Formation and Hydration/Dehydration of the Allalin Gabbro

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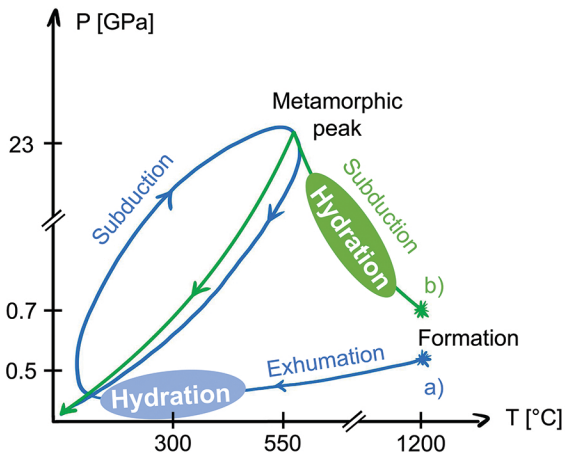
1. Introduction

The subduction of oceanic lithosphere is associated with important geodynamic processes such as dehydration reactions. The dehydration fluids promote element transfer, contribute to the formation of arc magmatism and cause seismicity. Depending on the type of rock being subducted, different amounts of fluid are set free. Hydrated mantle rocks and altered basalts are well studied and represent a significant fluid source in subduction zones (Schmidt & Poli, 1998), whereas the importance of hydrated gabbros has not been studied yet.

This study investigates the Eclogite-facies Allalin gabbro (Zermatt-Saas ophiolite). It has remained unclear in which geodynamic setting the fluid initially entered the gabbro and caused its hydration. To answer this question, we combine field work and petrographic studies. We then aim to quantify the importance of hydrated gabbros as a fluid source in subduction zones using geochemical data and modelling.



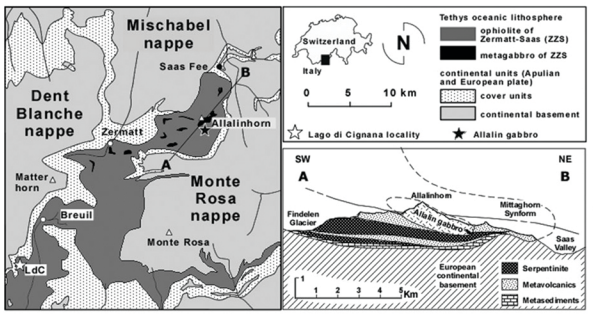
P-T evolution paths showing the two possible scenarios (axes not to scale):

(a) The Allalin gabbro is oceanic and hydration occurred near the seafloor (after Barnicoat & Cartwright, 1997; Angiboust et al., 2009; Meyer, 1983)

(b) The Allalin gabbro is continental and hydration occurred in the subduction zone (after Bucher & Grapes, 2009)

2. Geological Setting

The Allalin gabbro belongs to the Zermatt-Saas ophiolite which formed due to rifting that separated the European plate from the Apulian plate. The ophiolite was then subducted and acquired an eclogitic overprint (Angiboust et al., 2009).



Simplified tectonic map of the Zermatt-Saas ophiolite and cross-section of the Allalinhorn (Bucher & Grapes, 2009)

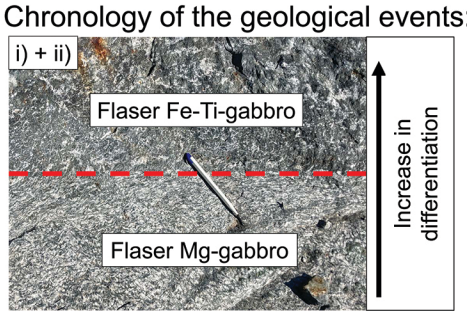
3. Methods

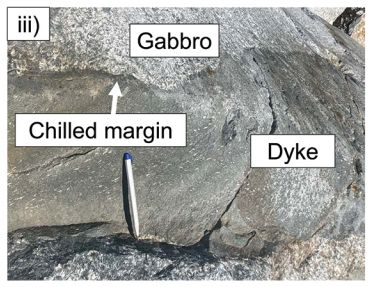
- Fieldwork including study of field relations and sampling
- Petrographic studies using optical microscopy and SEM
- Quantitative chemical analyses: Spot analyses and compositional mapping using EPMA and X-MAP-TOOLS (Lanari et al., 2019)

4. Results

4.1. Fieldwork

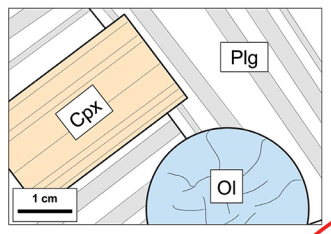
Chronology of the geological events:



