# THERMOBAROMETRY OF ECLOGITE FROM THE NORDØYANE ULTRA-HIGH PRESSURE DOMAIN, WESTERN GNEISS REGION, NORWAY

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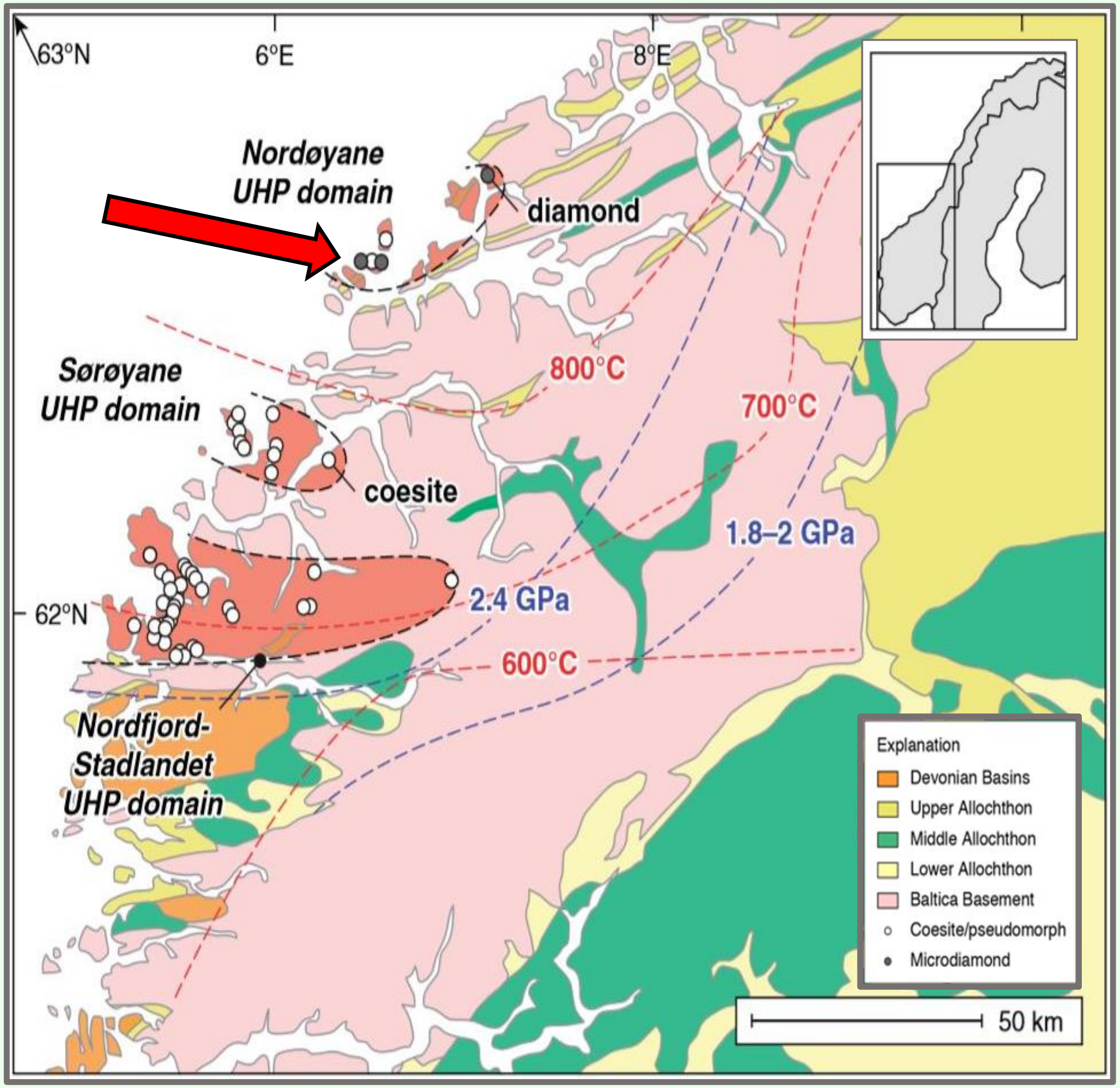
# Purpose and scope of study

- Analyze petrography of eclogites from Nordøyane
- Obtain EMP analyses from eclogite-facies minerals
- Use conventional and trace-element thermometry
- Construct an equilibrium phase diagram for a representative bulk composition
- Assess which thermobarometric methods are most robust for given mineral assemblage

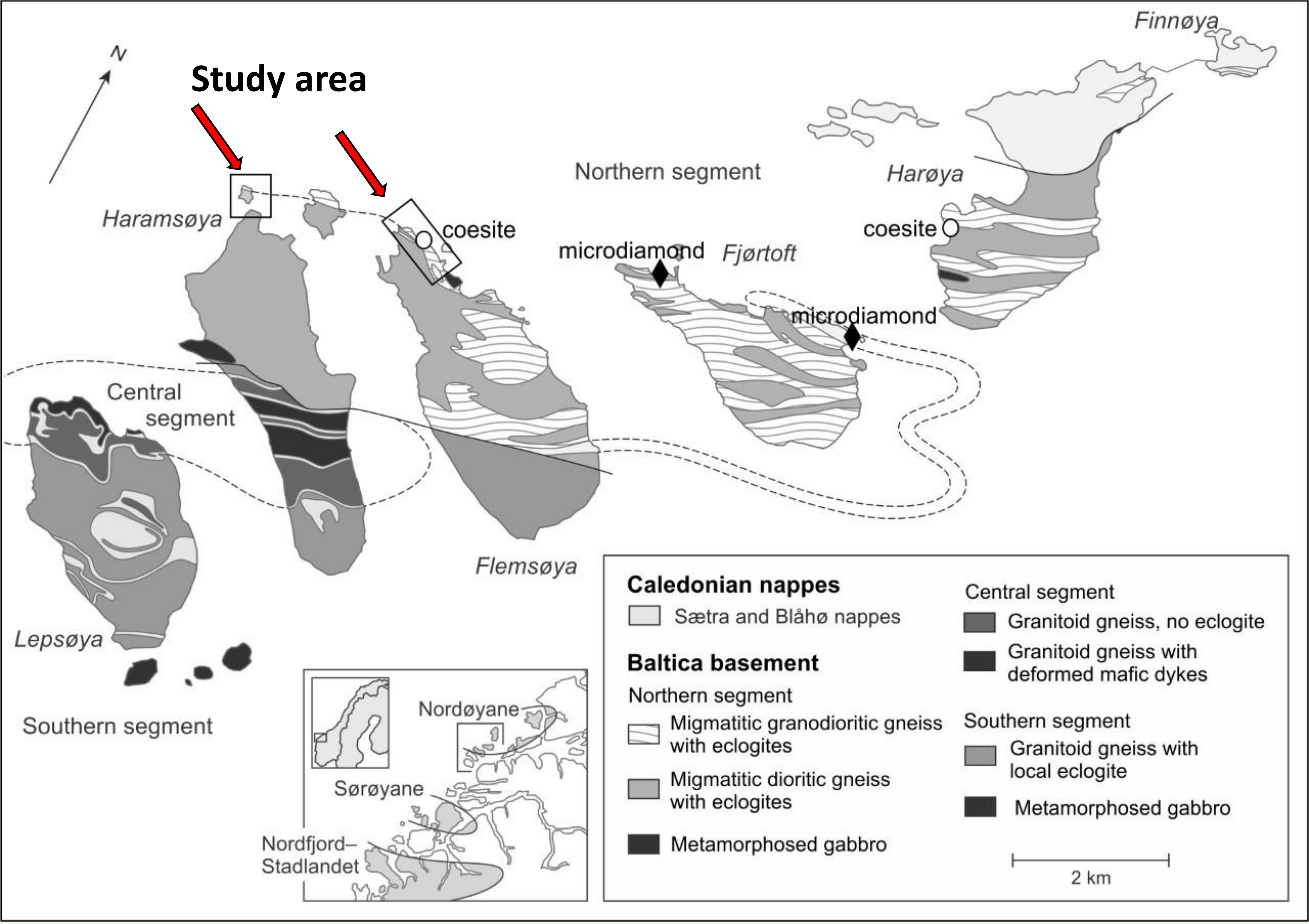
**Do the P-T conditions recorded in the eclogite bodies overlap with the UHP melting range for eclogites and their host rocks?**

# Regional geology of WGR

- Exposes Baltican Proterozoic basement gneisses
- Result of subduction of Baltican margin beneath Laurentia
    - Scandian phase of Caledonian Orogeny
    - Ca. 410 Ma
- Affected by ultra-high pressure (UHP) metamorphic conditions of ca. 800 °C, 30 kb
    - Corresponds to ca. 100 km depth
- Three UHP domains: Nordfjord /Stadlandet, Sorøyane, Nordøyane
    - All contain coesite-bearing eclogite




