Amphibolization of the Tso Morari UHP eclogites: a record of fluid infiltration at amphibolite-facies during uplift in the subduction channel

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November 23, 2022

Abstract

Ultra-high pressure (UHP) metamorphism of the Tso Morari coesite-eclogite during burial in NW Himalaya has been intensively studied over the past several decades. However, amphibolite-facies metamorphism and accompanying metasomatism occurring at lower-crustal depths in the Tso Morari terrane are less well-constrained. In this study, we characterize the eclogite amphibolization and related metasomatic fluids by systematically sampling and analyzing the eclogites at the core of an eclogite boudin and the amphiblolized eclogite (amphibolite) at the rim. Integrated techniques including modal mineralogy, mineral chemistry, whole-rock geochemistry, Mössbauer spectroscopy, and thermodynamic modelling are used to constrain the fluid-induced eclogite amphibolization and associated fluid behaviors. Petrographic observations show that infiltration of an external fluid caused complete amphibolite-facies overprinting of the eclogites at the boudin rim. This is recorded petrographically as increased modal proportions of amphibole, biotite, epidote, plagioclase, and calcite in the amphibolites. The infiltrating fluid caused increased K_2O and CO_2 concentrations and higher bulk-rock $Fe^{3+}/\Sigma Fe$ ratio for the amphibolites, as well as increased LILE (e.g., K, Rb, Cs, Sr, Ba) and ratios of Ba/Rb and Cs/Rb. Phase equilibria modelling using P–T–M(H_2O) pseudosections on the amphibolite and the surrounding gneiss indicate that the fluid infiltration occurred at 9.0–12.5 kbar and ˜608 °C with >2.6–3.1 mol % H_2O infiltration. The abrupt increase of bulk-rock $Fe^{3+}/\Sigma Fe$ ratio from 0.192 to 0.395 near the boudin rim indicate that this phase of fluid most likely derived from the mixing of dehydrated host orthogneiss and/or metasediments during uplift at the amphibolite-facies zone in the subduction channel. This study also demonstrates the need for using careful petrographic observations and geochemical analysis in parallel with thermodynamic modelling to achieve realistic results.

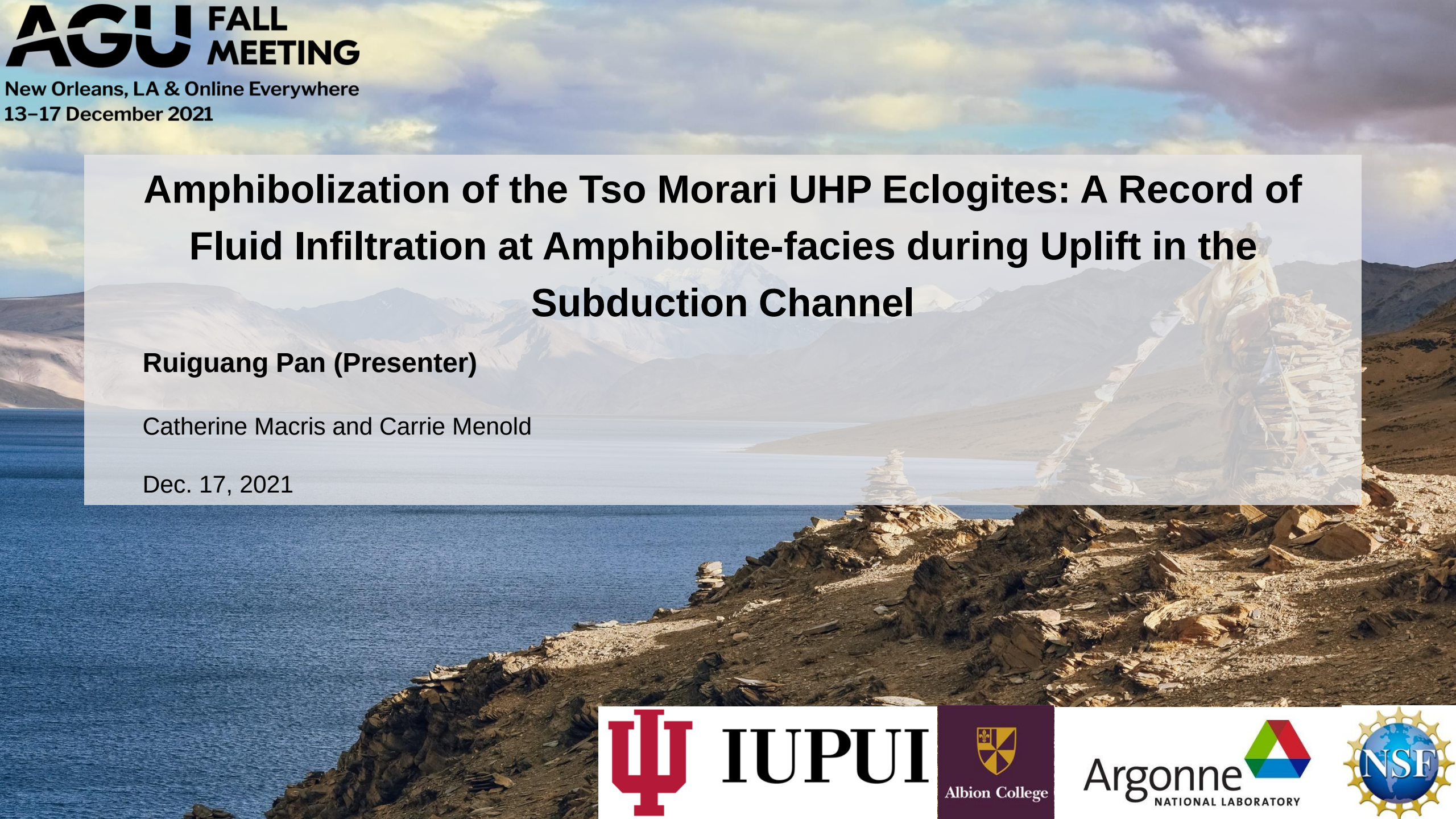
AGU FALL MEETING
New Orleans, LA & Online Everywhere
13–17 December 2021

Amphibolization of the Tso Morari UHP Eclogites: A Record of Fluid Infiltration at Amphibolite-facies during Uplift in the Subduction Channel

Ruiguang Pan (Presenter)

