Quartz-in-garnet elastic barometry vs. conventional thermobarometers: a comparison across diverse tectonic settings

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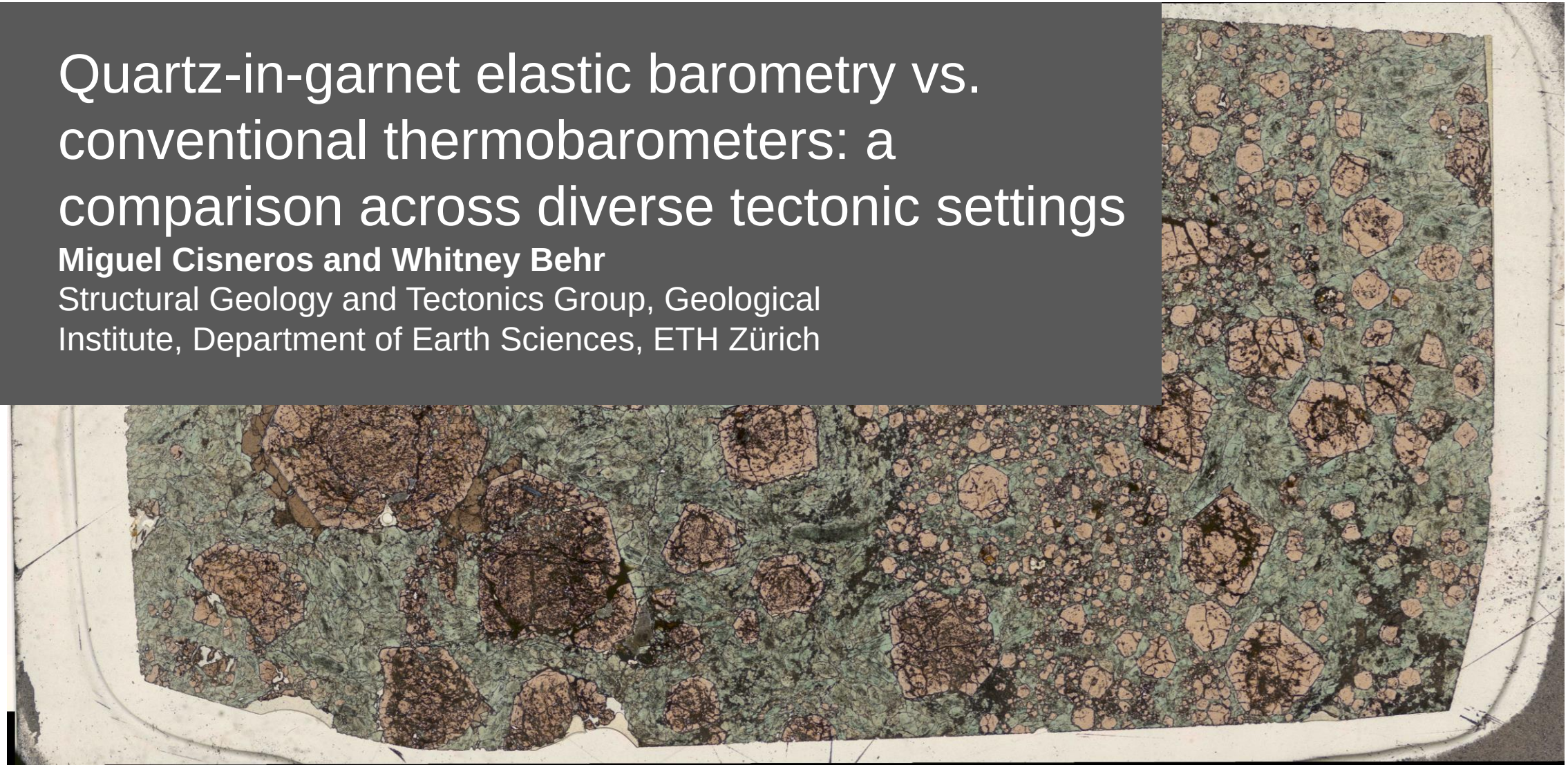

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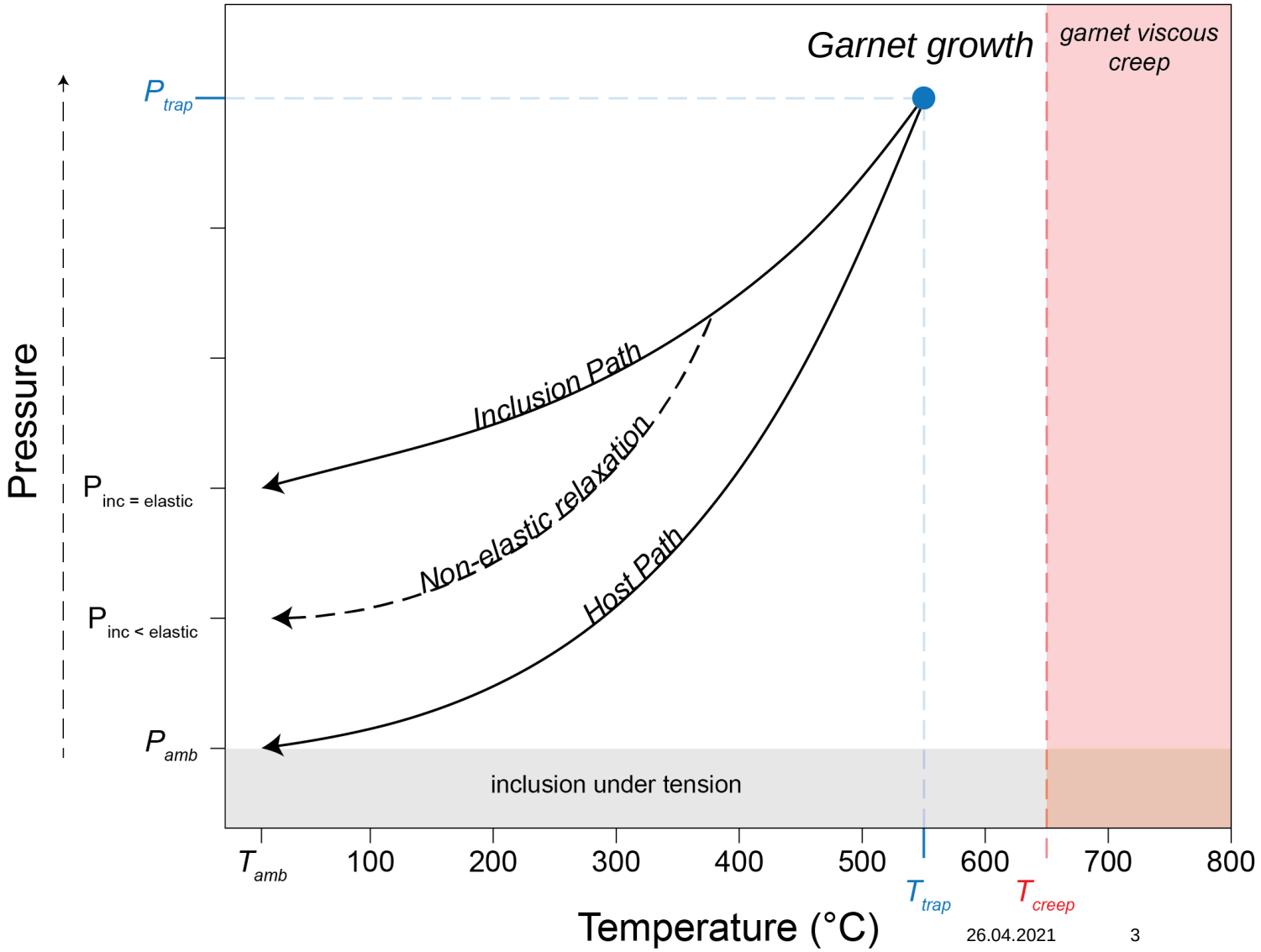
Motivation and elastic thermobarometry background

Motivation: *Current studies don't capture the reliability of the technique under disparate P-T and deformation conditions, and studies that systematically compare QuiG and conventional thermobarometry are lacking.*

Multiple processes can affect quartz-in-garnet barometry pressures.