*Butler et al (2015)*




*Bryden and Jamieson (submitted, 2020)*

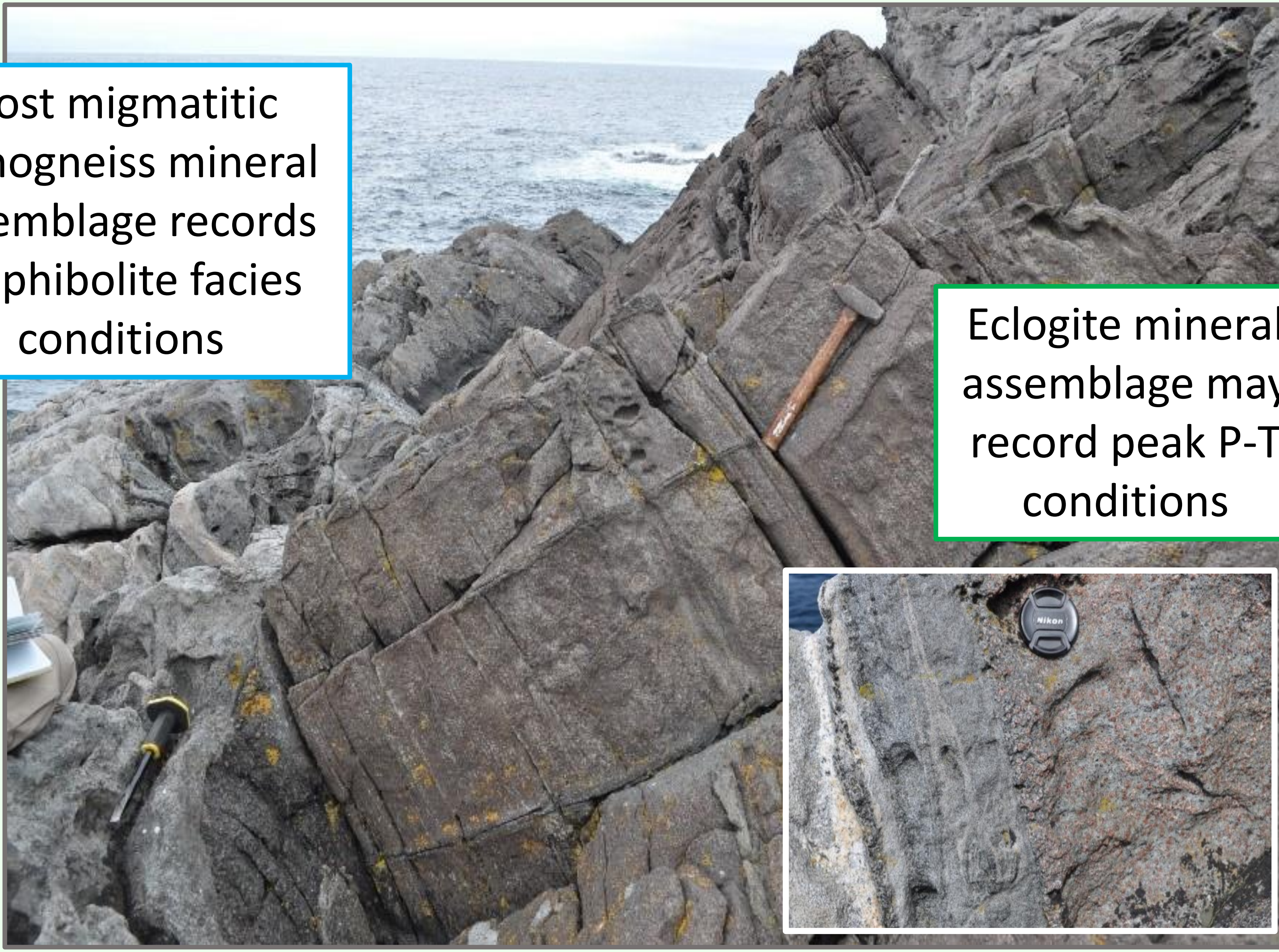
# Geology of study area

- Eclogite sampled from Haramsøya and Flemsøya
- Dioritic gneiss and augen gneiss comprise majority of study areas
- Minor granodiorites with mafic enclaves
- Eclogite bodies range from massive to layered
  - Some display amphibolite-facies retrogression
- Evidence suggesting UHP conditions supported by discovery of coesite-bearing eclogite in Flemsøya

*Photo by G. Chapman*

# Field relationship

Host migmatitic orthogneiss mineral assemblage records amphibolite facies conditions

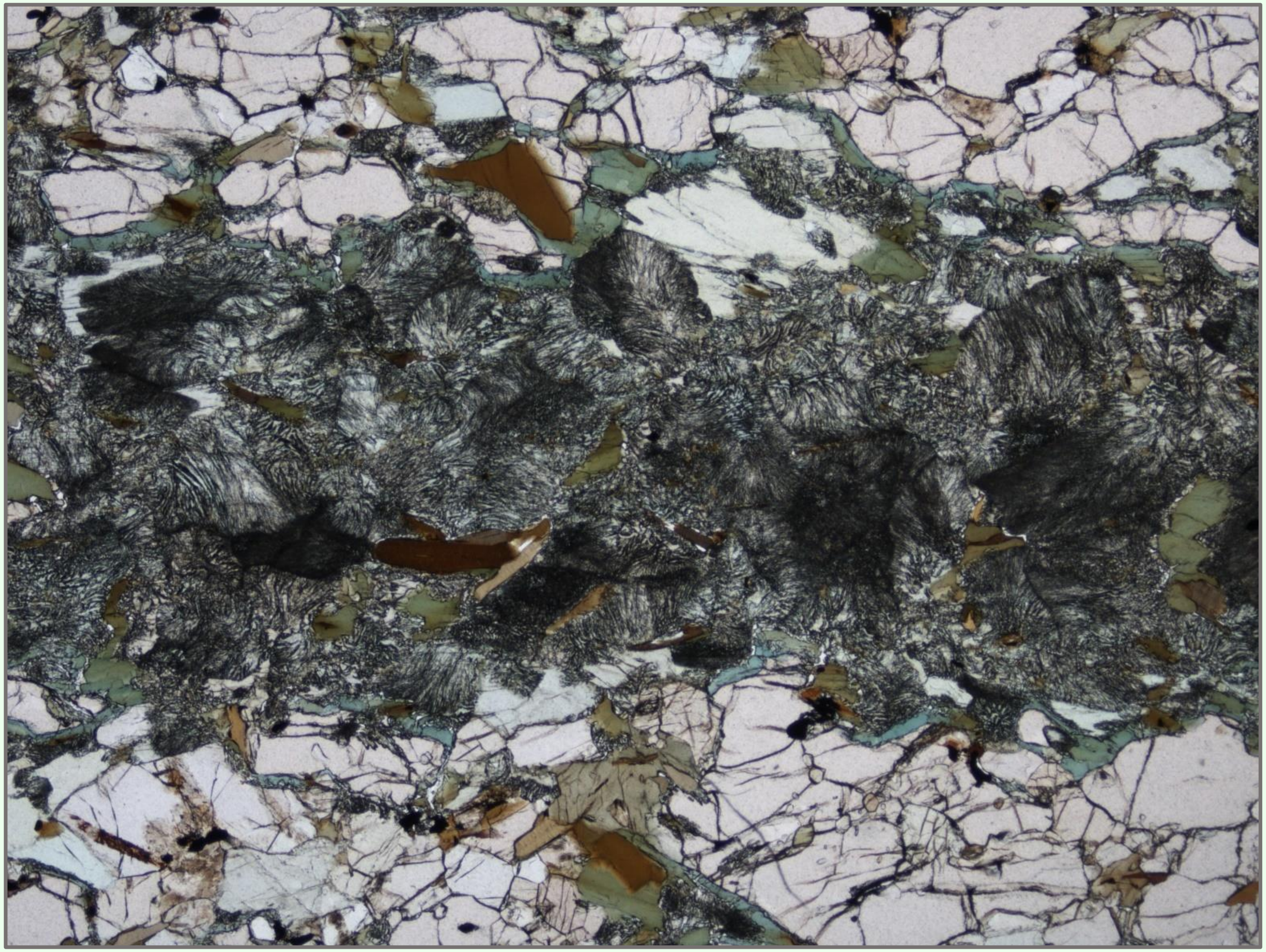


Eclogite mineral assemblage may record peak P-T conditions

*Photos by G. Chapman*

# General methods

Petrography



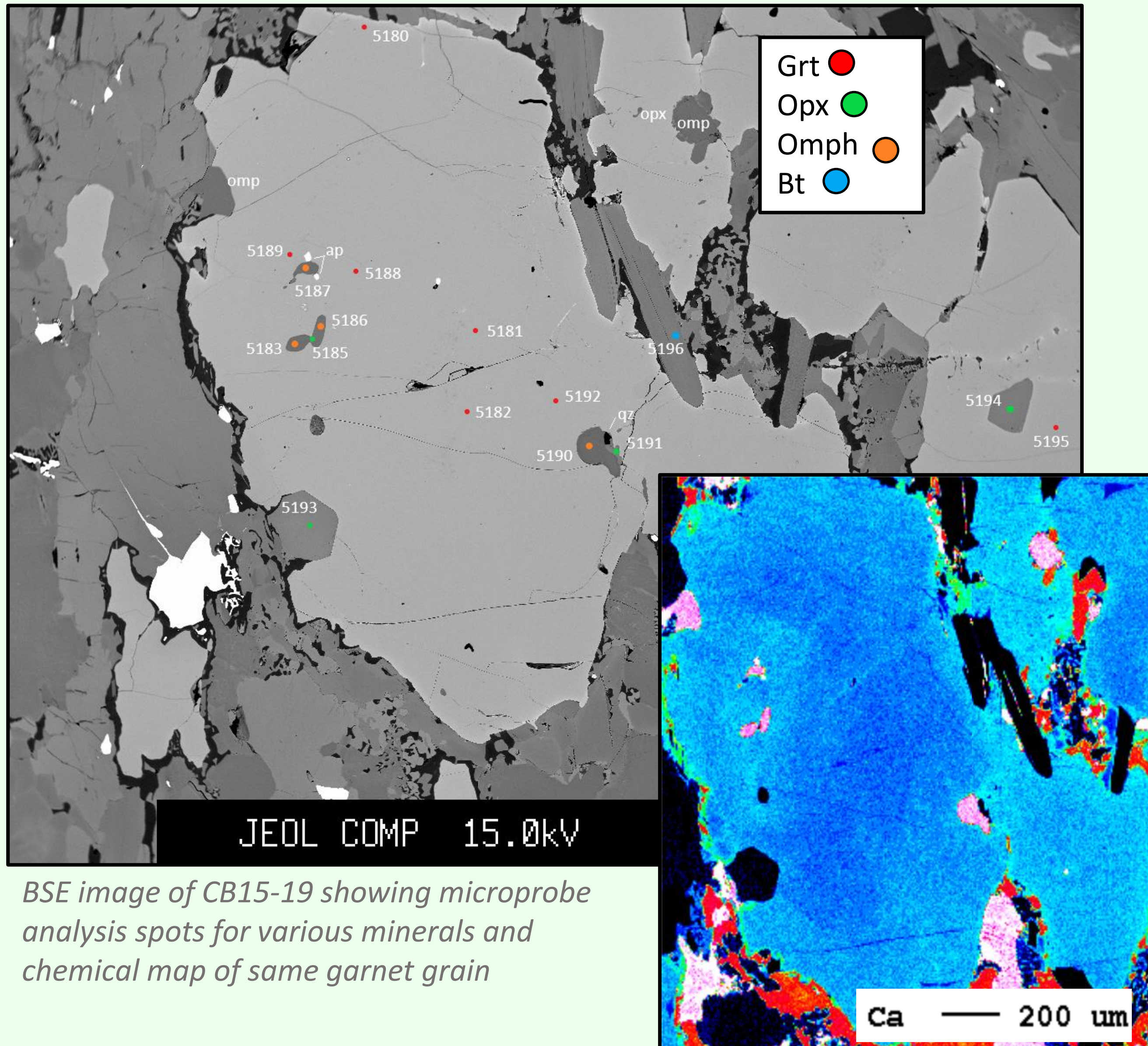
*Sample CB15-70 F.O.V 15 mm*

# General methods

Petrography

EMP and imaging

Conventional thermobarometry




*BSE image of CB15-19 showing microprobe analysis spots for various minerals and chemical map of same garnet grain*

