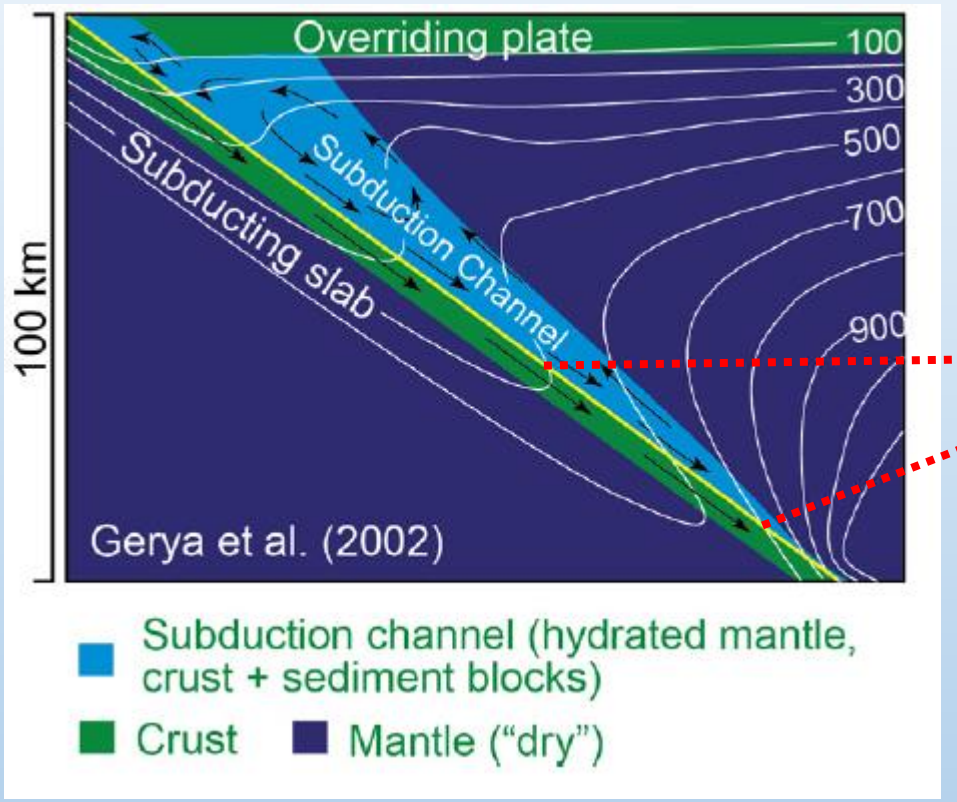
Deutsche Forschungsgemeinschaft

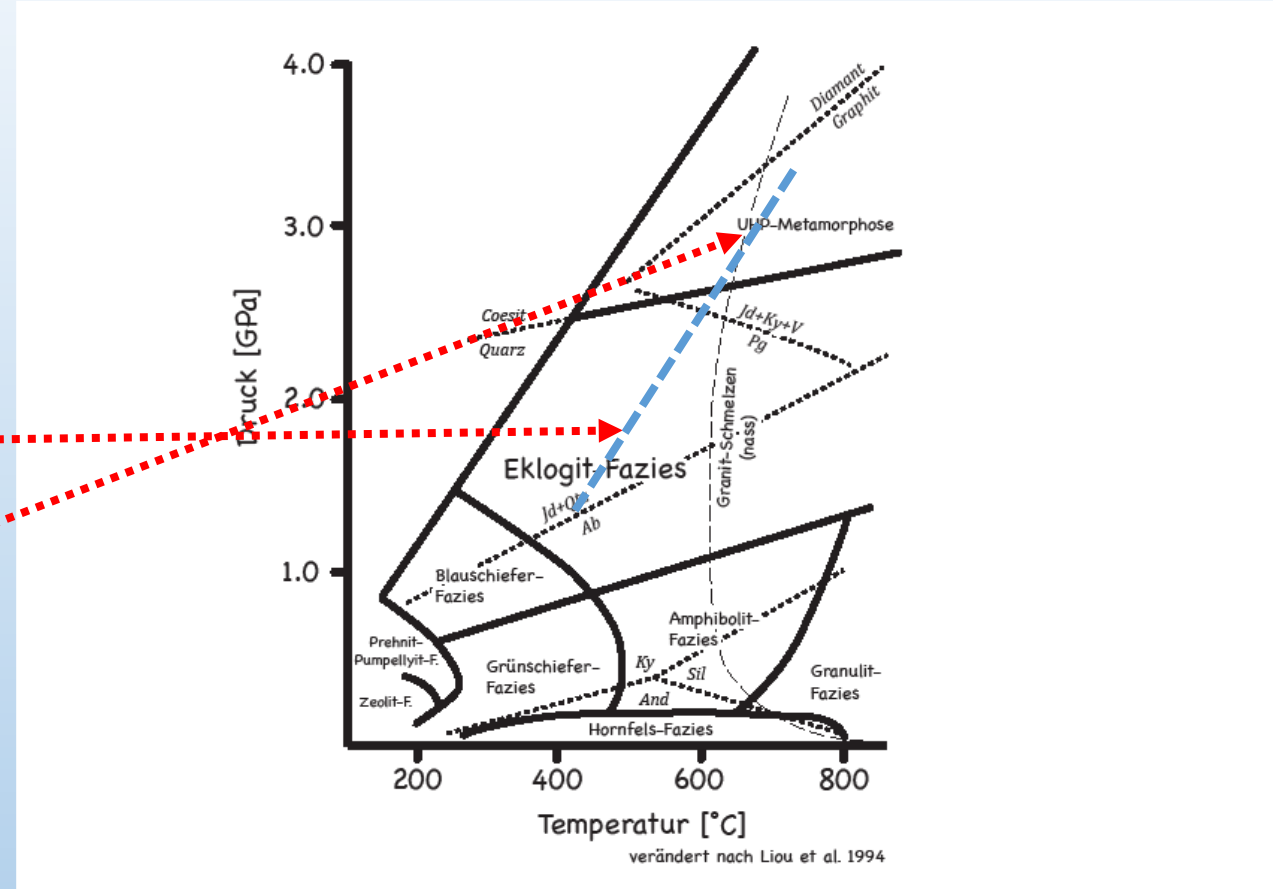
Mountain Building Processes in 4D

Record of subduction in the Alps

Nikolaus Froitzheim

Universität Bonn

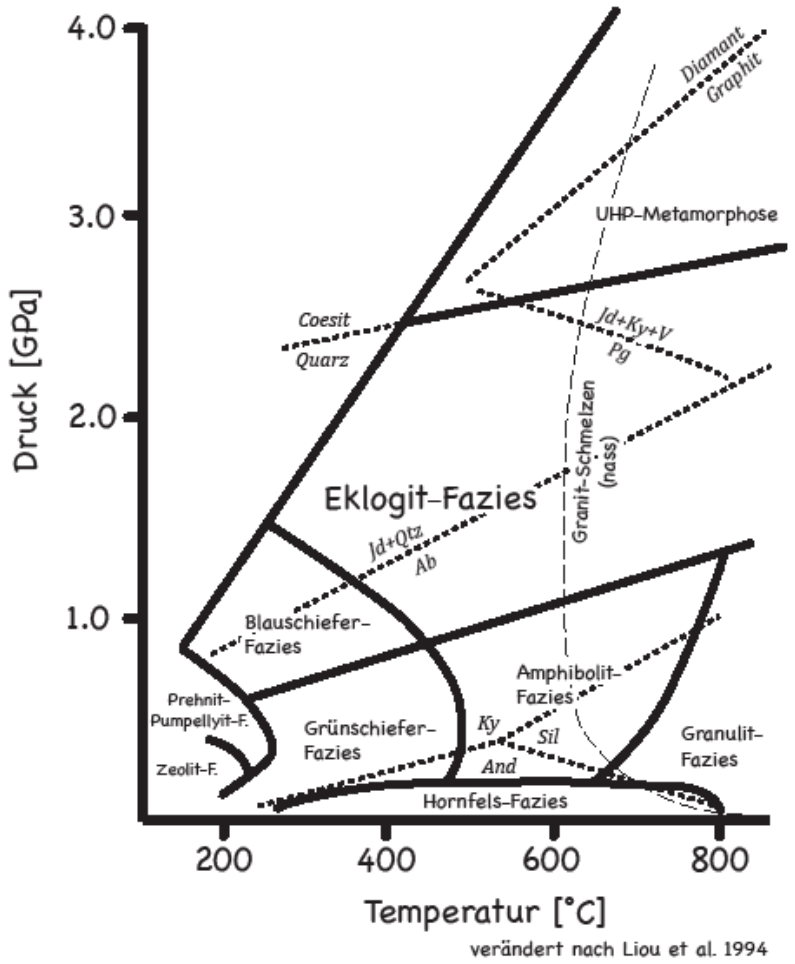


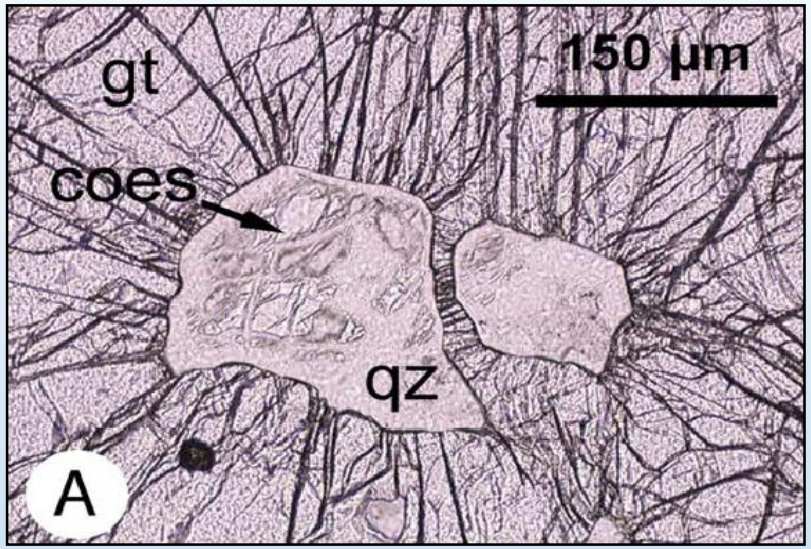


Subduction produces metamorphic rocks with high P/T ratio: blueschist facies, eclogite facies, and UHP