Catherine Macris and Carrie Menold

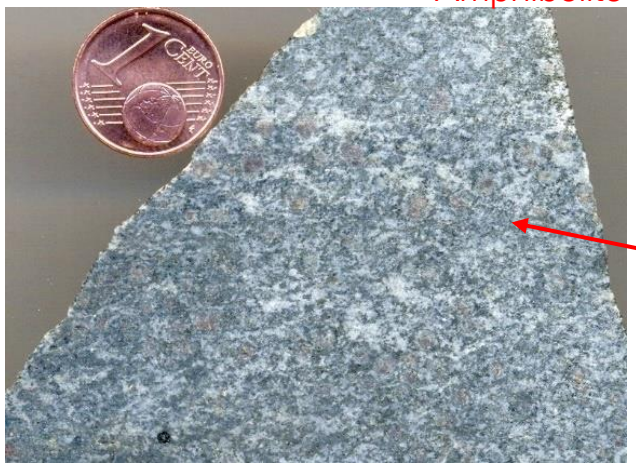
Dec. 17, 2021



Eclogite Amphibolization during Exhumation in Subduction Channel

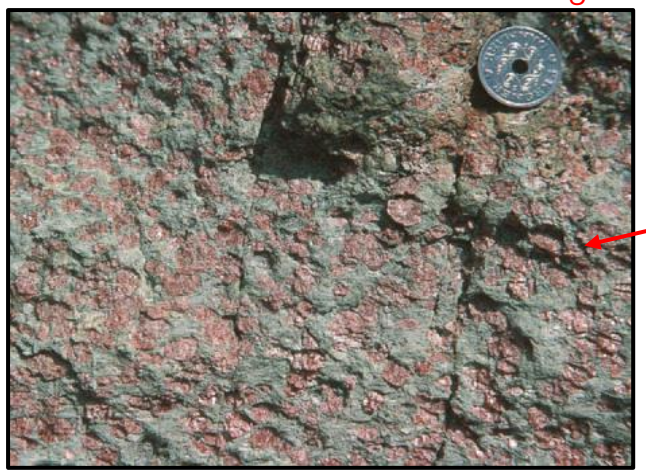
Mafic Rocks *Igneous* → Mantle-depth Subduction / Prograde Metamorphism *Ultra High-P, Hot Fluids* → **Eclogite** → Exhumation / Retrograde Metamorphism *Fluid events/metasomatism* → **Retrograded Eclogite**

