

# Timing of crustal melting and magma emplacement at different depths: insights from the Permian in the Western Alps



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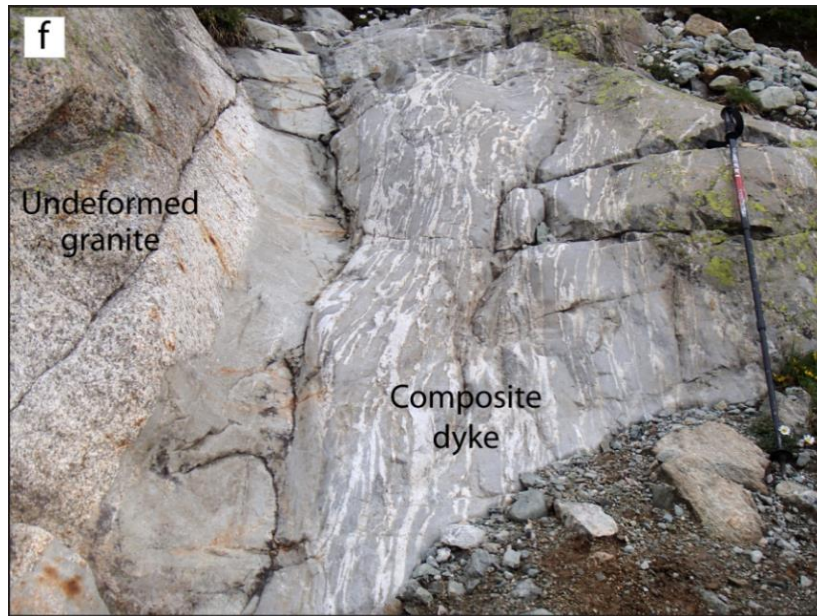
# Permian high temperature metamorphism in the Alps

- During the late Palaeozoic, lithospheric thinning in the future Alpine realm caused high-temperature low-to medium pressure metamorphism and partial melting in the lower crust. Permian metamorphism and magmatism are extensively preserved in the Alps (Schuster & Stüwe 2008).
- In the Western Alps, Adria-derived slices of continental crust (e.g. Sesia-Dent Blanche nappes) preserve evidence for Permian magmatism and metamorphism. The Dent Blanche nappe displays the best preserved example of Permian magmatism and metamorphism in the Alpine nappe stack in the Western Alps.
- This contribution will present an overview on the age and regional distribution of Permian magmatism and metamorphism in the Western Alps and will detail some exceptional examples from the Dent Blanche nappe.
- The results will be compared with existing data from the Southern, Central and Eastern Alps and will be used to discuss the Permian evolution in the future Alpine realm.



# Permian magmatism in the Western Alps

The Arolla Unit in the Dent Blanche is a fragment of upper continental crust, mostly consisting of Permian intrusive bodies (granitoids, diorite and gabbro) that were metamorphosed at upper greenschist facies conditions and deformed into orthogneisses during the Alpine evolution. Undeformed volumes during the Alpine orogeny nicely preserve the Permian structures.



Mont Morion biotite-bearing granite (Dent Blanche) cut by a composite dyke. The dyke displays mingling between coexisting felsic and mafic magma.