- When garnet grows (P_{trap}, T_{trap}), the P of quartz and garnet are equal.
- Upon exhumation, quartz (highly compressible) can expand more than garnet, and retain a pressure (P_{inc}) when P_{garnet} = 0.1 MPa (ambient, P_{amb})
- Use P_{inc} and elastic modeling to calculate P_{trap} (assume T_{trap}).
- Relaxation can deviate from being elastic ($P_{inc < or > elastic}$) if garnet flow (creep) occurs.



Questions that we test

- How accurate are the calculated entrapment pressures (P_{trap})?
- How large can quartz strain/stress anisotropy be?
- How large are the effects of viscous creep of garnet?
- How much tension can inclusions preserve (garnets that grow at low P and high T, will have inclusions that preserve tension)?
- Is reaction overstepping common?
- How do inclusion parameters (e.g., size, shape) affect calculated pressures?

Franciscan Complex: Sample localities and rock types

Samples *(Northern Franciscan: Central Belt)*

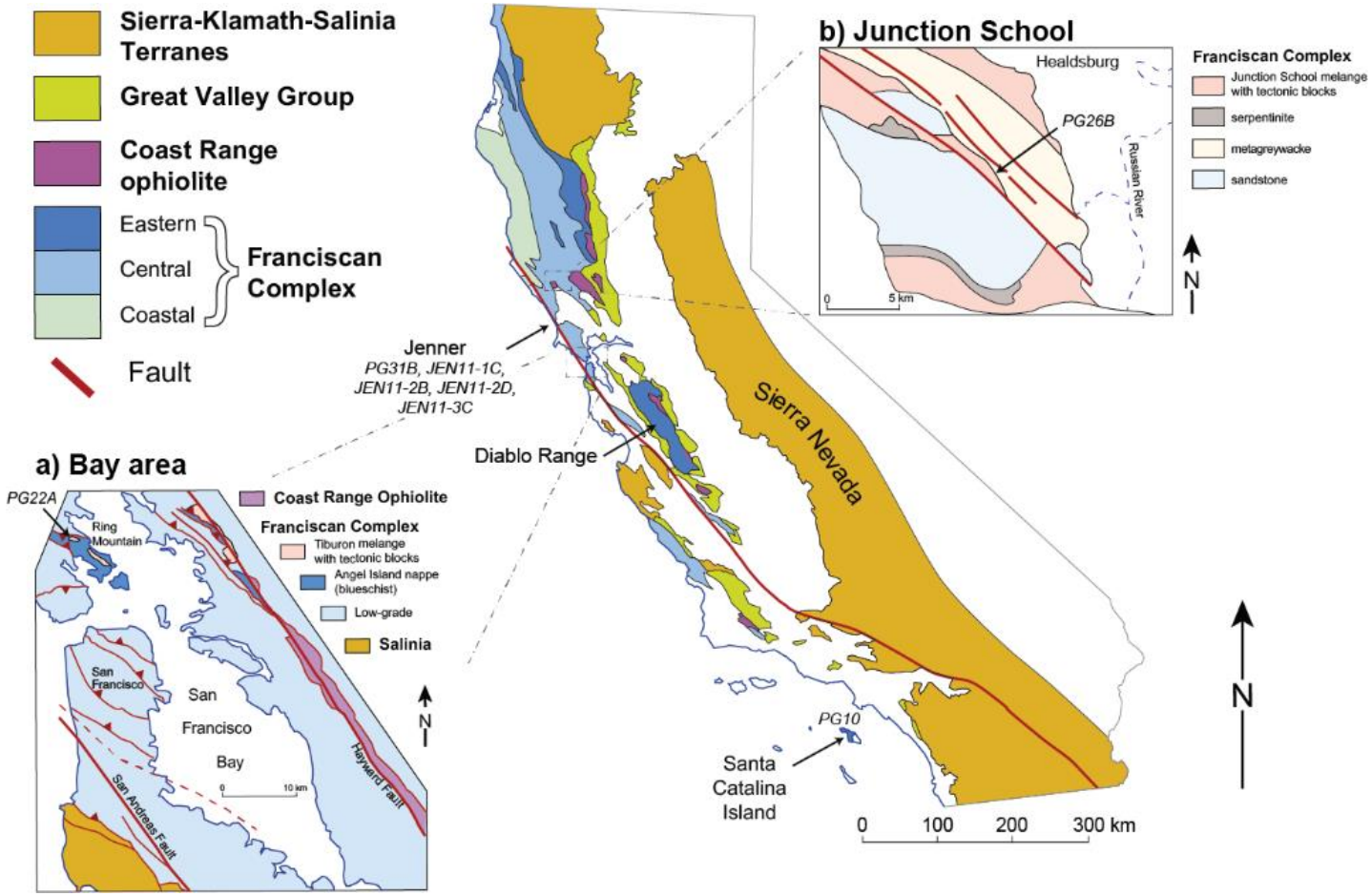
- Junction School: 1 eclogite (PG26B)
- Ring Mountain: 1 eclogite (PG22A)
- Jenner Beach: 5 eclogites

Reference max pressures and temperatures (eclogites): ~ 1.0 – 3.0 GPa and ~ 450 – 550 °C

Pressures of eclogites from different localities vary

Catalina Island: 1 eclogite (PG10)

Reference max pressures and temperatures (non-eclogites): ~ 1.0 – 1.4 GPa and ~ 650 °C – 700 °C



Cisneros et al., in prep

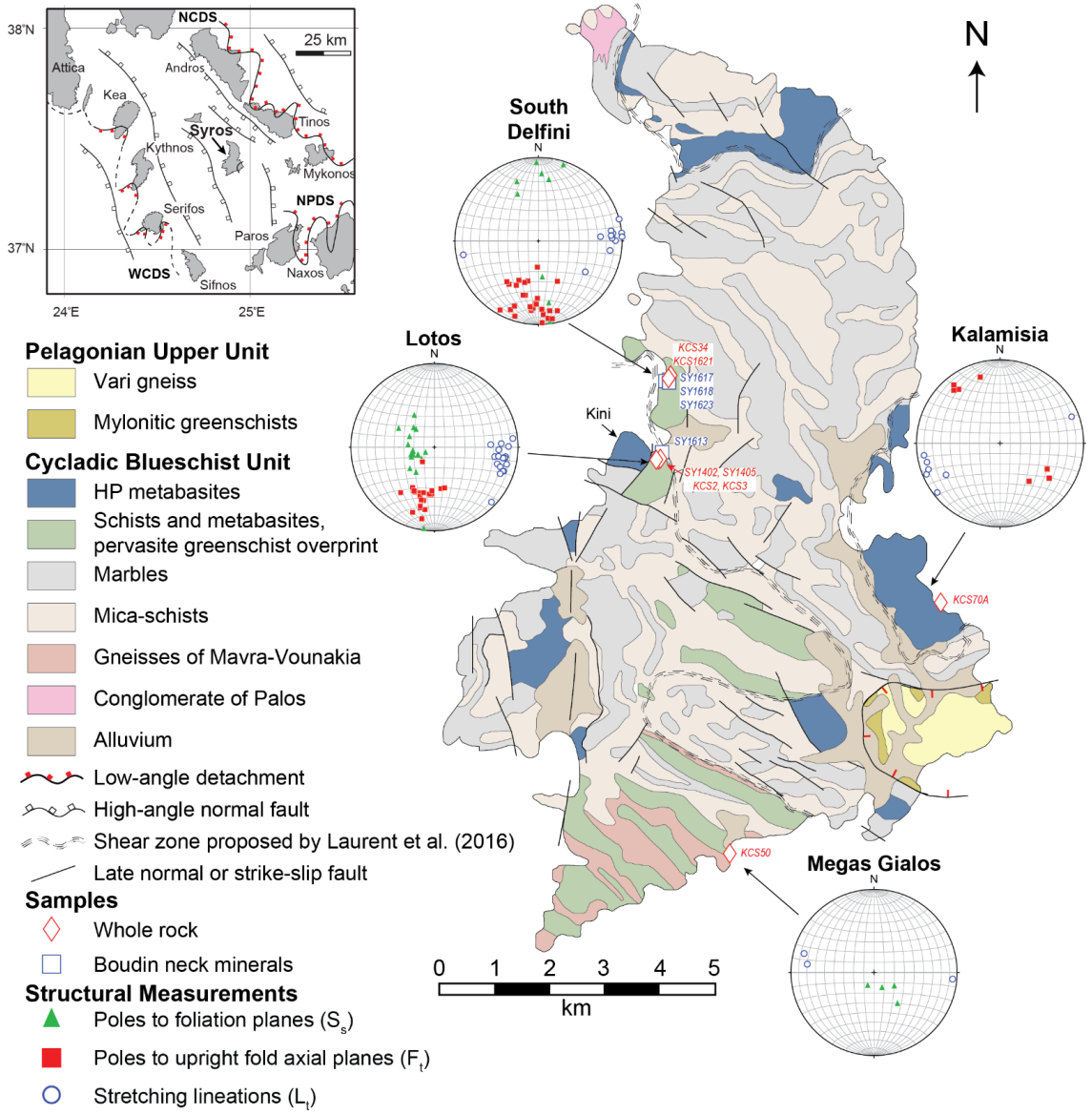
Syros, Greece: Sample localities and rock types