Amphibolite

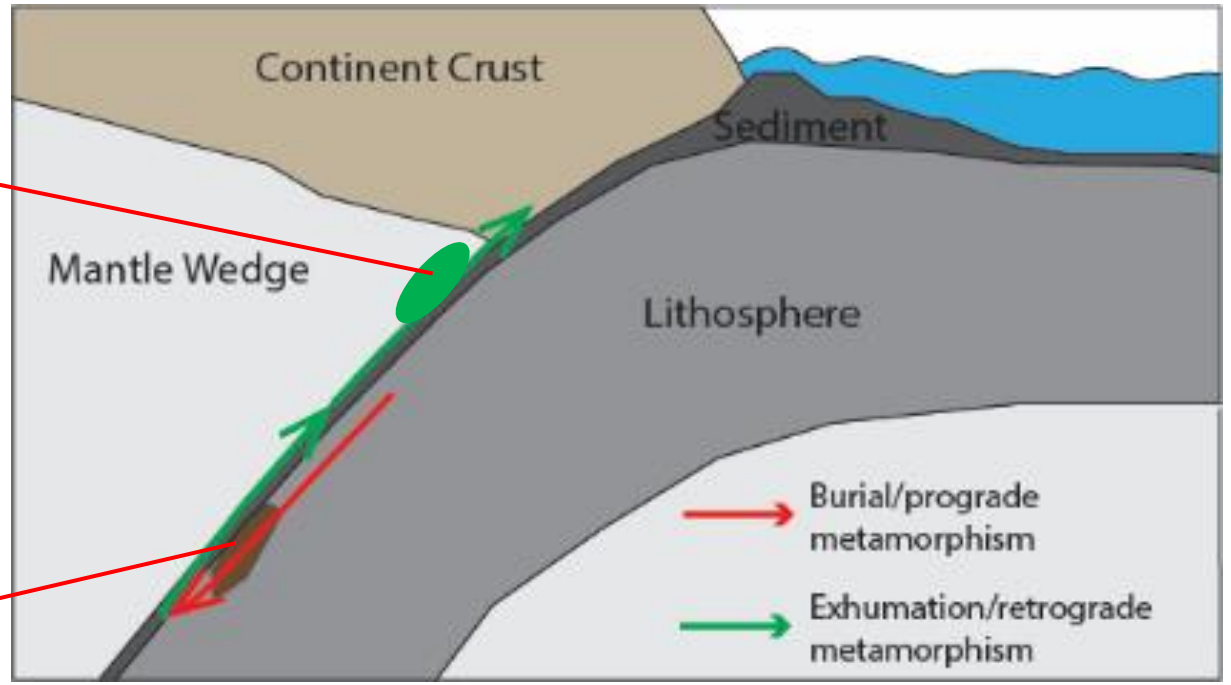


from Val di Fleres, Italy

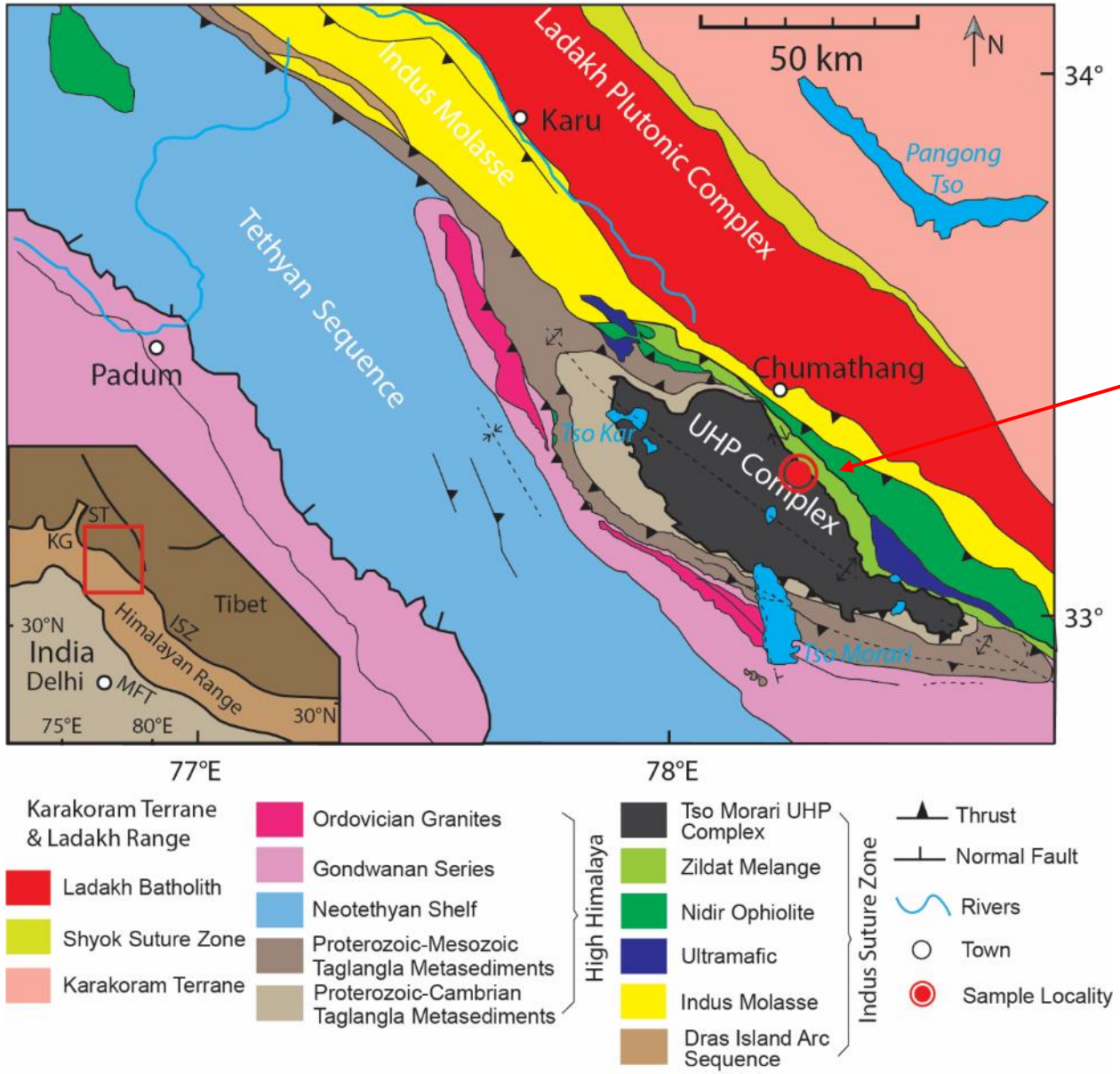
Eclogite



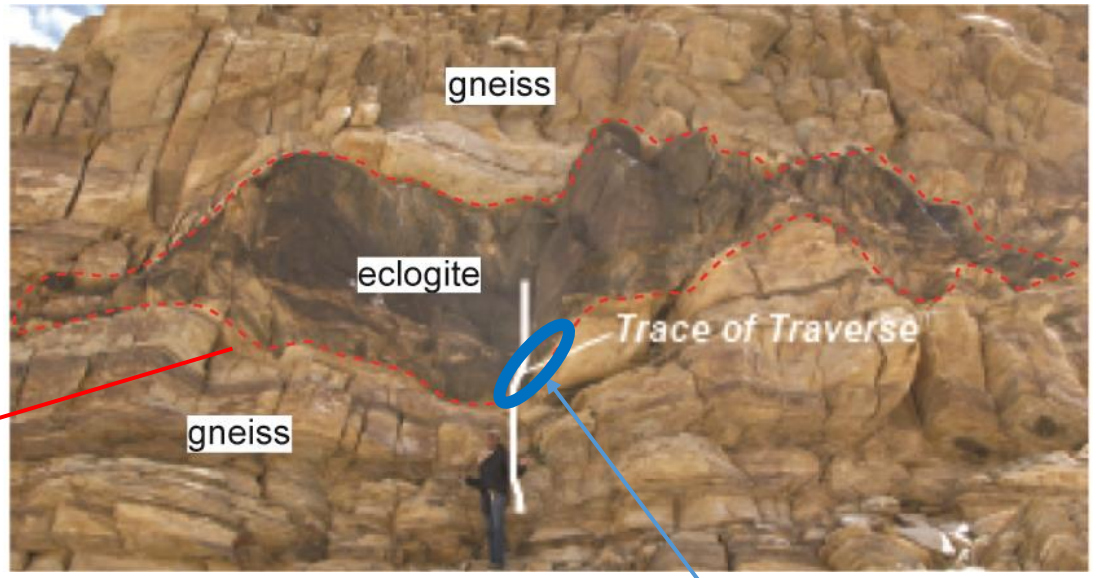
Gilotti, 2013



Geologic Setting



Modified from Steck, 2003



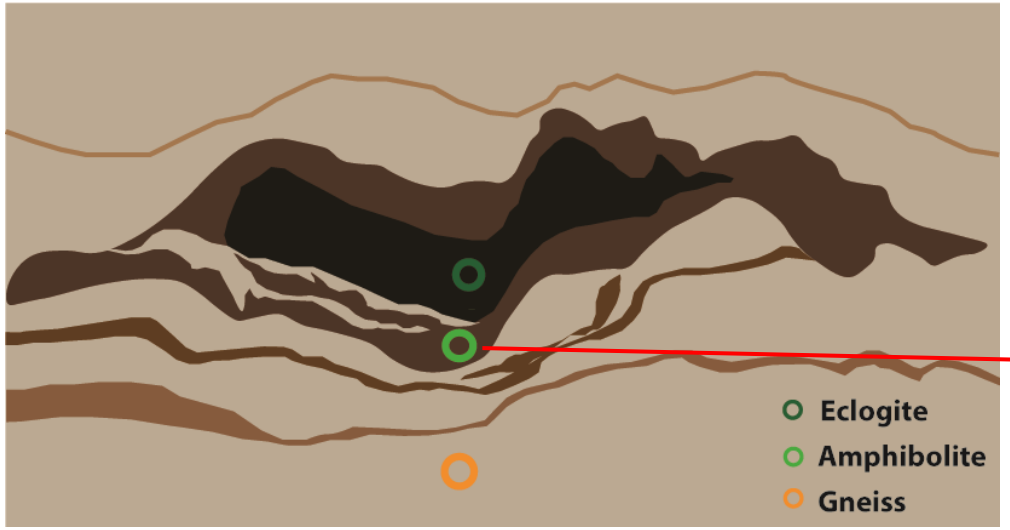
Pan et al., 2020

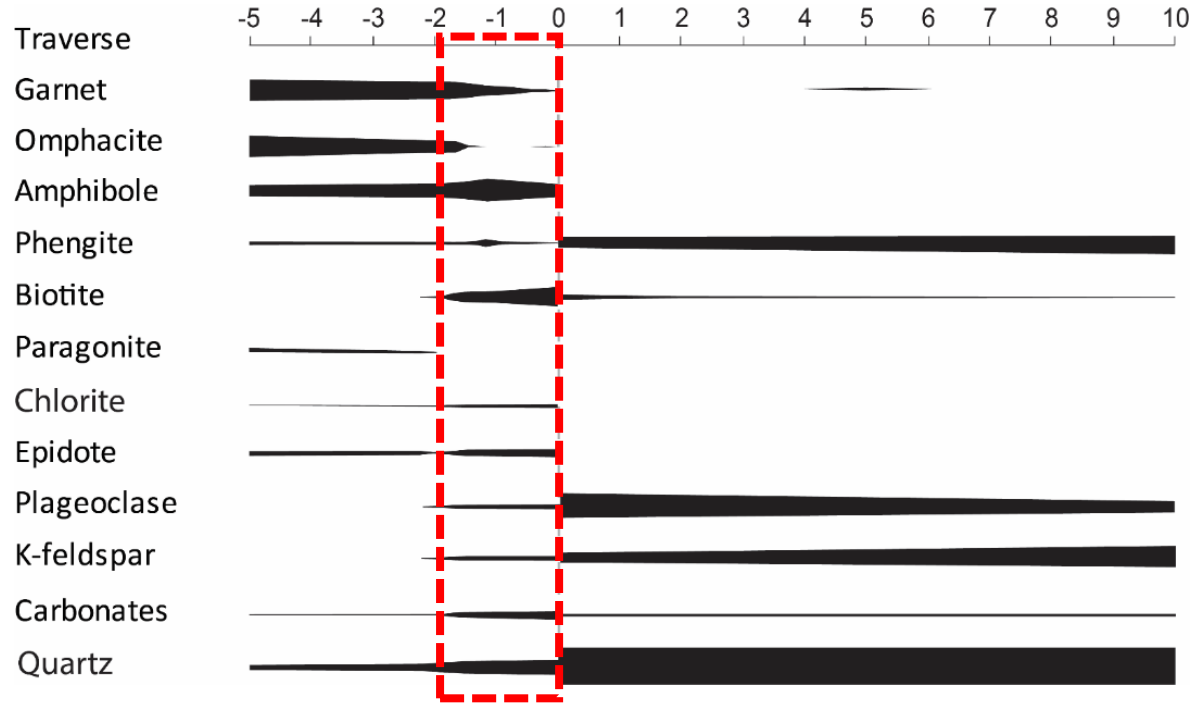
Amphibolite

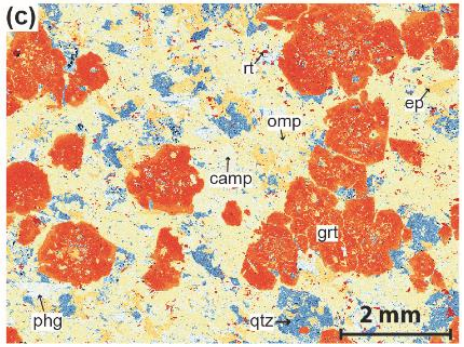
Within the Himalayan orogeny