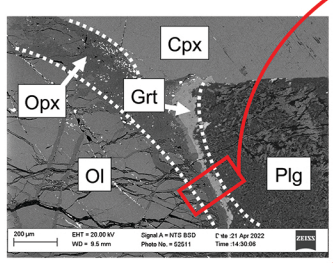


i) Intrusion and magmatic differentiation of coarse-grained gabbro
ii) Post-emplacement deformation to flaser gabbro
iii) Shallow intrusion of fine-grained basaltic dykes

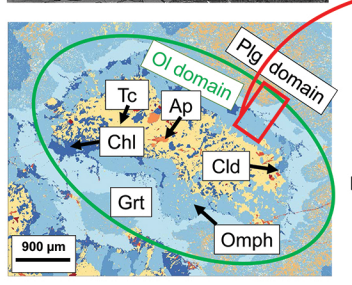
4.2. Petrographic studies: Mg-gabbro



Dry: Magmatic mineralogy and textures preserved



Partially hydrated : Magmatic relicts with metamorphic reaction coronas along mineral grain boundaries



Fully hydrated: Complete pseudomorphic replacement of magmatic minerals by metamorphic minerals

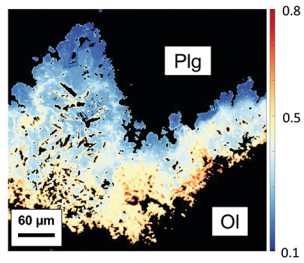
Abbreviations: Cpx = Clinopyroxene; Plg = Plagioclase; An = Anorthite; Ol = Olivine; Opx = Orthopyroxene; Tc = Talc; Ap = Apatite; Chl = Chlorite; Cld = Chloritoide; Omph = Omphacite

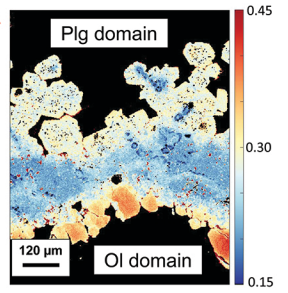
4.3. Chemical compositions

Magmatic minerals:

- Plg (XAn = 0.65)
- Cpx (Mg# = 0.86)
- Ol (Mg# = 0.85)

Garnet corona (XAlm):





5. Conclusions

Our data convincingly demonstrate that scenario (a) applies:

- Fine-grained basaltic dykes and chilled margins indicate shallow dyke intrusion prior to Alpine metamorphism
- Magmatic differentiation from Mg- to Fe-Ti-gabbro corresponds to a typical MOR setting
- Zonation in Grt chemistry corresponds to a prograde path contradictory to a zonation expected near peak metamorphism for scenario (b)

6. Outlook

6.1. Further research concerning the seafloor hydration signal recorded in the gabbro:

- Bulk rock analysis of dykes (LA-ICP-MS)
- Measurement of trace elements typical for seawater interaction (e.g. B, As, Sb) in hydrous phases (LA-ICP-MS)

6.2. Quantification of the importance of hydrated Mg-gabbros as a fluid source in subduction zones:

- Modelling of breakdown of fully hydrated Mg-gabbro with progressive subduction to quantify dehydration conditions (P, T) and mass of fluid liberated

Acknowledgements
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References
Angiboust, S., Agard, P., Jolivet L. & Beyssac O., 2009. The Zermatt-Saas ophiolite: The largest (60-km wide) and deepest (c. 70 – 80 km) continuous slice of oceanic lithosphere detached from a subduction zone? Terra Nova, 21, 171 – 180; Barnicoat, A. C. & Cartwright, I. , 1997. The gabbro-eclogite transformation: an oxygen isotope and petrographic study of west Alpine ophiolites. Journal of Metamorphic Geology, 15, 93-104; Bucher K. & Grapes, R., 2009. The eclogite-facies allalin gabbro of the Zermatt-Saas ophiolite, Western Alps: A record of subduction zone hydration. Journal of Petrology, 50, 1405-1442; Lanari, P., Vho, A., Bovay, T., Airaghi, L. & Centrella, S., 2019. Quantitative compositional mapping of mineral phases by electron probe micro-analyser. Geological Society of London, Special Publications, 478, 39 – 63; Meyer, J., 1983. Mineralogie und Petrologie des Allalingabbros. Doctoral dissertation, University of Basel, 329 pp; Schmidt, M. W. & Poli, S., 1998. Experimentally based water budgets for dehydrating slabs and consequences for arc magma generation. Earth and Planetary Science Letters, 163, 361 – 79.

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