Samples *(Cycladic Blueschist Unit)*

- Delfini Beach: 1 metasediment (retrograde)
- Kalamisia: 1 mafic blueschist (retrograde)
- Megas Gialos: 1 metasediment (retrograde)
- *Kini: 4 blueschists/eclogites (prograde)**
  **reference P constraints*

Reference max pressures of CBU (Syros): ~1.5 – 2.4 GPa

Reference temperatures: ~500 – 550 °C

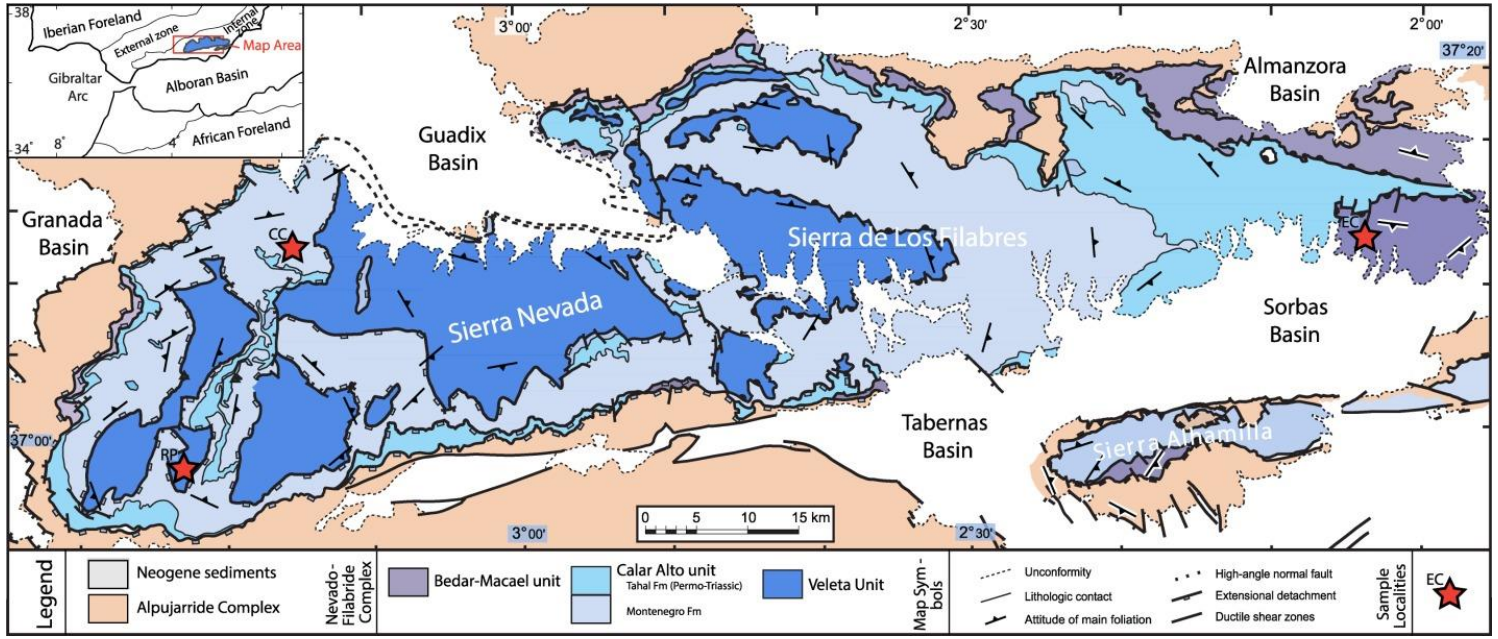


Cisneros et al., in review

Betics, Spain: Sample localities and rock types

Samples *(Nevado-Filabride Complex)*

- Mulcahen Unit: 1 metasediment (WB137)
- Mulcahen Unit : 1 eclogite (KB20)



Kirchner et al., 2016

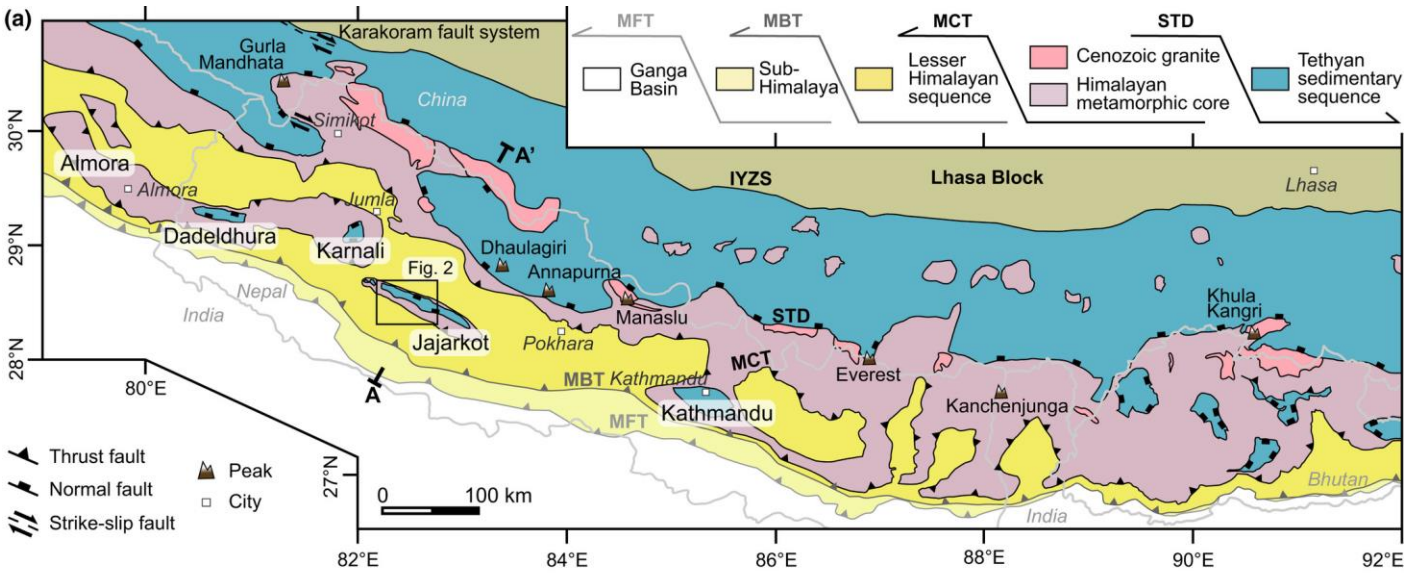
Reference max pressures and temperatures (eclogites): ~ 1.0 – 1.6 GPa and ~ 450 – 550 °C

