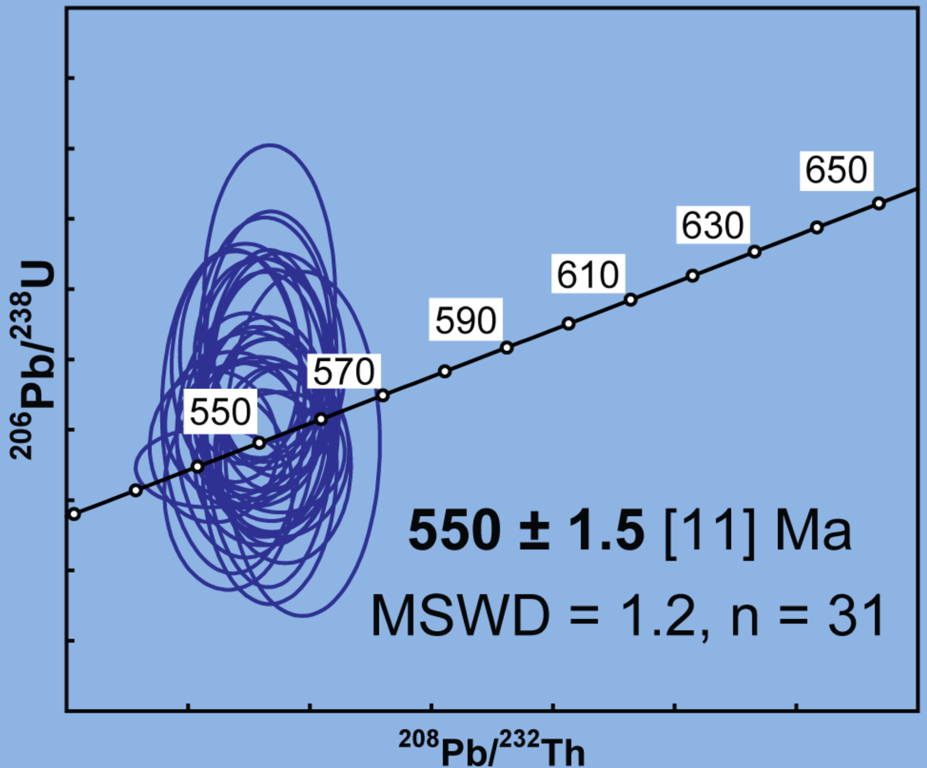
Timing of peak metamorphism

duration of UHT < 16 ± 2.5 Myr

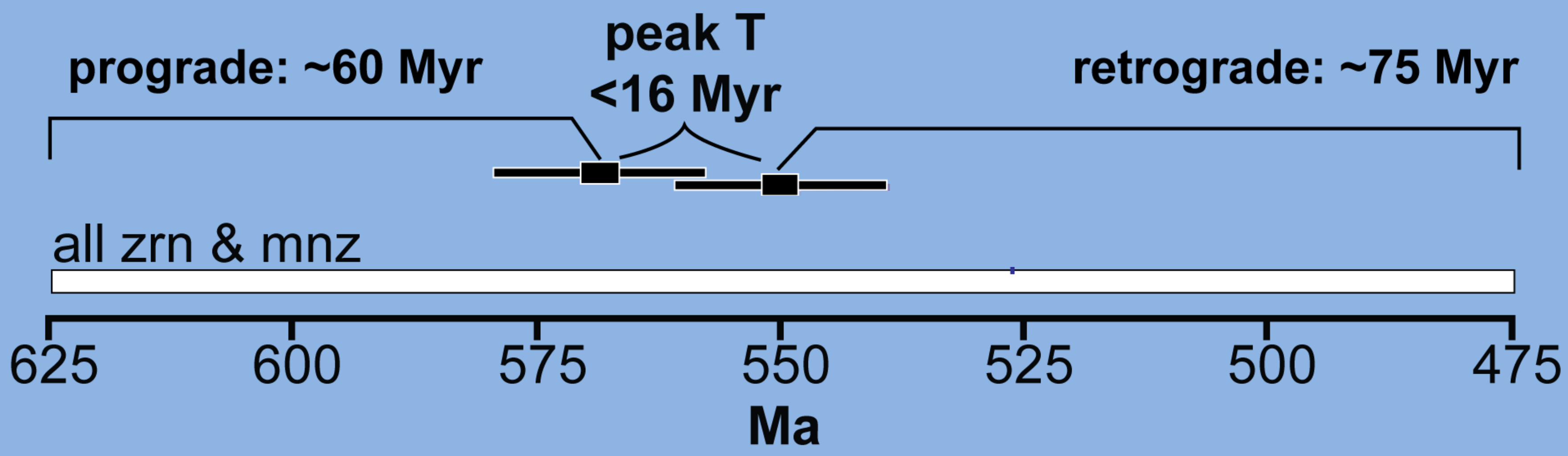
T ≥ 850 ºC



T ≤ 925 ºC



Metamorphic timeline

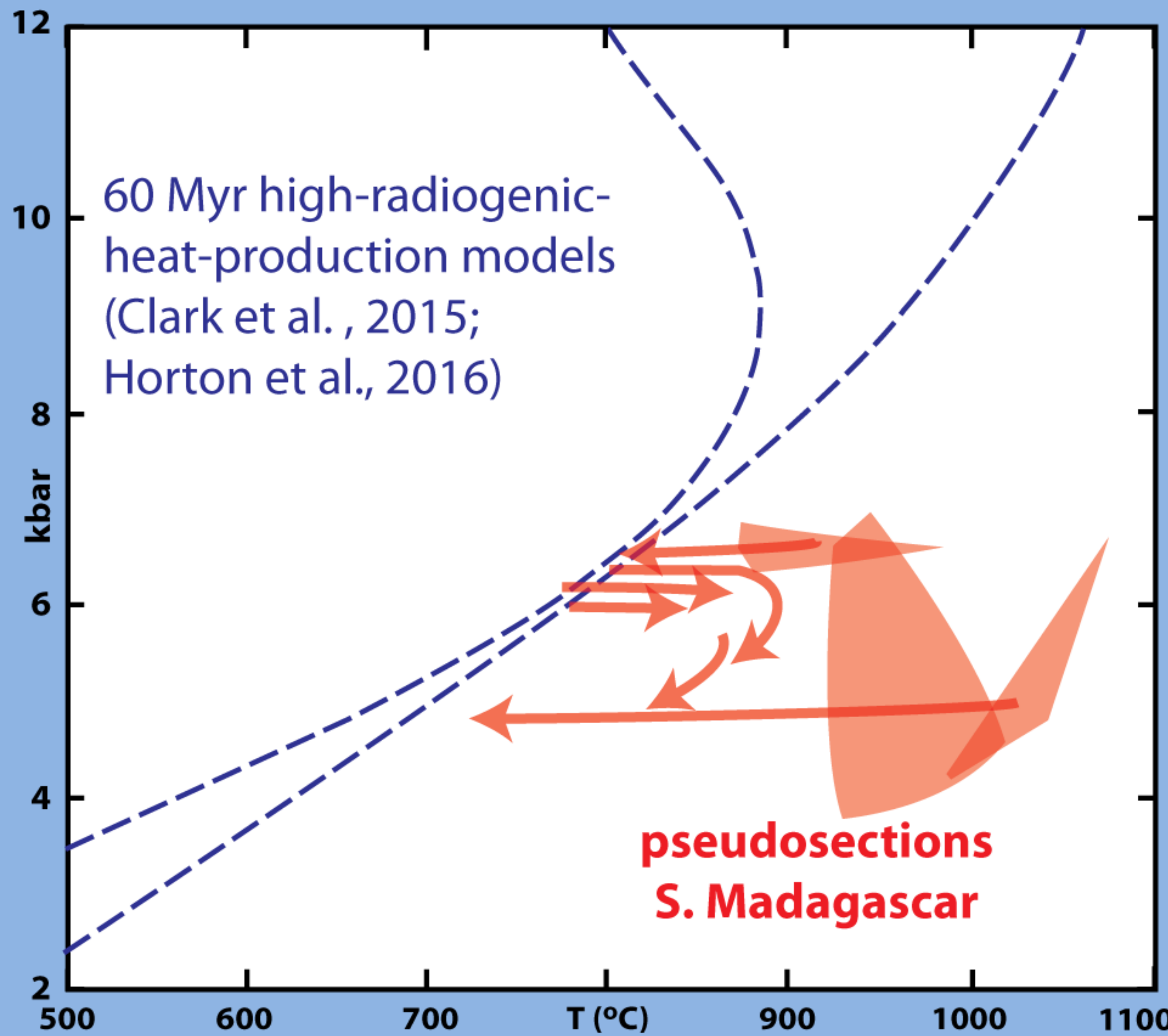