The Tso Morari UHP eclogite is hosted in the Puga gneiss as a boudin

Amphibolite Petrography & Fluid Infiltration in Boudin Rim

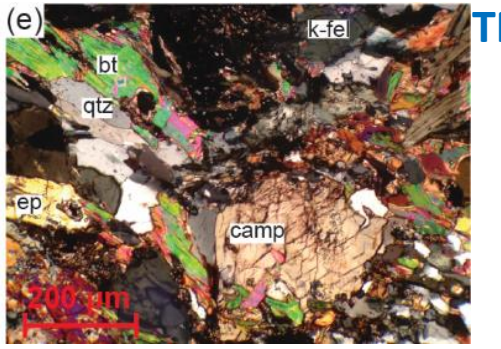






TM-15

Sample	grt	omp	phg	qtz	Ti-oxides	cal	camp	ep
TM-15	28.5	30.5	3	8.5	1	1.5	21	6



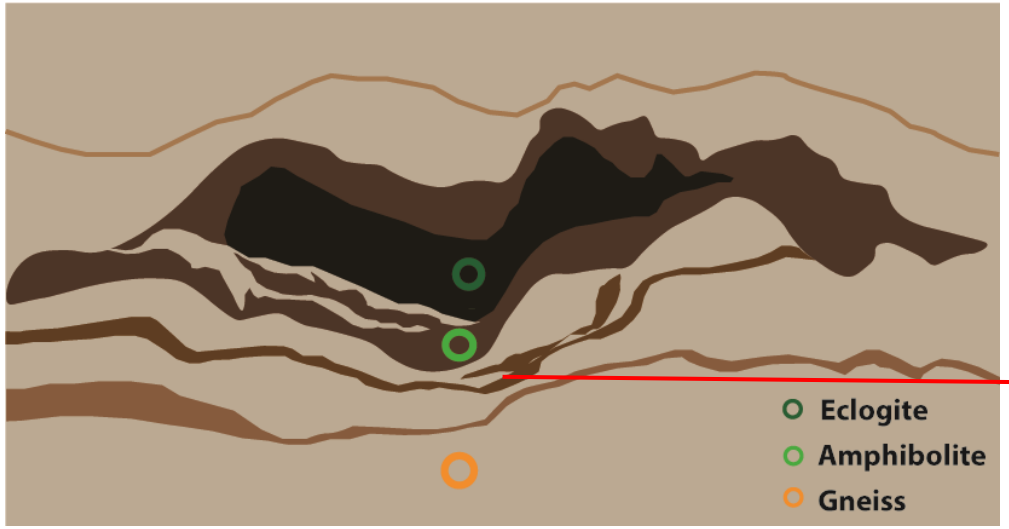
TM-12

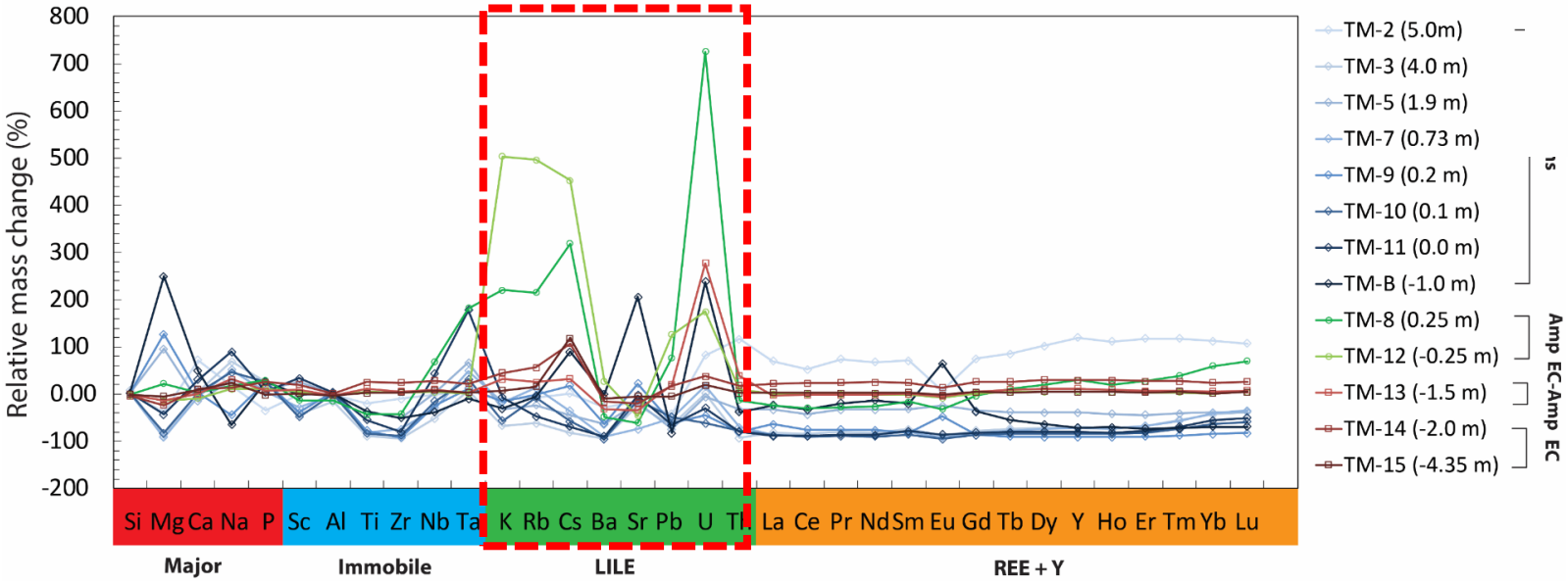
Sample	grt	omp	camp	phg	bt	qtz	ep	pl	Ti-oxides	cal
TM-12	0.5	0.5	26.5	1.5	31.0	20.5	11.5	2.0	2.0	5.0