Pressures of eclogites from different localities vary

Himalayas: Sample localities and rock types

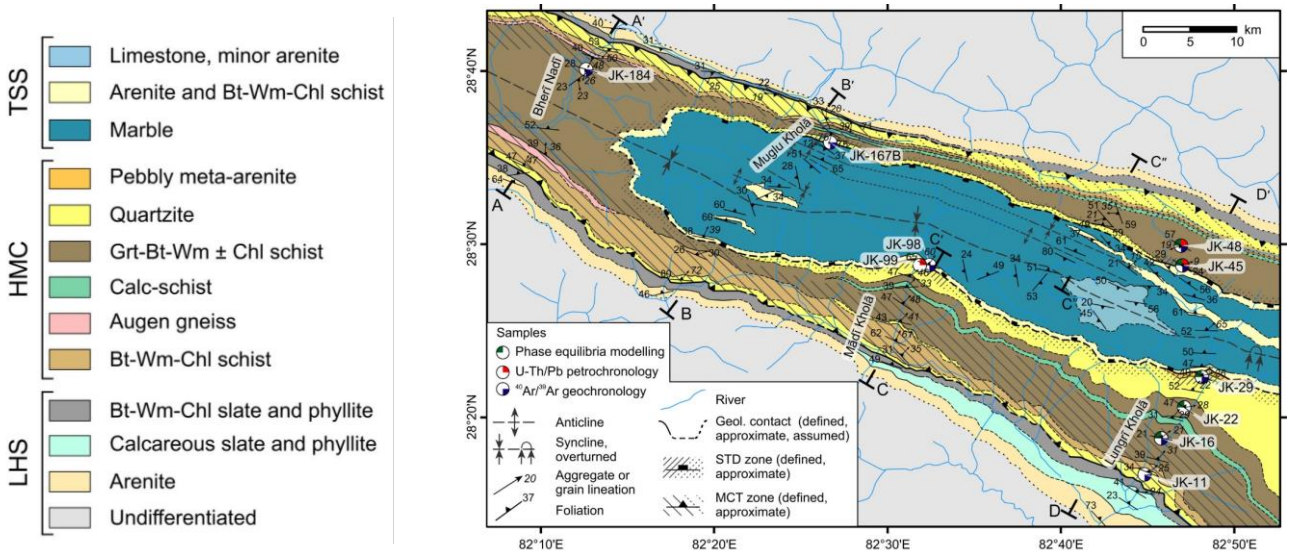
Samples *(Jajarkot Klippe)*

- JK-16: metasediment
- JK-22: metasediment



JK-16 reference conditions (La Roche et al., 2019)
Core: 0.73 GPa and 545 °C
Rim: 0.96 GPa and 580 °C

JK-22 reference conditions (La Roche et al., 2019)
Core: 0.72 GPa and 525 °C
Rim: 0.9 - 0.92 GPa and 570-580 °C



La Roche et al., 2019

Calculating inclusion pressures

- ΔP_{inc} calculated from hydrostatic calibrations, and by accounting for anisotropy, generally < 0.1 GPa (~80%).

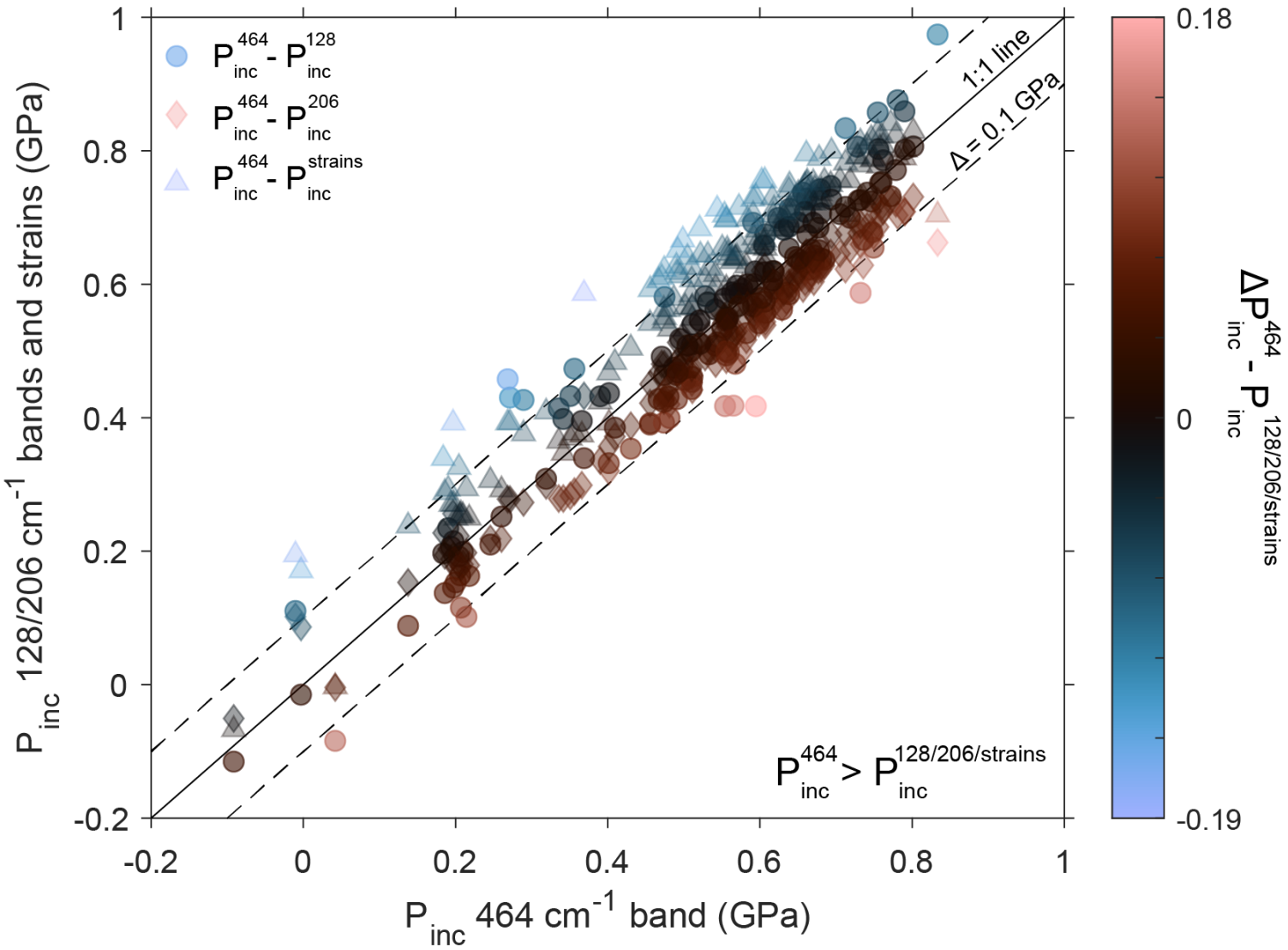
- P_{inc} calculated from quartz strains (accounting for anisotropy) > P_{inc} from 464 cm^{-1} band (~ 95%).

- P_{inc} 464 cm^{-1} band > P_{inc} 128 cm^{-1} band (~ 57%); P_{inc} 464 cm^{-1} band > P_{inc} 206 cm^{-1} band (~ 87%).

- Large ΔP_{inc} not seen.