Comparison with radiogenic-heating models

prograde metamorphism ~60 Myr

radiogenic heating alone not enough

Madagascar
> 100 °C hotter



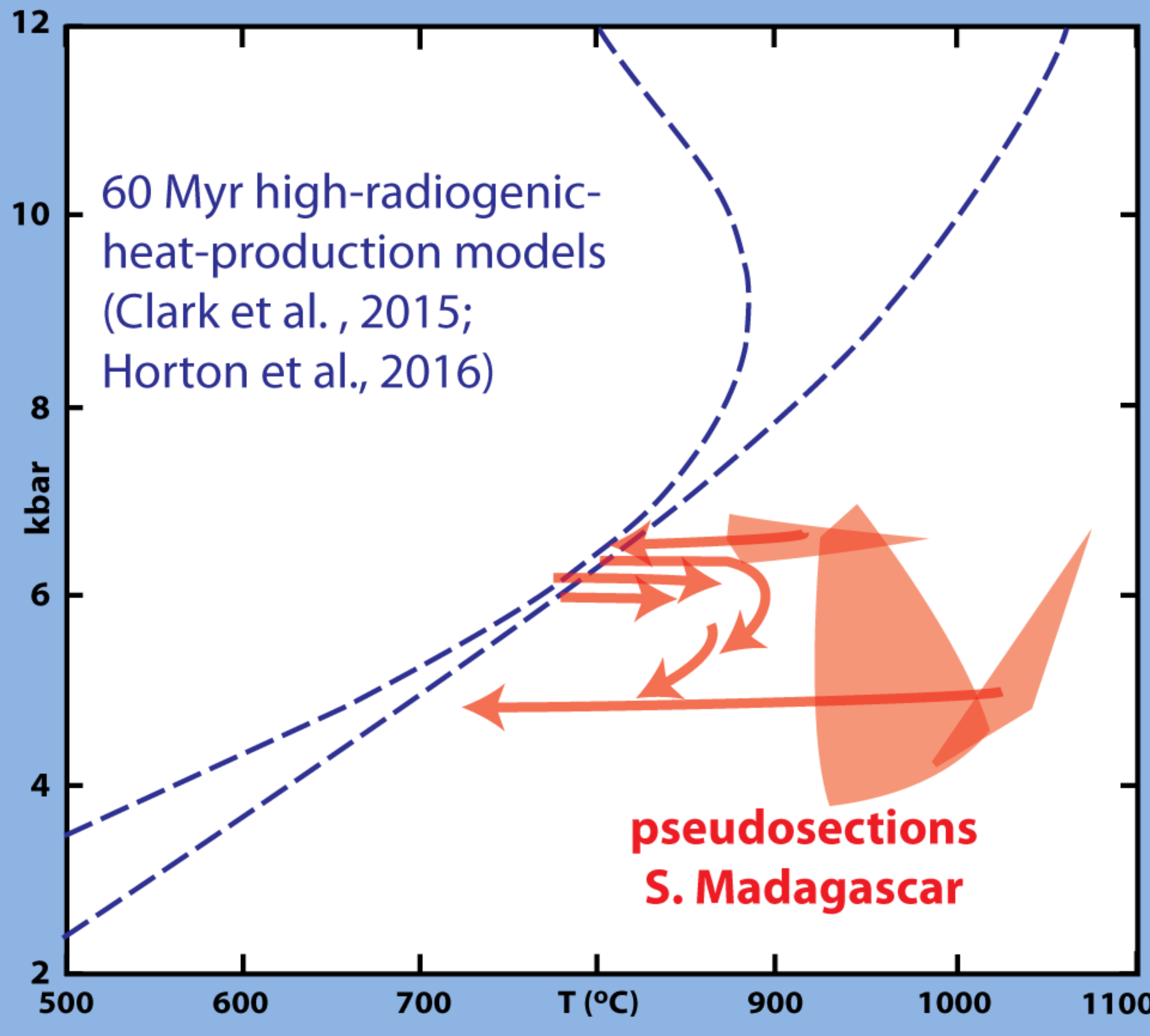
Comparison with radiogenic-heating models