# General methods

Petrography

↓

EMP and imaging

↓

Conventional thermobarometry

↓

Thermodynamic modelling

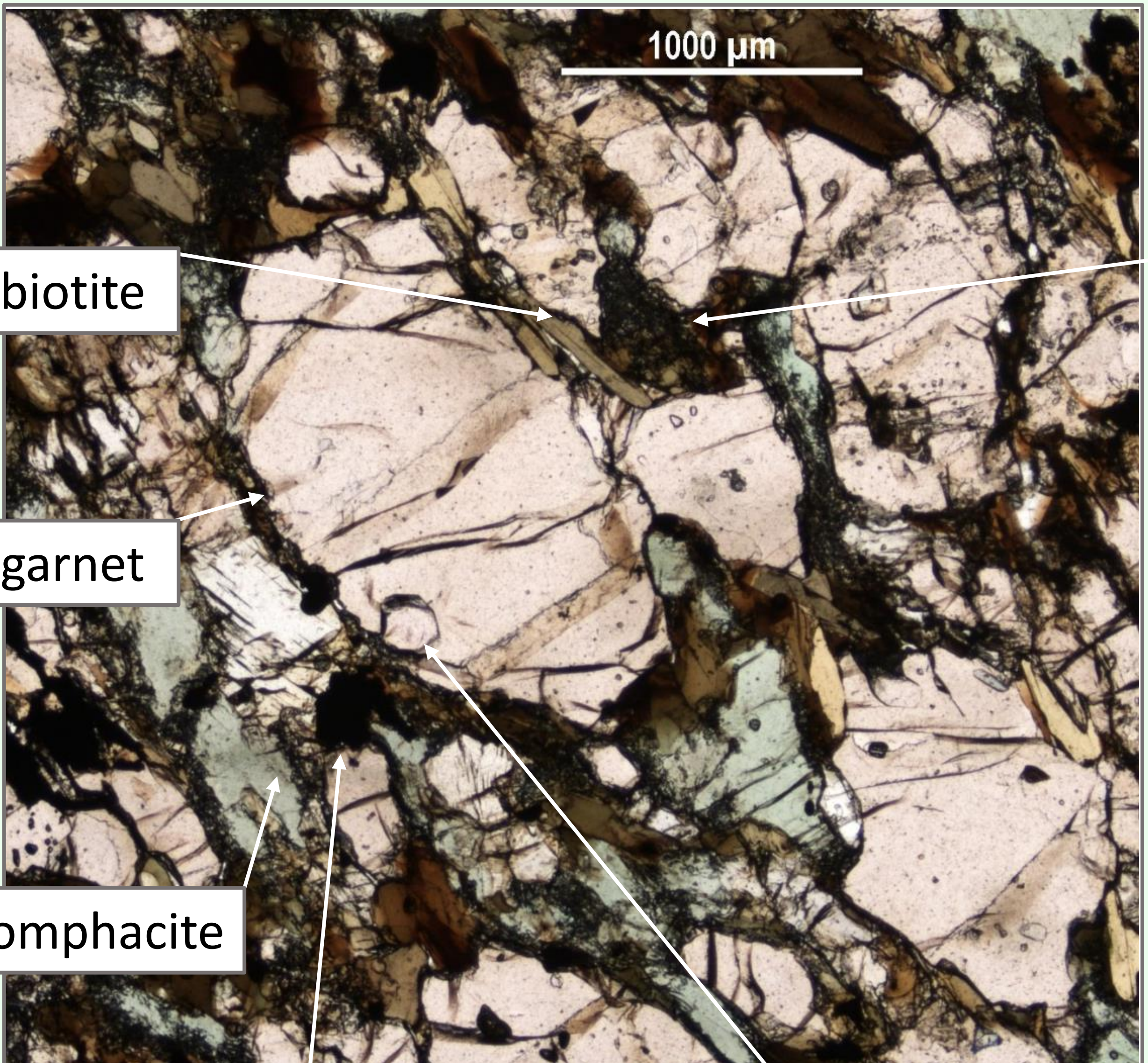
## Conventional thermobarometry

- Reverse approach
- Assumes equilibrium compositions
- Produces P-T estimates using equations derived from experimental calibrations

## Thermodynamic modelling

- Forward approach
- Based on internally consistent databases
- Predicts equilibrium phase assemblages for P-T ranges

# Petrography




**Retrograde**
clinopyroxene$_2$ + amphibole + plagioclase symplectite

Garnet inclusions:
- omphacite
- rutile
- zircon
- apatite
- idioblastic biotite

Rare quartz, absent coesite, kyanite, phengite

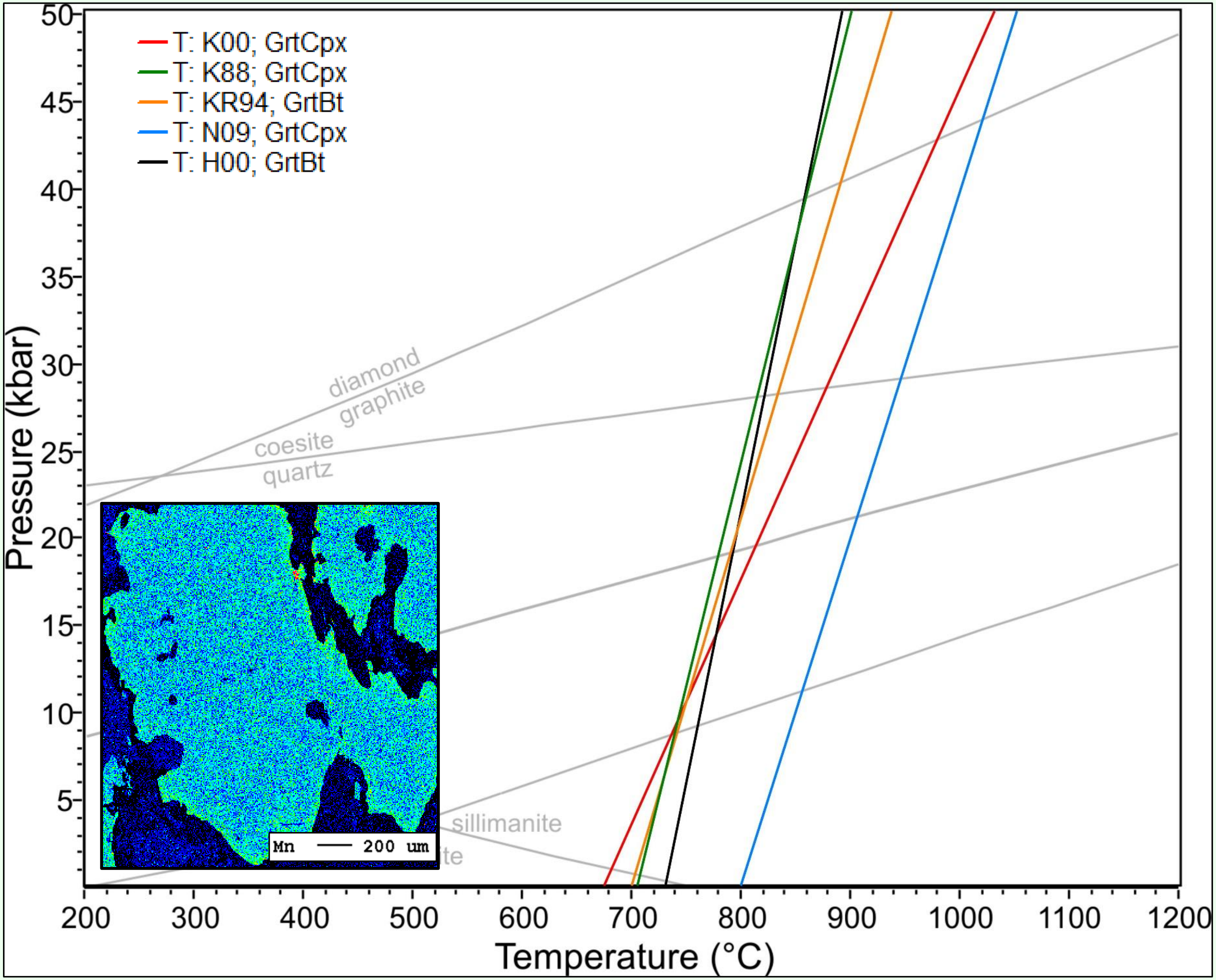
## Method 1A: conventional thermobarometry

- P and T dependent equilibria
- Minerals present mean heavy reliance on Fe-Mg exchange thermometry
  - Garnet-clinopyroxene (e.g. Krogh Ravna, 2000)
  - Garnet-biotite (e.g. Holdaway, 2000)
- **Issues:**
  - Unknown $Fe^{3+}$ values
  - Mineral assemblages sensitive to retrograde exchange