P_{inc} calculated from different quartz bands and from strains:

$\Delta P_{inc} = P_{inc}$ 464 (cm^{-1}) - P_{inc} 128/206 (cm^{-1}) or strains

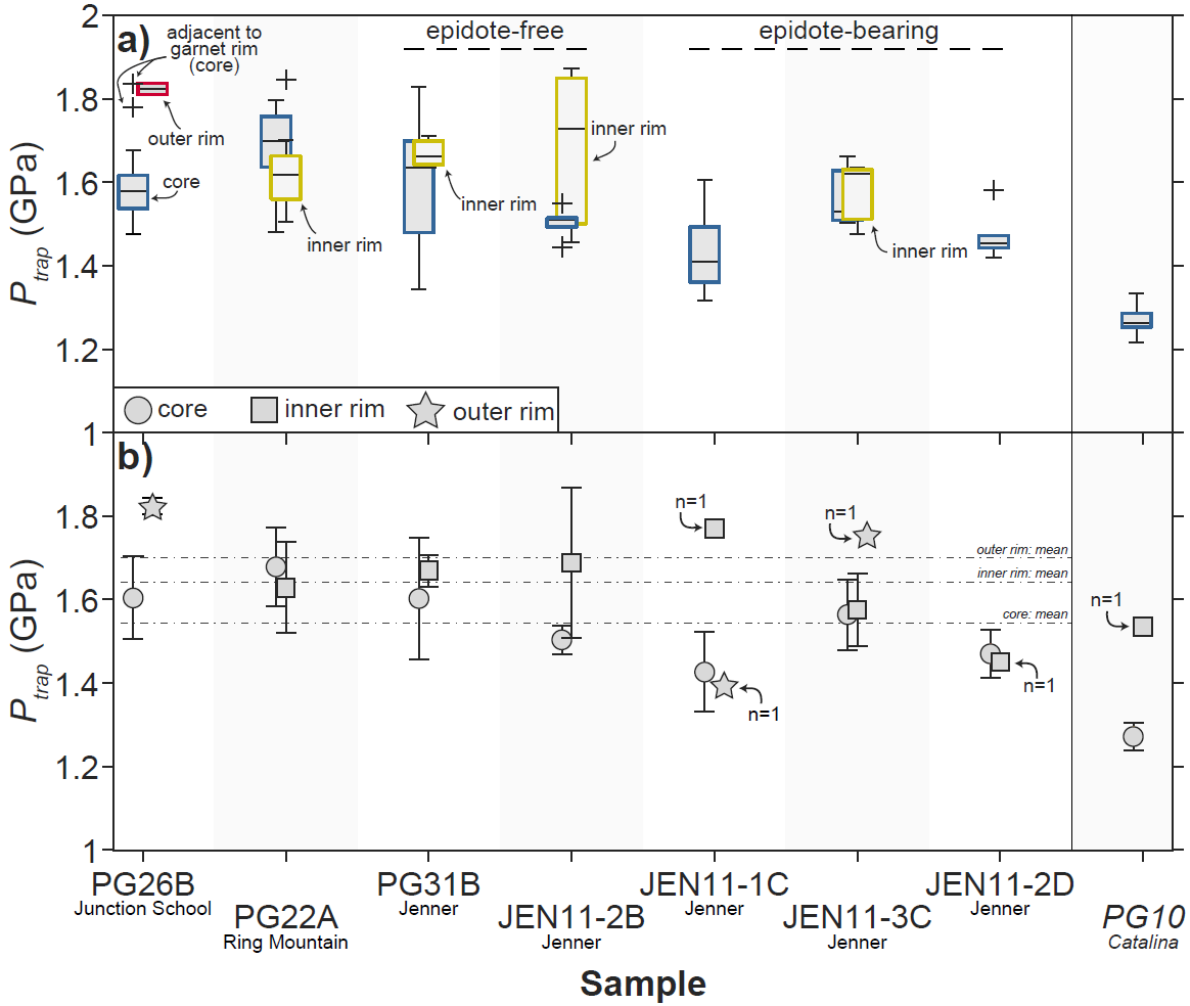


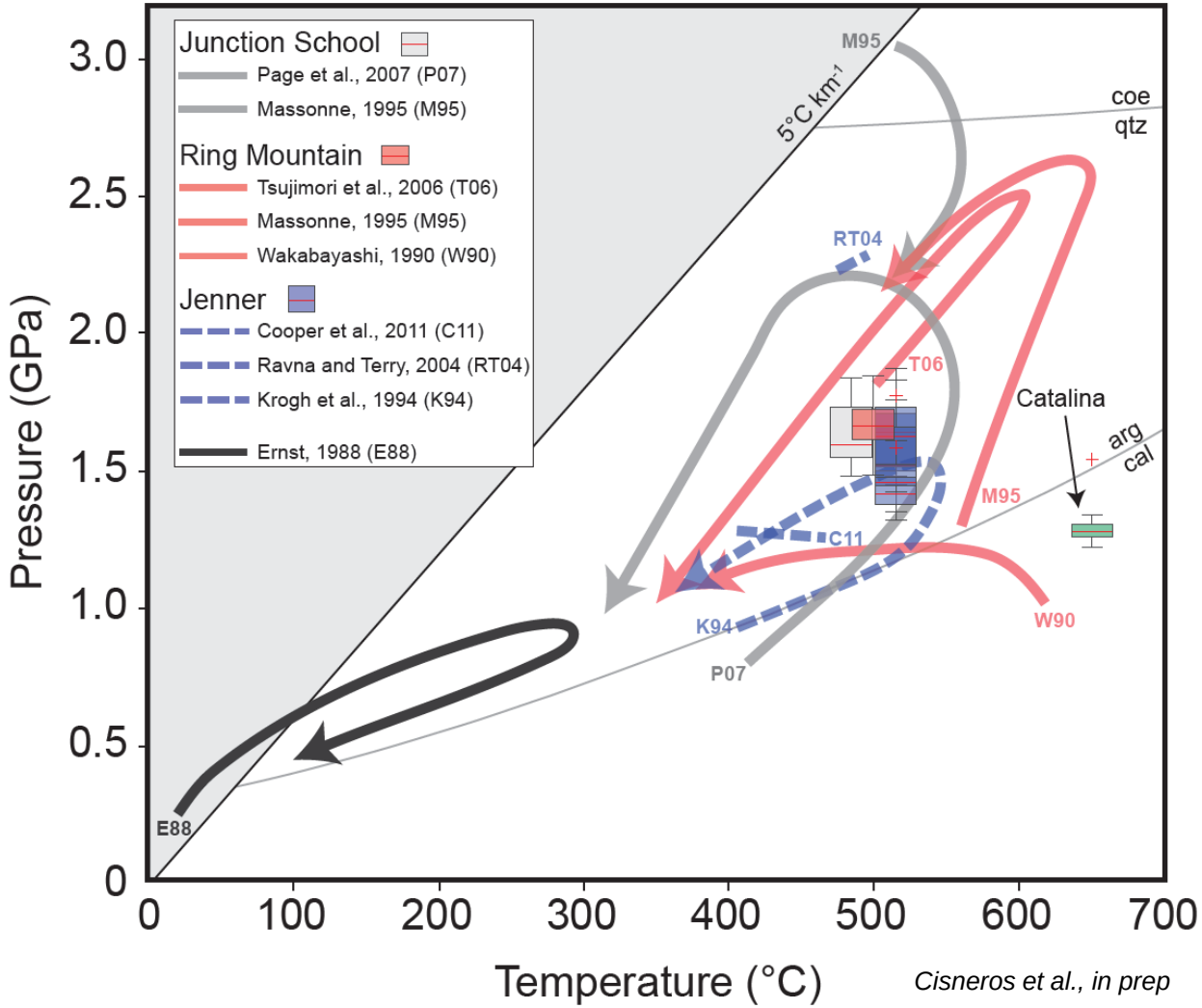
Franciscan Complex Pressures

Northern Franciscan: Similar P from different eclogite blocks
**most reference constraints from grt-px-wm thermobarometry*