isobaric heating &

< 2 kbar decompression during cooling

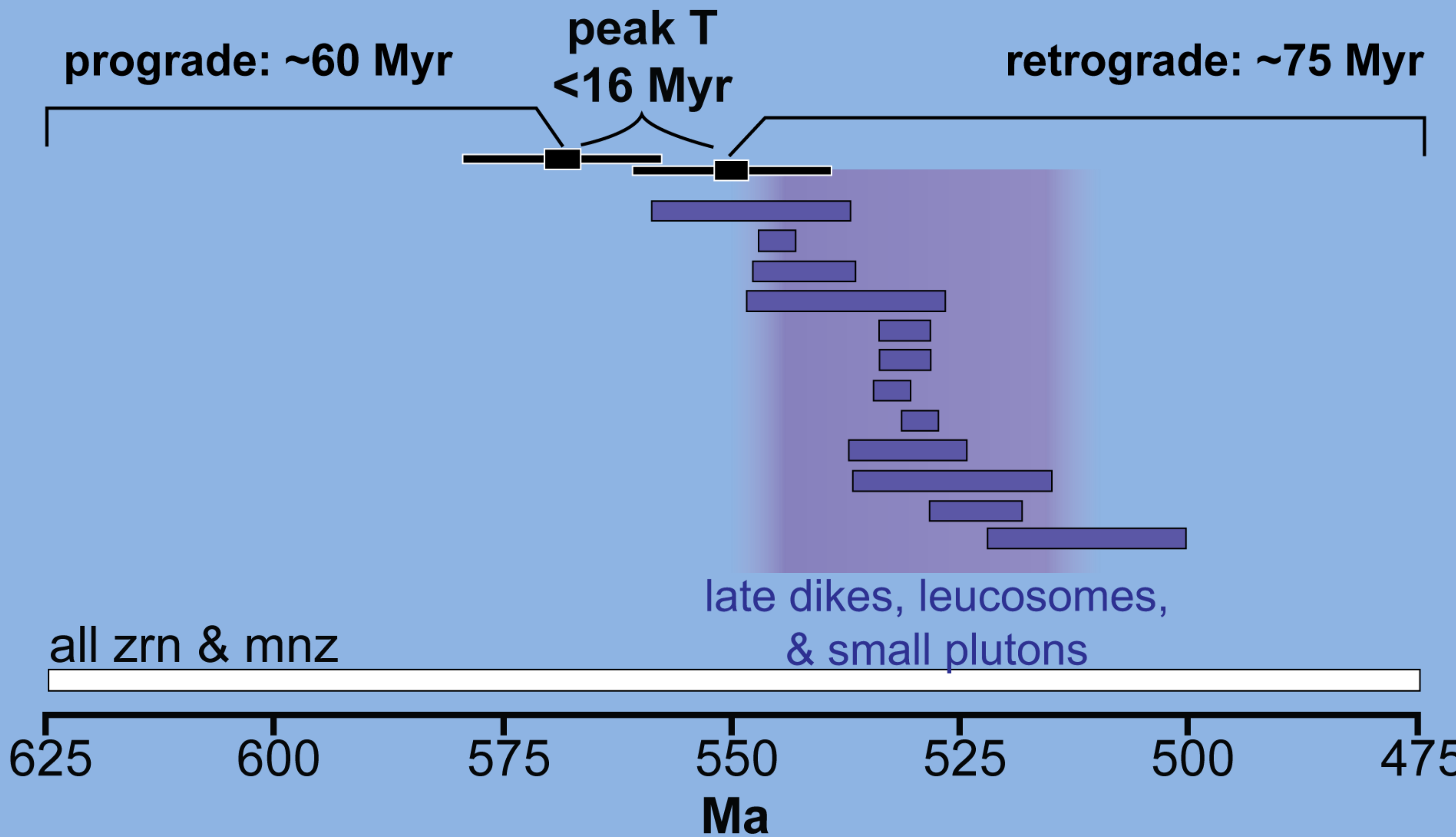
consistent with advective heat source…

…is there other evidence?