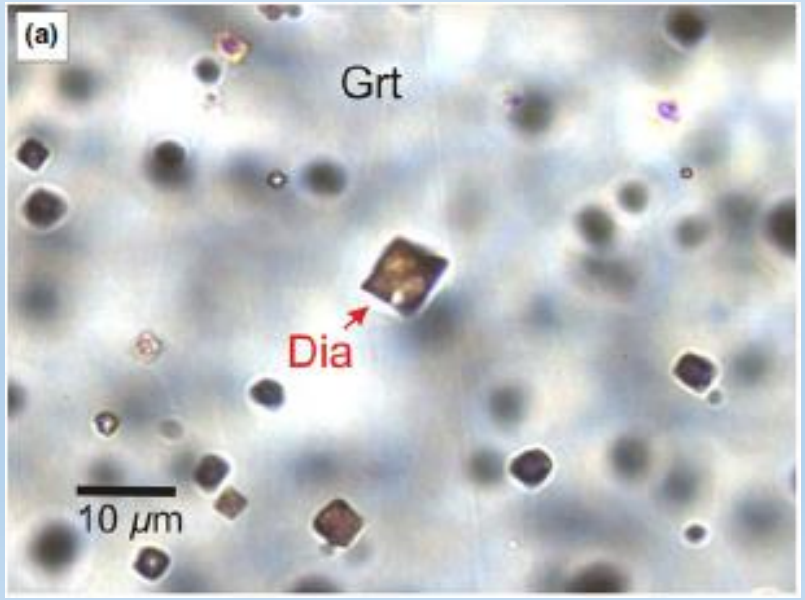
Eclogite: garnet, omphacite, +- kyanite

Blueschist: glaucophane, garnet

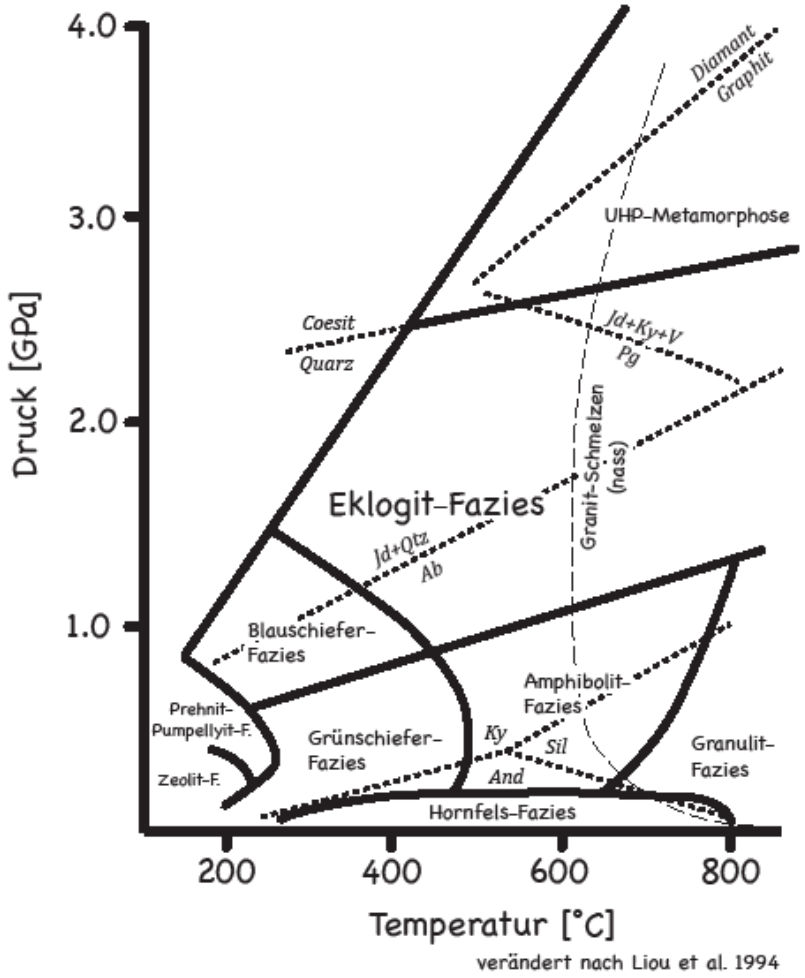




Dora-Maira, Western Alps



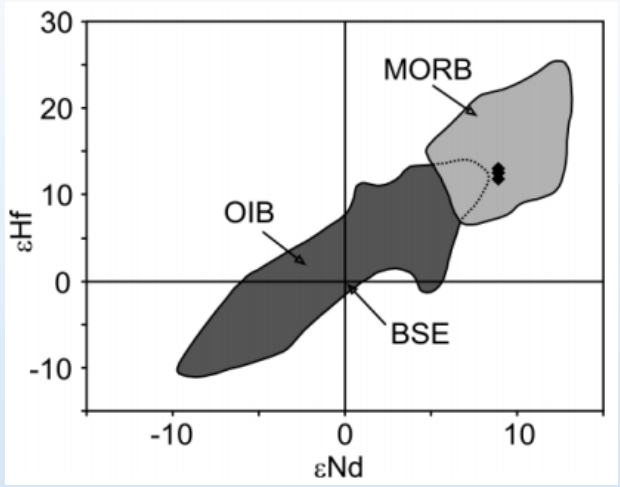
Pohorje, Eastern Alps



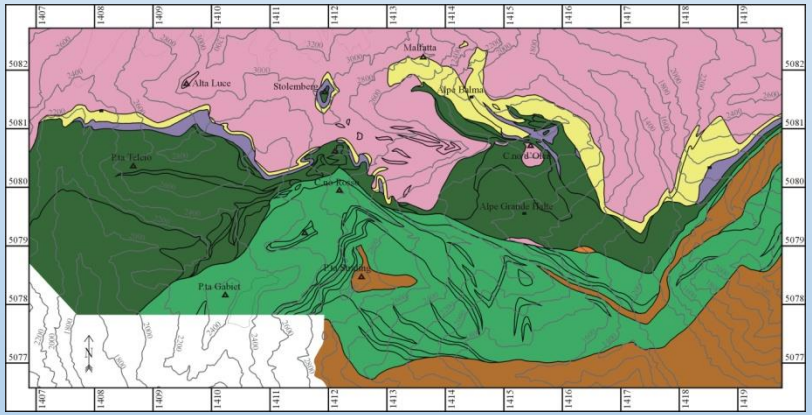
verändert nach Liou et al. 1994

How to retrieve tectonic information from eclogites

Structural analysis



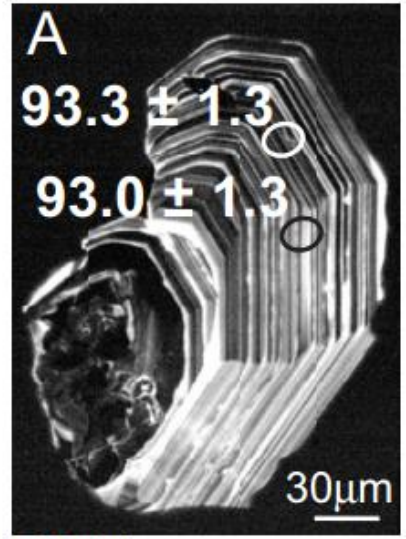
Geochemistry



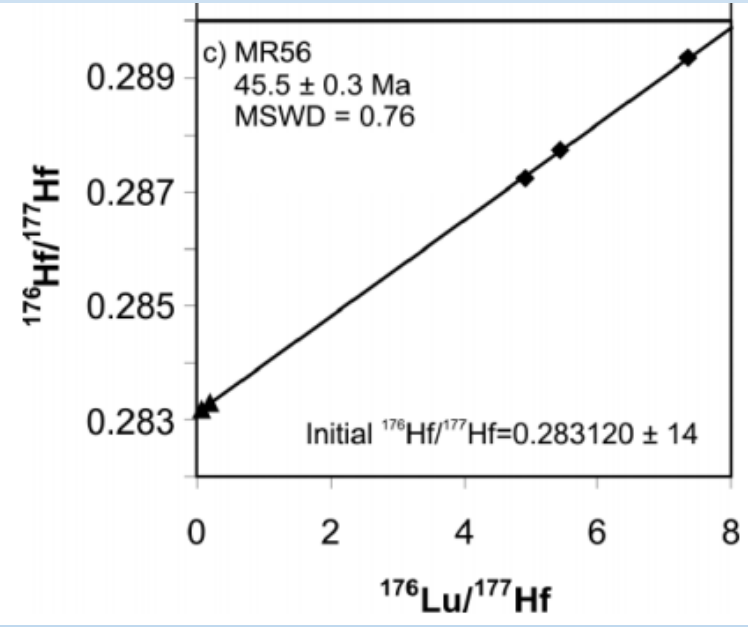
Mapping

Pleuger et al., 2005; Herwartz et al., 2008, Liati et al., 2006,

U-Pb zircon
Protolith
dating
-> spreading



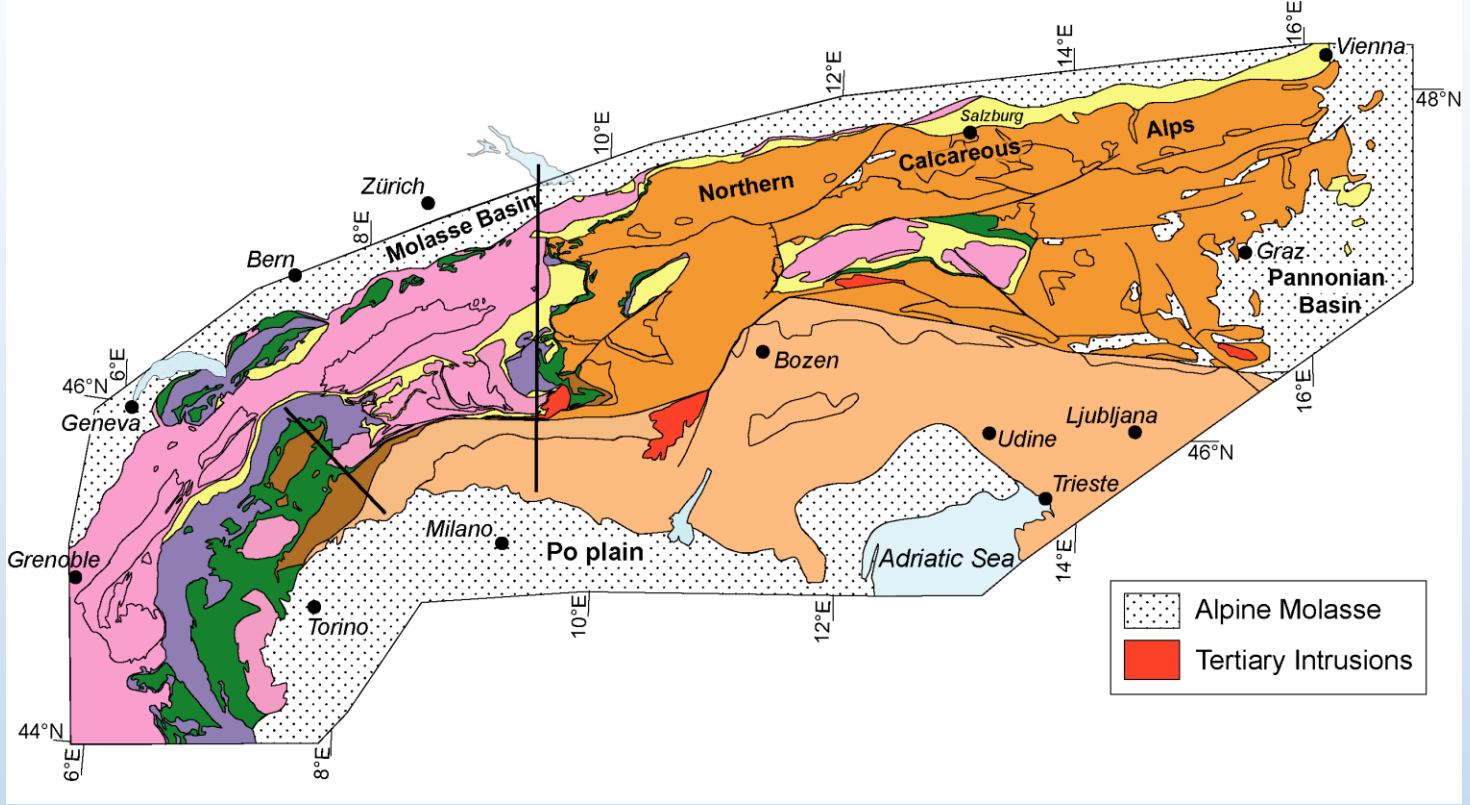
PIS1-4



Lu-Hf garnet dating → subduction

However, the record is incomplete

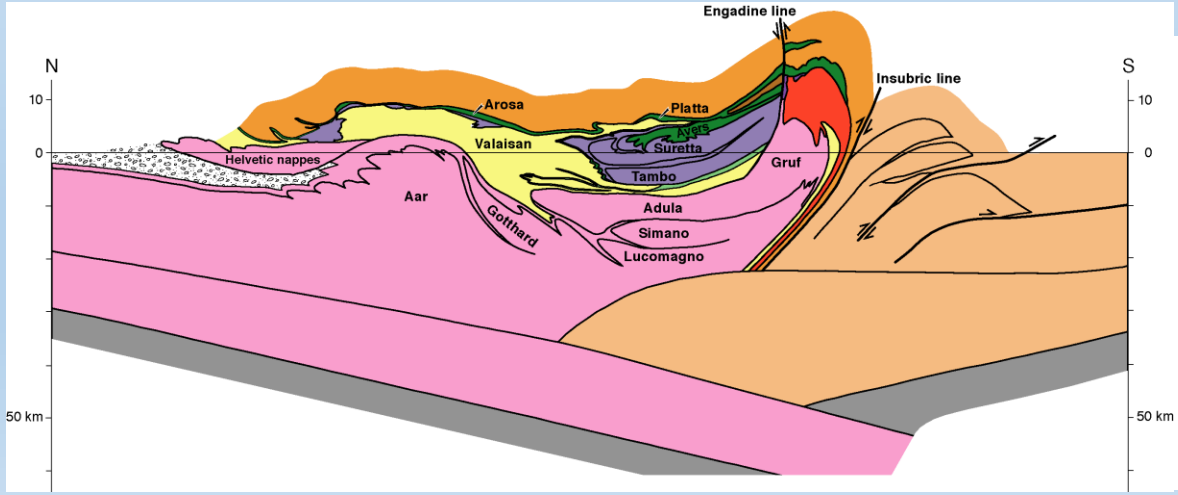
- We can only study the eclogites that have come back to the surface („exhumed“)

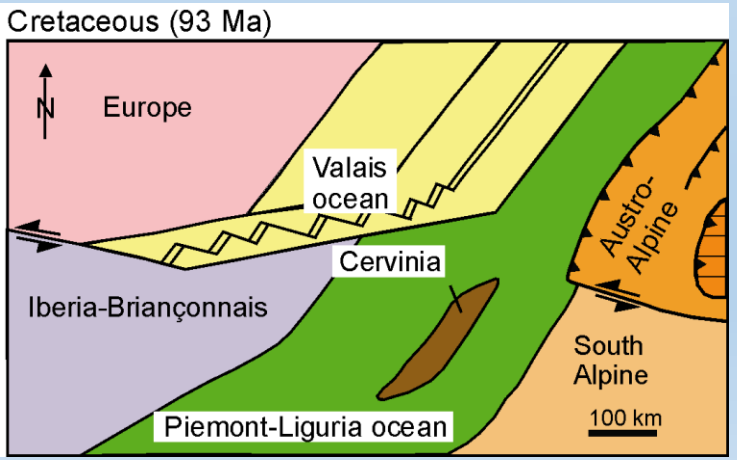


Helvetic and Sub-Penninic: European continent

Penninic: Mesozoic oceans, continental margins, continental fragments

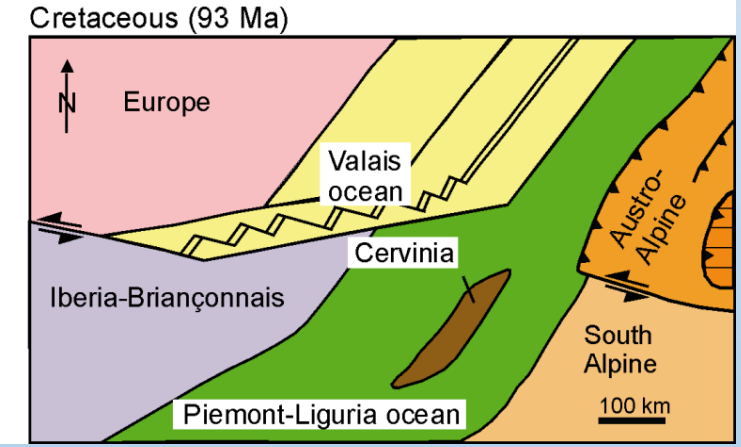
Austroalpine, South Alpine: Adria continent