Catalina: Lower P, good agreement with previous P constraints

Minor P increase from core-to-rim

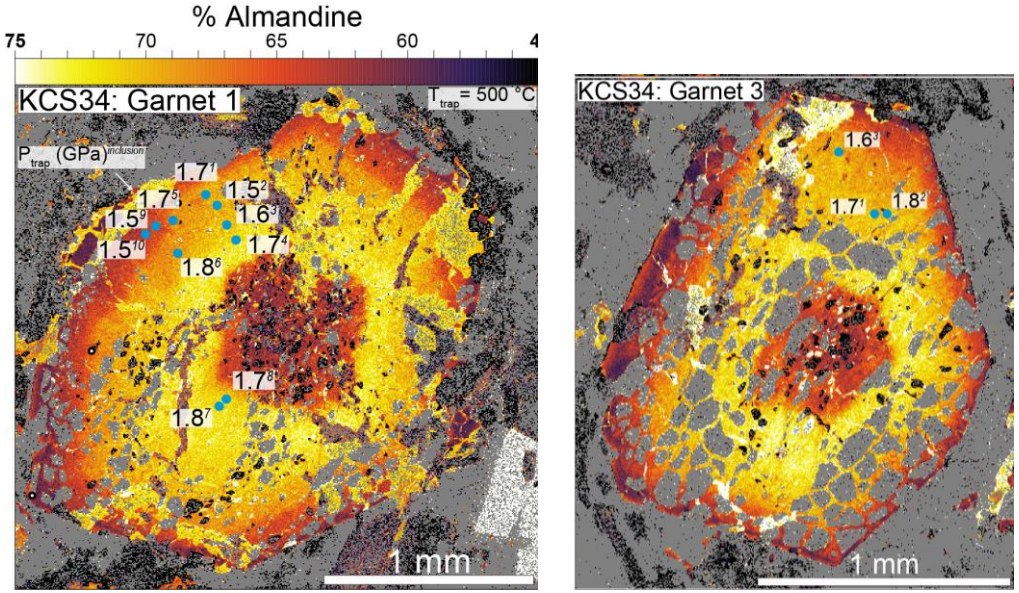




Cisneros et al., in prep

Syros, Greece Pressures

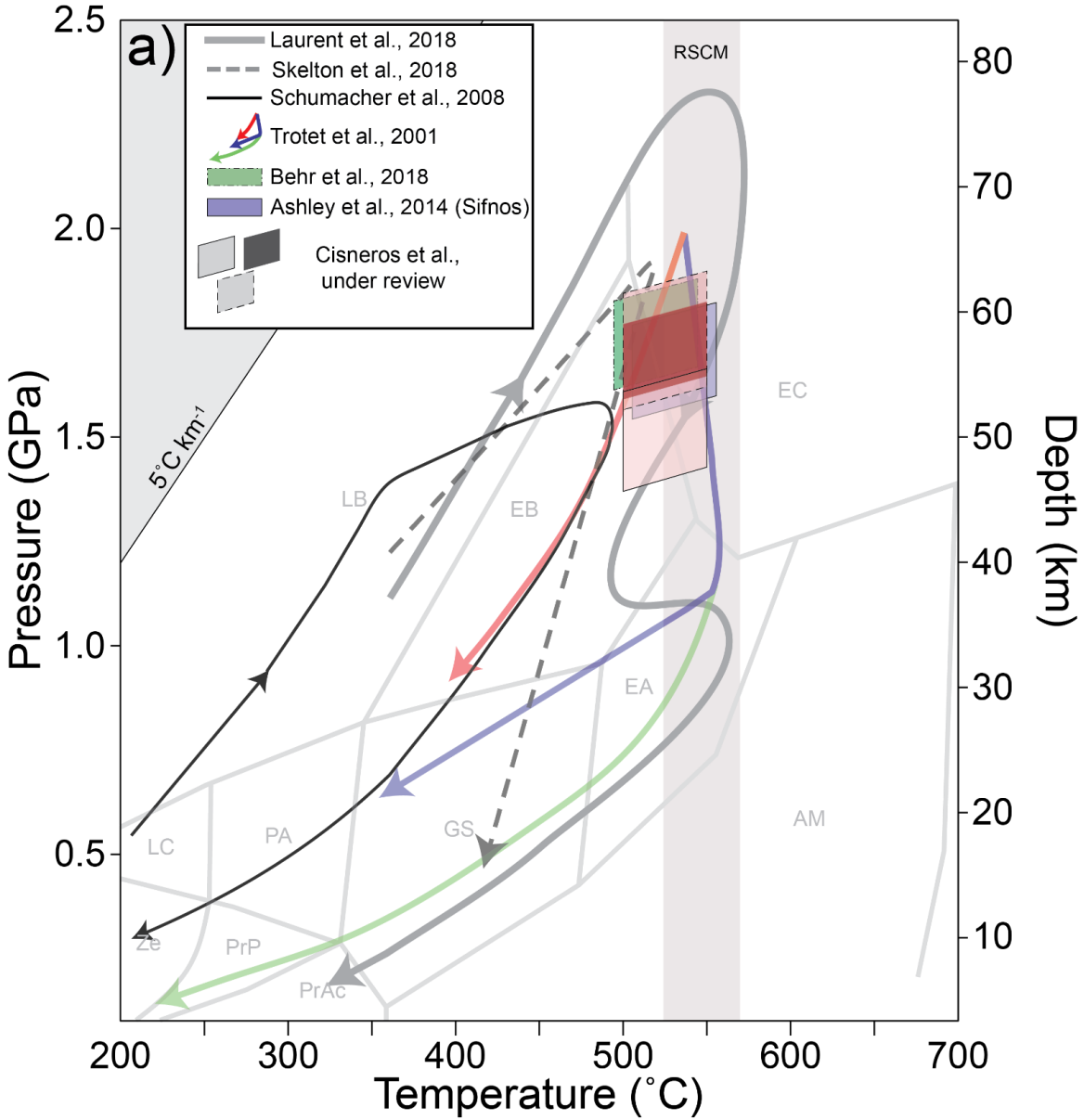
- Garnets exhibit near isobaric growth (no systematic P change from core-to-rim).



- Good agreement with some reference P-T constraints (lower pressures).

- Good agreement with phase stability relationships.

- Disagreement with high pressures from thermodynamic modeling.