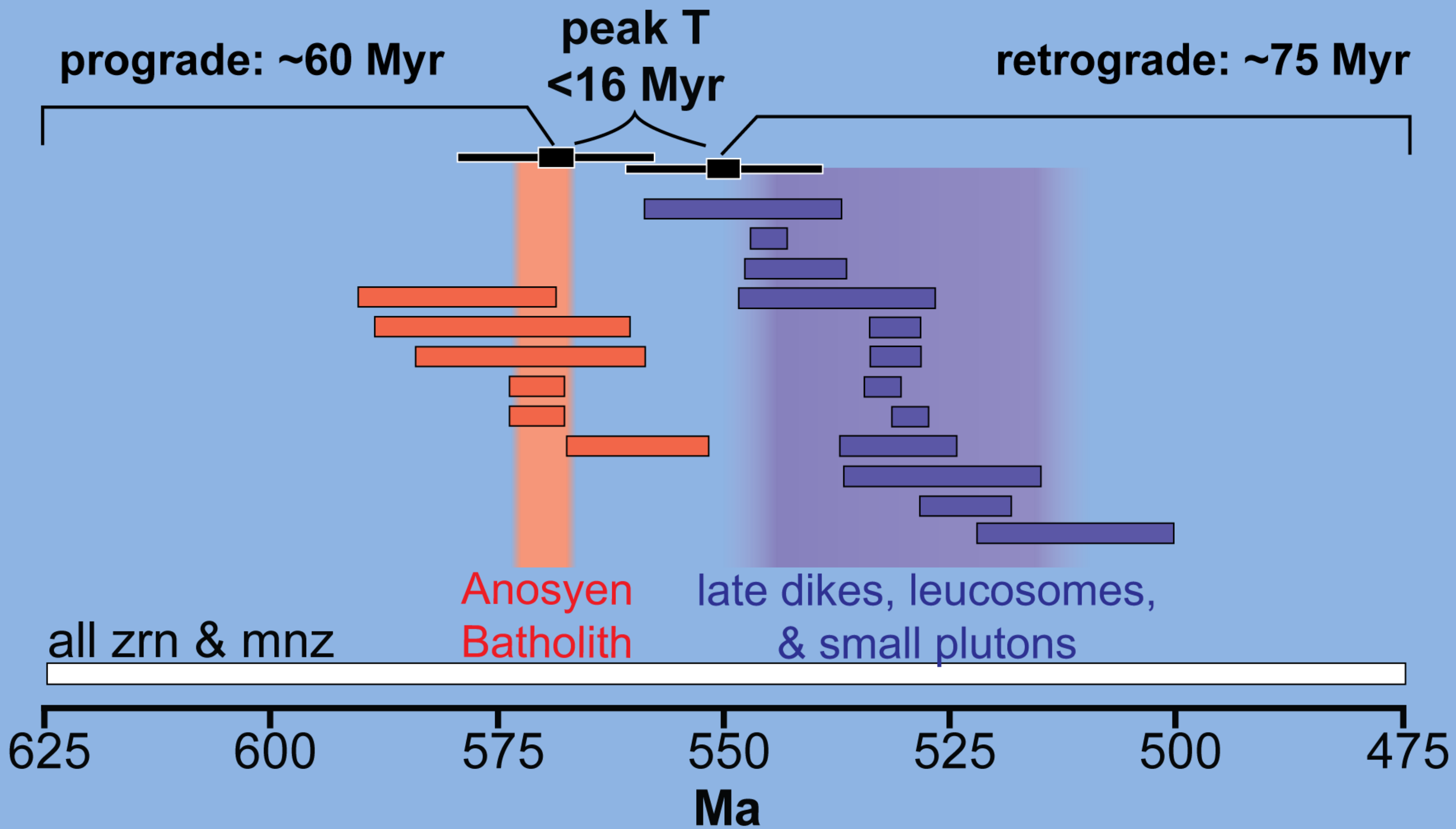
Metamorphism & magmatism

- late-magmatic dates, regional cooling



Metamorphism & magmatism

- Anosyen Batholith: just before/during peak T

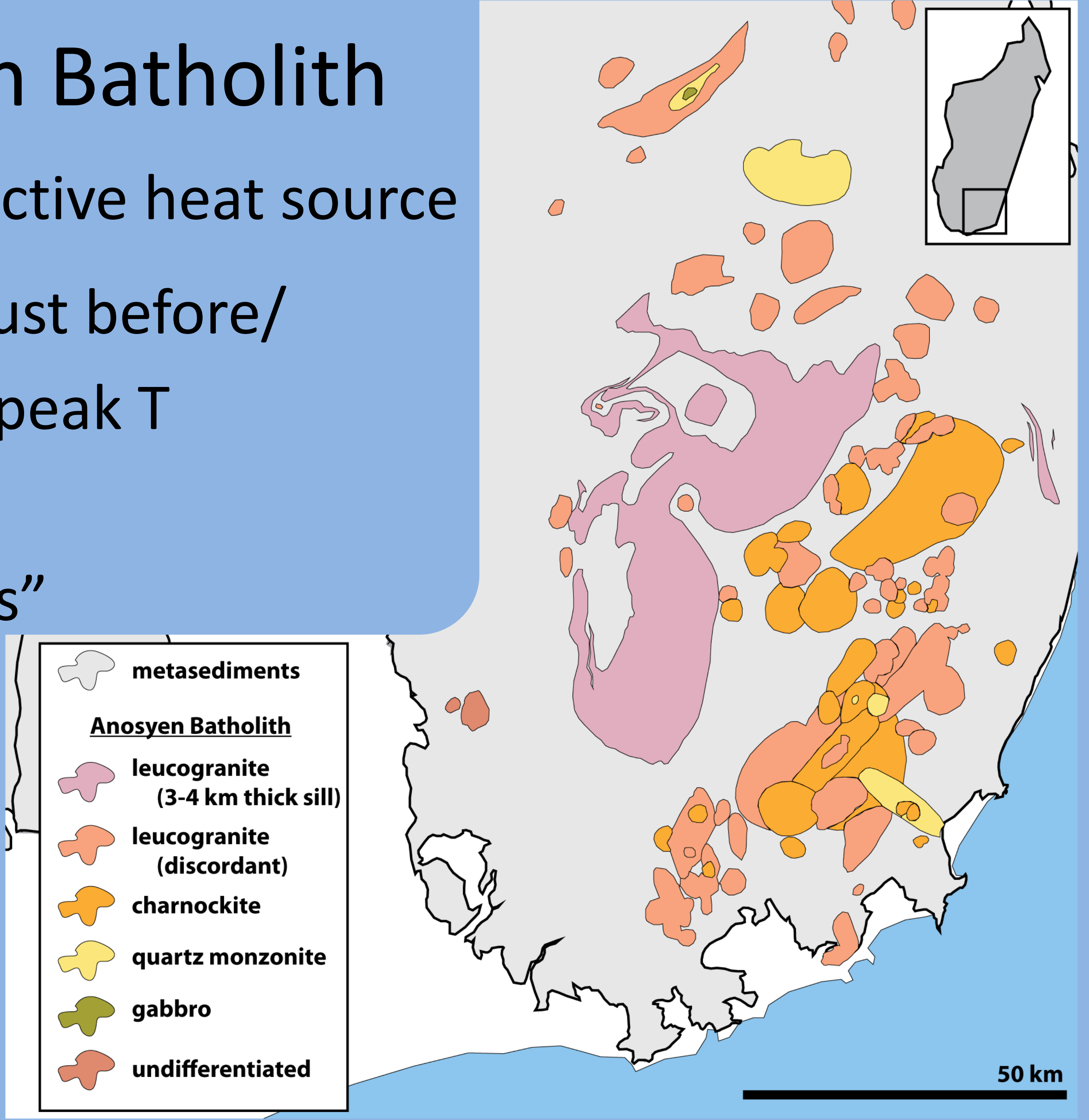


Anosyen Batholith

possible advective heat source

- emplaced just before/ during peak T

"charnockites"