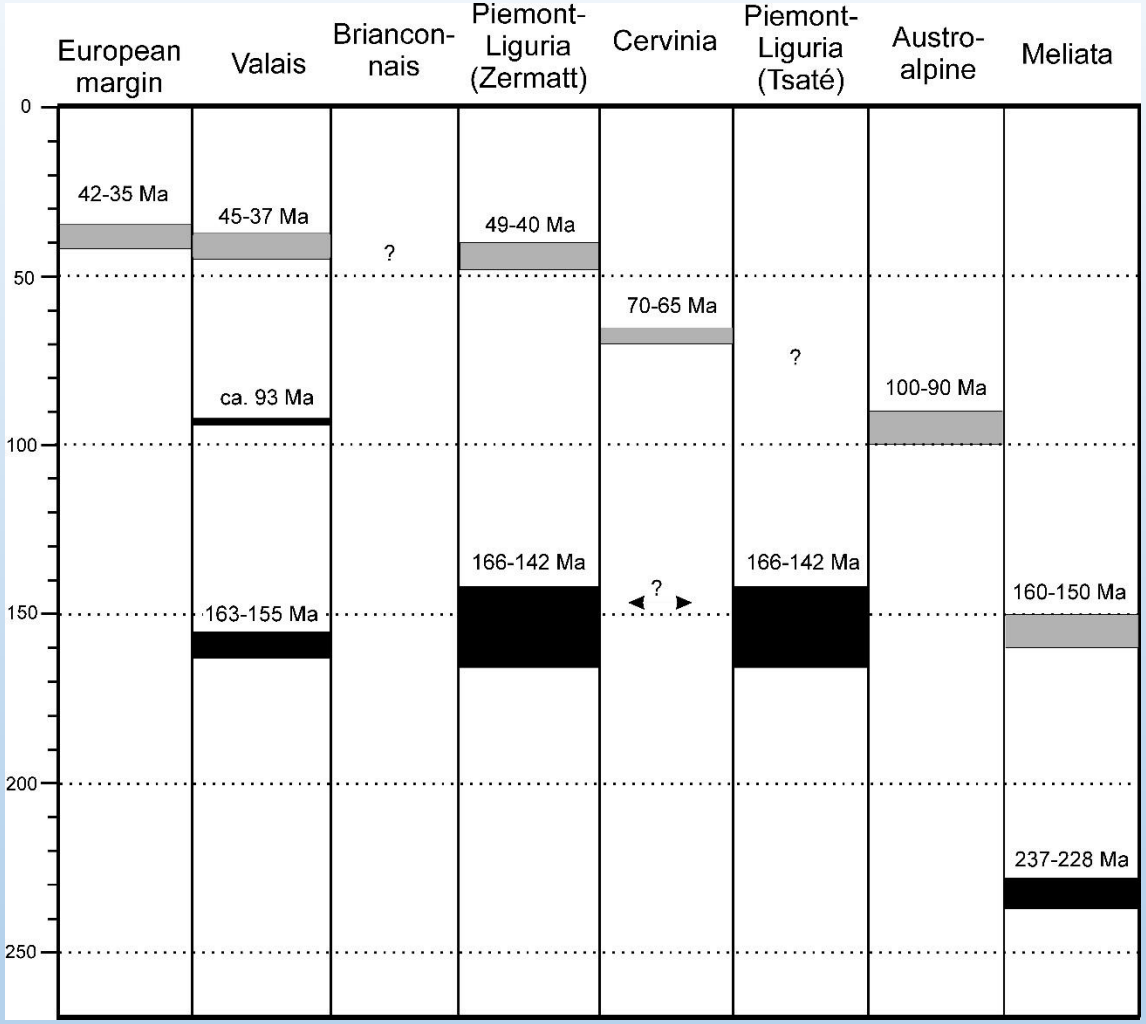


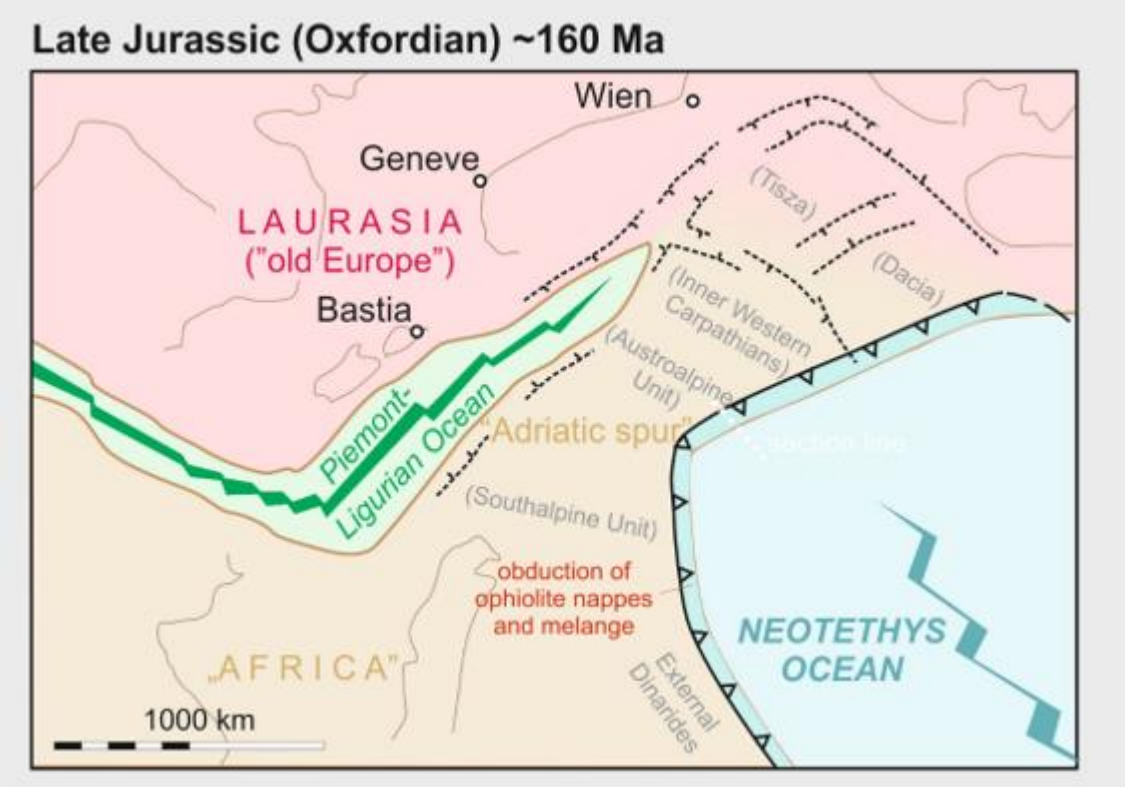


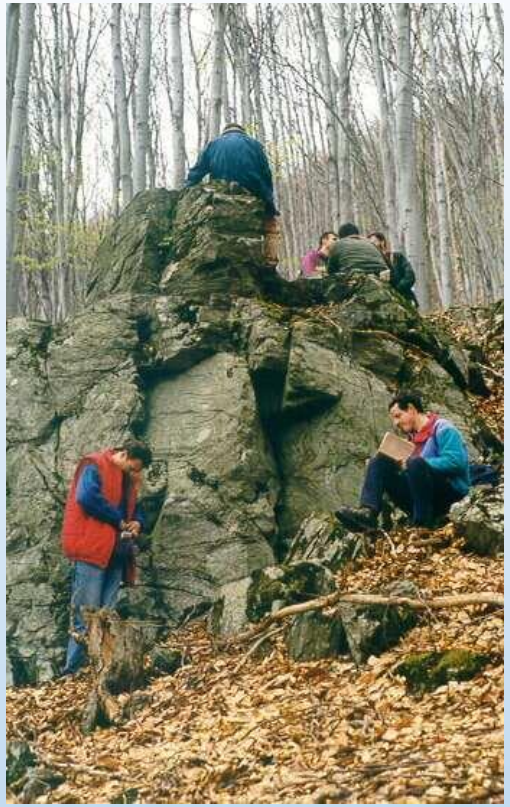
NW SE

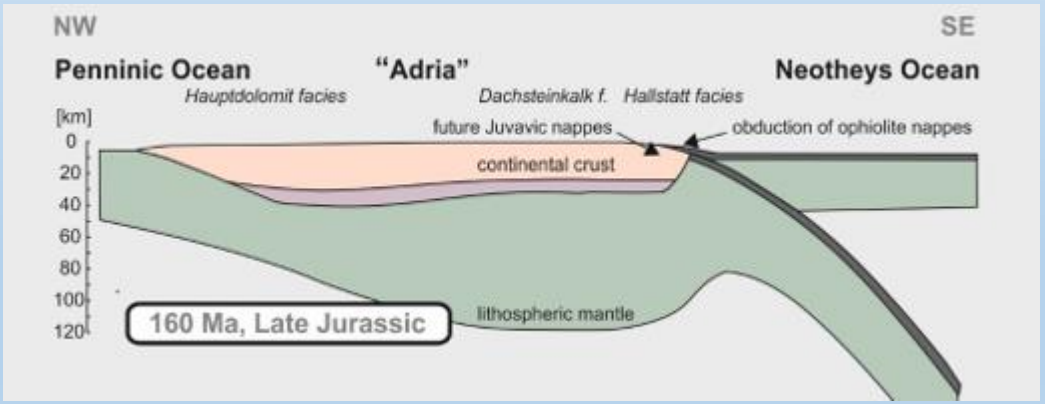
black: oceanic spreading
gray: subduction (blueschist, eclogite, UHP)





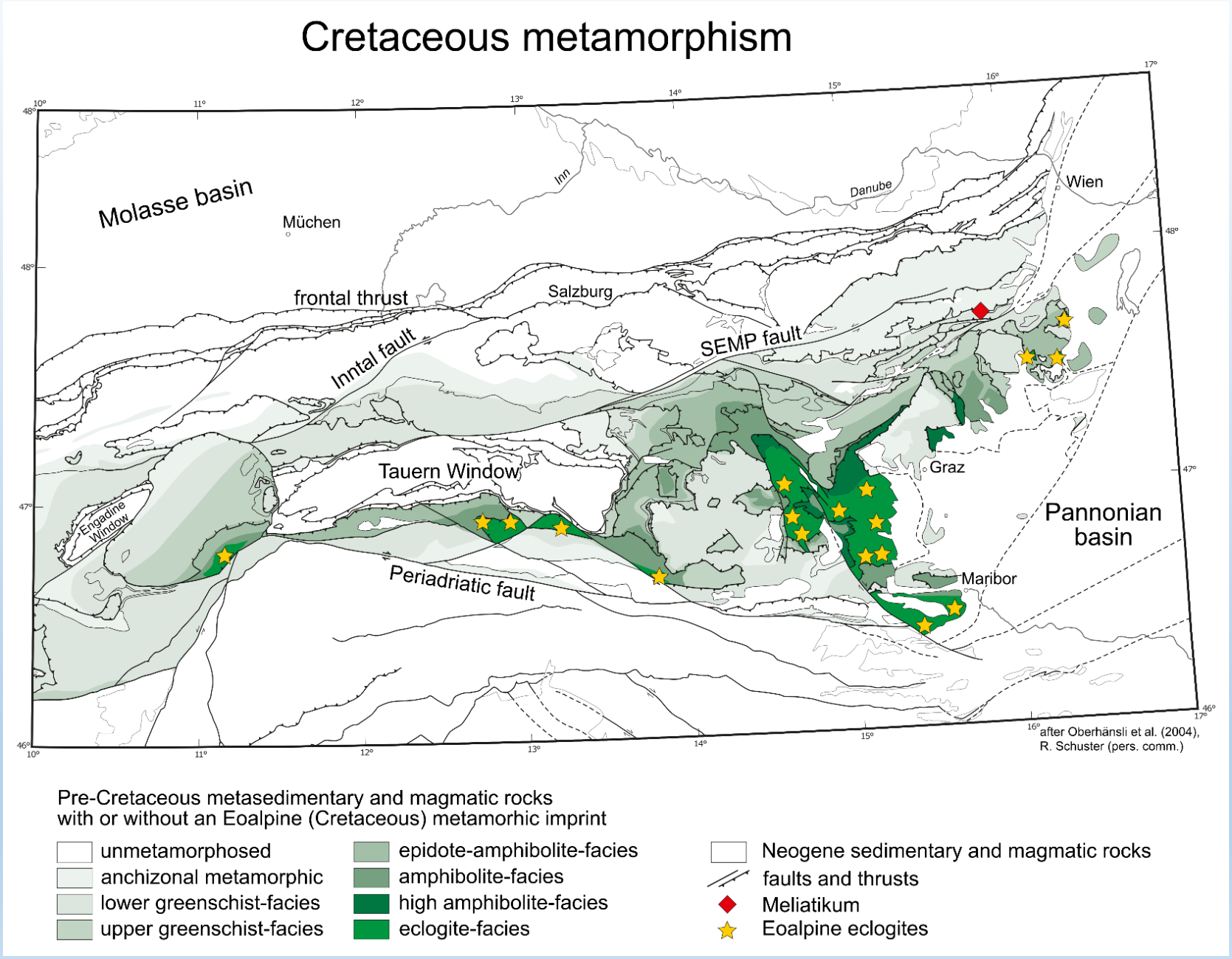






R. Schuster after Schmid et al (2008) and Stüwe & Schuster (2010)

- Meliata (West Carpathians): 160 Ma blueschist.
- Large obducted sheets of oceanic crust in the Dinarides.
- Alps: only slivers of oceanic rocks on top of Austroalpine units, plus detritus of ophiolites and metamorphic sole in Cretaceous sediments

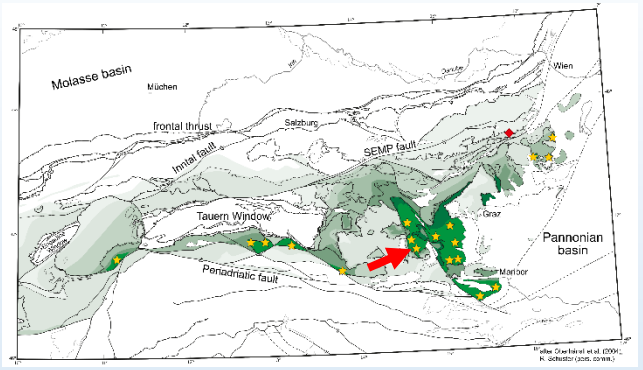


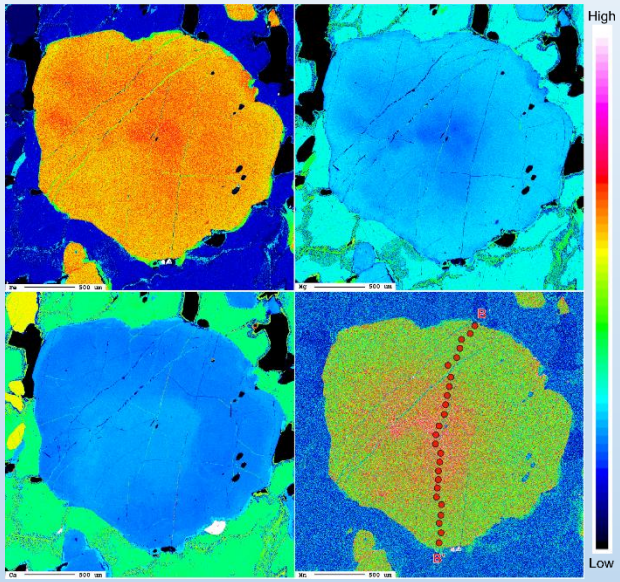
Austroalpine:

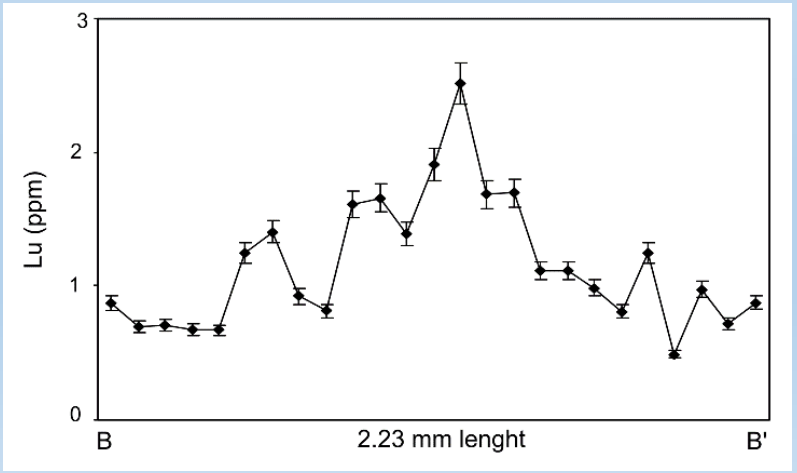
- Upper units: max. greenschist facies
- Lower units: up to UHP