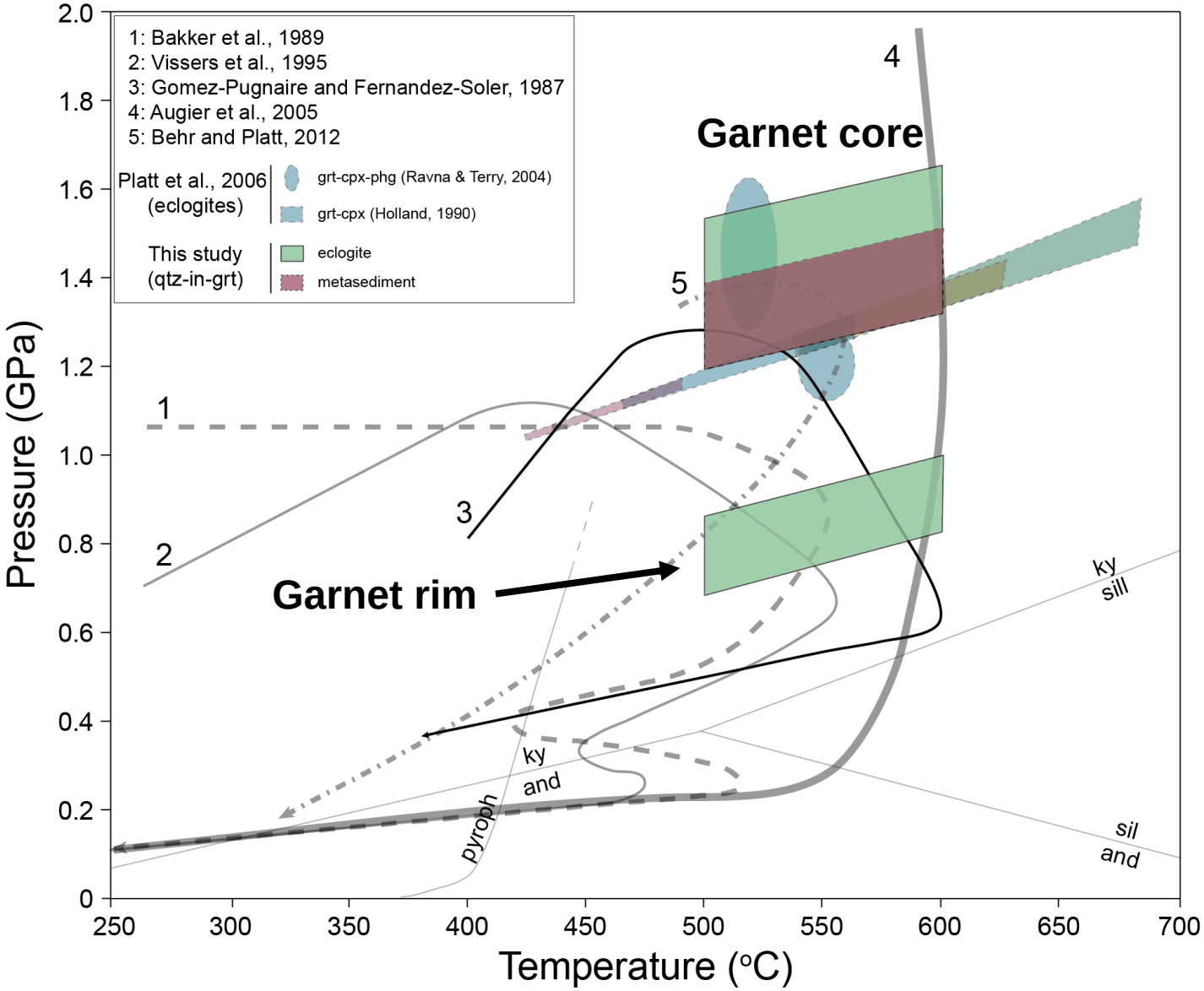


Cisneros et al., under review

Betics, Spain Pressures

- Good agreement with higher P reference constraints.

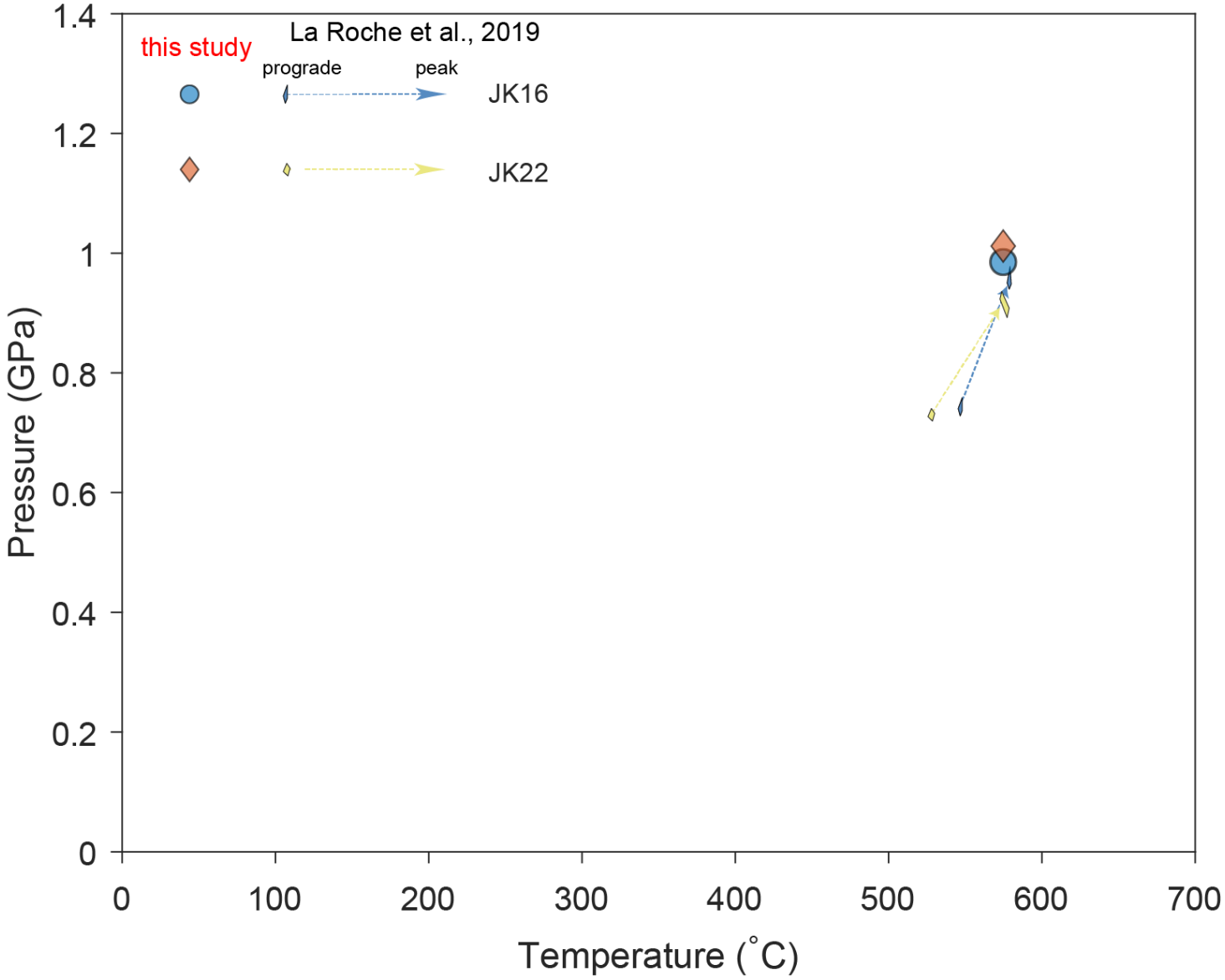
- Garnets may show very protracted growth.



Himalayas Pressures

- Quartz-in-garnet barometry and thermodynamic modeling from the same samples.

- Excellent agreement with pressures from the same samples (pressures from near rims).



