Pressure variations in the Monte Rosa nappe: new results from staurolite bearing metapelites

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Pressure variations in the Monte Rosa nappe

Why pressure difference?
Possible explanations:
1) Tectonic mélange
2) Granite did not record peak-P
   (a) sluggish kinetics
   (b) retrogression
3) Thermodynamic database
4) Mechanical P variations

Alpine peak pressure:
Whiteschist: ca 2.2 GPa
Metagranite: ca 1.6 GPa
Aims of this study:

(*manuscript under review)

- Continue to investigate P-variations in the Monte Rosa nappe

- Analyse basement metapelite samples:
  
  Newly discovered peak Alpine assemblages
  
  Calculate P and T

- Pressure variations:
  
  Mechanically induced
  
  Chemically induced

- Geodynamic implications

\[ \Delta P = 0.8 \pm 0.3 \text{ GPa} \]
Tectonic location of the Monte Rosa:

Modified from Steck et al., (2015)

Field area:
Cirque du Verra

Modified from Beltrando et al., (2010)

Modified from Steck et al., (2015)
Field area:  

”Cirque du Verra”

- Far western extent of Monte Rosa nappe
- Recent glacial retreat has uncovered fresh exposure for mapping
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Metapelite sample: outcrop observations

A - Large scale igneous textures.

B - Igneous contact => coherent unit and therefore not a tectonic mélange.

C - High pressure Alpine imprint is preserved within a pre-Alpine schistosity unaffected by late-Alpine greenschist overprinting.

D - High pressure assemblages within pseudomorphs replacing former contact metamorphic andalusite....
Schematic geological history of metapelite:

*Interpretation of observations from this study

** age dates from Engi et al., 2001, Pawlig and Baumgartner, 2001
Lapen et al., 2007
Metapelite petrology: 3x equilibrium assemblages

Sample 16MR-17 & 19MR-04: unique staurolite + chloritoid bearing assemblages:

Grt + Ms + Pg + Cld + St + Chl + Bt + Qtz + Als (+ accessory mineral Ap, Rt and Mz)

- Representing peak Alpine metamorphism
- Water saturated conditions (no sluggish kinetics)
Chemistry of peak metamorphic minerals:

A - Si in phengite.
B - Mg and Fe-total in chloritoid.
C - Na in paragonite and K in phengite mixing gap.
D - Ternary plot for garnet compositions in assemblage 2, and ternary plot for staurolite compositions in assemblage 1.

*note non-negligible Zn
Zn in staurolite activity reduction:

- In order to account for the lack of solution models for Zn in staurolite we have employed a method to adjust the activity of available solid solution end-member data.
- Only Mg and Fe end-member data is available, therefore an entropy adjustment is needed:
  \[ S^{\text{corr}} = S^o - R \ln a \]
  - \( a = 1 \) for a pure phase.
  - Site multiplicity of staurolite being 4 (Fe\(^{2+}\) = Mg = Zn = Mn).

Molecular mixing model: \( a = X_{Mg} = \left( 1 - \left( \frac{Zn}{4} \right) \right) \)

Site mixing model: \( a = X_{Mg} = \left( 1 - \left( \frac{Zn}{4} \right) \right)^4 \)
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Pseudosection results:

assemblage 1

Molecular mixing:

Site mixing:

1.6 ± 0.1 GPa, 600 ± 5 °C

1.6 ± 0.2 GPa, 580 ± 15 °C
Pseudosection results: assemblages 2 and 3

1.3 – 1.4 GPa, ca. 575 °C

ca. 1.6 GPa at 575 °C
Comparison with whiteschist:

- Peak Metamorphic conditions from metapelitic samples re-affirm pressure variations
- Whiteschist is consistently at a higher pressures compared to all metagranite and metapelite lithologies examined
- Varying P but consistently similar T conditions => isothermal decompression?
- Rapid isothermal exhumation, or mechanical P variations?
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Mechanical P variation: ....the options

Reaction-induced stress
Dehydration under isochoric conditions

Compression-induced stress
Weak inclusion in strong host

In reality it can be a mixture of both processes...
What is needed are **rheological heterogeneities**

$0.4 - 0.5 \text{ GPa}$

\[
\Delta V_{tot} = \Delta V_{ela} + \Delta V_{rea} = 0
\]

\[
\Delta p = K \frac{\Delta V_{ela}}{\Delta V_0} = -K \frac{\Delta V_{rea}}{\Delta V_0}
\]

\[
\Delta p = -\frac{1}{\beta} \frac{\Delta V_{rea}}{\Delta V_0} = -\rho \frac{dp}{d\rho} \frac{\Delta V_{rea}}{\Delta V_0}
\]

$\Delta P \sim T_{xx}$
Pressure variations in the Monte Rosa nappe

Geodynamic implications:

- **Deep subduction**
  - Mechanically weak and homogeneous rock unit

- **Moderate subduction**
  - Mechanically heterogeneous rock unit

### Lithostatic depth assumption

- **Lithostatic pressure**
- Pressure directly related to Depth

- Peak P = deepest burial of the Monte Rosa nappe

### Pressure variations

- **P variations**
- Whiteschist represents local pressure variations
- Metapelite and Metagranite lithologies represent regional peak pressure of the Monte Rosa nappe
Thank you