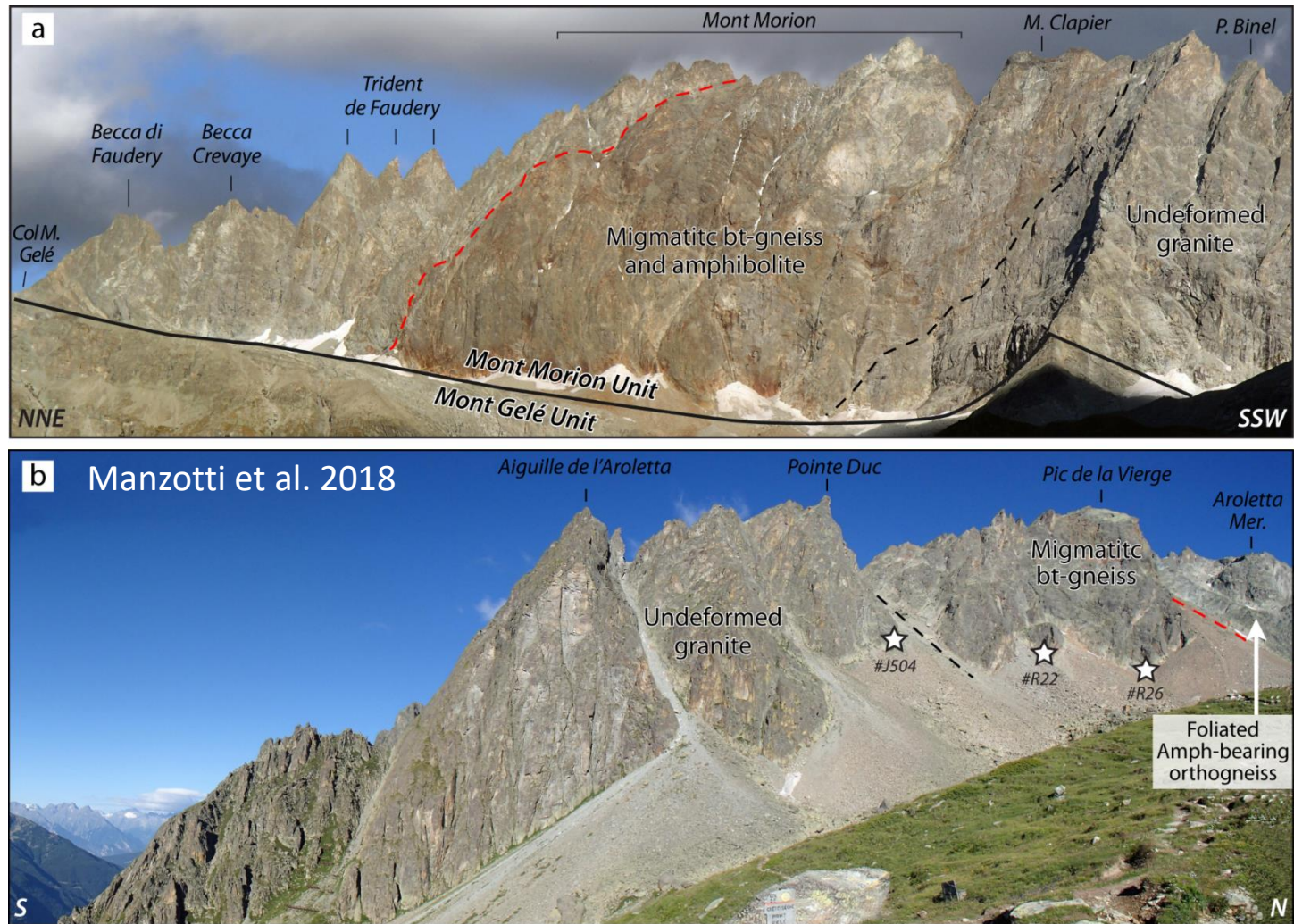


Undeformed coarse-grained gabbro from the Monte Cervino (Dent Blanche).