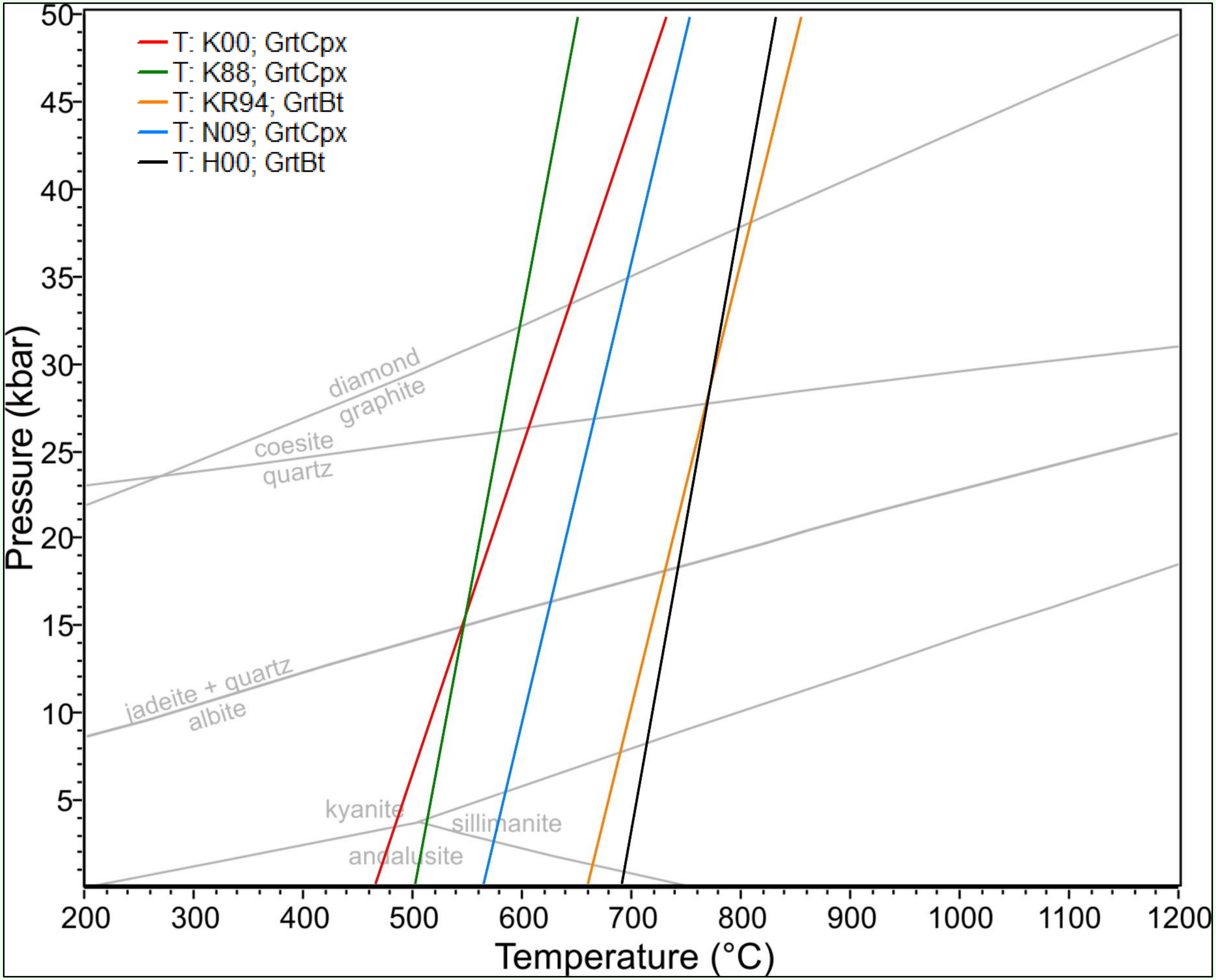
## Method 1B: trace-element thermometry

- Type of conventional thermometry based on calibrated reactions
- Zr-in-rutile thermometer (Tomkins et al. 2007)
- Exchange between $Ti^{4+}$ and $Zr^{4+}$ in rutile + zircon + quartz assemblages
- Less sensitive to issues such as retrograde exchange

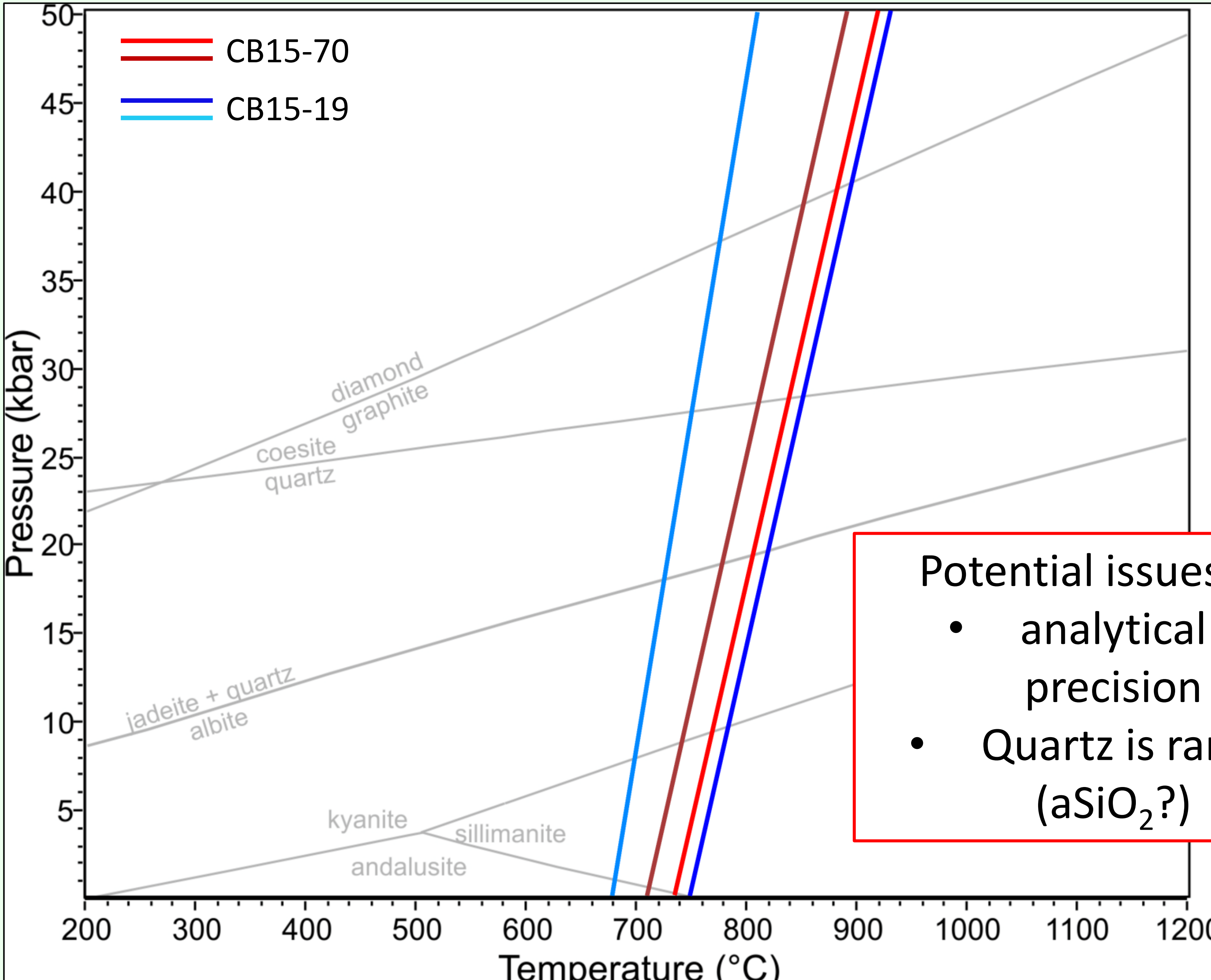
# Assuming Fe as $Fe^{2+}$



## Using calculated $Fe^{3+}/Fe^{2+}$



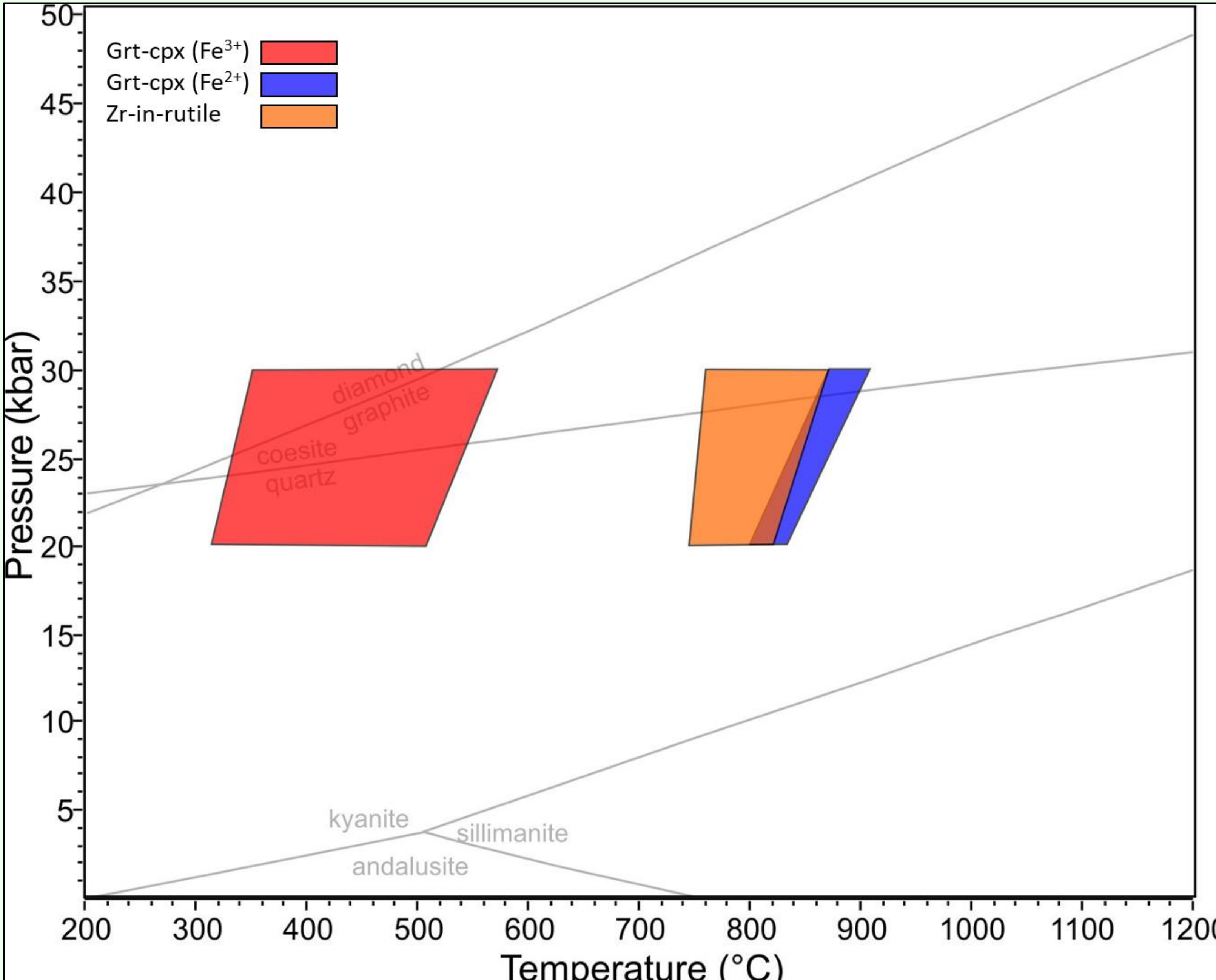
# Zr-in-Rutile thermometry




Potential issues:

- analytical precision
- Quartz is rare ($aSiO_2$?)