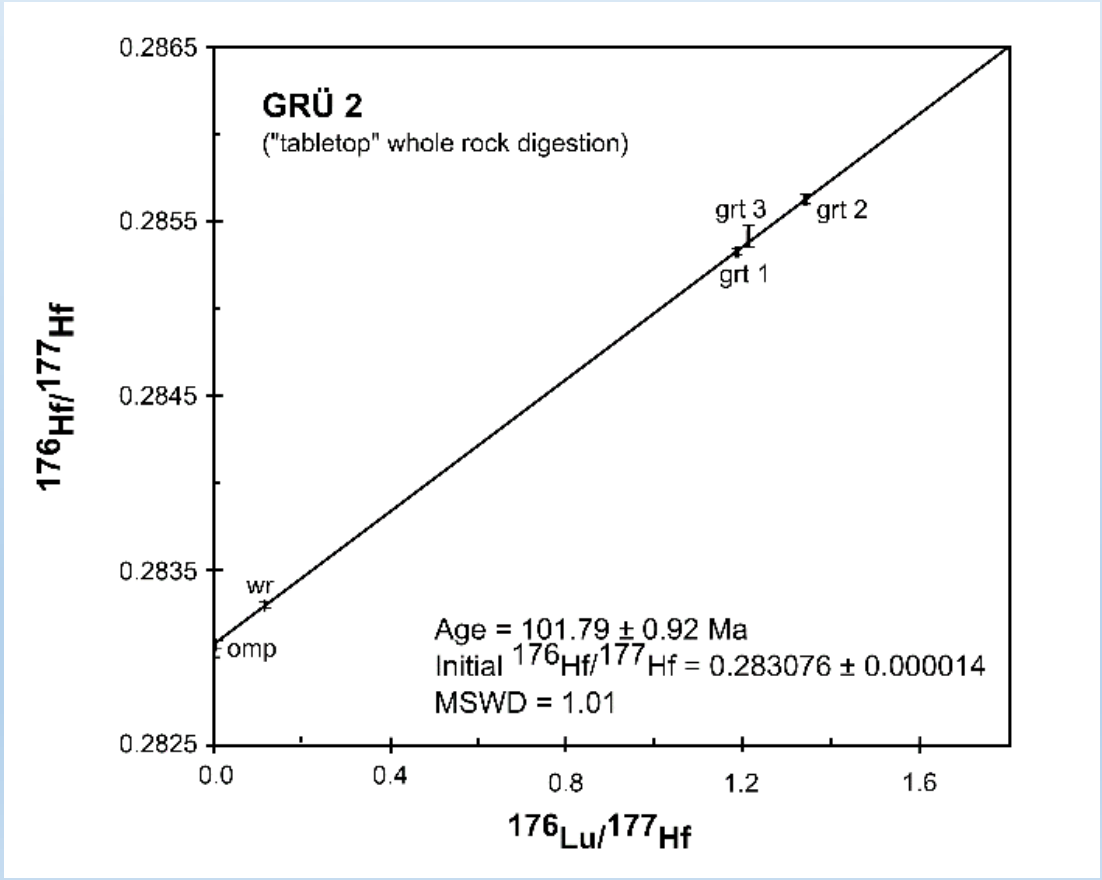
Ralf Schuster

Saualpe (Grünburgerbach)
protolith: Permian gabbro





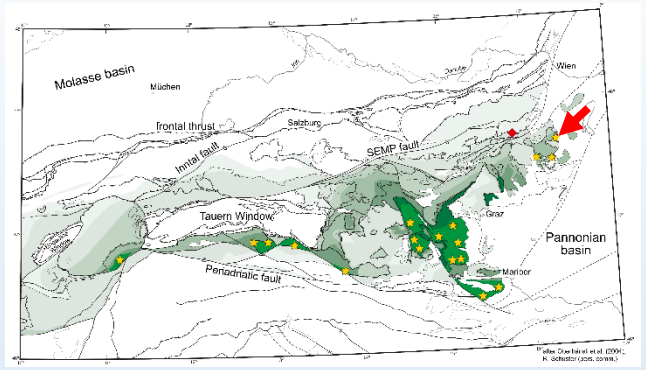


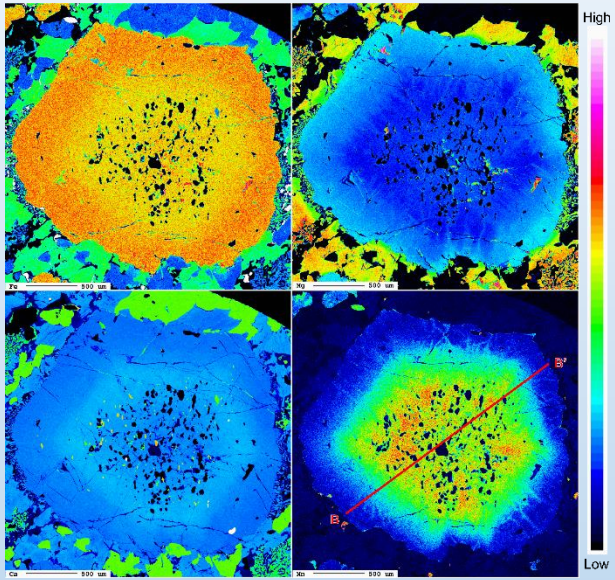


- P-T conditions: 2.2-2.5 GPa and 650-700 °C
- Age: 101.79 ± 0.92 Ma

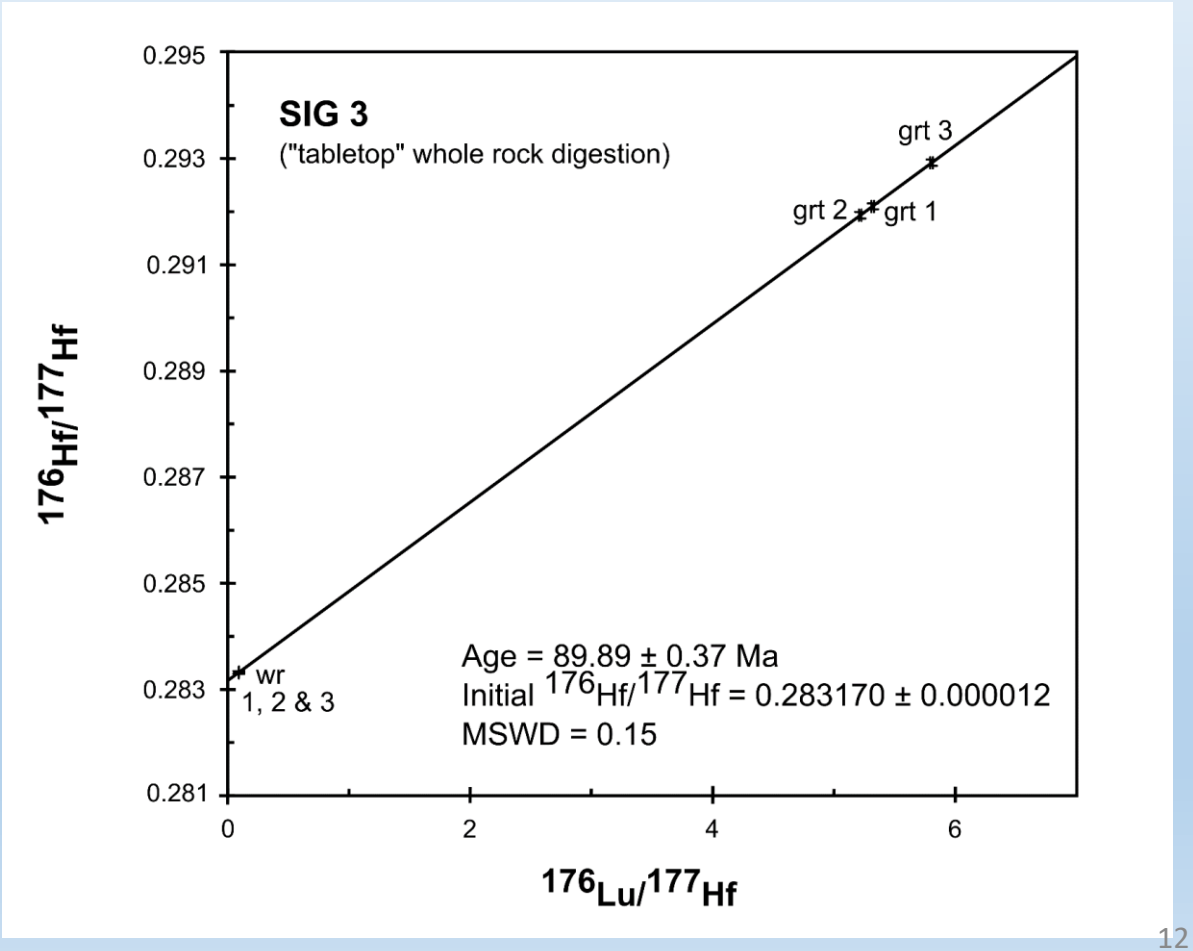
I. Miladinova in prep.

Sieggraben Unit



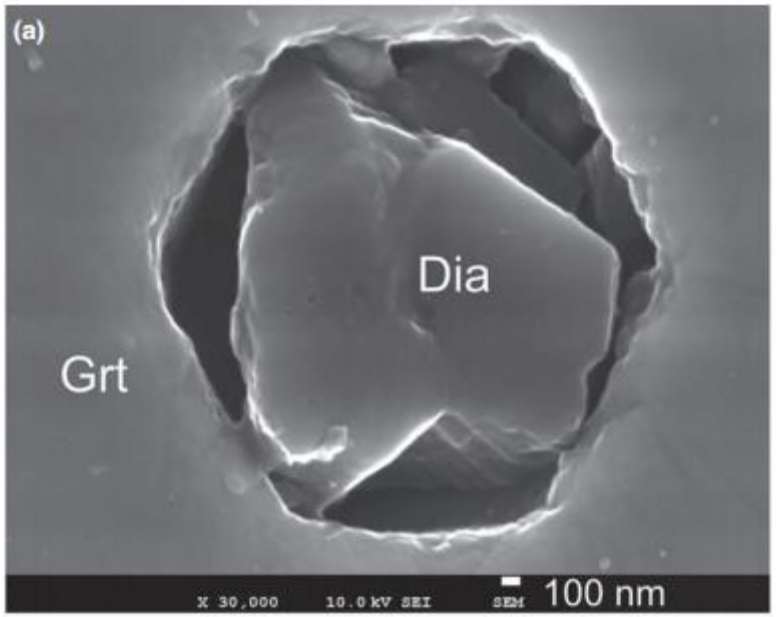


I. Miladinova in prep.

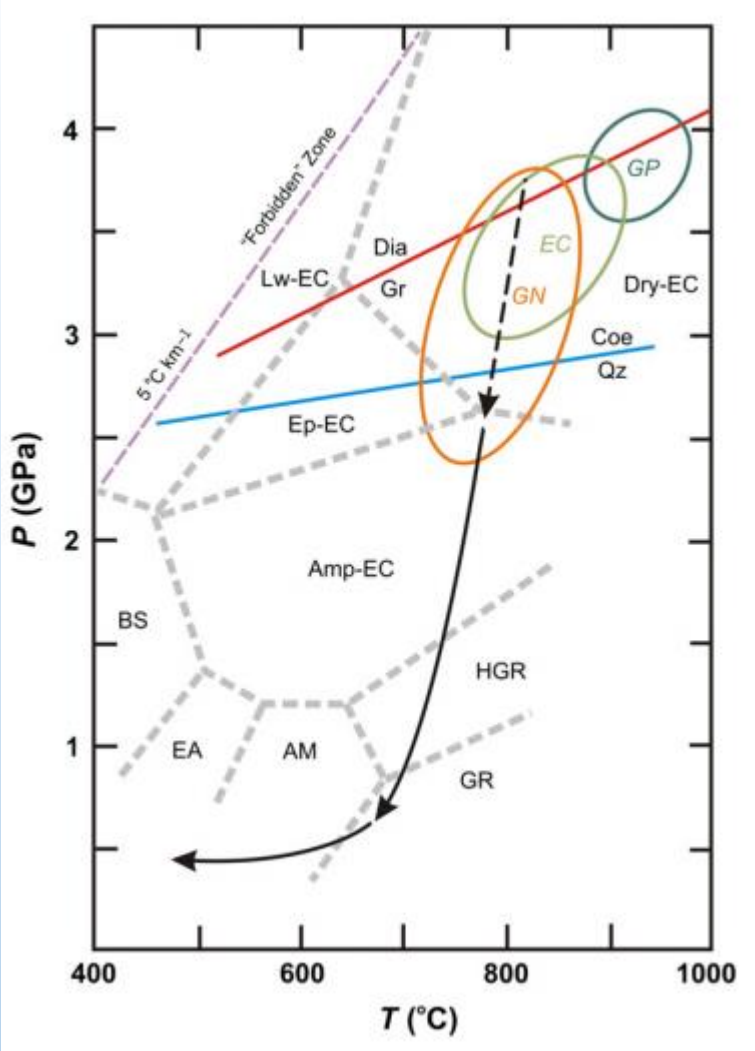


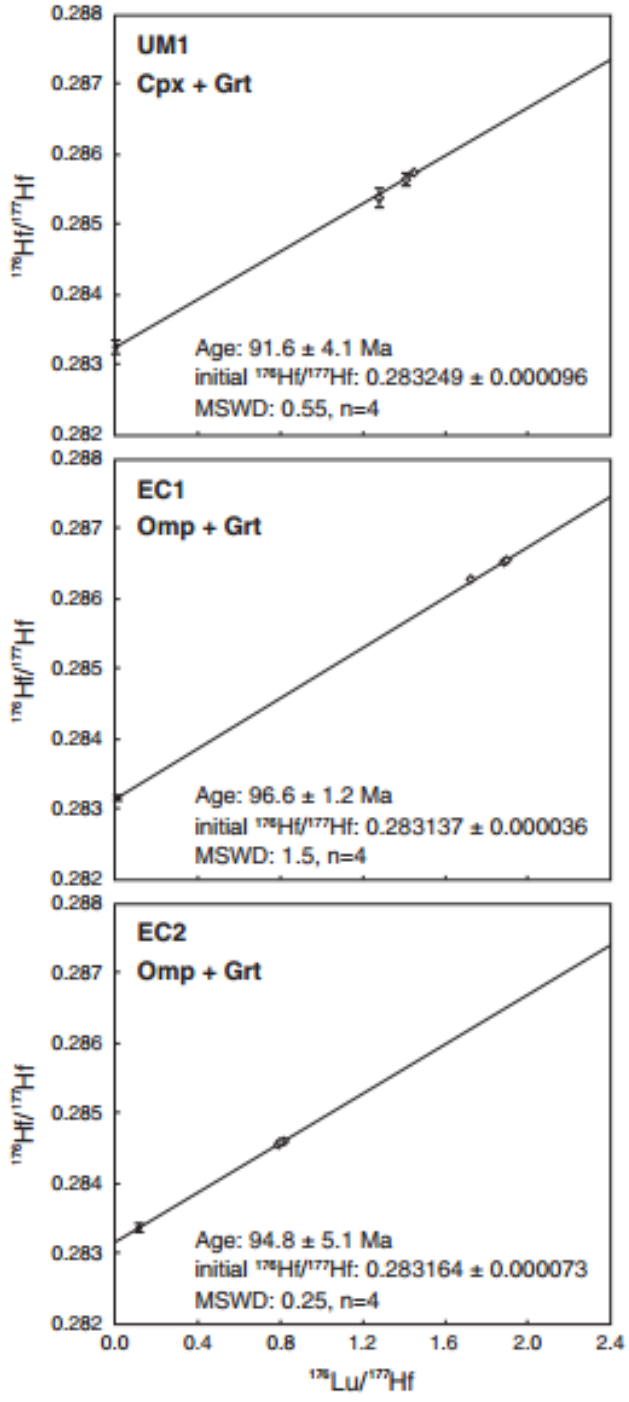
- P-T conditions: ~1.7-1.8 GPa and 650 - 680 °C
- Age: 89.89 ± 0.37 Ma

Pohorje



Janak et al. 2015

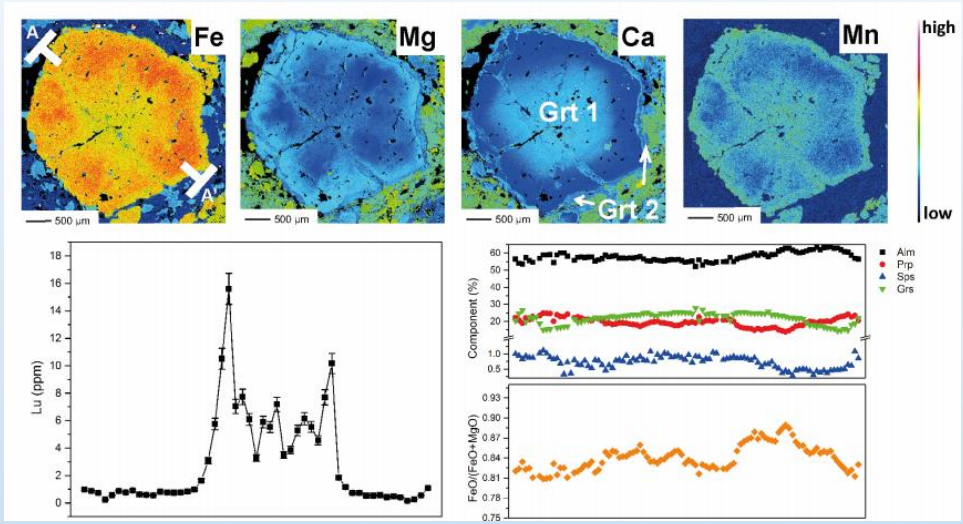




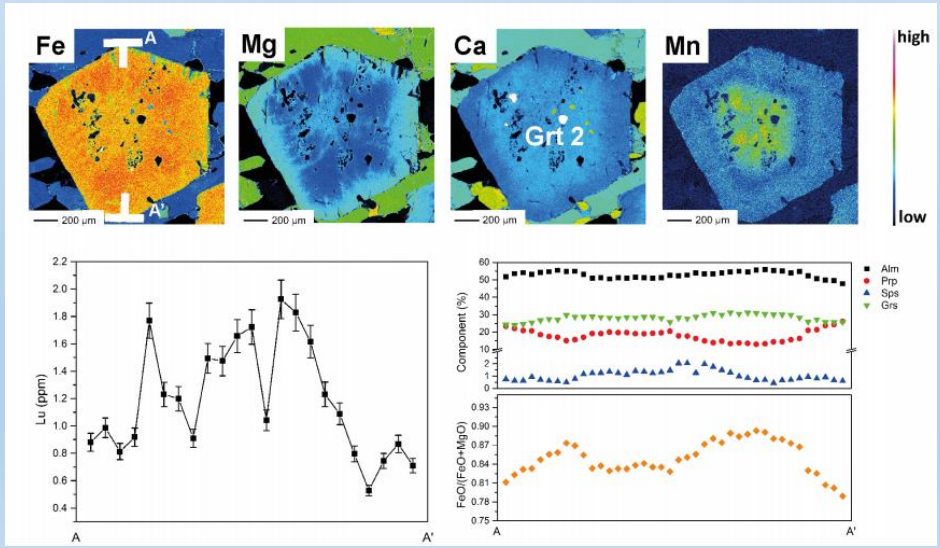
UHP eclogite, garnet peridotite,
and diamond-bearing gneiss.
Age of metamorphism: 91 – 96 Ma

Sandmann
et al. 2016

Schobergruppe (Prijakt)