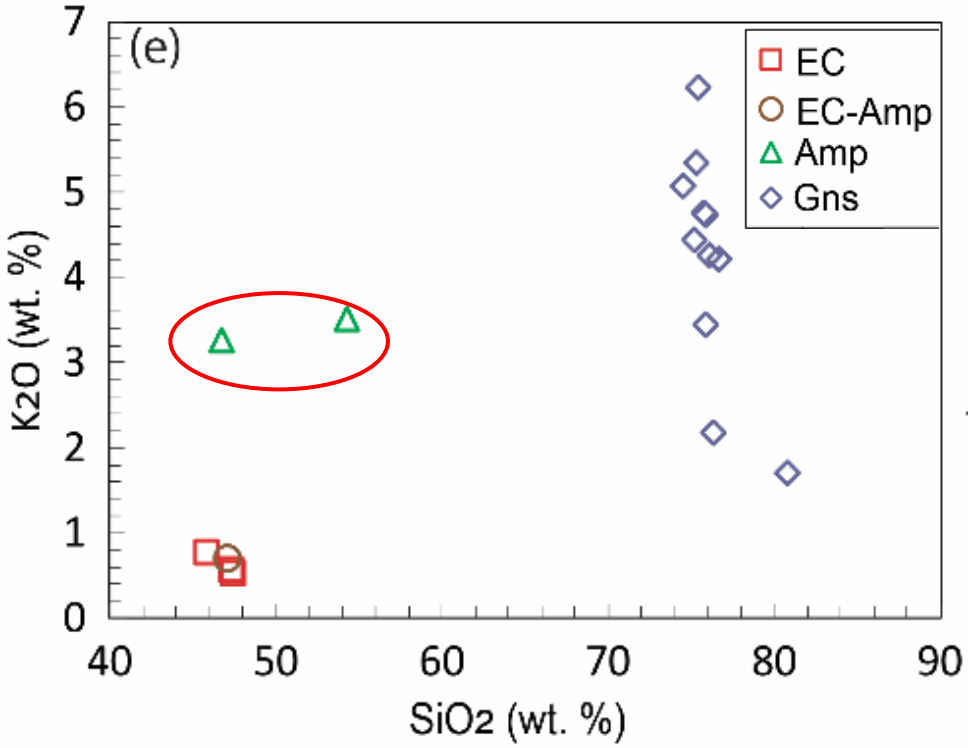
Garnet and omphacite break down due to resorption;

Amphibole, epidote, biotite, and feldspar abundance increase;