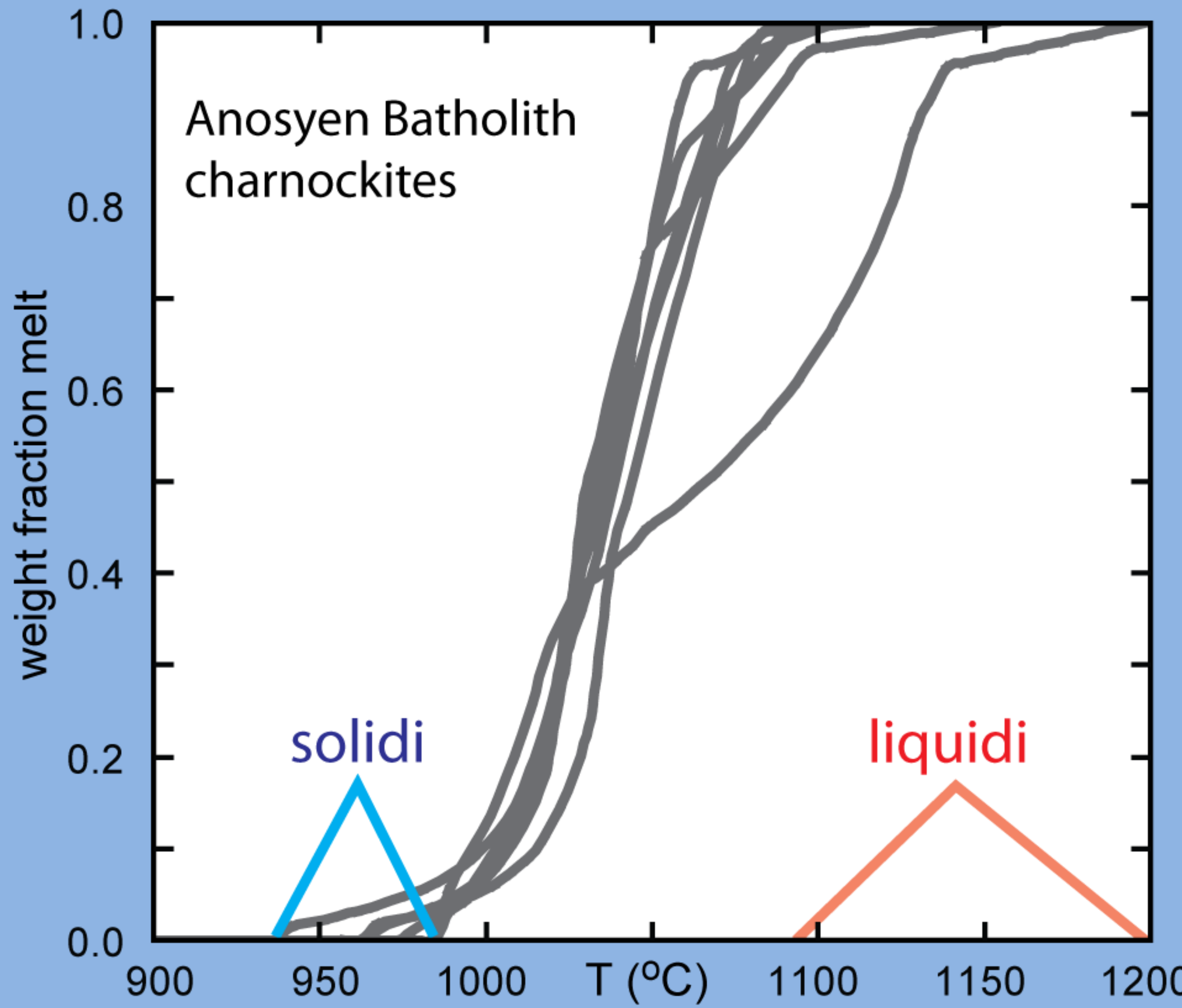


Anosyen Batholith

anhydrous, orthopyroxene-phenocryst granites

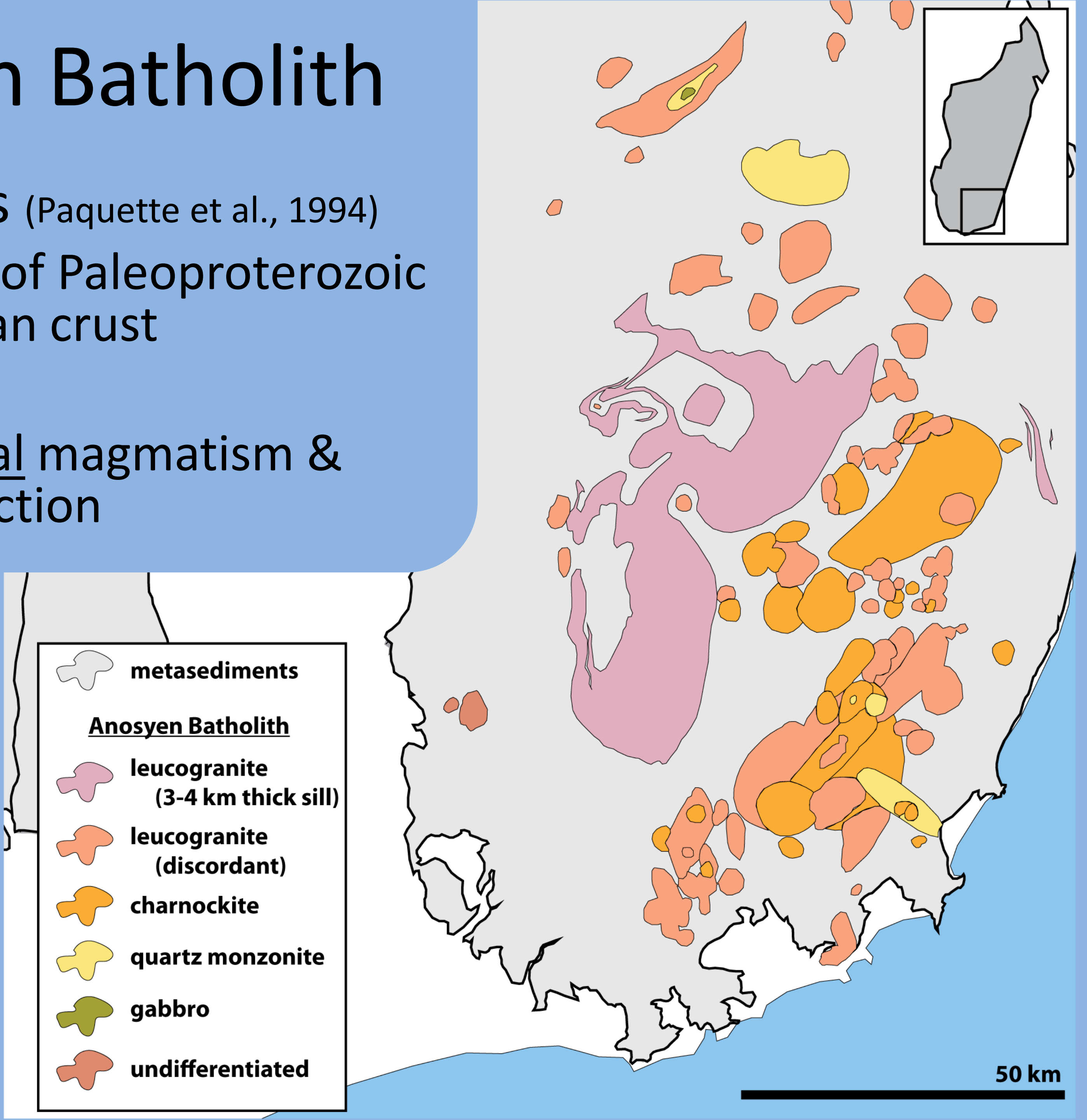
"charnockites"

emplaced
> 1000 °C
likely > 1100 °C



Anosyen Batholith

- Nd isotopes (Paquette et al., 1994)
  - remelting of Paleoproterozoic /Neorchean crust
  - intracrustal magmatism & heat advection

