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Garnet compositional re-adjustment: cooling rate constraint in metapelites from the Lepontine dome (Central European Alps)

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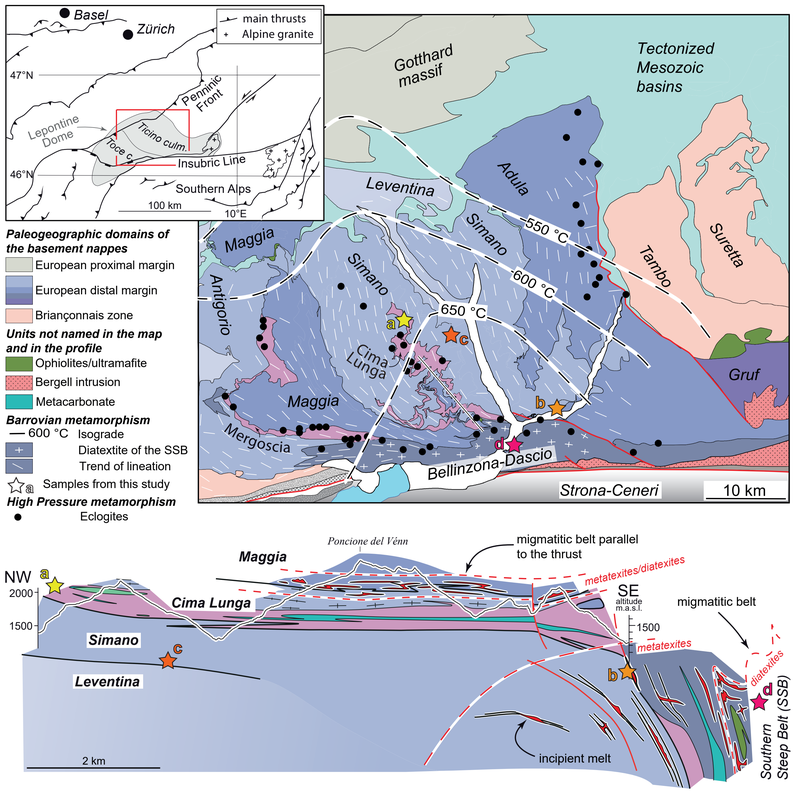
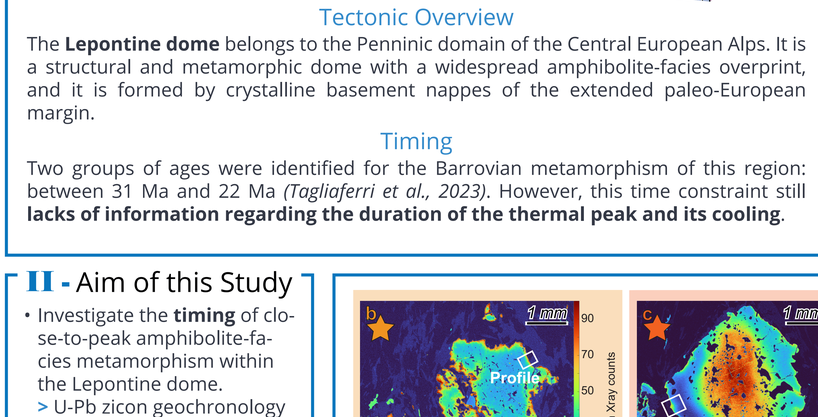
I - Overview on the Study Area





Tectonic Overview

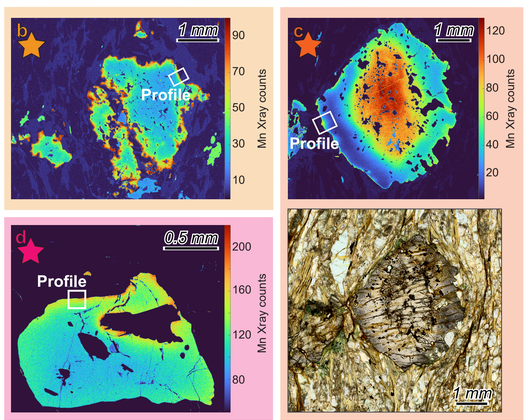
The **Lepontine dome** belongs to the Penninic domain of the Central European Alps. It is a structural and metamorphic dome with a widespread amphibolite-facies overprint, and it is formed by crystalline basement nappes of the extended paleo-European margin.