Amphibolite Major & Trace Elements & Fluid Infiltration in Boudin Rim





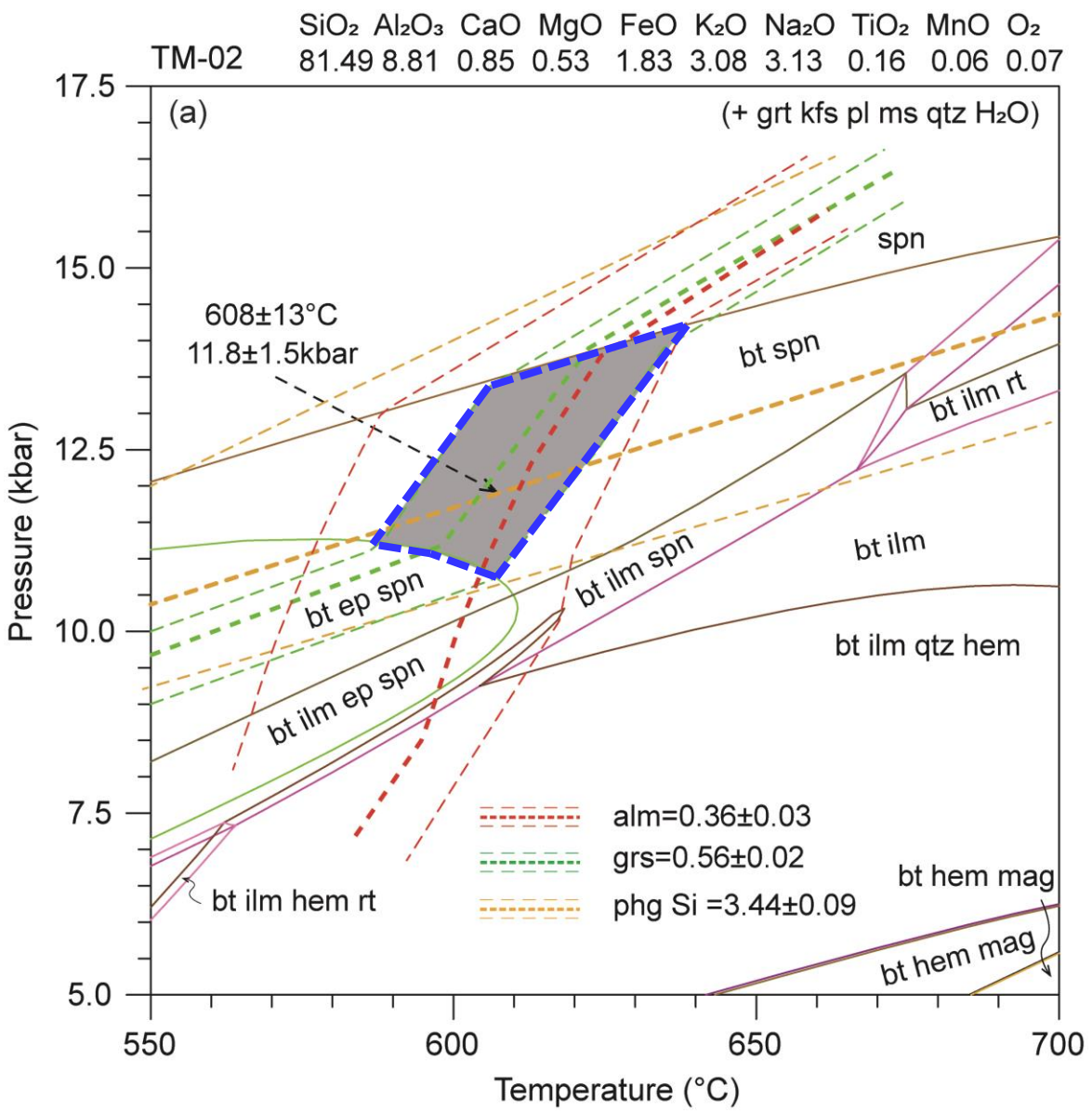


K_2O increases dramatically in amphibolite samples

LILE (e.g., Rb, Cs, Sr, Ba) enriched in the amphibolite samples

Indicating a strong **fluid infiltration** in an open system at the boudin rim

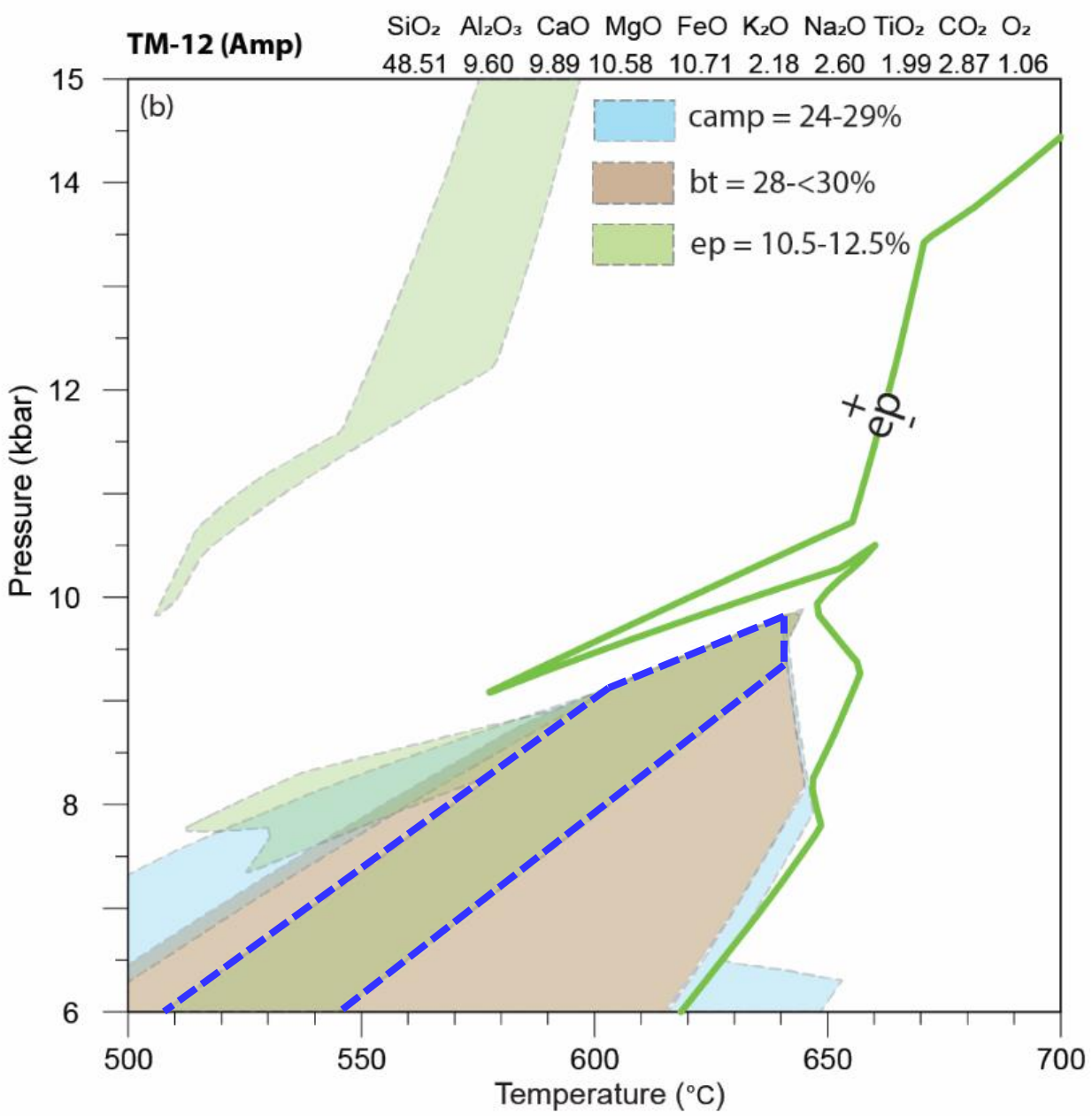
Pressure-Temperature Conditions of the Amphibolization



Garnet =$Alm_{37}Grs_{58}Sps_5Prp_0$
Phengite Si p.f.u.= 3.33–3.48
Minerals: grt + kfs + pl + bt + ms + spn + qtz

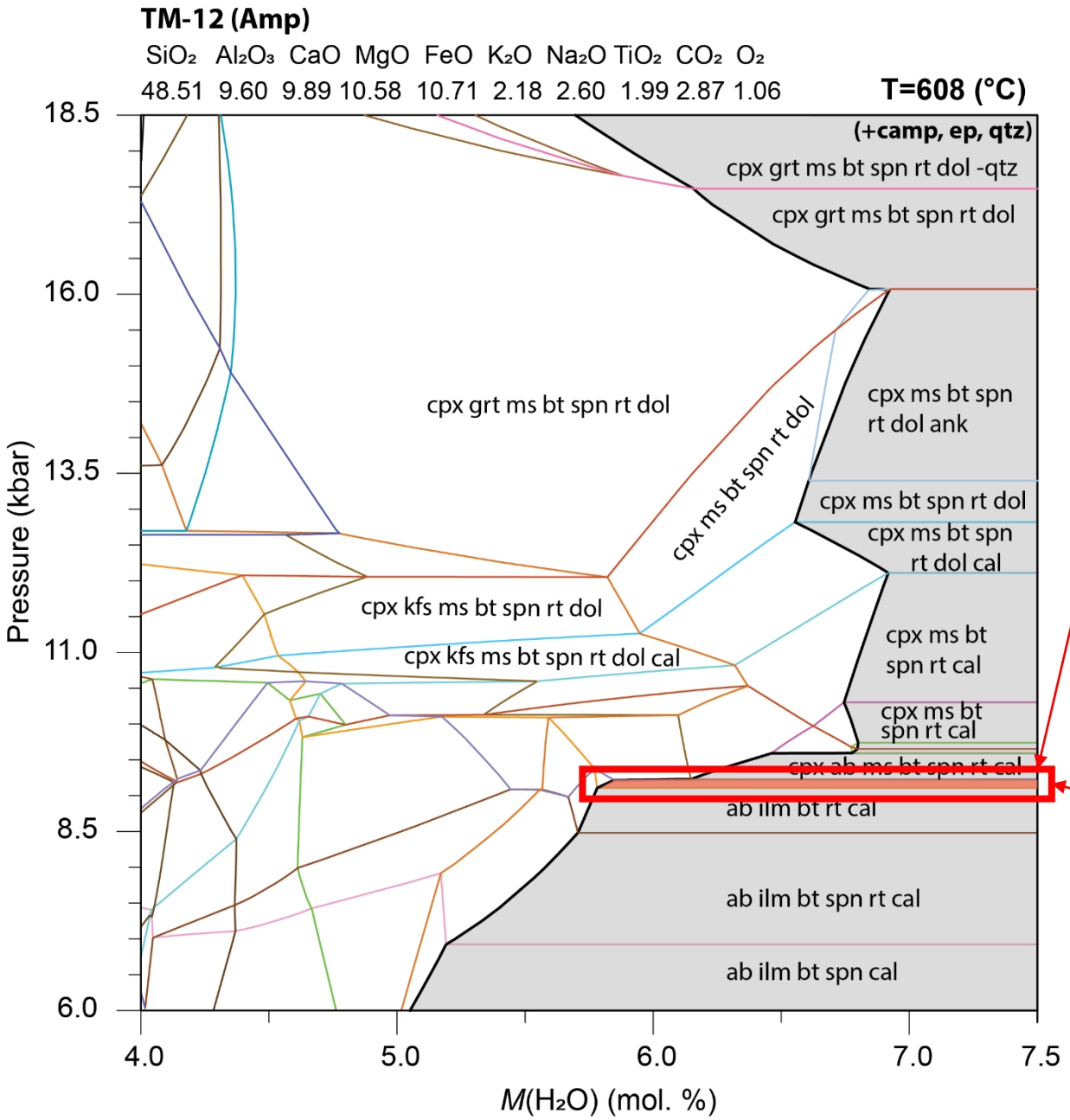
Last stage of retrograde metamorphism in gneiss: **608 ± 13 °C and 11.8 ± 1.5 kbar**

Pressure-Temperature Conditions of the Amphibolization



Amphibole, epidote, and biotite modal proportions limit the *P-T* conditions to **< 9.5 kbar and < 650 °C**