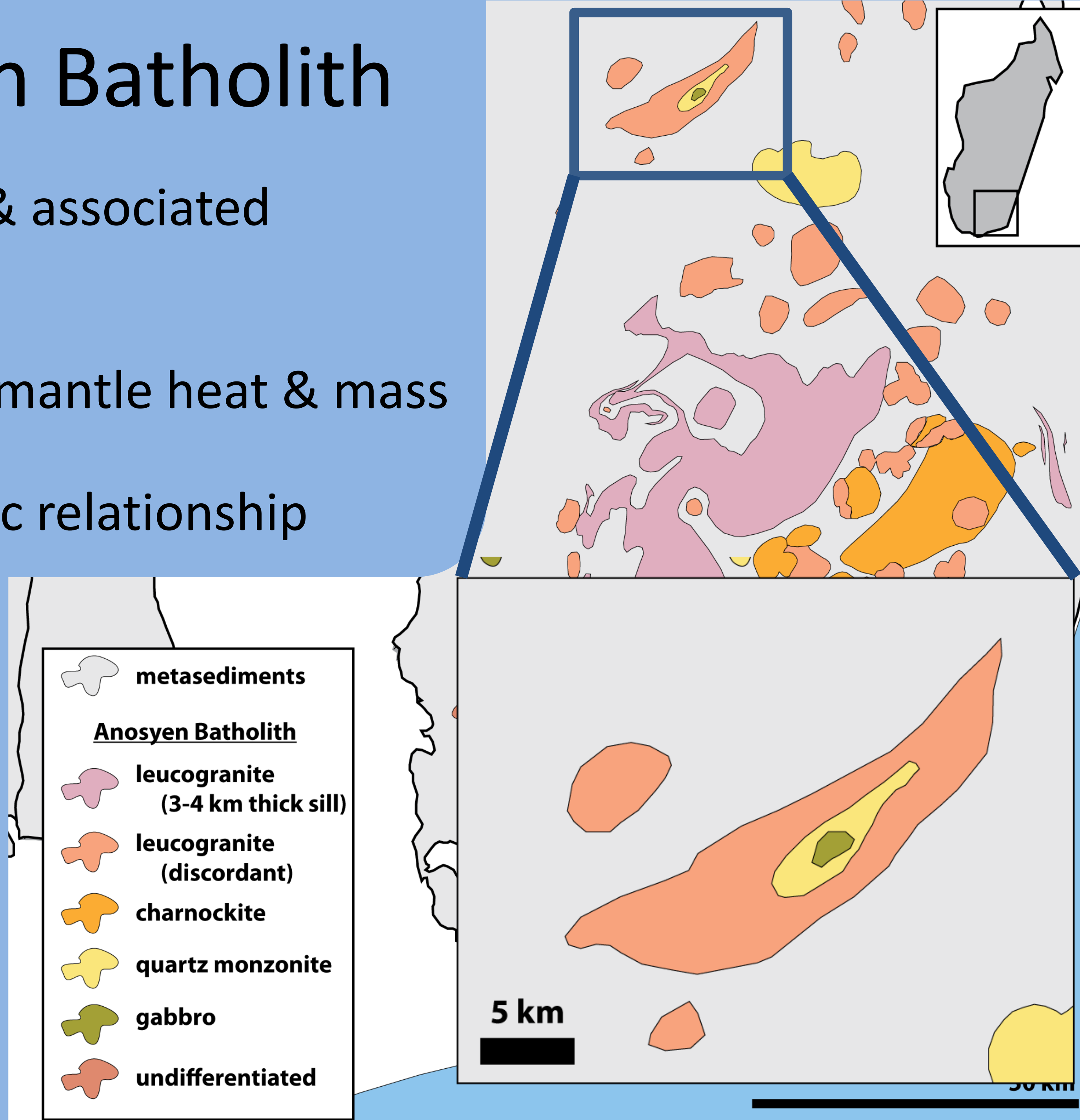


Anosyen Batholith

minor gabbro & associated monzonite

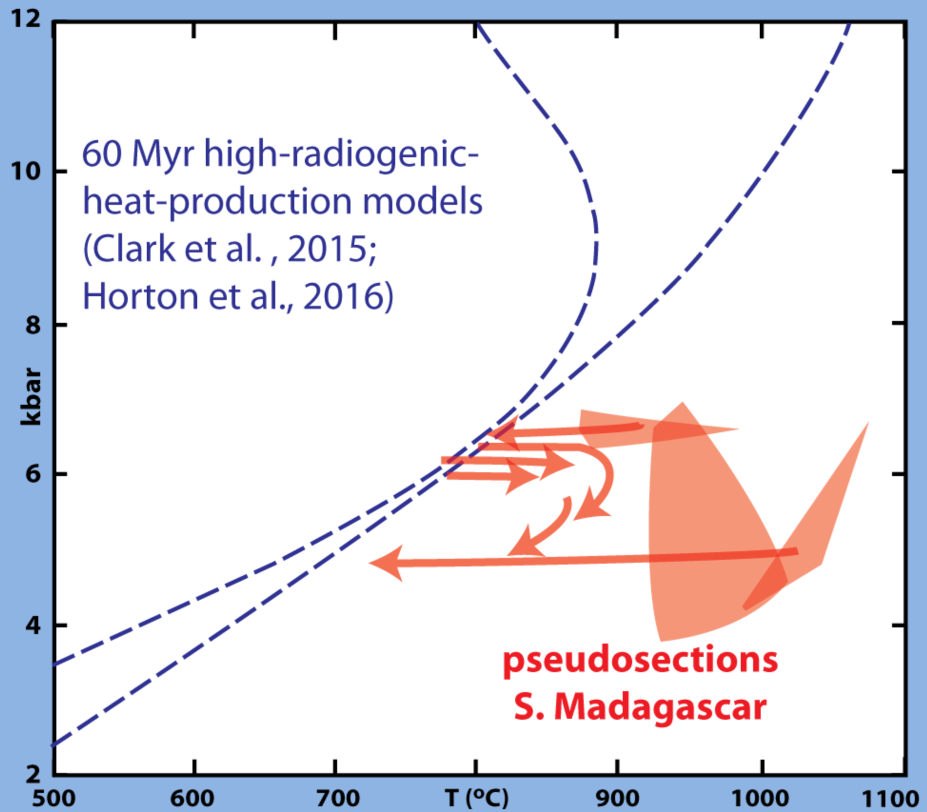
component of mantle heat & mass

possible genetic relationship



Conclusions

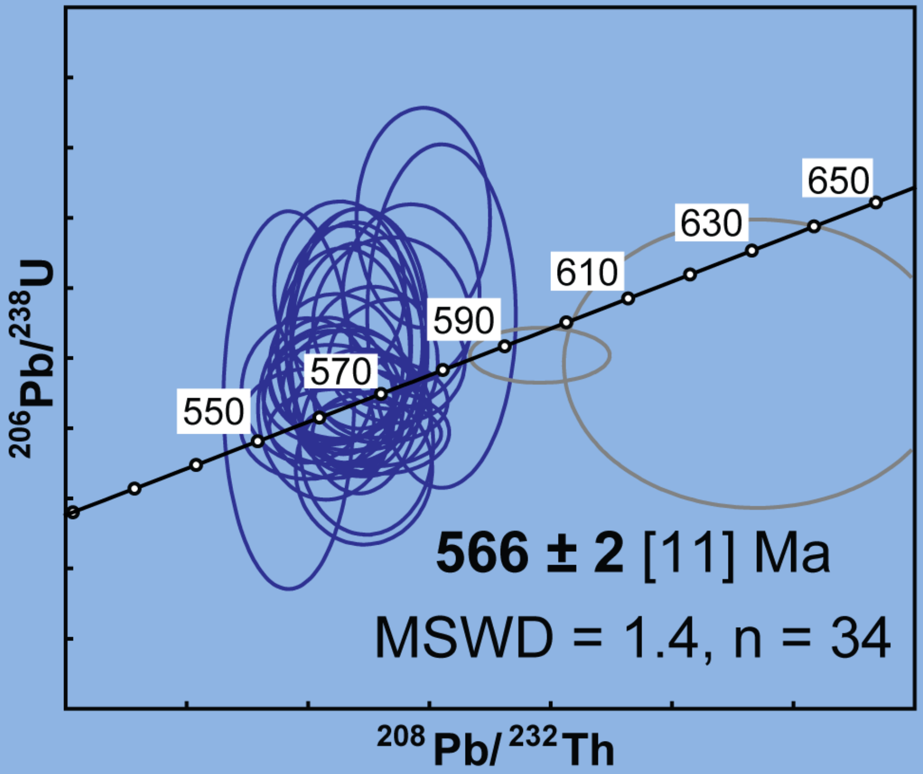
- How did the UHT rocks in Madagascar get so hot?
  - even high radiogenic heat production is not enough to produce UHT rocks in Madagascar