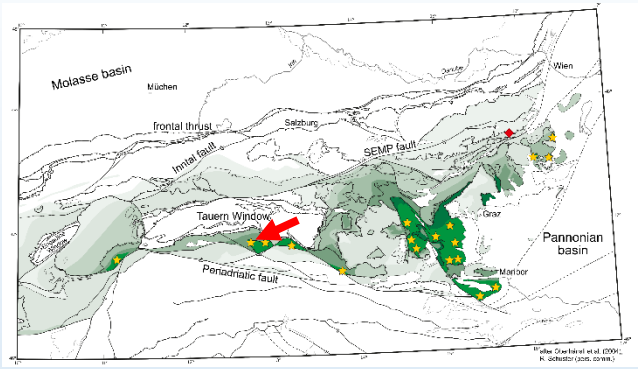


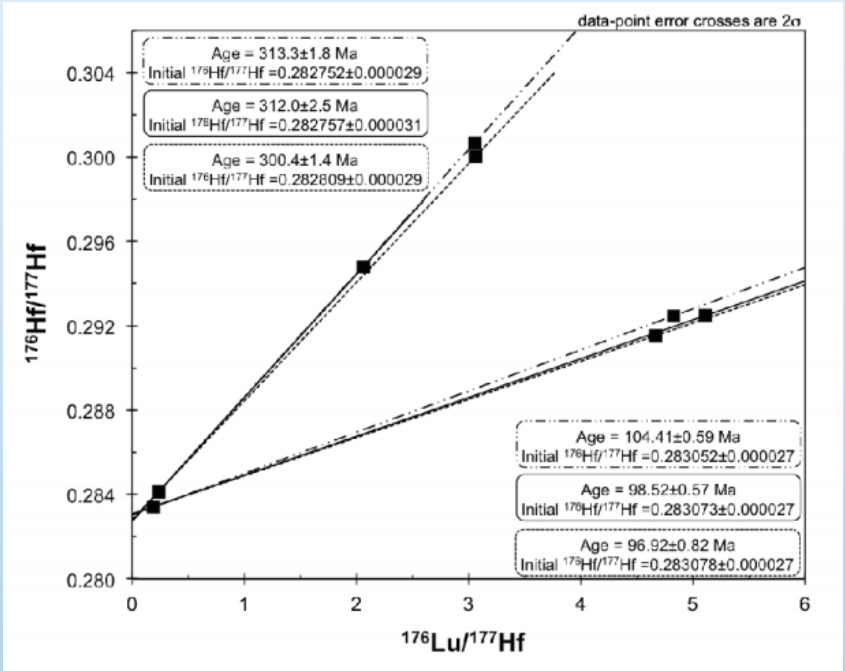
Variscan eclogite



Hauke et al. In revision

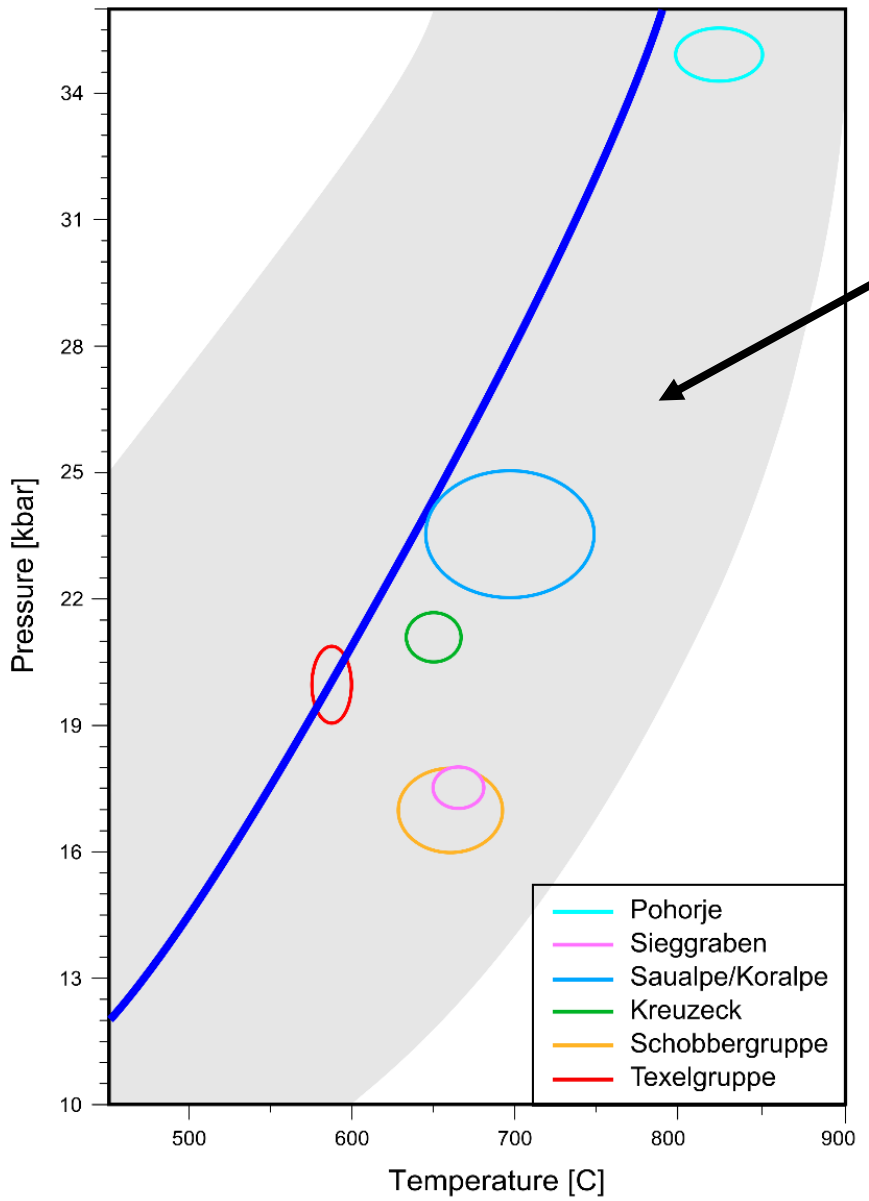
Alpine eclogite





- Alpine age: <97 Ma; Variscan age: >313 Ma
- Variscan continental crust was subducted in the Late Cretaceous

Summary of P-T (Austroalpine eclogites)



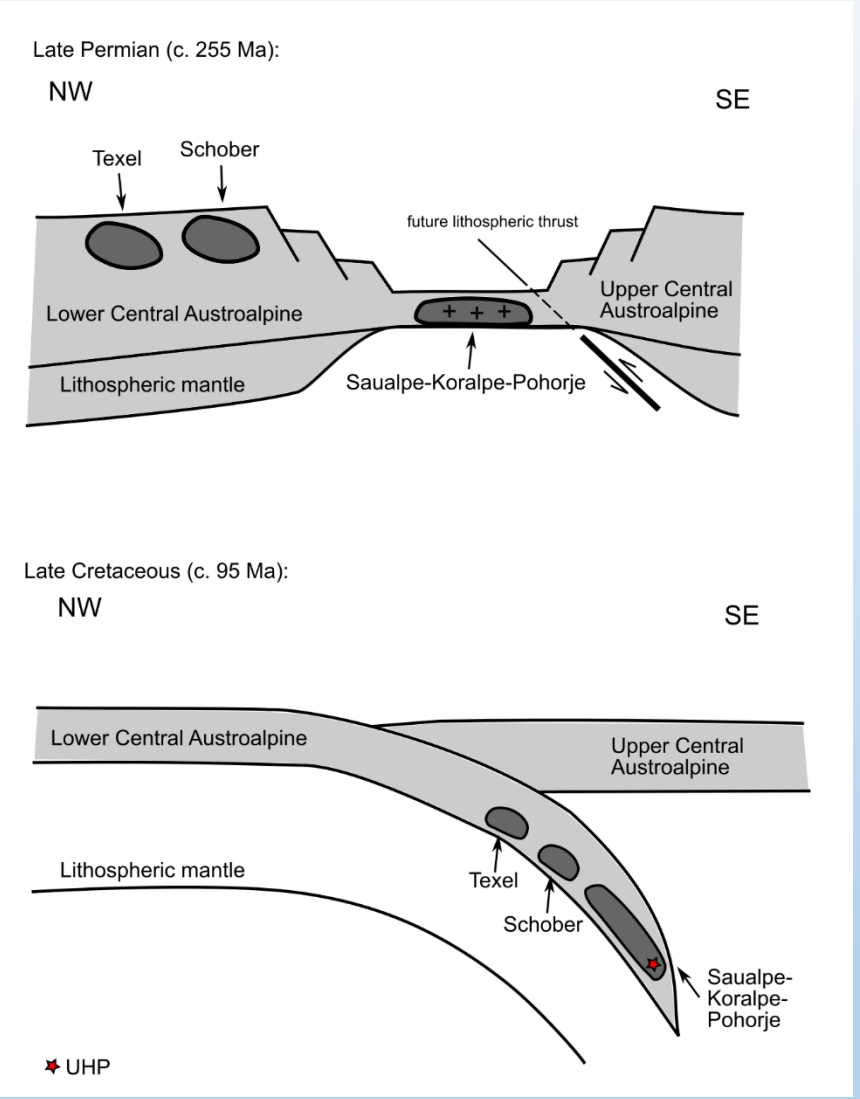
Global range of subduction zone P-T conditions

- The P-T estimates from the Austroalpine HP belt are on the „warm“ side of typical subduction zone conditions

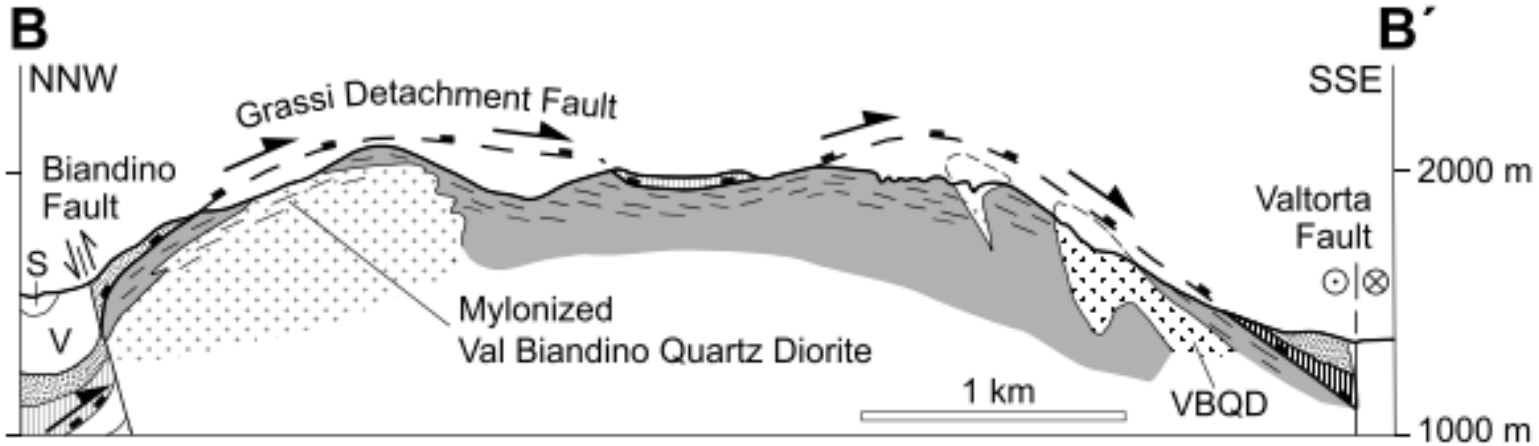
Miladinova in prep.,
Penniston-Dorland et al. 2015

Main results for the Austroalpine

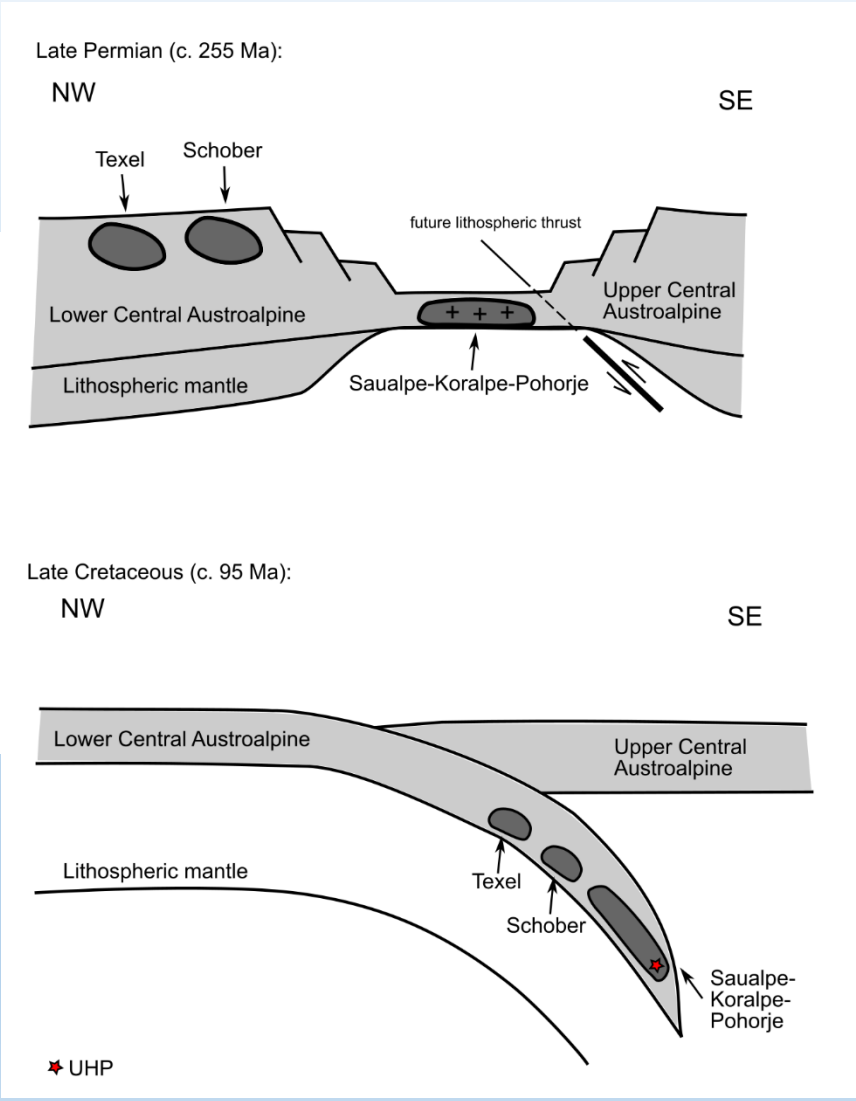
- Short period of (U)HP metamorphism: ~102 to ~90 Ma
- „warm“ eclogites
- Partly „re-subduction“ of Variscan eclogite
- No evidence for Mesozoic ophiolites
- Subduction localised in a Permian rift

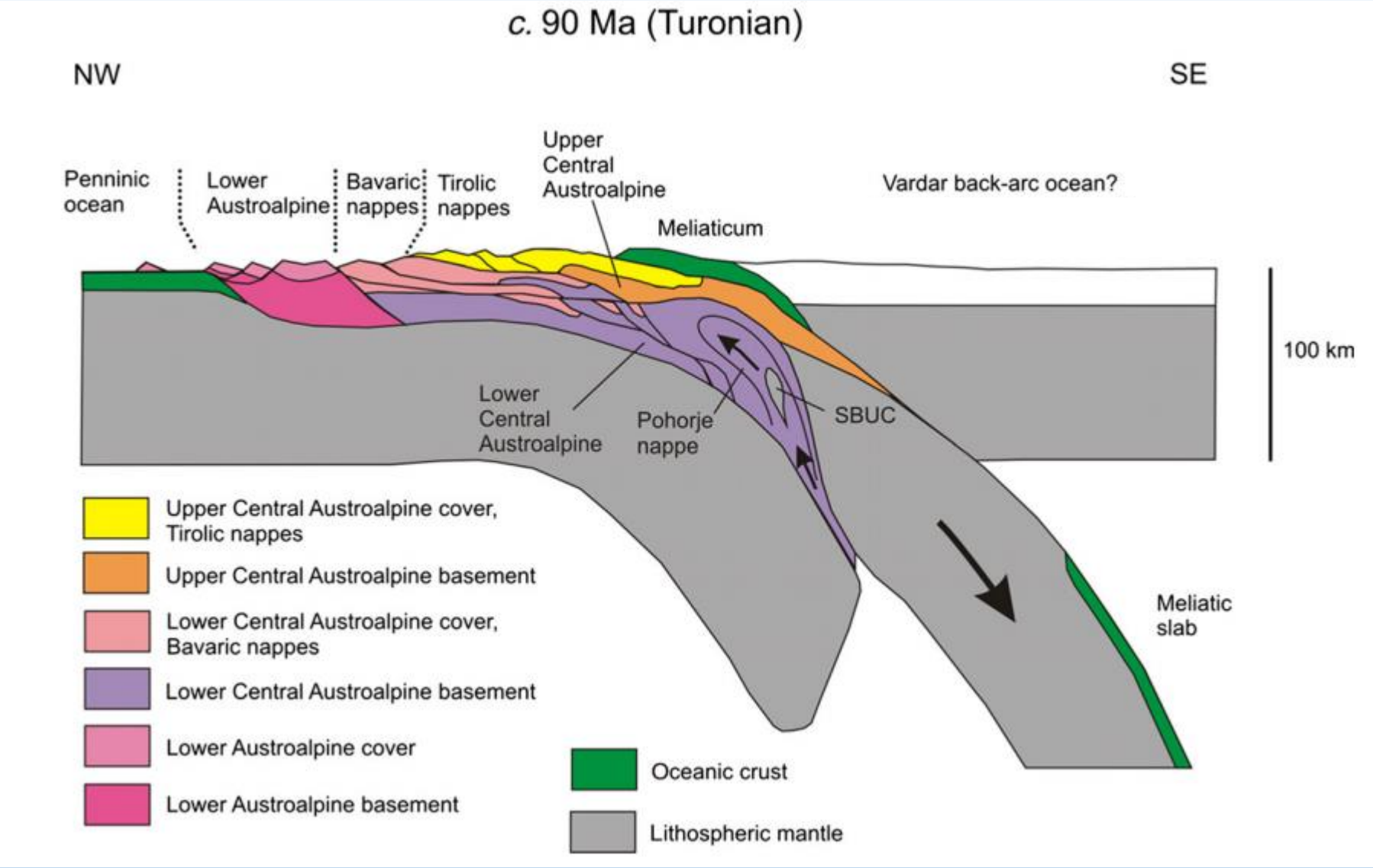


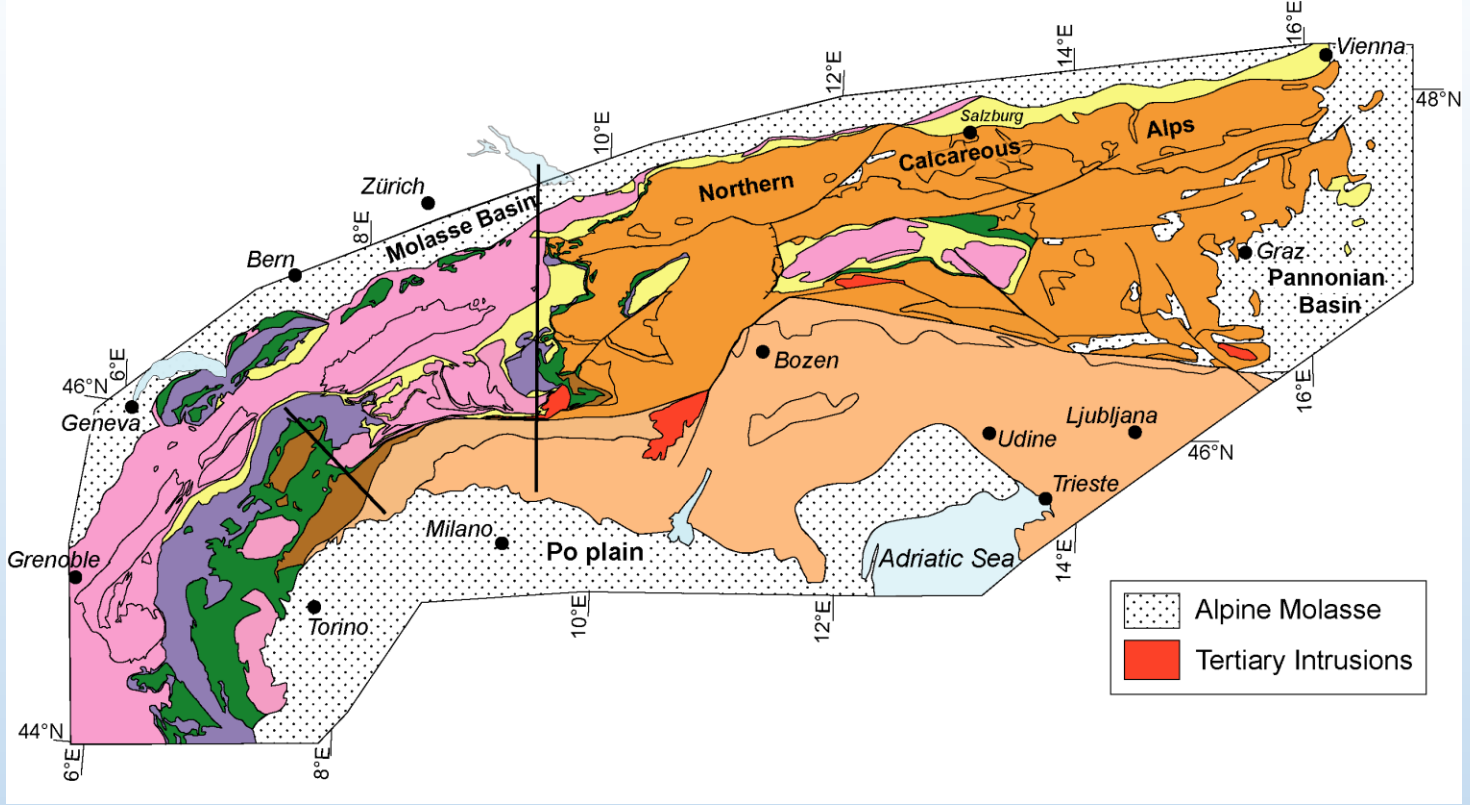
Reactivation of a Permian extensional detachment fault?