Timing

Two groups of ages were identified for the Barrovian metamorphism of this region: between 31 Ma and 22 Ma *(Tagliaferri et al., 2023)*. However, this time constraint still **lacks of information regarding the duration of the thermal peak and its cooling**.

II - Aim of this Study

- Investigate the **timing** of close-to-peak amphibolite-facies metamorphism within the Lepontine dome.
  > U-Pb zicon geochronology (*Tagliaferri et al., 2023*).
- Constrain the **duration** of the cooling subsequent to the temperature peak.
  > **Geospeedometry** on garnets (method of *Burg & Moulas, 2022*).
- Determine the **nature of the cooling process**.
  > Compare with thermo-mechanical numerical models *[work in progress]*.



III - Methods

1 Sample Collection

- Geological survey at scale 1:10.000 in the core of the Lepontine dome.
- Selection of grt-paragneisses ☆a at different tectonic levels in the nappe pile.

2 Electron Microprobe Analyses

Garnet Xray maps and selection of linear profiles at garnet rim. ▭ Profile

SELECTION CRITERION: Garnet-biotite border, where garnet rim shows a decreasing #Mg in combination with sharp increase in spessartine component > evidence for retrograde diffusional modification.

3 P-T estimates *[work in progress]*

Post-peak-temperature of re-equilibration and pressure estimated with garnet-biotite thermometer *(Holdaway, 2000)*, GASP barometer *(Caddick & Thompson, 2008)* and phase equilibria modelling *(Perple_X, Connolly, 2005, 2009)* at garnet rim.

4 Diffusion Numerical Models

GDIFF Matlab routines
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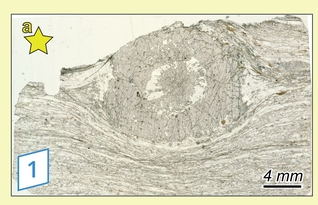
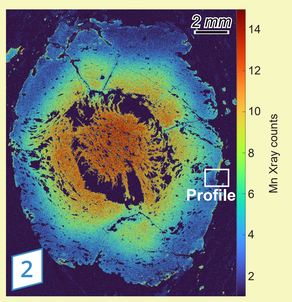
GDIFF Matlab routines, based on the conservative, finite-difference method, are used to calculate garnet's concentration profiles (——).

Input parameters are T and P calculated at the garnet rim: *Ti* = T input, *Pi* = P input. Initial conditions are user-defined step-function concentration profiles (- - - -), which are set for pyrope (*Prp*), spessartine (*Sps*) and grossular (*Grs*) components based on measured microprobe data (○○○○). GDIFF computes new concentrations after diffusion from the step-profiles and diffusion duration (*time* = total diffusion time).

Two routines of GDIFF:
- Calculation with **constant T** > output: duration (*time*).
- Calculation for a **cooling history** (from initial temperature *Ti* to final temperature *Tf*) > outputs: duration, cooling rate (*CR*).