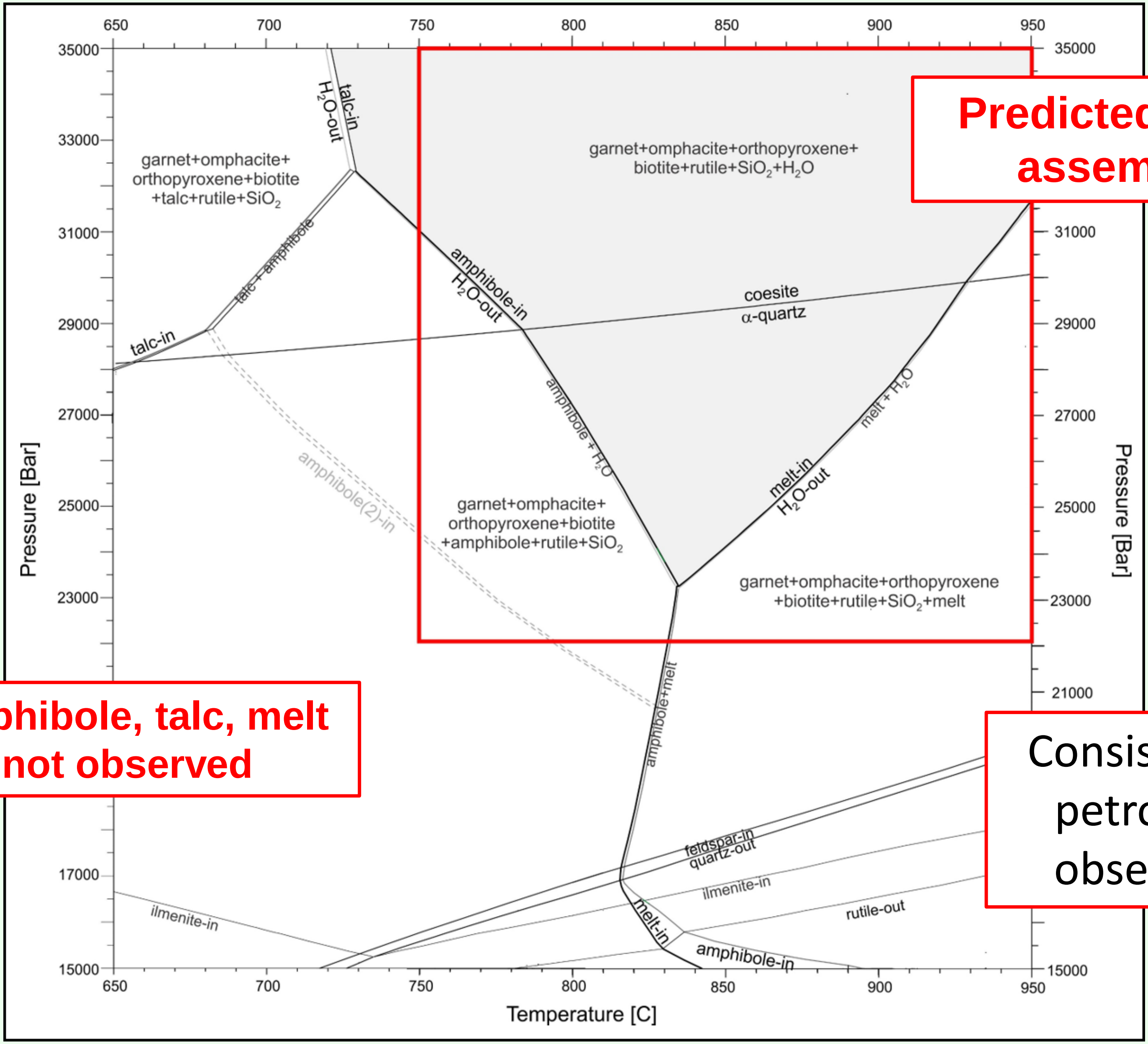
# P-T assessment



# Method 2: equilibrium phase diagram

- Given bulk composition, program predicts mineral assemblage, modal proportions, mineral compositions
- Independent of conventional thermobarometry
- Theriak-Domino in family of programs such as THERMOCALC and Perplex
  - Differ in algorithm used, activity models, databases
- Results use TC55 database (Holland and Powell, 1998)
- Input: measured bulk composition of sample CB15-19