Comparison of garnet growth pressures

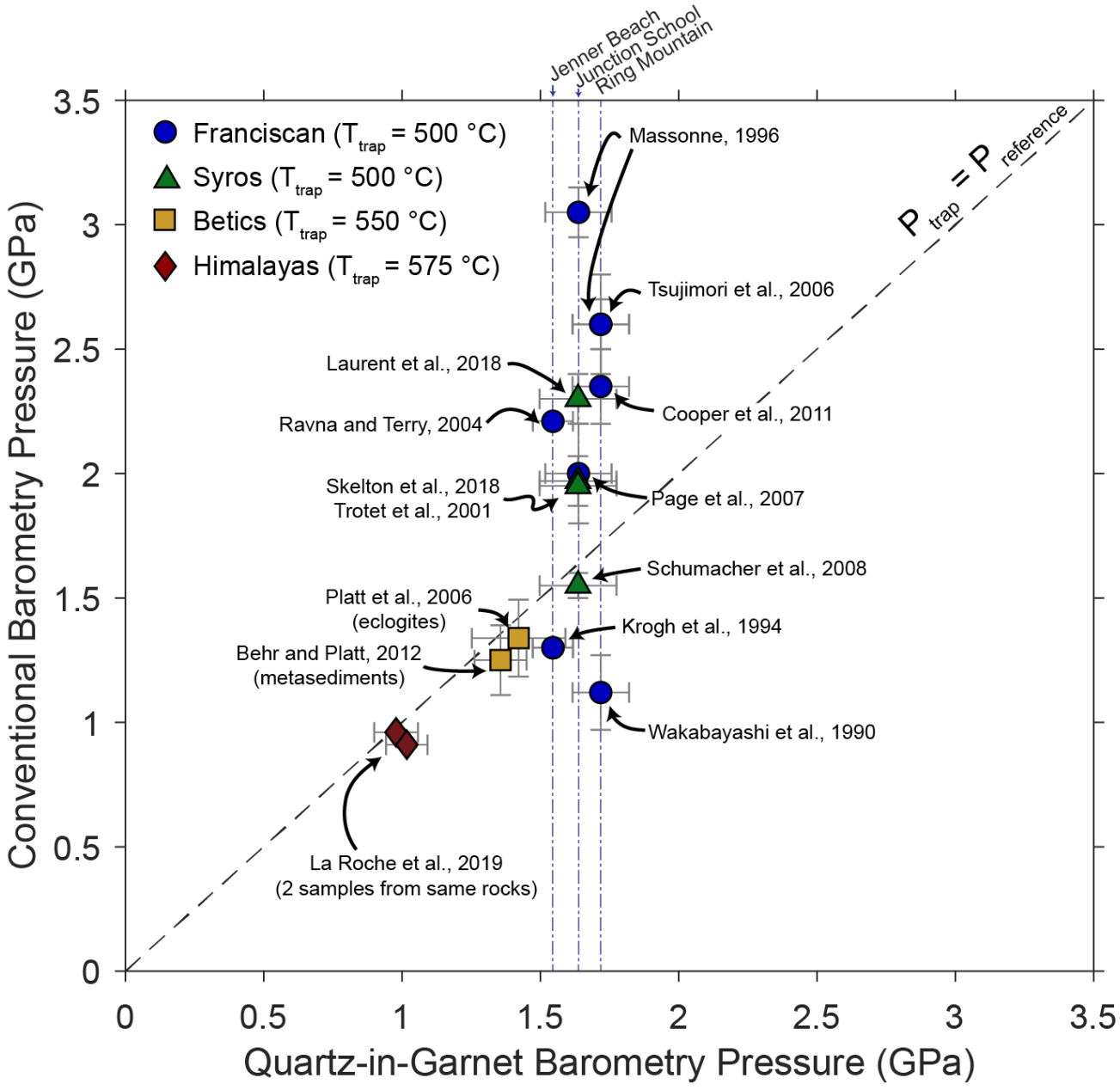
- Franciscan: quartz-in-garnet barometry results do no agree with most previous studies. Most previous studies estimate higher pressures.

- Syros: pressure agreement with some previous studies (lower pressures), most studies estimate higher pressures.

- Himalayas, Betics: good pressure agreement with max pressures

- Similar pressures from rocks from different subduction zones (Betics, Syros, Franciscan).

- Maximum pressures recorded by quartz-in-garnet barometry ~ 1.8 GPa.



Conclusions and insights

Franciscan Complex:

- Quartz-in-garnet barometry tends to agrees with low P constraints.
- Inconsistent agreement with grt-px-wm thermobarometry calibrations (seems calibrations lead to large P ranges). This issue has been documented in Page et al. (2007).

Syros, Greece:

- Pressures near constant across garnets.
- Inconsistent agreement with thermodynamic modeling results.

Betics:

- Inconsistent agreement with previous P-T constraints.
- Good agreement with max pressures from Ravna and Terry (2004) grt-px-wm calibration.

Himalayas:

- Very good pressure agreement with rocks from the same study.

Broader Insights:

- Pressures remarkably similar between rocks from different subduction zones, suggests garnet growth is occurring at similar pressures (under similar geothermal gradient)?
- Or some issue with quartz-in-garnet barometry?
- What is the most accurate calibration for grt-wm-px thermobarometry?

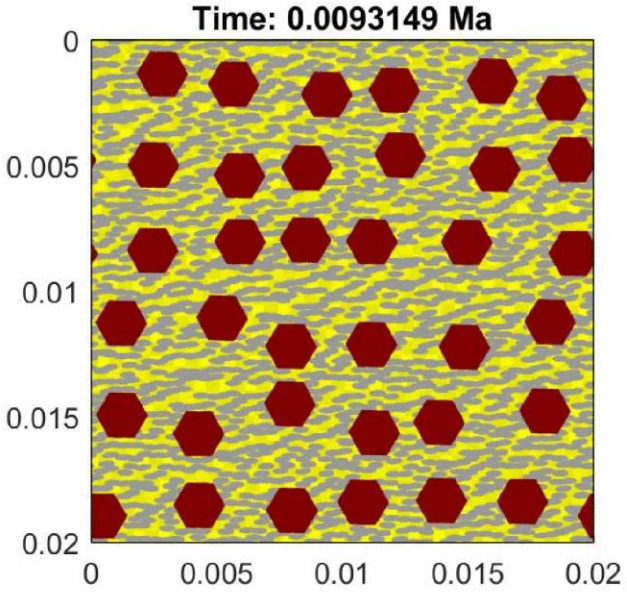
Future Work

- Test higher temperature samples.

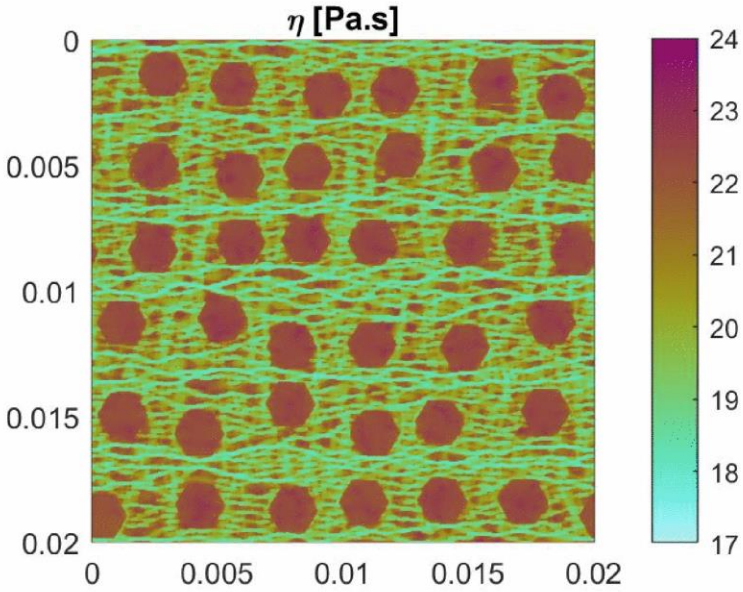
Numerical modling of viscous strain accomodated by garnet under different conditions

Test total viscous strain accomodated by garnet for different “rock types”

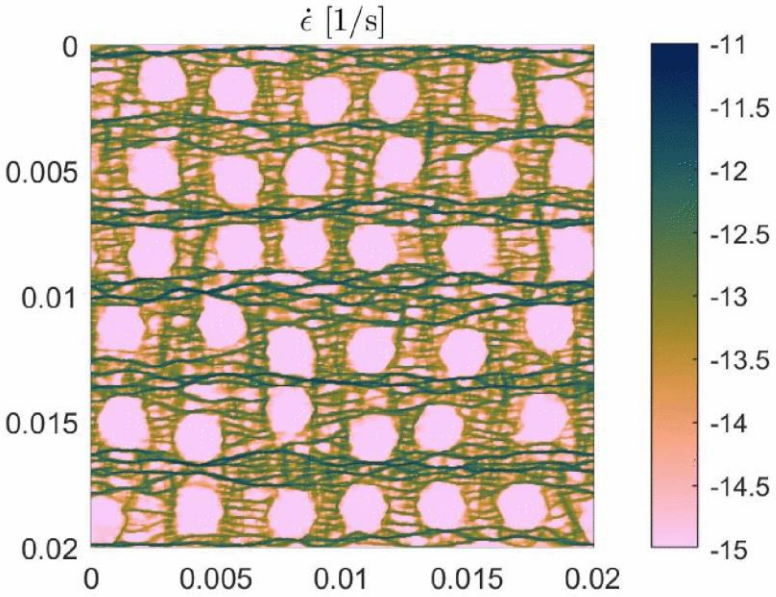
Garnet + quartz + white mica under shear (T = 750˚C)



Viscosity



Strain Rate



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