Orobic anticline, Southern Alps; Pohl et al. 2018




c. 90 Ma (Turonian)
NW
SE
Penninic ocean
Lower Austroalpine
Bavaric nappes
Tirolic nappes
Upper Central Austroalpine
Meliaticum
Vardar back-arc ocean?
100 km
Lower Central Austroalpine
Pohorje nappe
SBUC
Meliatic slab
Upper Central Austroalpine cover, Tirolic nappes
Upper Central Austroalpine basement
Lower Central Austroalpine cover, Bavaric nappes
Lower Central Austroalpine basement
Lower Austroalpine cover
Lower Austroalpine basement
Oceanic crust
Lithospheric mantle

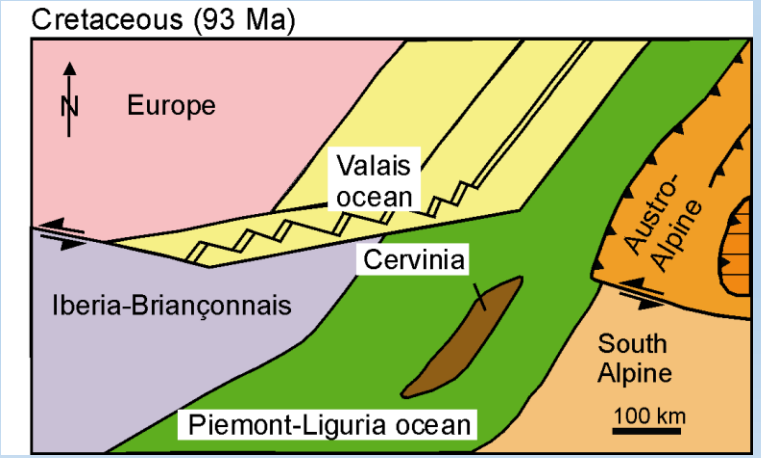


Helvetic and Sub-Penninic: European continent

Penninic: Mesozoic oceans, continental margins, continental fragments

Austroalpine, South Alpine: Adria continent

The next younger dated eclogites:
Sesia Nappe (continental fragment): 70-65 Ma

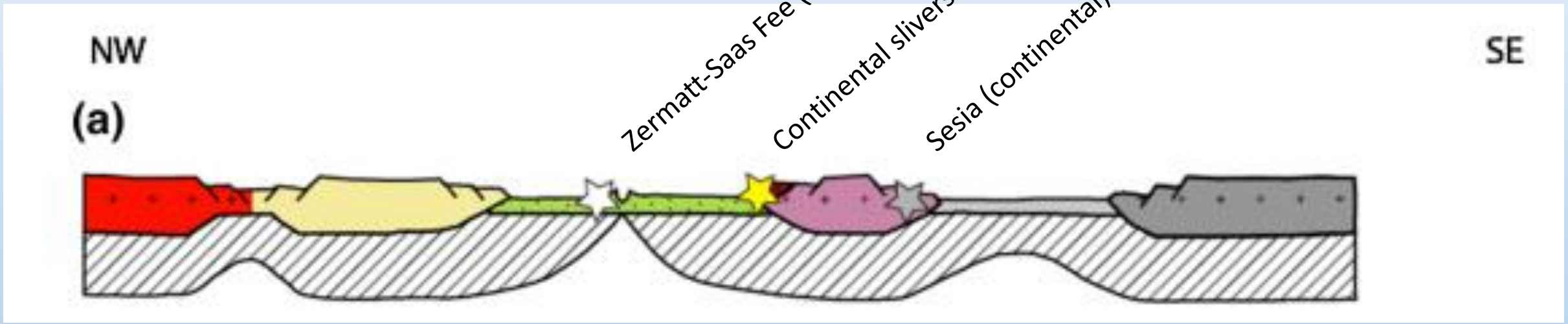


Age progression

Zermatt-Saas Fee (oceanic): 52-40 Ma

Continental slivers: 62-52 Ma

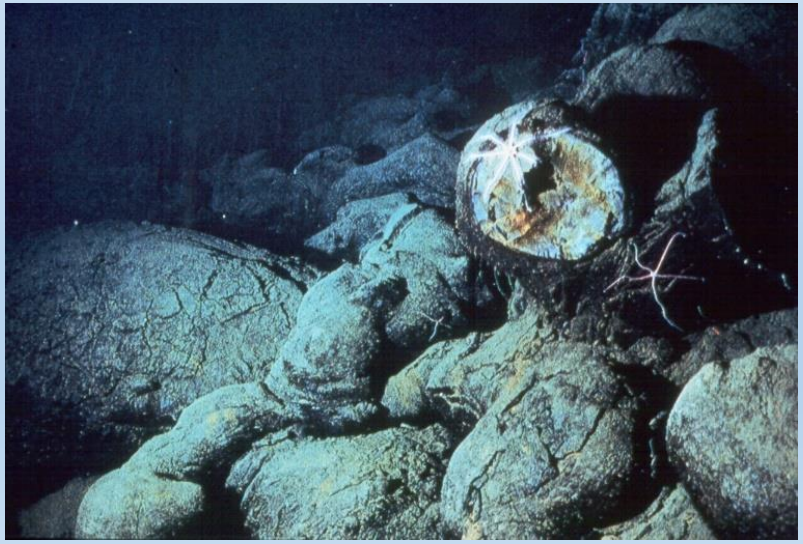
Sesia (continental): 70-65 Ma

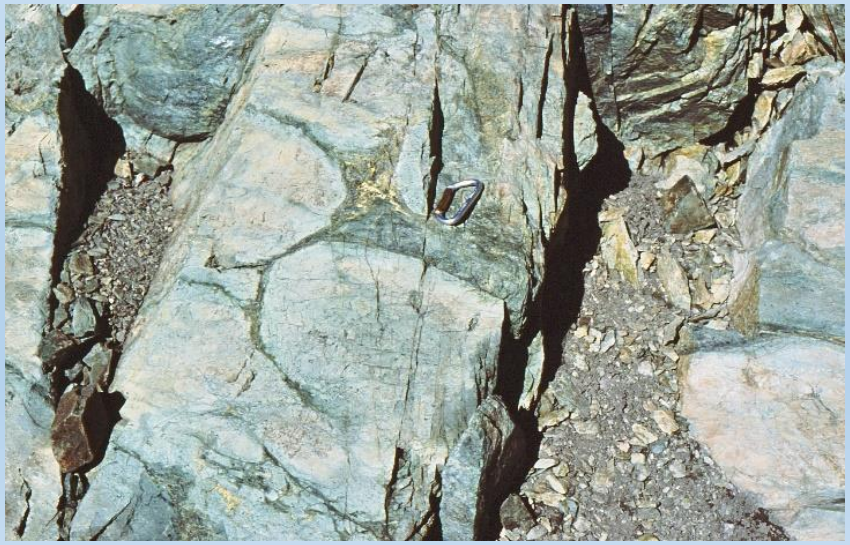


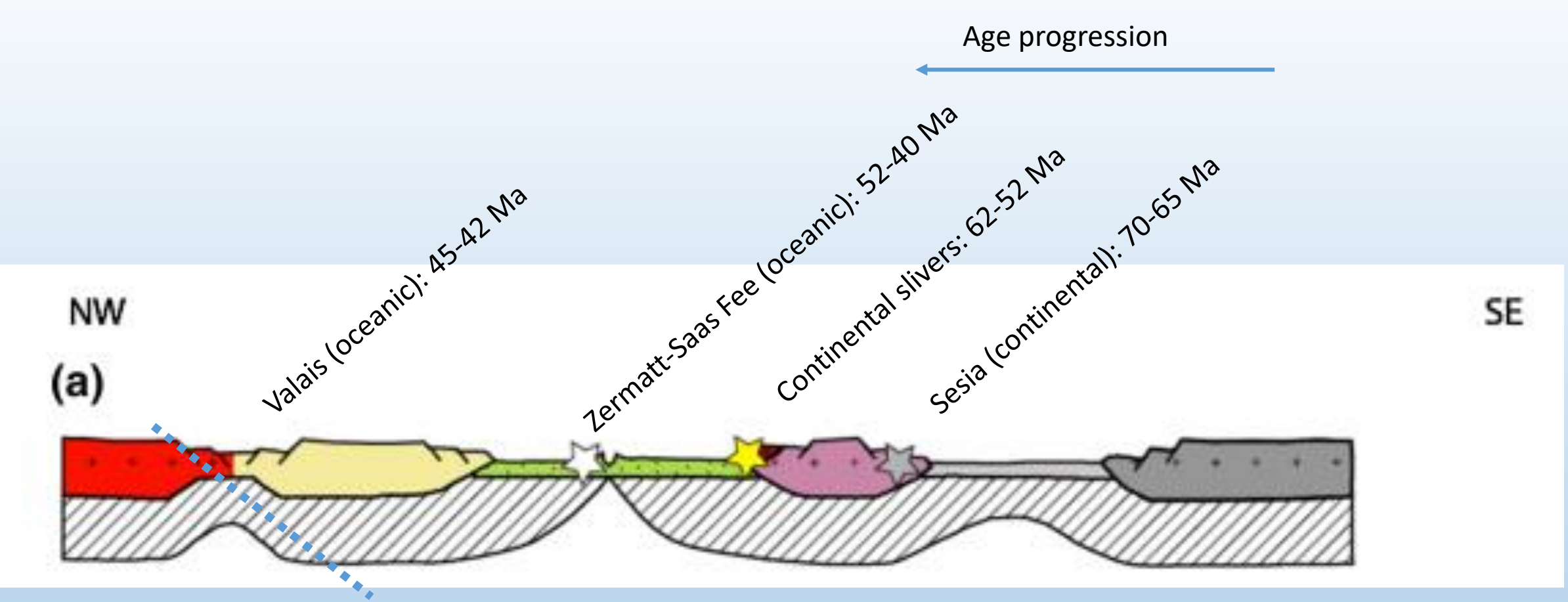
Zermatt-Saas zone: Former oceanic crust, up to UHP conditions (coesite, diamond at Lago di Cignana)

Jurassic (~160 Ma) pillow basalt from Piemont-Ligurian Ocean, metamorphosed to eclogite at ~44 Ma

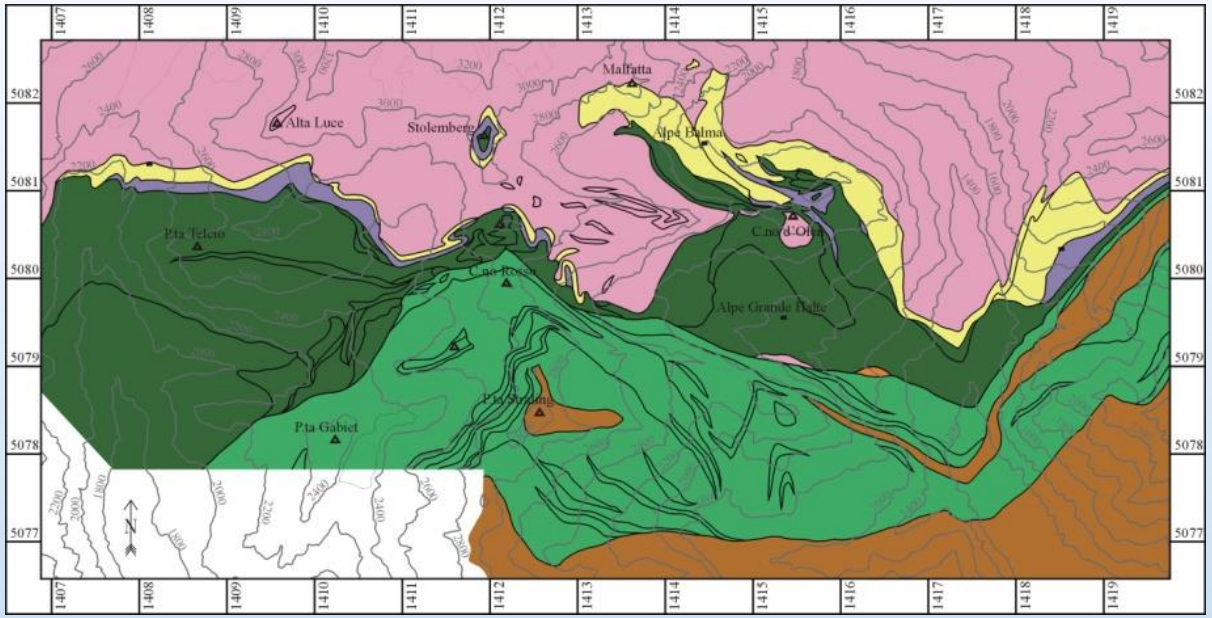
„Cold“ eclogites (cooled by downgoing oceanic crust)