# Method 2 equilibrium phase diagram (Theriak-Domino)

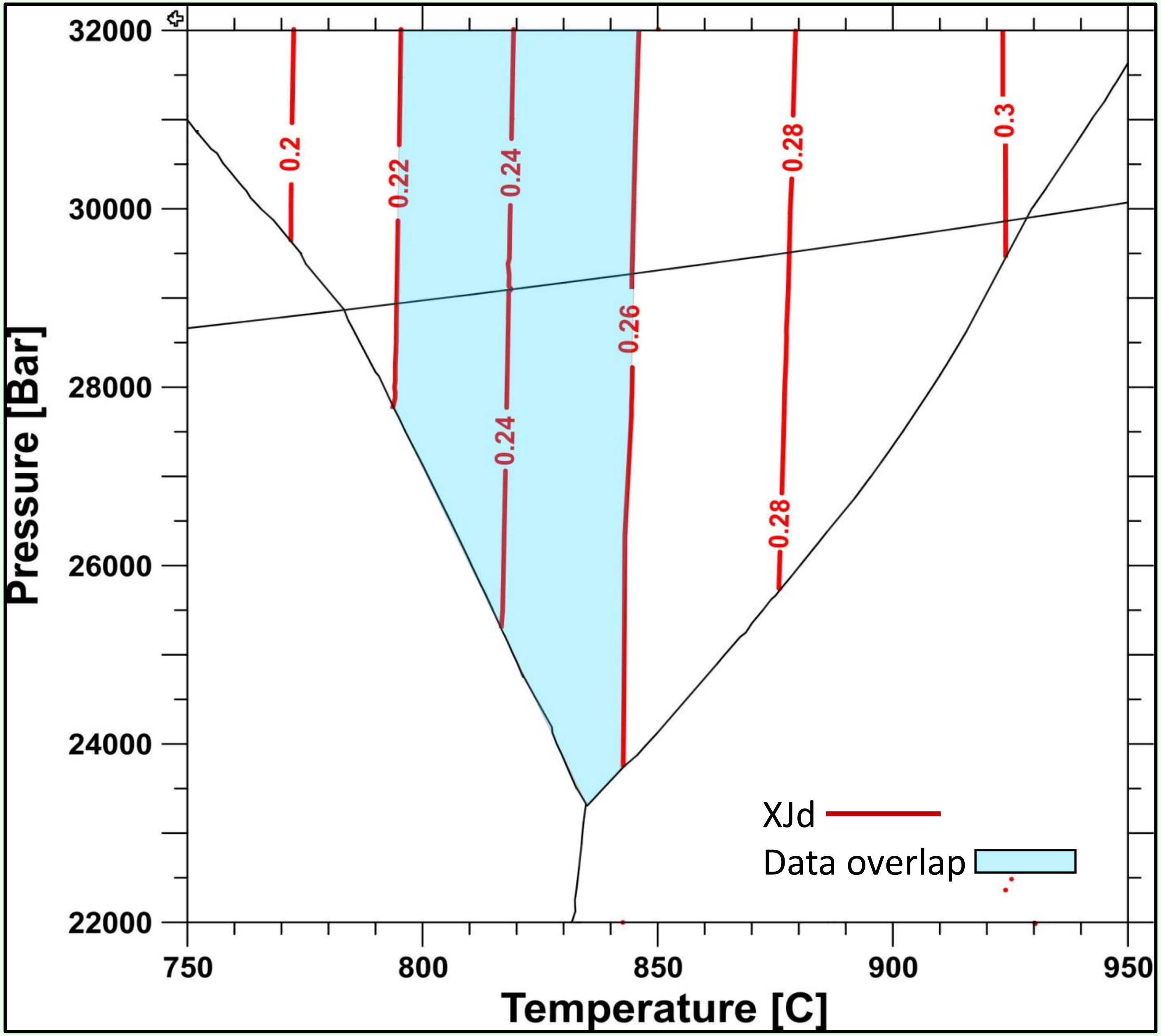



**Predicted mineral assemblage**

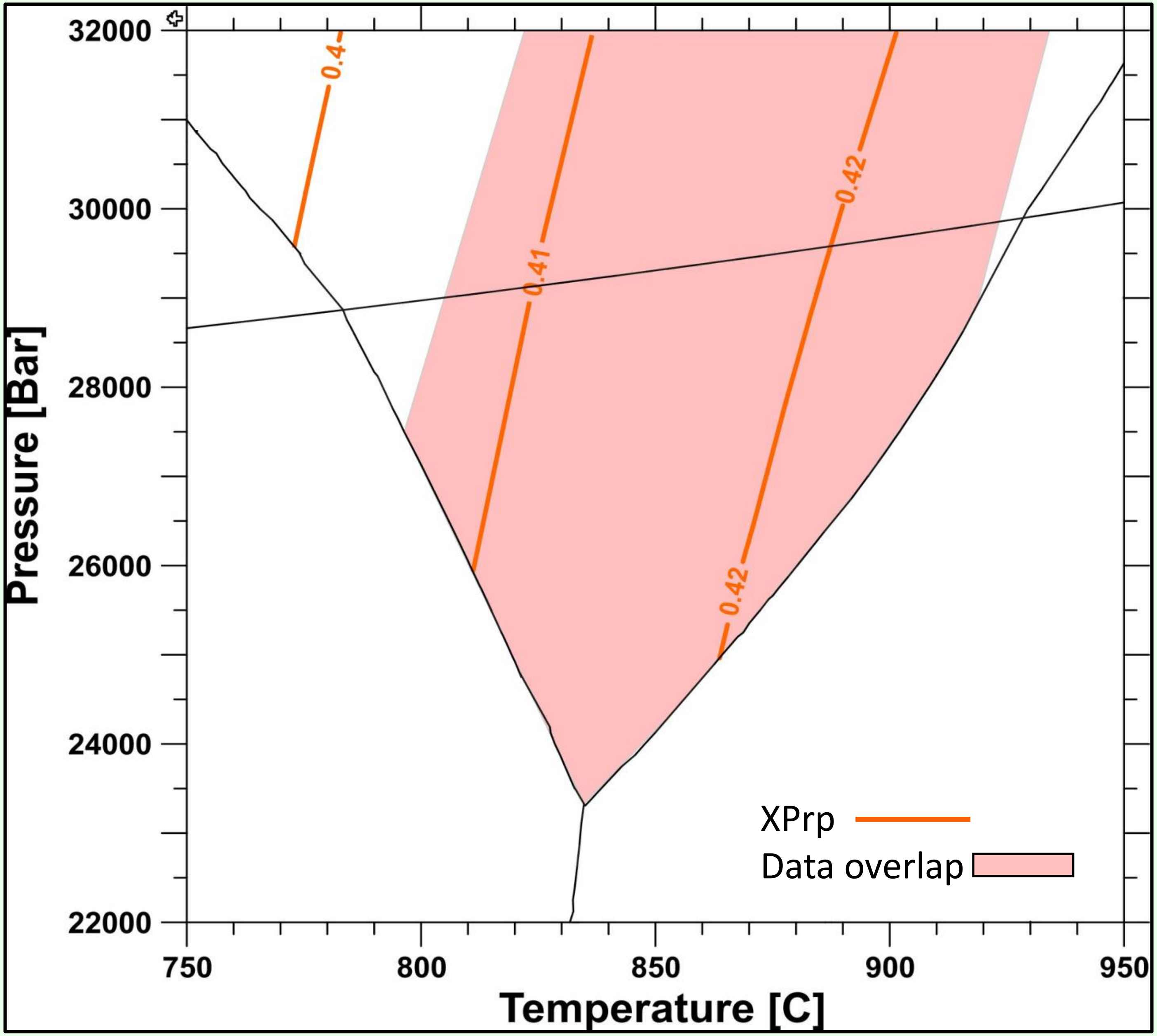
**Amphibole, talc, melt not observed**

Consistent with petrographic observations

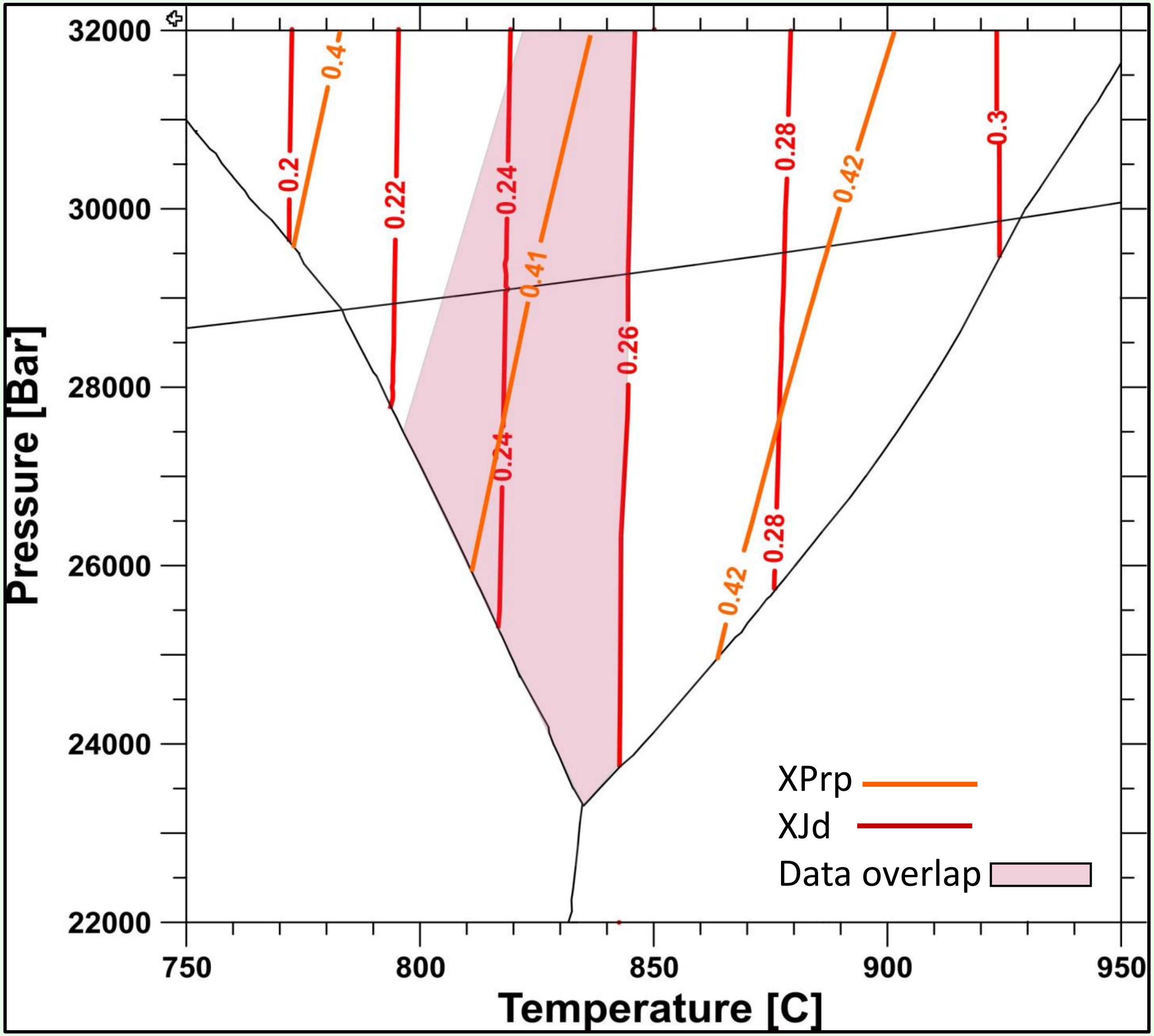
# Predicted mole fractions



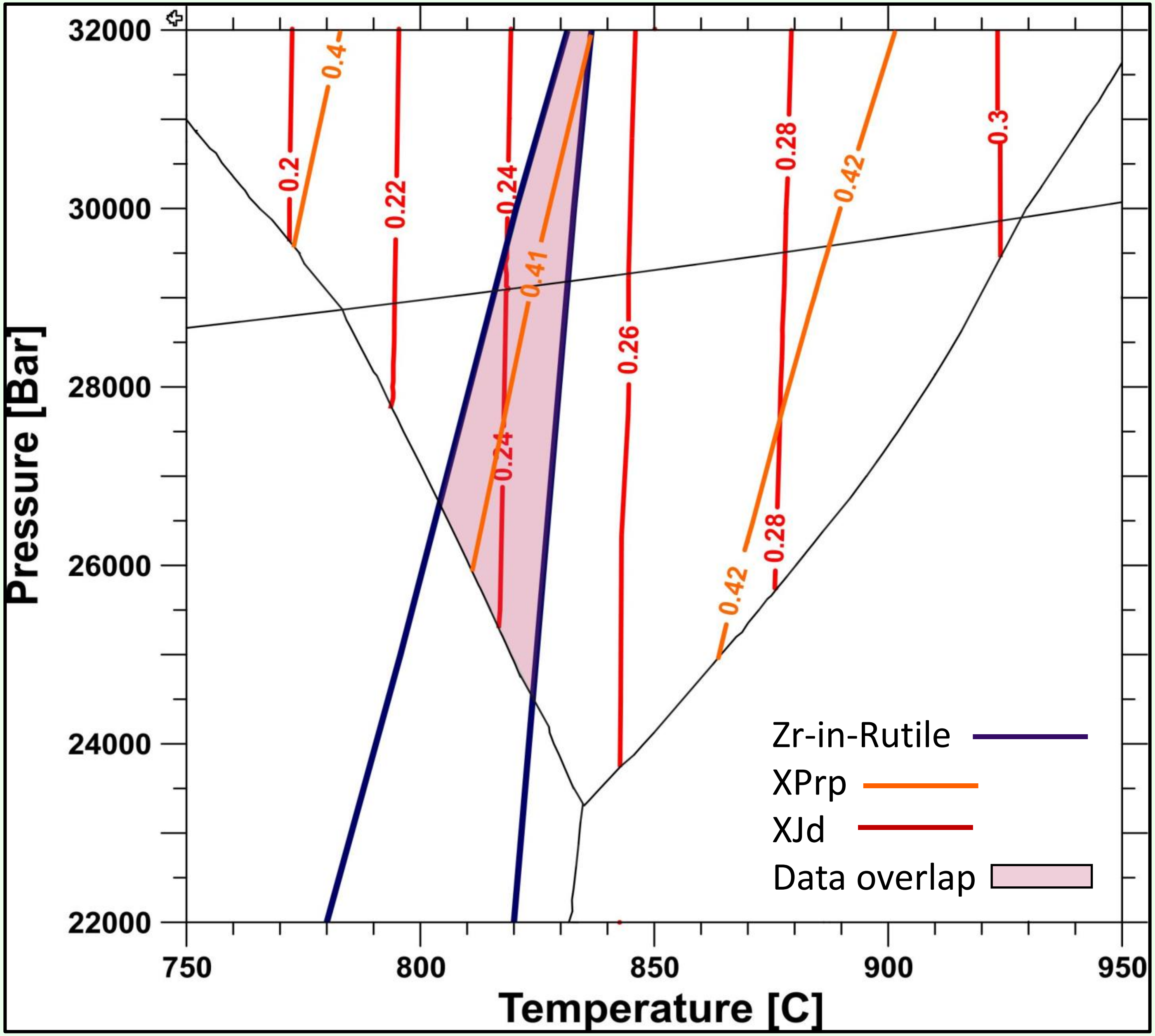
# Predicted mole fractions



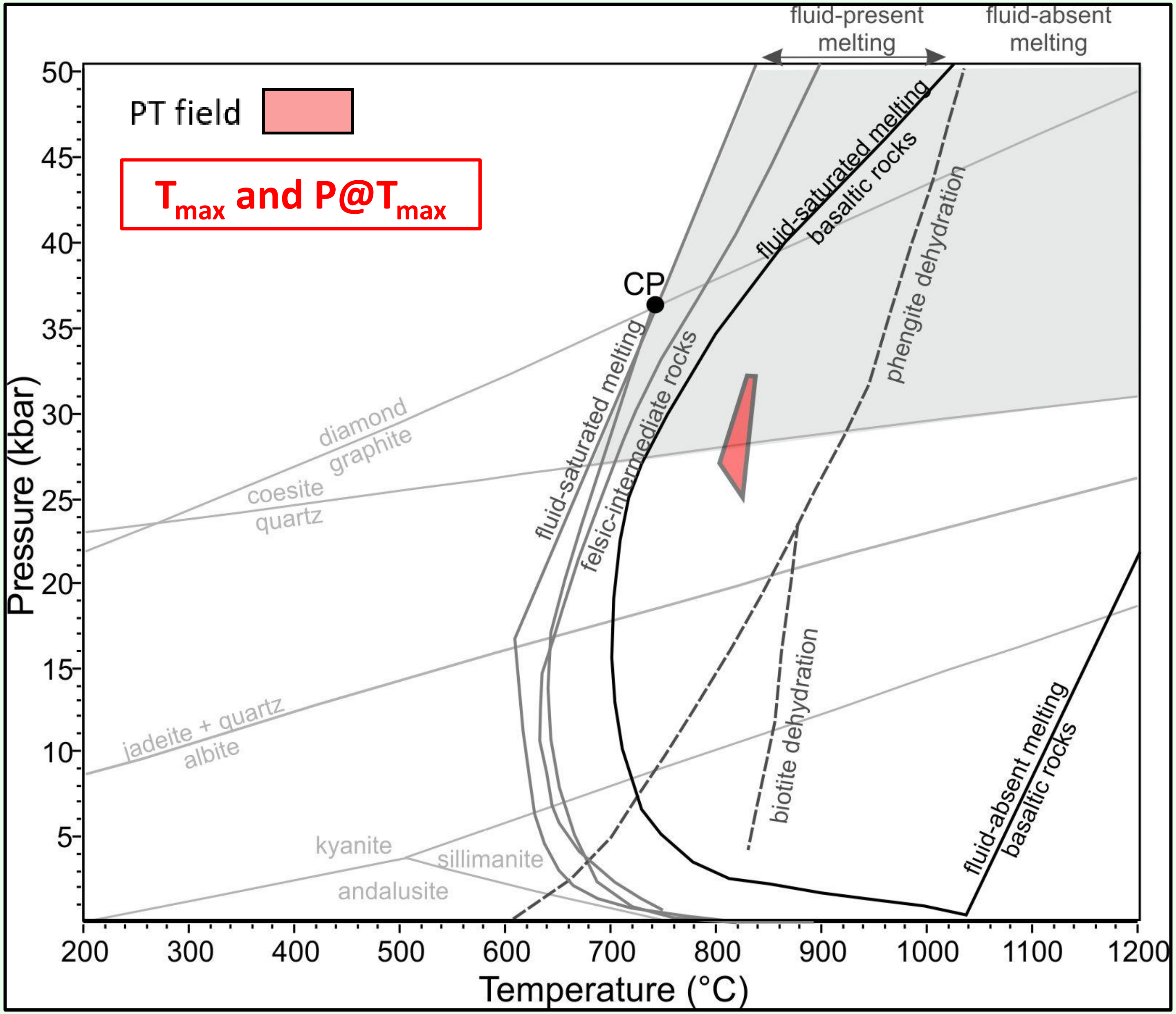
# Predicted mole fractions



## Predicted mole fractions with Zr-in-Rutile



# Fluid-present melting




*various melting curves of crustal compositions*

*(Kessel et al. 2005, Patiño Douce 2005, Hermann & Spandler 2008, Auzanneau et al. 2010)*