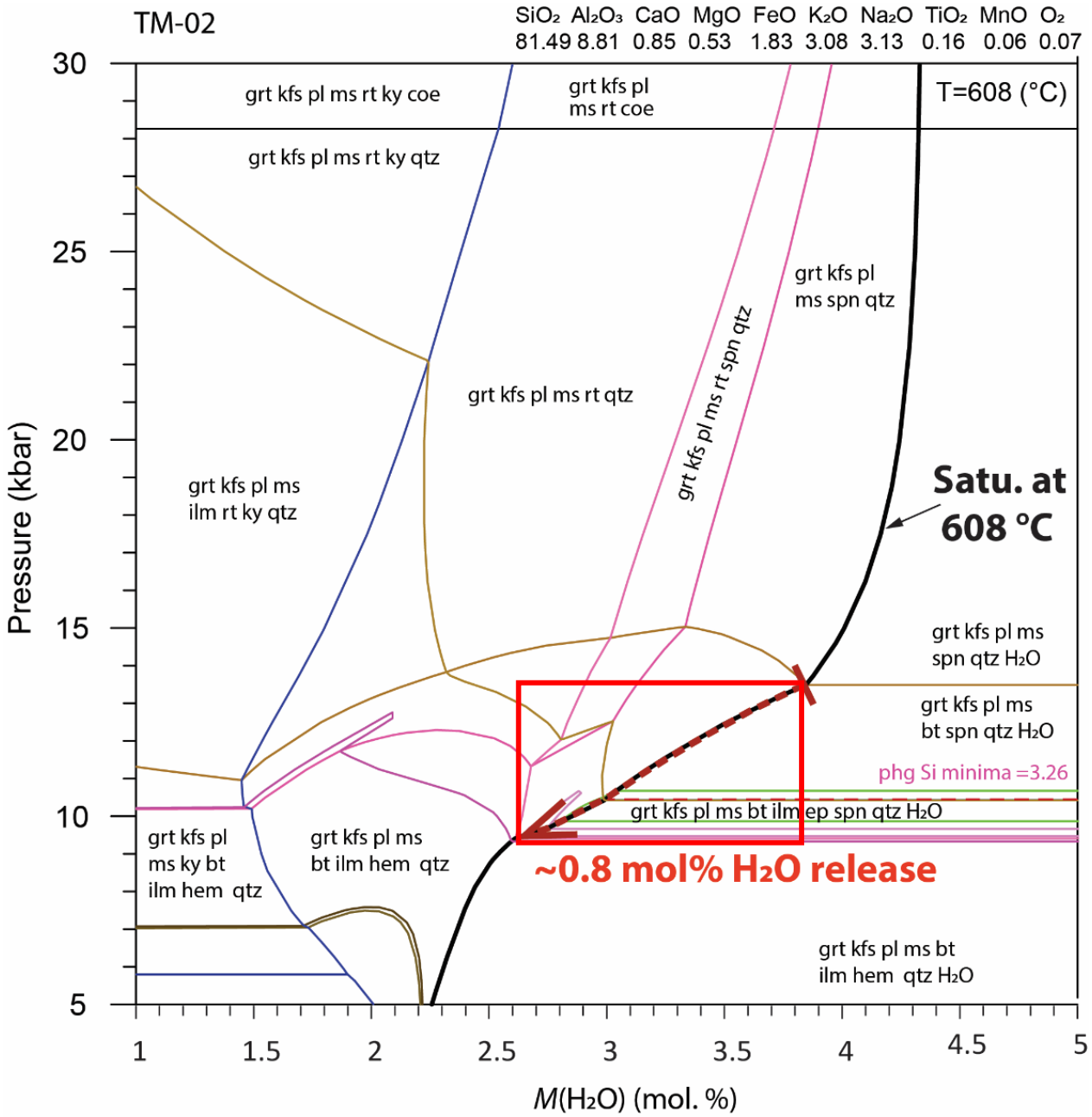
Fluid Content associated with the Amphibolization



Determined by major mineral proportions (amp = 23.5–29.5%, bt = 28.0–34.0%, ep = 10.5–12.5%, and cal = 4.5–5.5%), and key minor phases (phengite and plagioclase)

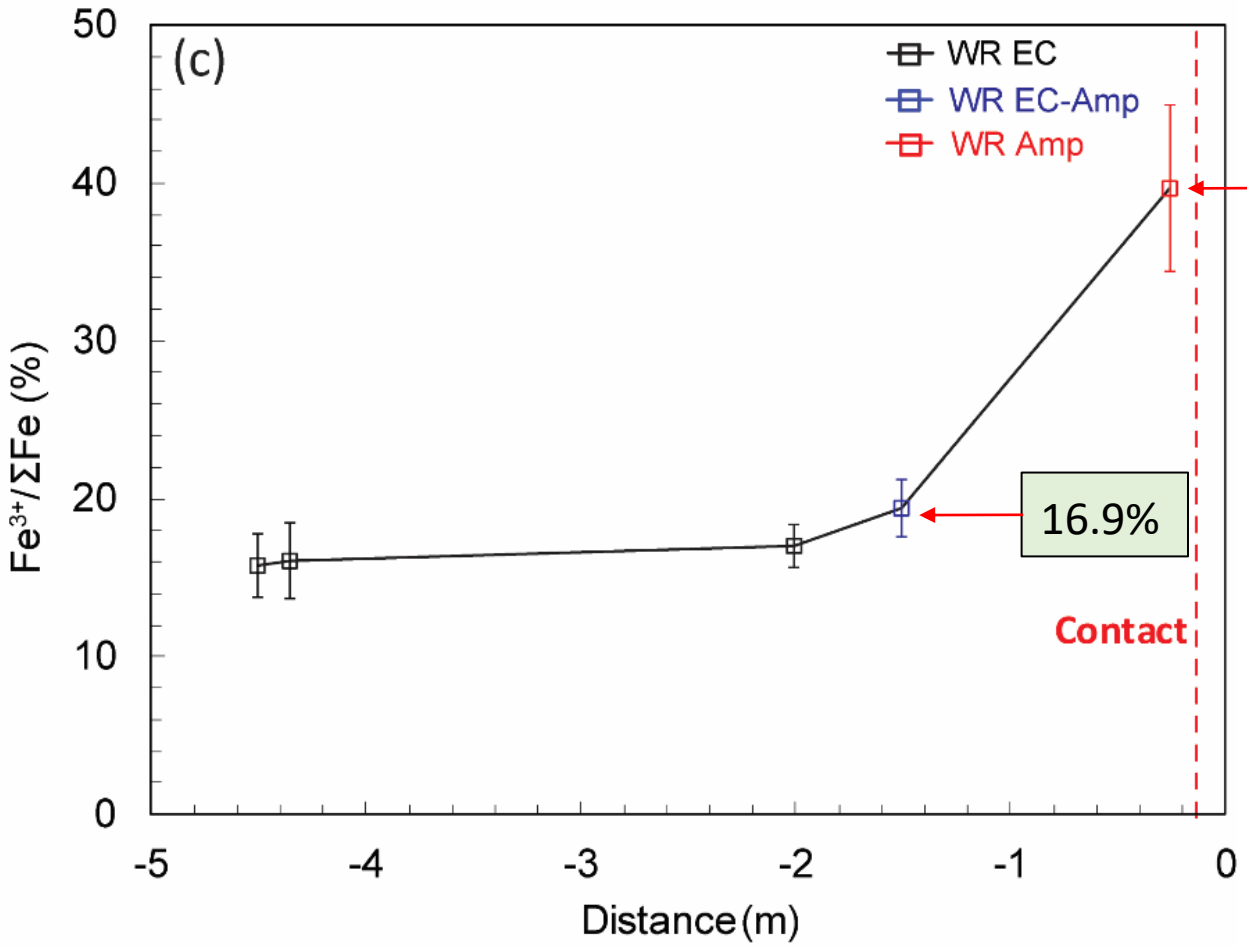
Stability field: **~9.0–9.5 kbar at ~608 °C** with **>~3.0 mol%** H_2O infiltration (~5.8 mol% for amphibolite and ~2.8 mol% for eclogite).

