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

Miguel Cisneros and Whitney Behr

Structural Geology and Tectonics Group, Geological Institute, Department of Earth Sciences, ETH Zürich
# Table of Contents

1. **Elastic thermobarometry background** (pg. 3)
2. **Questions that we test** (pg. 4)
3. **Sample localities** (pg. 5 – 8)
4. **Calculating inclusion pressures** (pg. 9)
5. **Pressures from each locality** (pg. 10 – 13)
6. **Comparison of garnet growth pressures** (pg. 14)
7. **Conclusions and insights** (pg. 15)
8. **Future work** (pg. 16)
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 ($P_{\text{trap}}$, $T_{\text{trap}}$), the P of quartz and garnet are equal.

• Upon exhumation, quartz (highly compressible) can expand more than garnet, and retain a pressure ($P_{\text{inc}}$) when $P_{\text{garnet}} = 0.1$ MPa (ambient, $P_{\text{amb}}$).

• Use $P_{\text{inc}}$ and elastic modeling to calculate $P_{\text{trap}}$ (assume $T_{\text{trap}}$).

• Relaxation can deviate from being elastic ($P_{\text{inc}} <$ or $> $ elastic) if garnet flow (creep) occurs.
Questions that we test

- How accurate are the calculated entrapment pressures ($P_{\text{trap}}$)?

- 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
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
Samples (*Nevado-Filabride Complex*)

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

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

*Pressures of eclogites from different localities vary*

*Kirchner et al., 2016*
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

\[ \Delta P_{\text{inc}} = P_{\text{inc \, 464 \, cm}^{-1}} - P_{\text{inc \, 128/206 \, cm}^{-1}} \]

• \( \Delta P_{\text{inc}} \) calculated from hydrostatic calibrations, and by accounting for anisotropy, generally < 0.1 GPa (~80%).

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

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

• Large \( \Delta P_{\text{inc}} \) not seen.
Franciscan Complex Pressures

Minor P increase from core-to-rim

**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
• 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.
• 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).
• 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 agree 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 modeling of viscous strain accommodated by garnet under different conditions
Test total viscous strain accommodated by garnet for different “rock types”
Miguel Cisneros
Postdoc
miguel.cisneros@erdw.ethz.ch

ETH Zürich
Department of Earth Sciences
NO E1
Sonneggstrasse 5
8092 Zurich
Switzerland