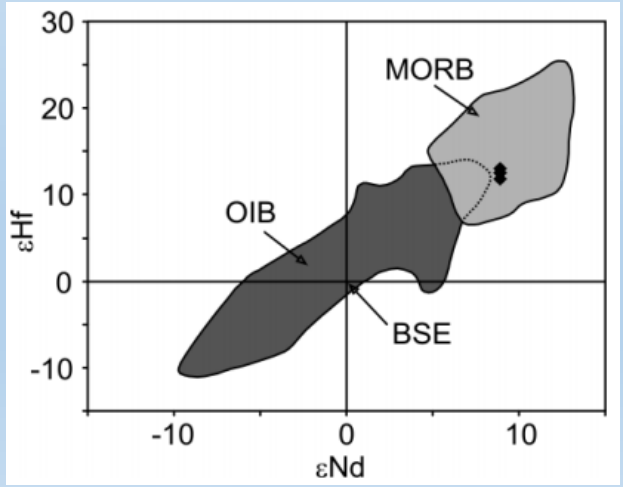




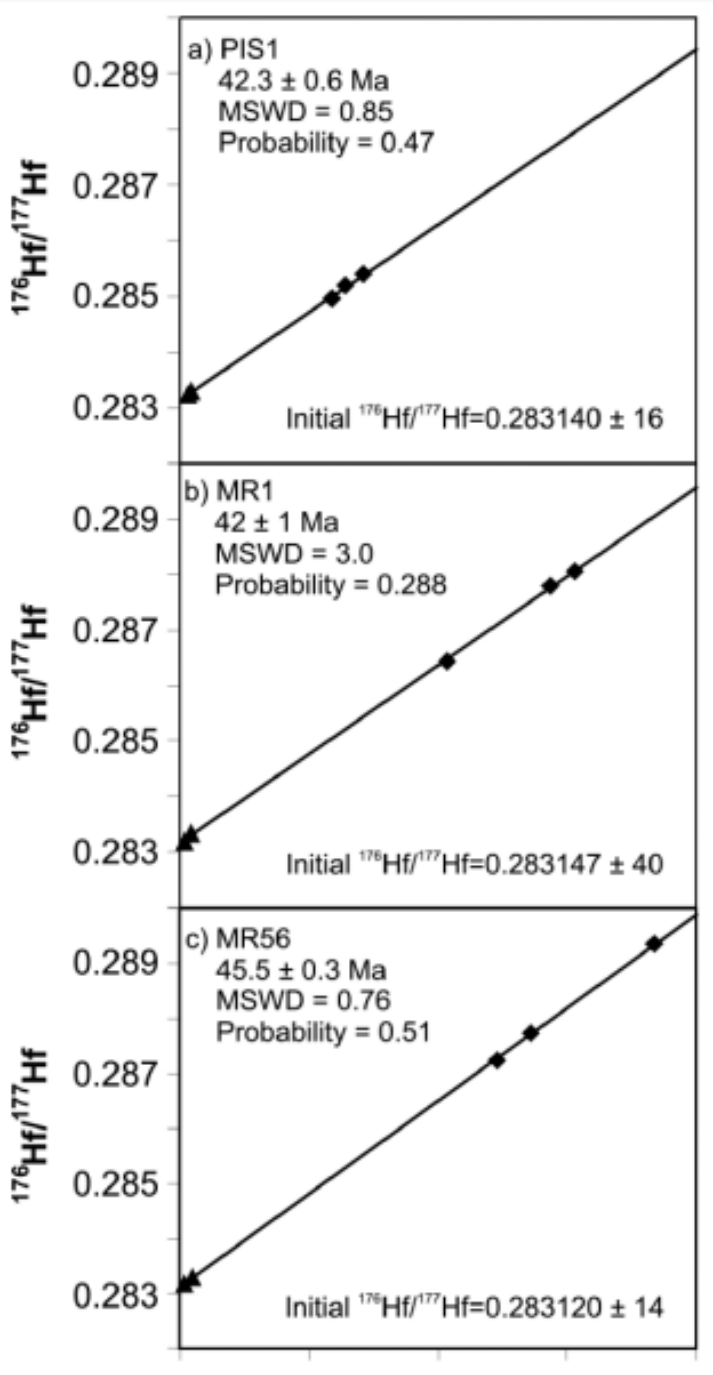


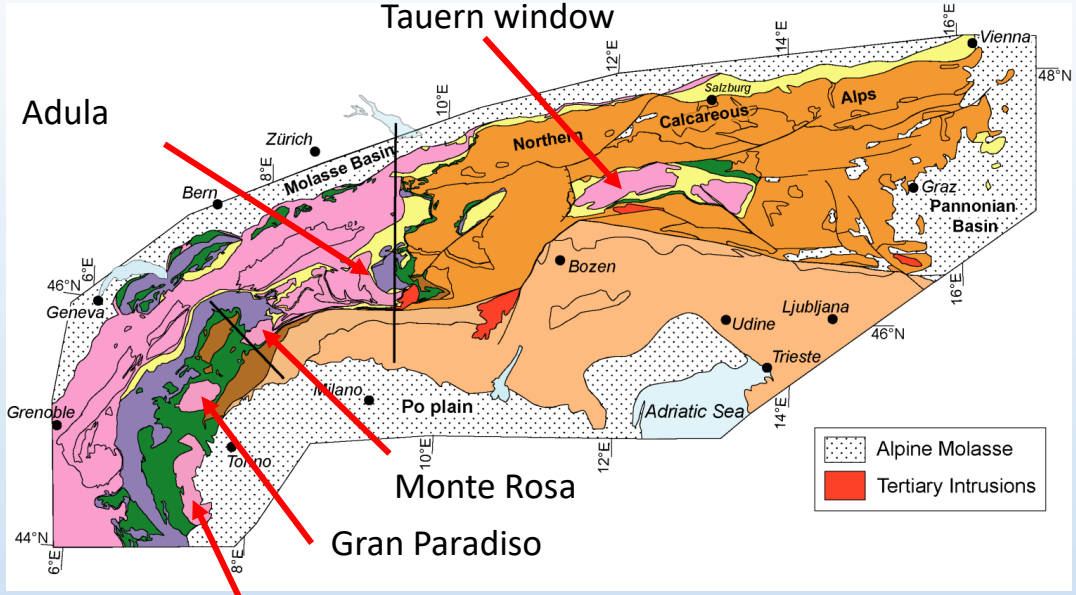
Simultaneous subduction of Piemont-Ligurian and Valais ophiolites suggests formation of a new (third) subduction zone. Attention: only few data so far!

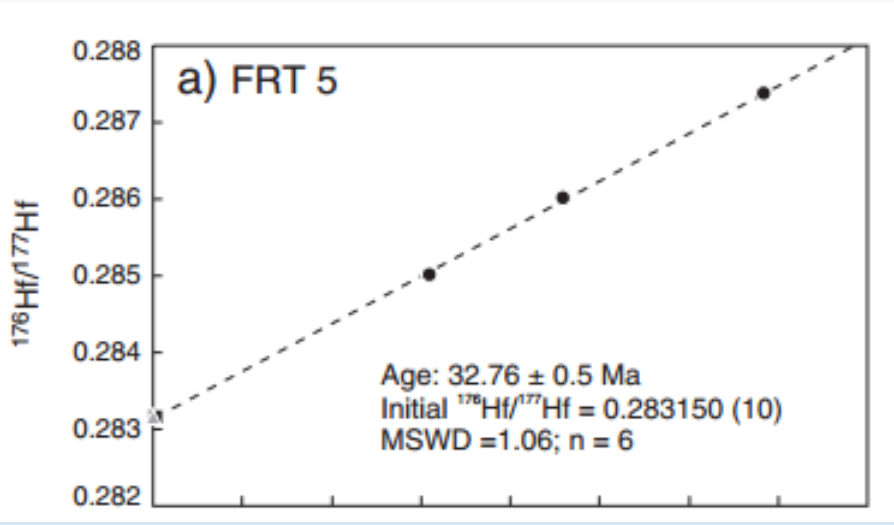




Herwartz et al., 2008

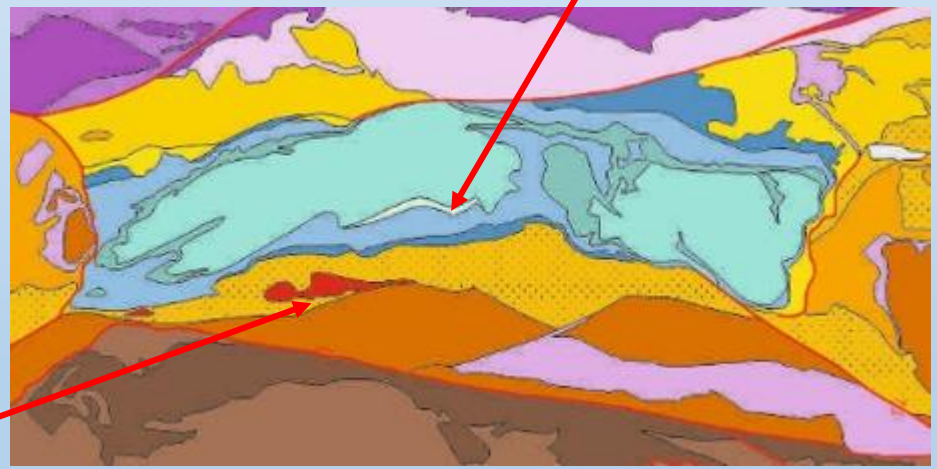






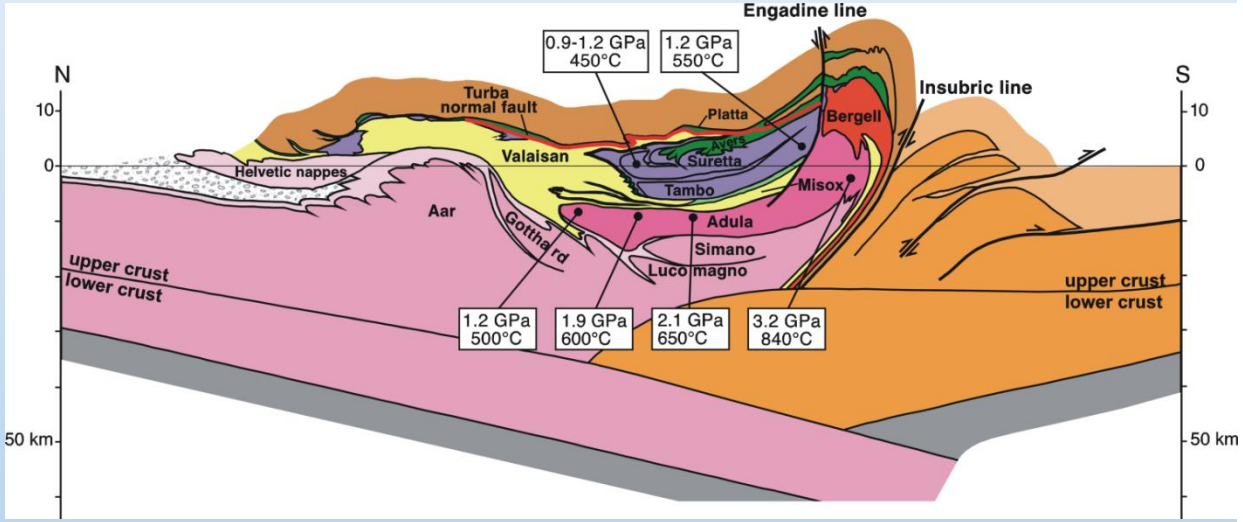
Nagel et al. 2013

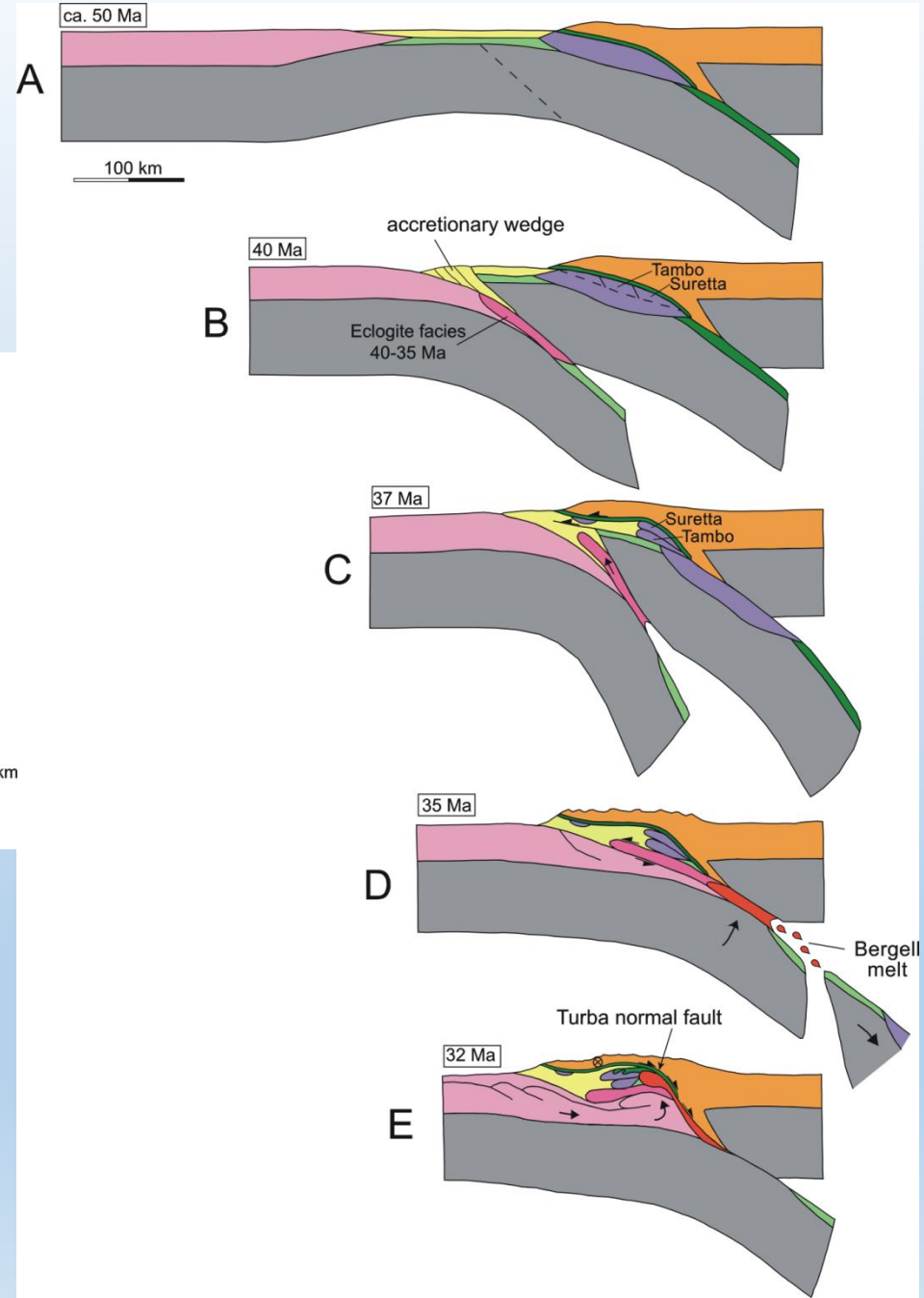
Tauern eclogite: ~33 Ma



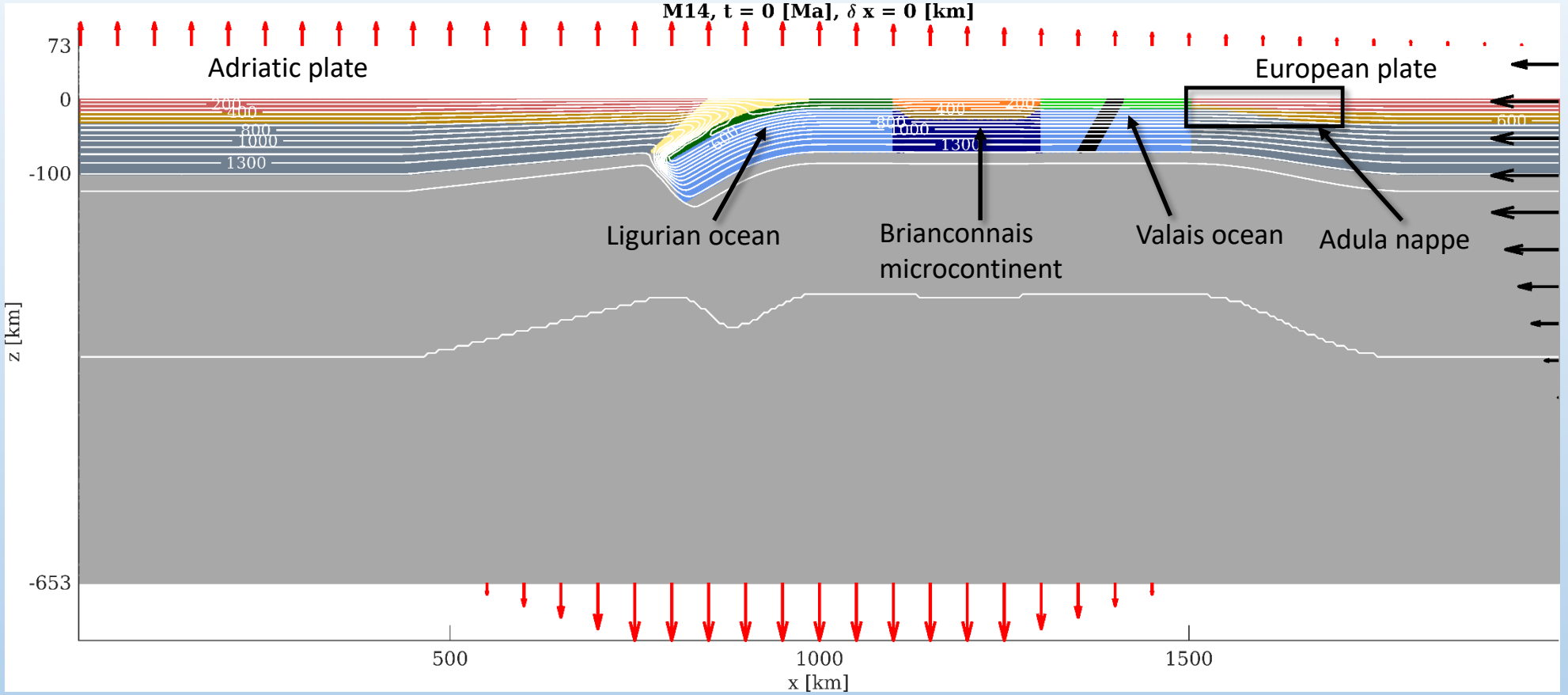
Eclogites of the European continental margin: The youngest Alpine high-pressure rocks (40-33 Ma).