  - PT paths suggest an advected component
  - high-temperature crustal melts may be responsible
  - some component of mantle involvement

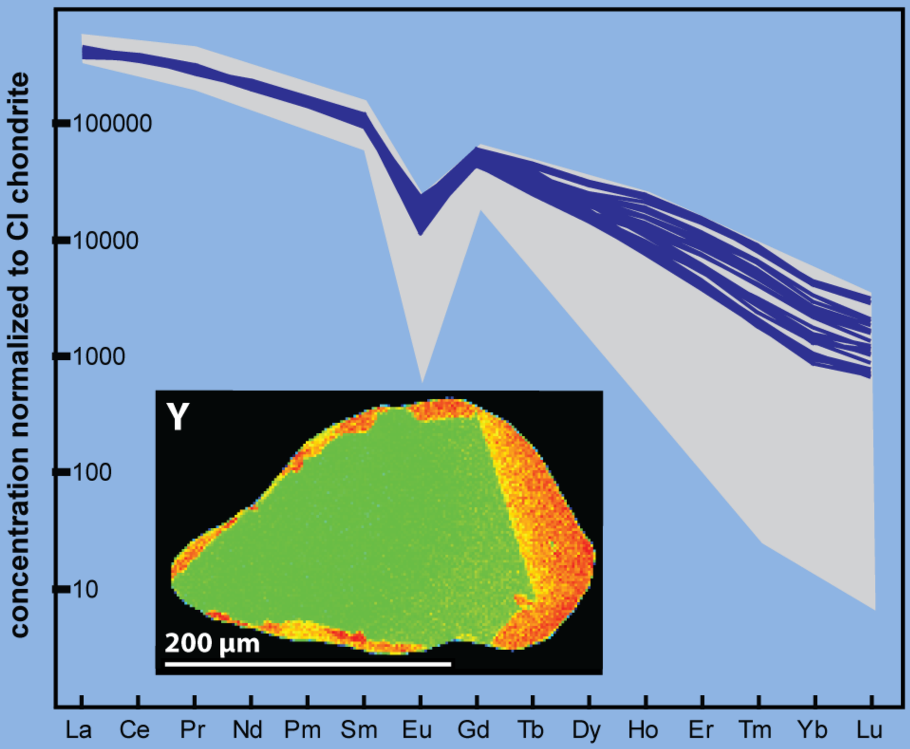


Timing of peak metamorphism

monazite inclusions in osumilite pseudomorphs

-max. date for osm growth ($T \geq 850\ ^oC$)





Timing of peak metamorphism

monazite in leucosomes at osumilite outcrop

-date of leucosome crystallization (T ≤ 925 ^{o}C)