Fluid Sources for the Amphibolization -- Gneiss



Dehydration reactions at **~9.5–13.5 kbar at ~608 °C and 0.8 mol% H_2O release**, which provides one of fluid sources for eclogite amphibolization

Fluid Sources for the Amphibolization -- Metasediments



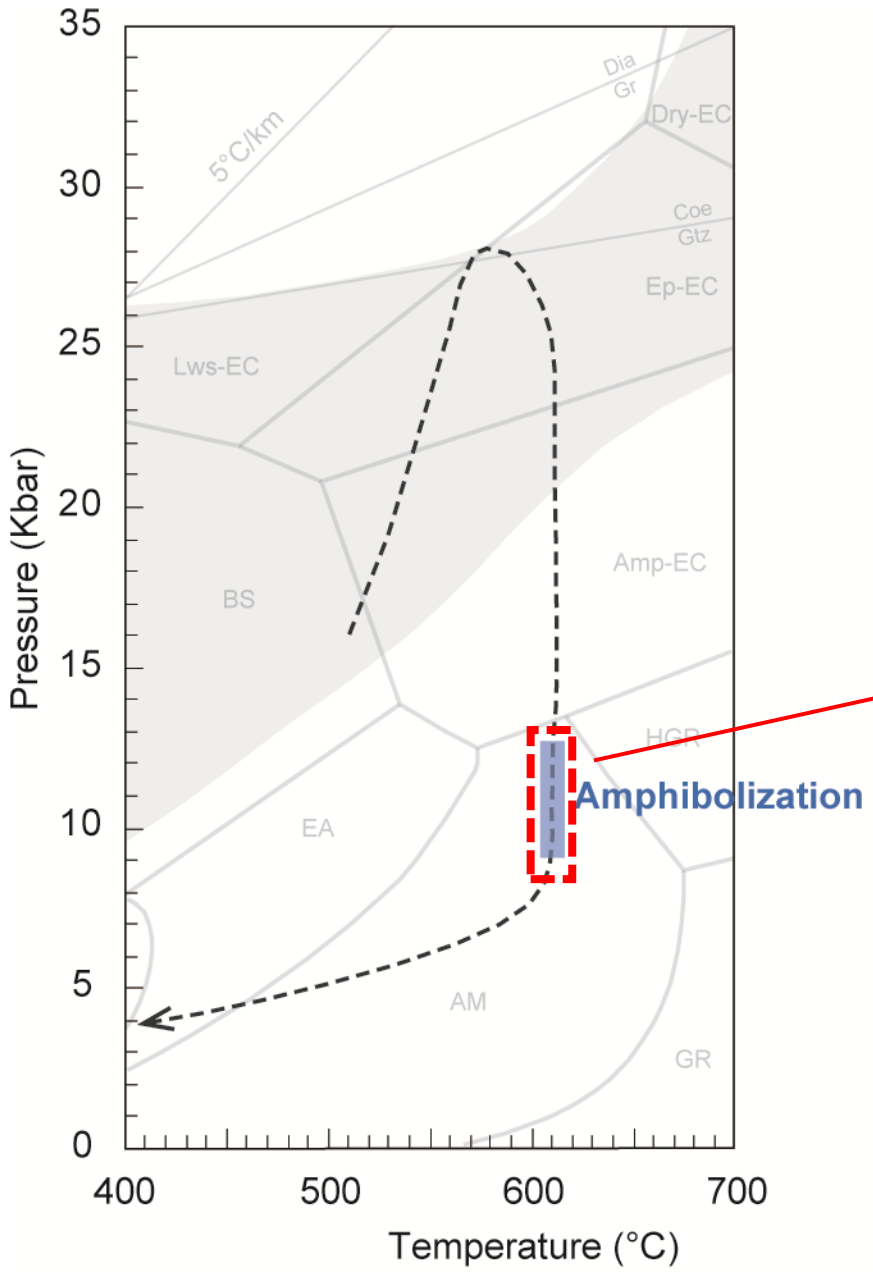
Mössbauer spectroscopy

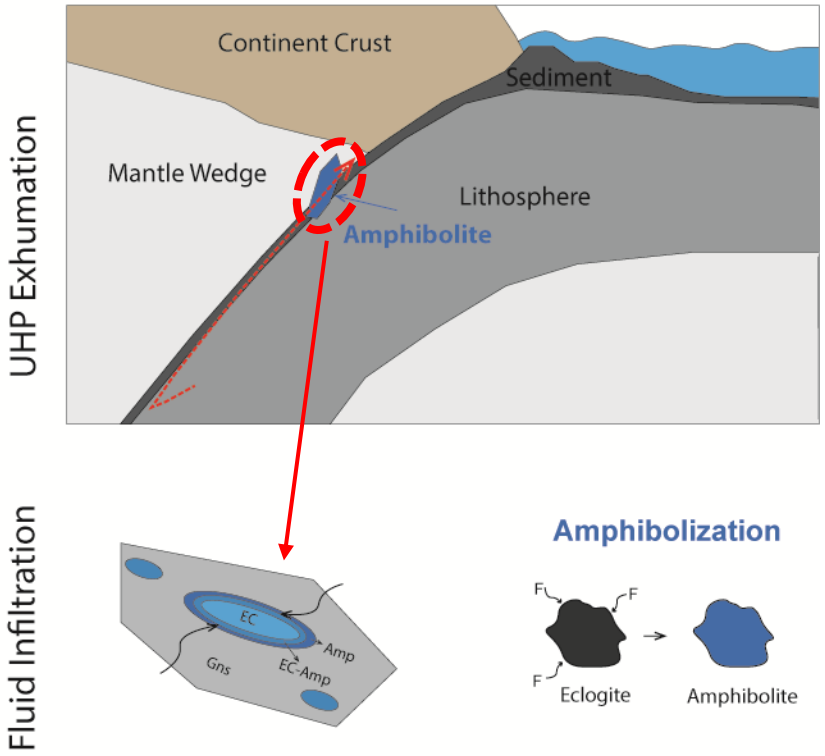
$Fe^{3+}/\Sigma Fe$
- **Metasediments** = ~82%
- Altered ocean crust = ~22 %
- Mantle lithosphere = ~1–3%

$Fe^{3+}/\Sigma Fe$ ratio remains constant from -4.6 to -1.5 m, abruptly increases at the contact, indicating **external fluid origin** in an open system

Chester, 1990; Evans, 2012; Woodland et al., 2006

Conclusions





Eclogite Amphibolization

- **Location:** boudin rim
- **Petrography:** grt and omp decrease, and amp, bt, ep, and pl increase
- **Geochemistry:** K_2O and LILE increase
- **Pressure-Temperature:** 9-9.5 kbar and < 650 °C (~608 °C)
- **H_2O infiltration:** ~3.0 mol%
- **Fluid sources:** gneiss and/or metasediments

Acknowledgement

Funding Sources: NSF EAR -1822524 & Mirsky Fellowship

Main Collaborators: Carrie A. Menold (Albion College)

Esen E. Alp (Argonne National Laboratory)

Thank You!

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