# Conclusions

- Peak mineral assemblage comprises garnet + omphacite + biotite + rutile + orthopyroxene
- Fe-Mg exchange thermometry proved to be unreliable for P-T estimates
  - Two factors: $Fe^{3+}$ and grain scale diffusion during retrogression
- Trace and minor element thermometers yielded T of 780-870 °C for 20-30 kb
- Thermodynamic modelling coupled with Zr-in-Rutile isopleths suggests P-T field of ca. 800-820 °C and ca. 23-32 kb
- $T_{max}$ and P@$T_{max}$ overlap with field where UHP melting is possible in presence of fluid
- Cannot conclude if UHP melting assisted exhumation
  - No independent P constraint
  - No evidence of *in situ* melting or fluid infiltration

Acknowledgments

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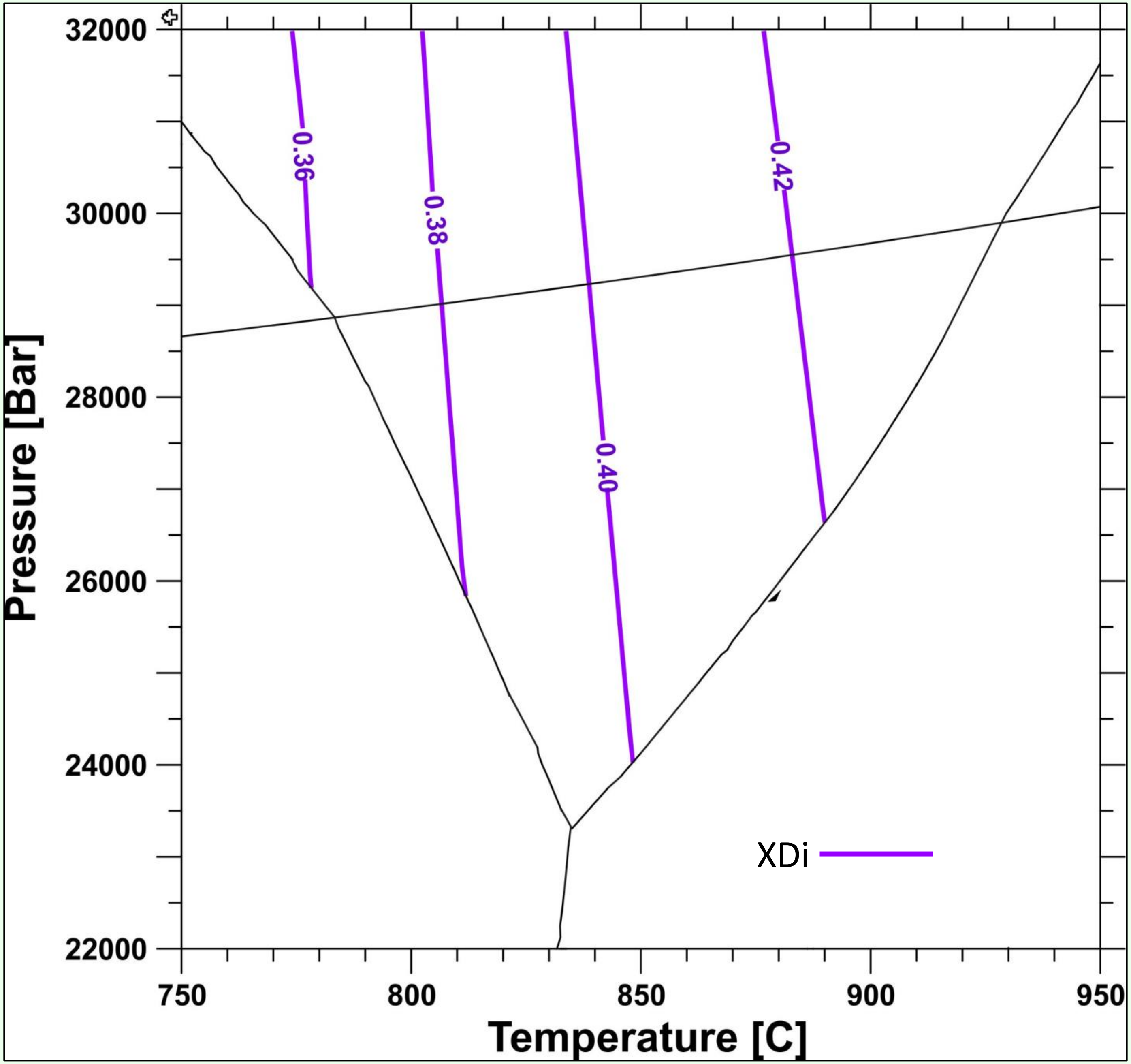
Department of Earth and Environmental Sciences

**Thank you!**



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26000
24000
22000
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850
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950
Temperature [C]
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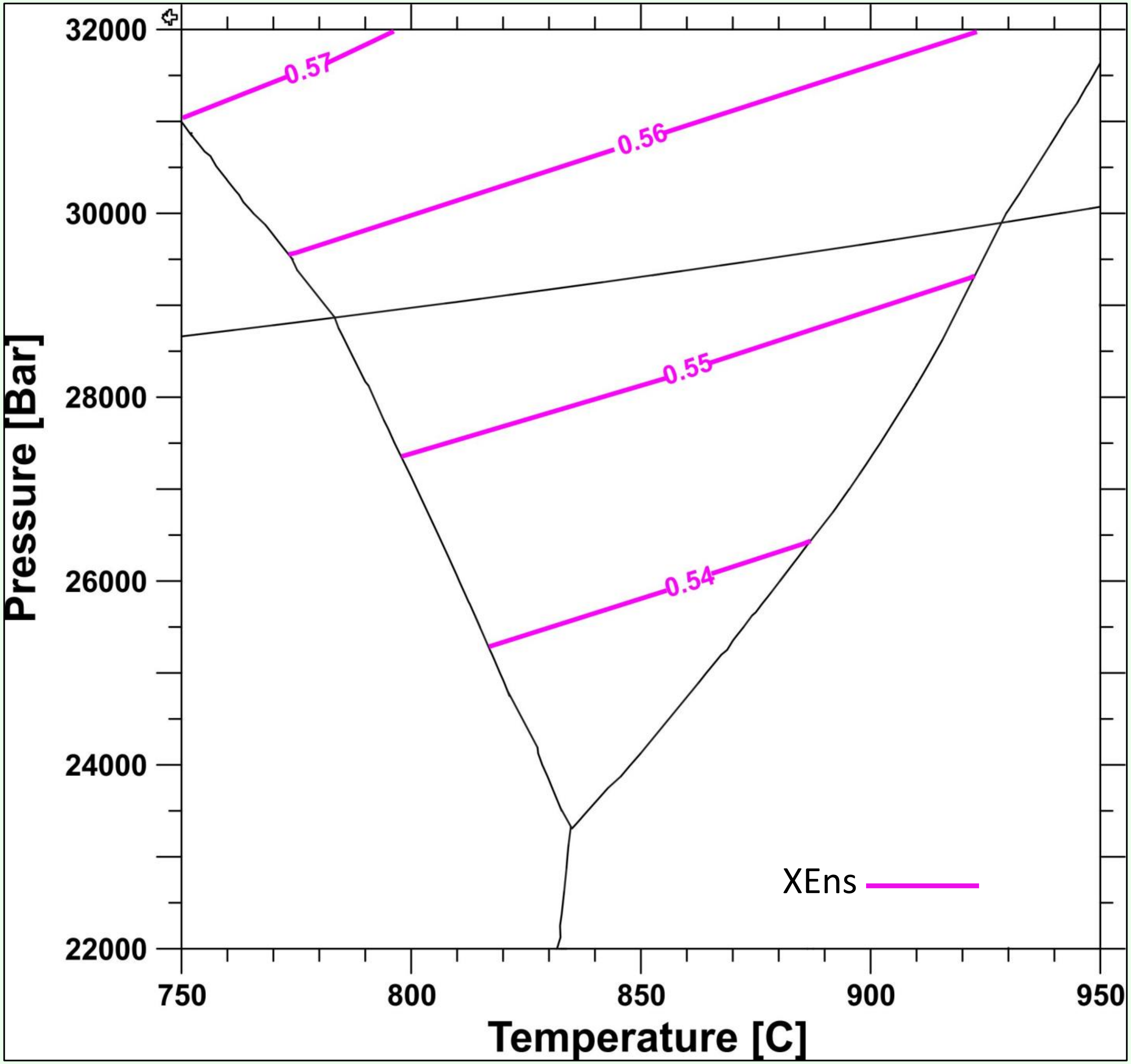
0.40
0.42
XDi