Rieserferner granitoid pluton: ~33-30 Ma


Engadine line
0.9-1.2 GPa
450°C
1.2 GPa
550°C
N
S
Turba
normal fault
Platta
Bergell
Insubric line
10
0
Valaisan
Ayets
Suretta
Helvetic nappes
Tambo
Misox
Aar
Gotthard
Adula
Simano
Luco magno
upper crust
lower crust
upper crust
lower crust
1.2 GPa
500°C
1.9 GPa
600°C
2.1 GPa
650°C
3.2 GPa
840°C
50 km
50 km


ca. 50 Ma
A
100 km
accretionary wedge
40 Ma
B
Tambo
Suretta
Eclogite facies
40-35 Ma
37 Ma
C
Suretta
Tambo
35 Ma
D
Bergell
melt
Turba normal fault
32 Ma
E

Model setup (FDCON)

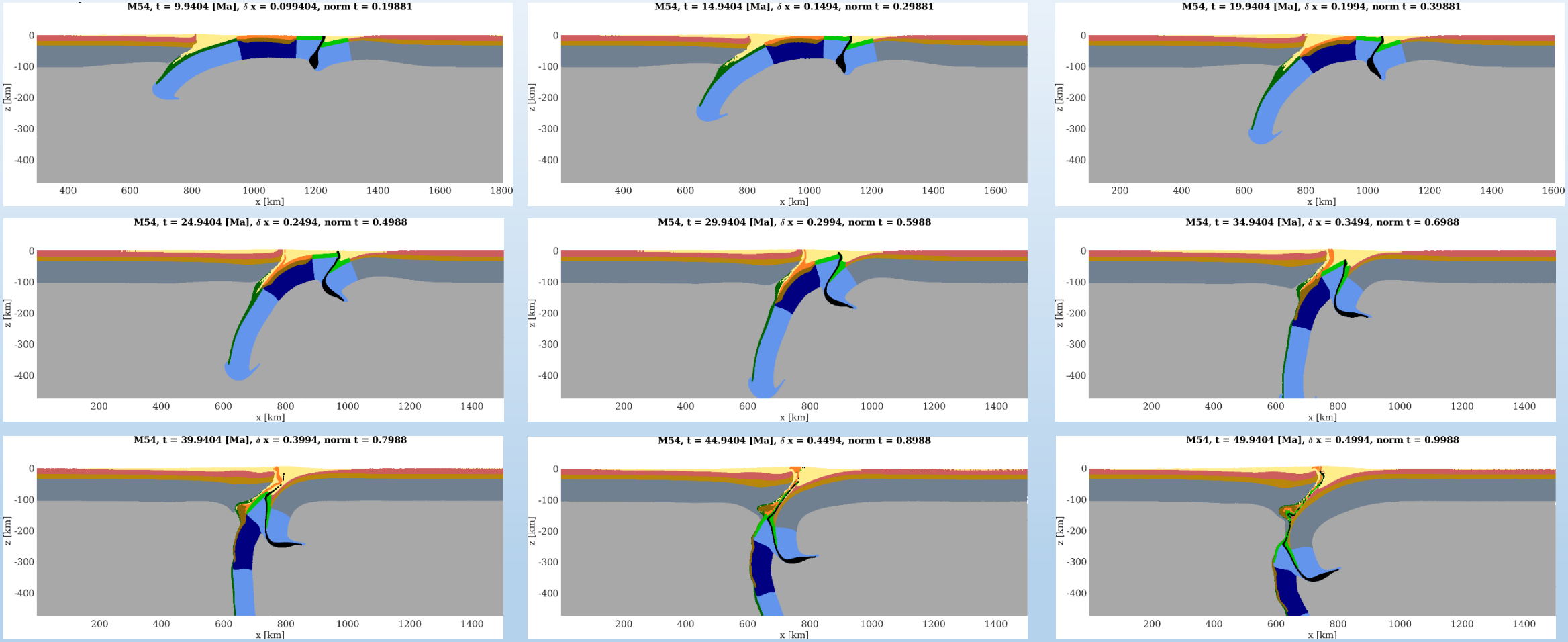


- All boundaries are mechanically free slip
- Erosion & Sedimention via Advection + Diffusion
- Sticky air layer → Free surface

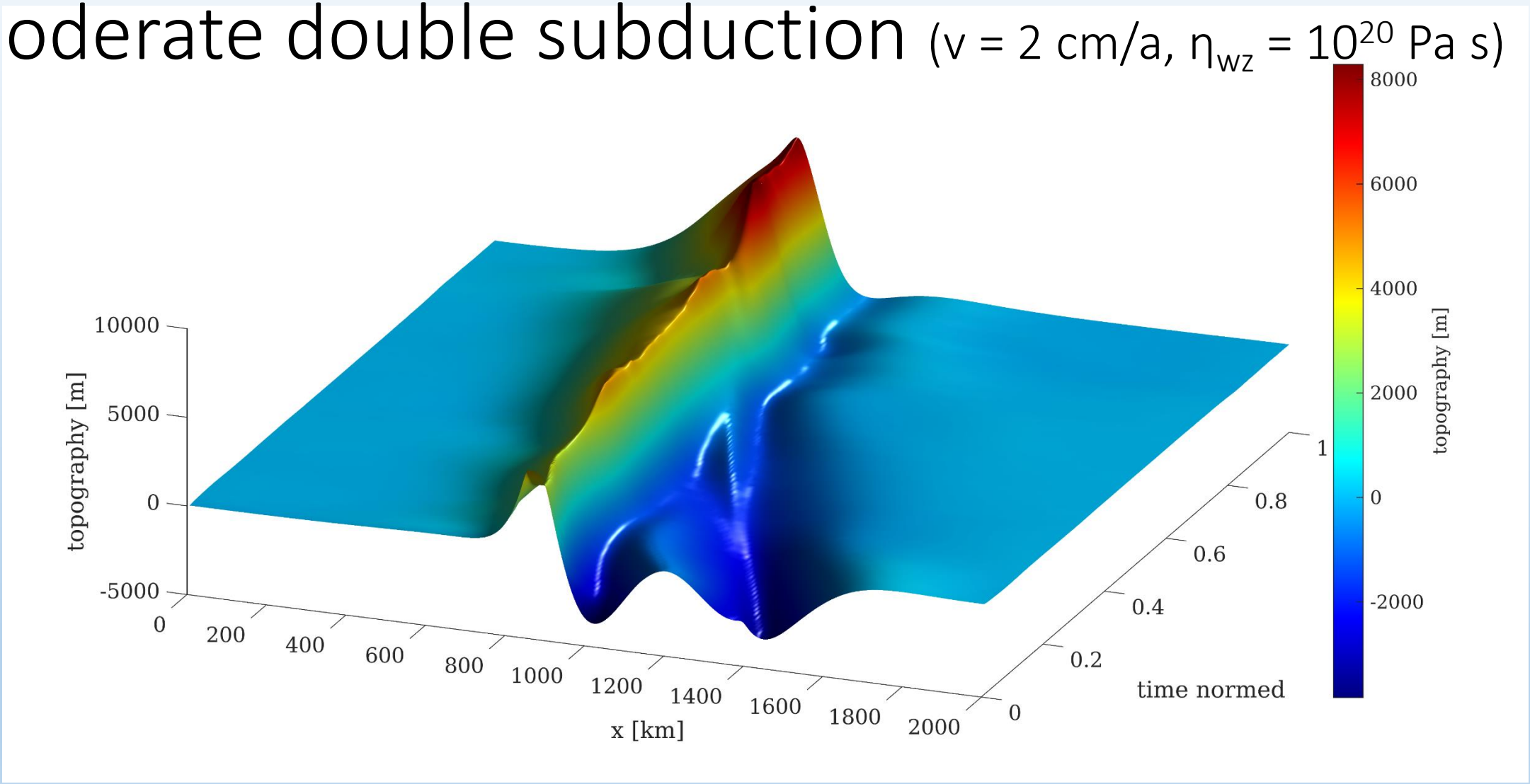
Variation of convergence velocity, weak zone viscosity and plastic sediment strength

Jan-Philipp Kruse

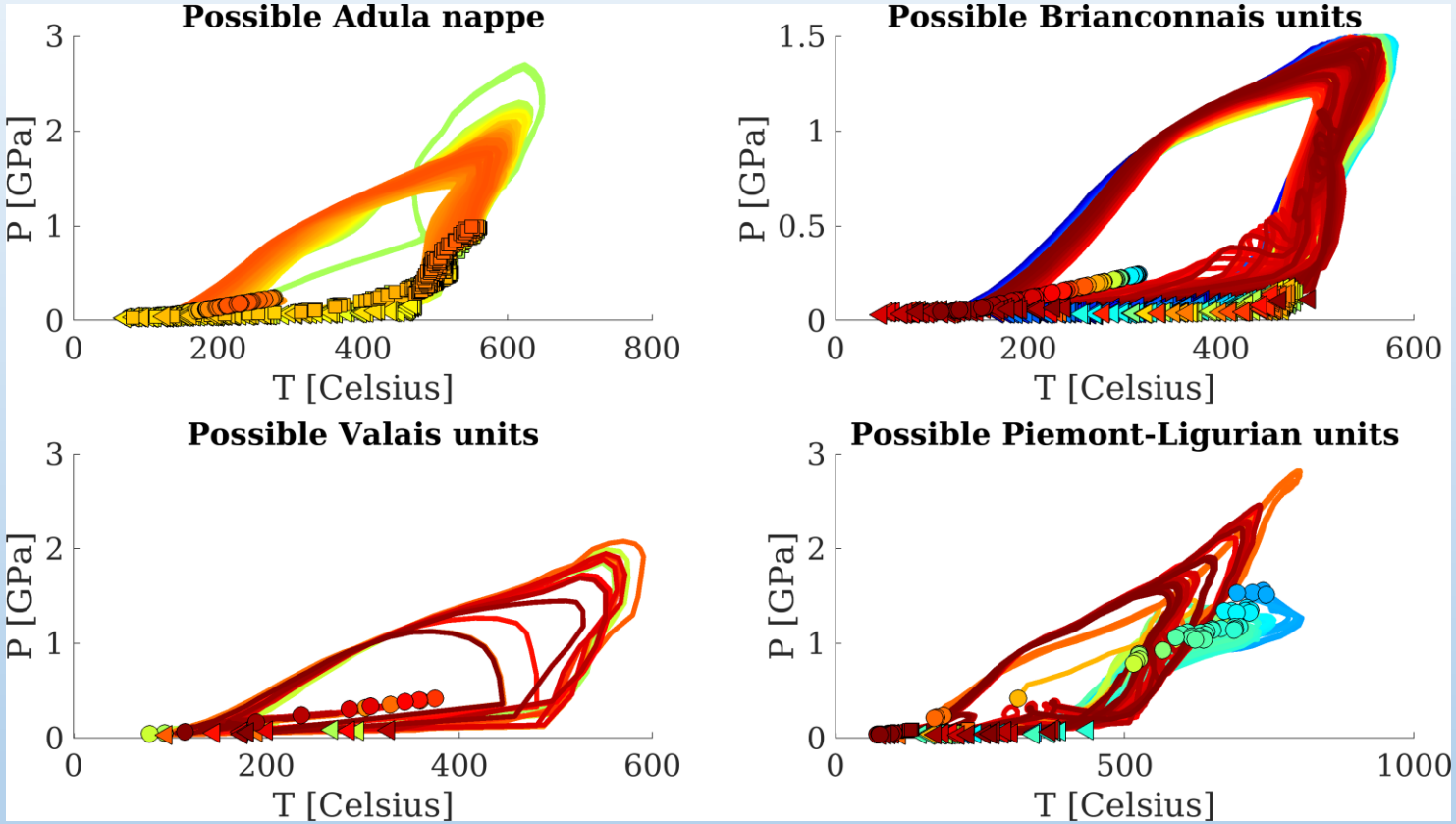
Moderate double subduction (v = 2 cm/a, $\eta_{wz} = 10^{20}$ Pa

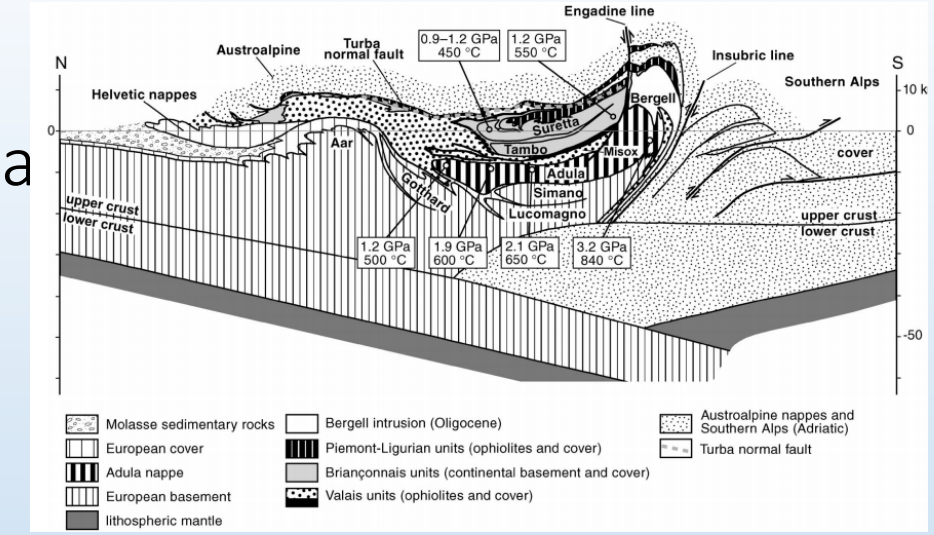


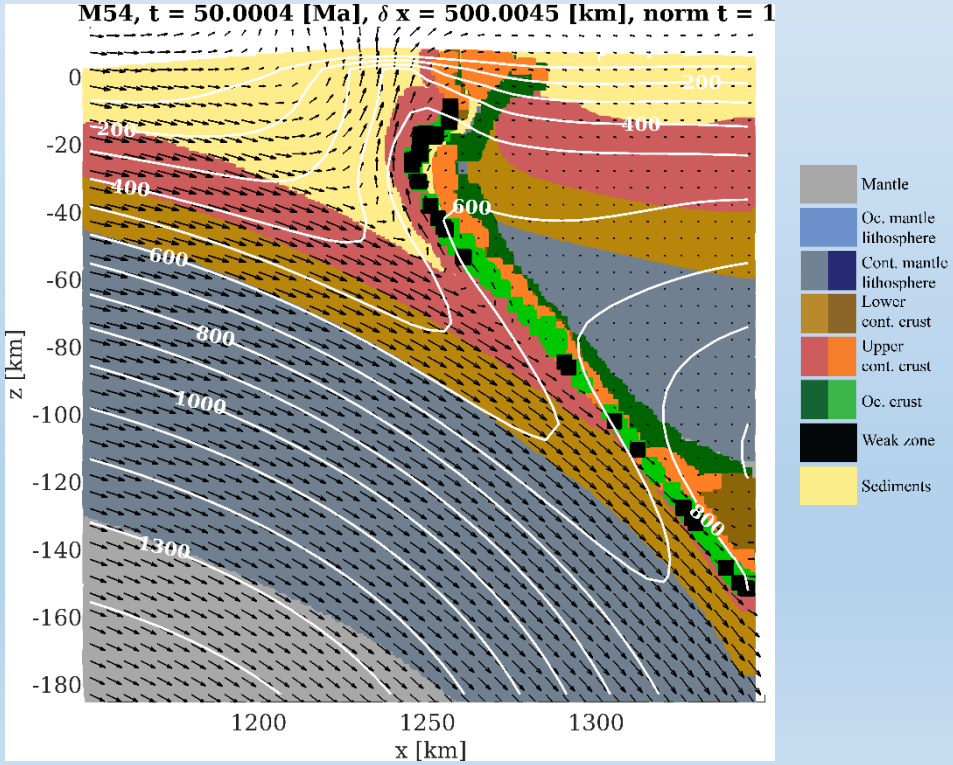
Moderate double subduction (v = 2 cm/a, $\eta_{wz} = 10^{20}$ Pa s)



PT conditions (v = 2 cm/a, $\eta_{wz} = 10^{20}$ Pa







Evidence for three subduction zones:

- **(1) Intra-oceanic subduction zone in the Neotethys colliding with Adria at 160 Ma.**
- **(2) New SE-dipping subduction zone installed within the Austroalpine at ~110 Ma. Progression of subduction towards NW: Austroalpine, Cervinia Fragment (70-65 Ma), Piemont-Ligurian ocean (52-40 Ma).**
- **(3) New SE-dipping Valais subduction zone, active simultaneously with (2) between 45 and 40 Ma.**
- **More data needed; iterative improvement of models**