IV - Results

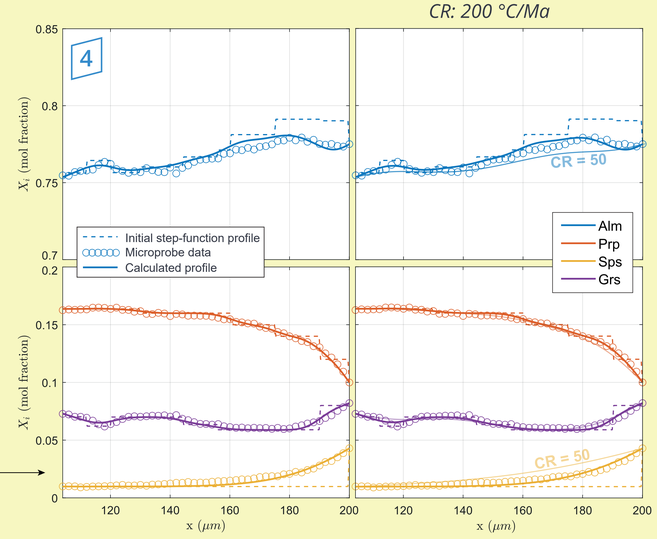




CR best fit is 200 °C/Ma.
50 °C/Ma cooling rate (*CR=50*) does not fit microprobe data.

Model Results

T constant — *Ti: 640 °C - time: 0.1 Ma*
Cooling — *Ti: 640 °C - Tf: 480° C - time: 0.8 Ma - CR: 200 °C/Ma*



Samples across the Lepontine dome — T constant — T cooling

Sample	Tectonic Location	T input (°C)	P input (bar)	Duration (Ma)	Tf (°C)	Duration (Ma)	CR (°C/Ma)
☆a	Maggia/Adula - Simano nappe contact (Cima Lunga unit)	640	7400	0.1	480	0.8	200
☆b	Maggia/Adula - Simano nappe contact	650	10000	0.45	480	3.4	50
☆c	Simano - Leventina nappe contact	615	8500	2	480	13.5	10
☆d	Southern Steep Belt	600	5400	0.5	480	3	40

Highest — *Lowest*

- Higher CR are computed for rocks at **higher tectonic levels** (☆a and b), associated with higher *Ti*.
- **Highest CR** for the garnet-paragneiss from the Cima Lunga shear zone (☆a).
- **Lowest CR** for the sample at the lowest structural level (☆c).
- Similar CR for samples close (☆b) and within the Southern Steep Belt (☆d).

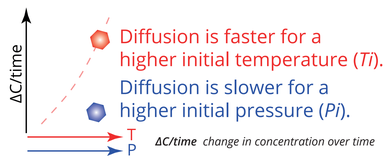
[work in progress]

V - Discussion & Conclusions

Effects of the input conditions on the model results: strengths and weaknesses

- The initial step-profiles used to fit measured data are **not unique**. Different profiles can give similar final concentration trends when similar cooling rates are considered.
- Results are **not dependent on the prograde P-T path or rock chemistry**.
- Results are highly **sensitive to initial T**.
  > Retrograde reactions may obliterate garnet rims, therefore in this case peak-T estimates must be considered as minimal.
- P and T dependence of the tracer diffusion coefficients (D^*) is given by the Arrhenius form:

$$D^* = D_0 \cdot exp\left(-\frac{Q + (P-1)\cdot\Delta V}{RT}\right)$$



D_0 pre-exponential factor
Q activation energy
P pressure
ΔV activation volume
R gas constant
T absolute temperature

Dependence on the diffusion numerical model

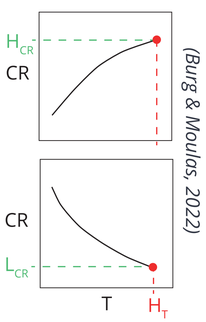
Diffusion time is **longer when a cooling history** is considered, independently of the initial step-function set for the model.

Implications of our preliminary results on the type of thermal regime & evolution of the Lepontine dome

The combination of all possible T and CR outputs which make a good fit to measured data can be represented as a CR-T plot:

Case of **high CR**:
High temperatures in a localized area developed in a small time frame, due to a short thermal pulse (e.g. shear heating).
Cima Lunga rock units.

Case of **slow CR**:
Regional thermal history along a normal geotherm.
Tectonically lower rock units.



[work in progress]

Further questions on this topic?
Check out also Poster X2.246 by Burg & Moulas or contact me at: alessia.tagliaferri@supsi.ch