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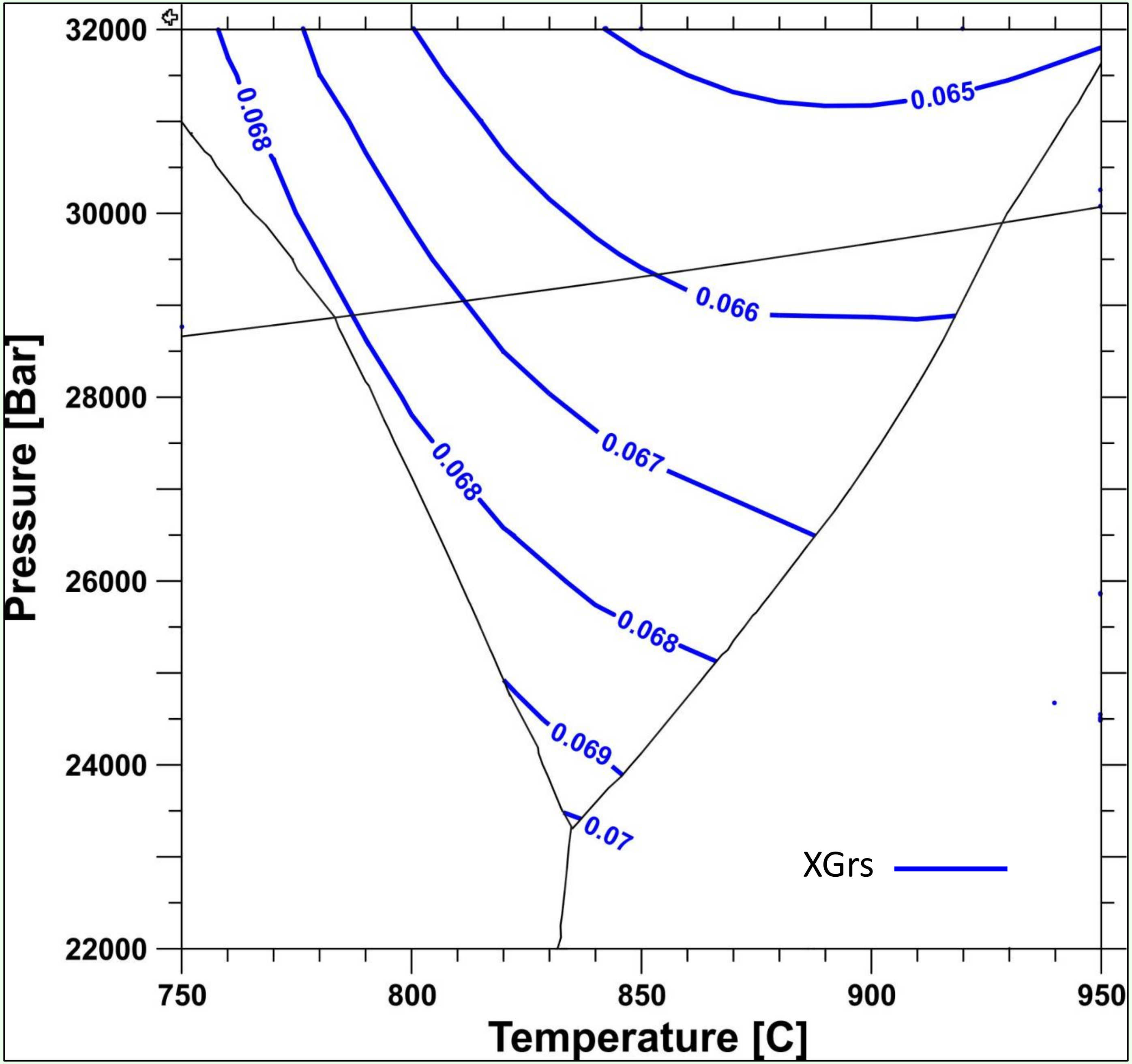
XEns



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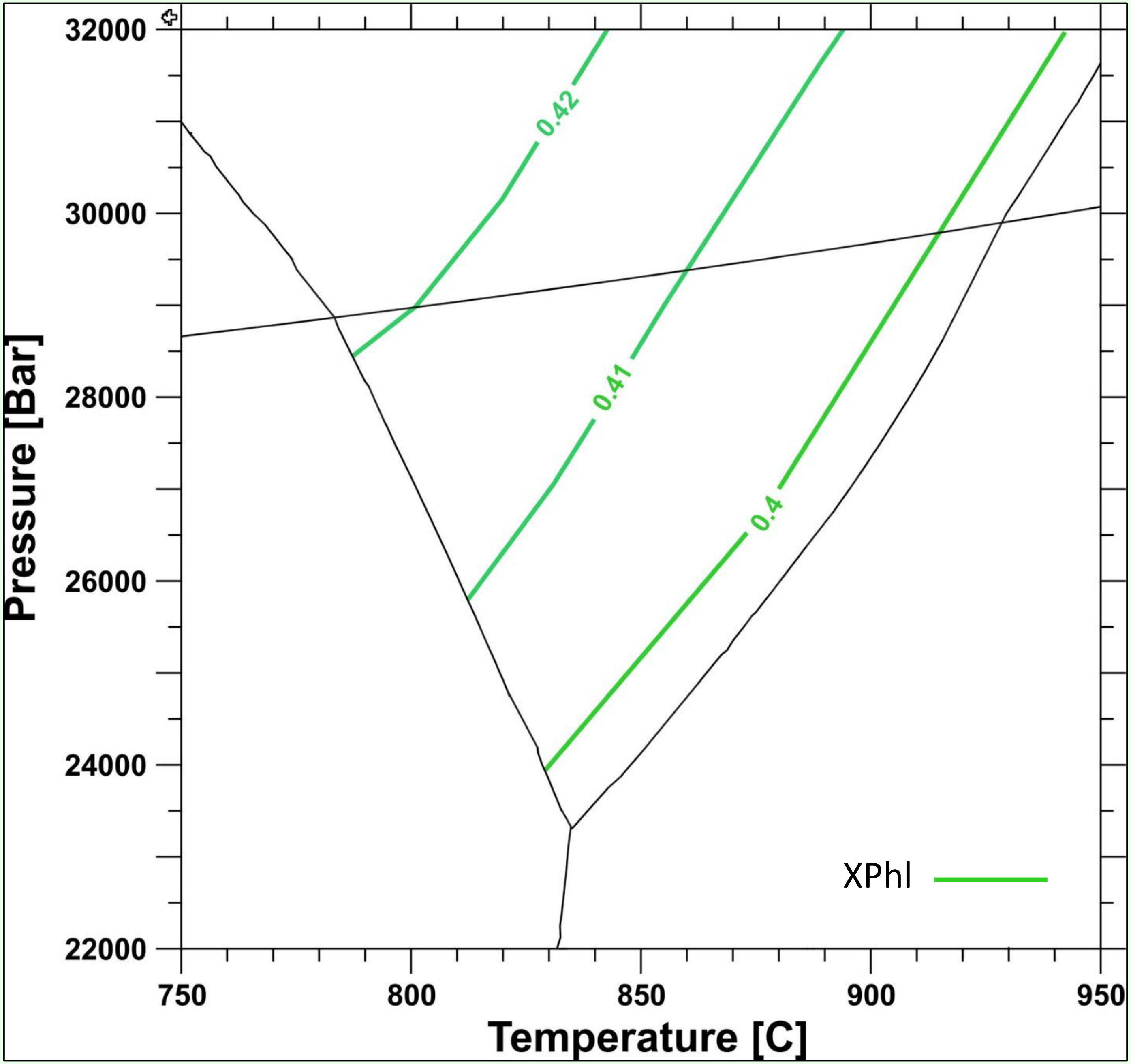

32000
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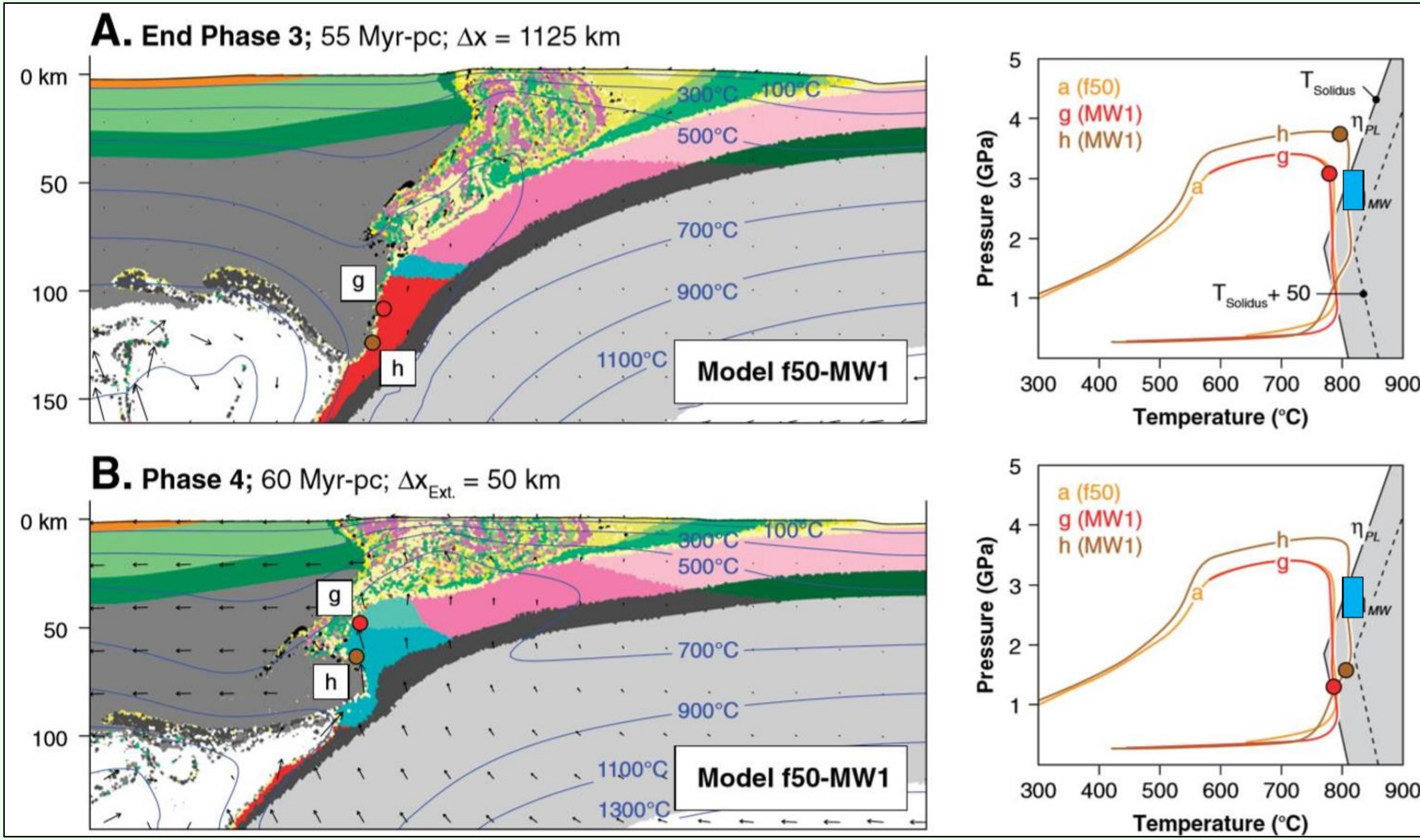


*Modified from Butler et al (2015)*