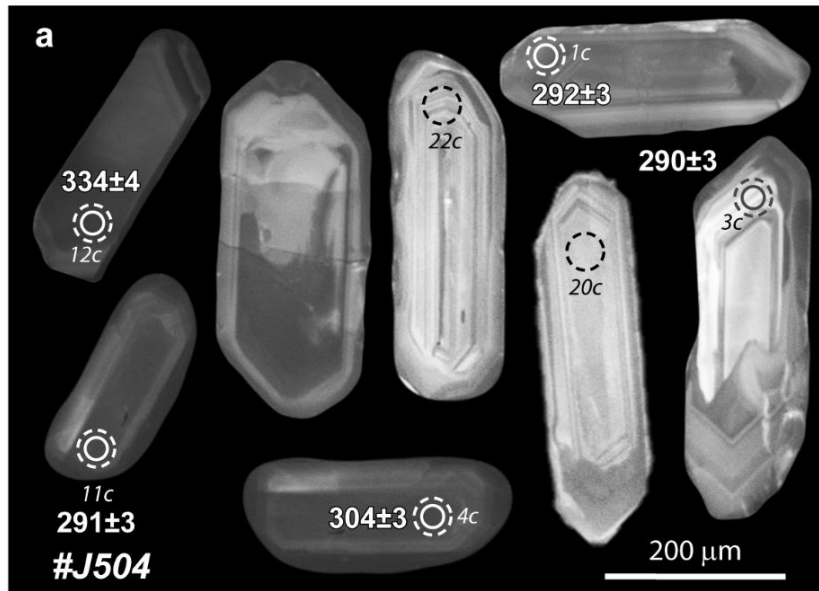


# Permian magmatism in the Western Alps

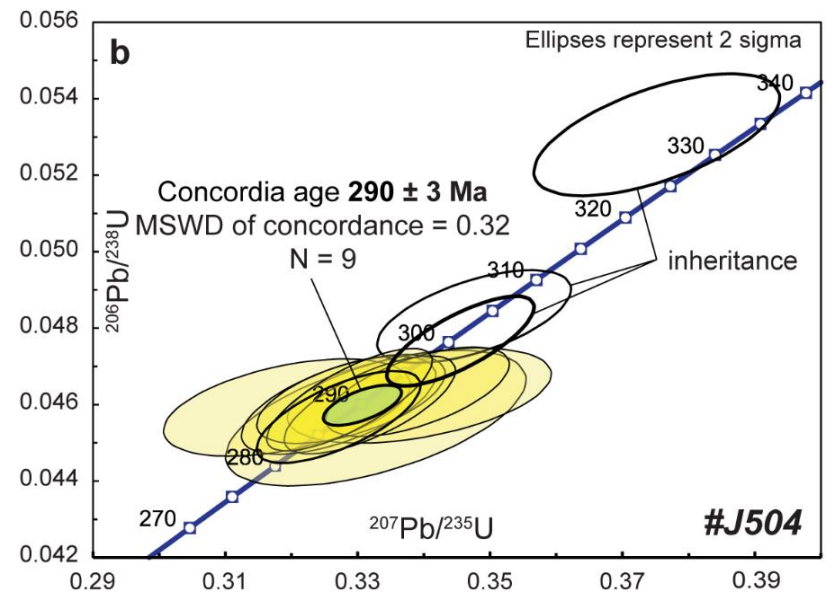
The Mont Morion biotite-bearing granite in the Arolla Unit is a km-scale intrusion preserved in a low-strain volume. Migmatitic biotite-gneiss and amphibolite are found as xenoliths within the Mont Morion granite and constitute its country-rocks.



# Permian magmatism in the Western Alps



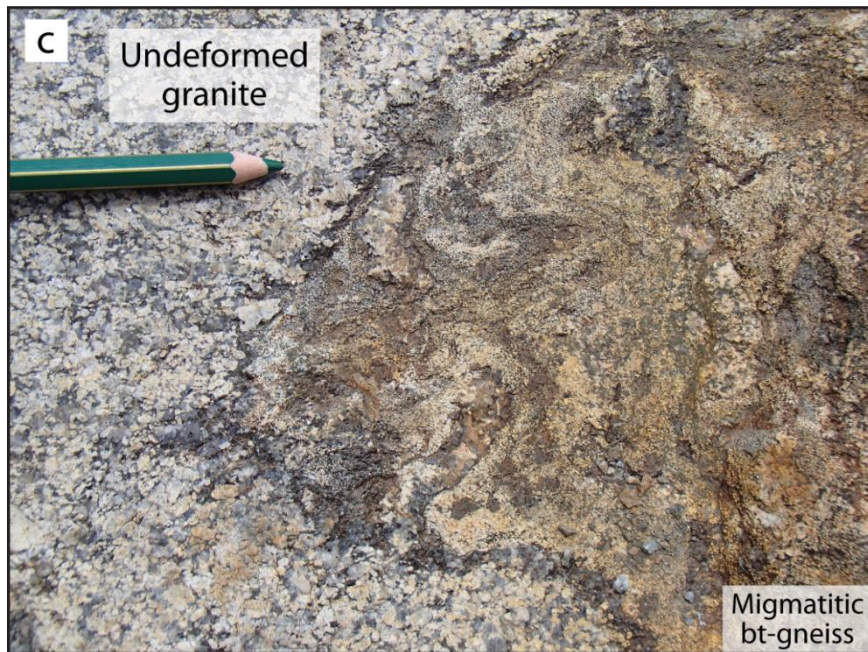
- Zircon saturation thermometry suggests that the Mont Morion granite crystallised from a melt at about 800 °C.
- U–Pb zircon geochronology indicates crystallization of the magma in the Permian ( $290 \pm 3$  Ma).





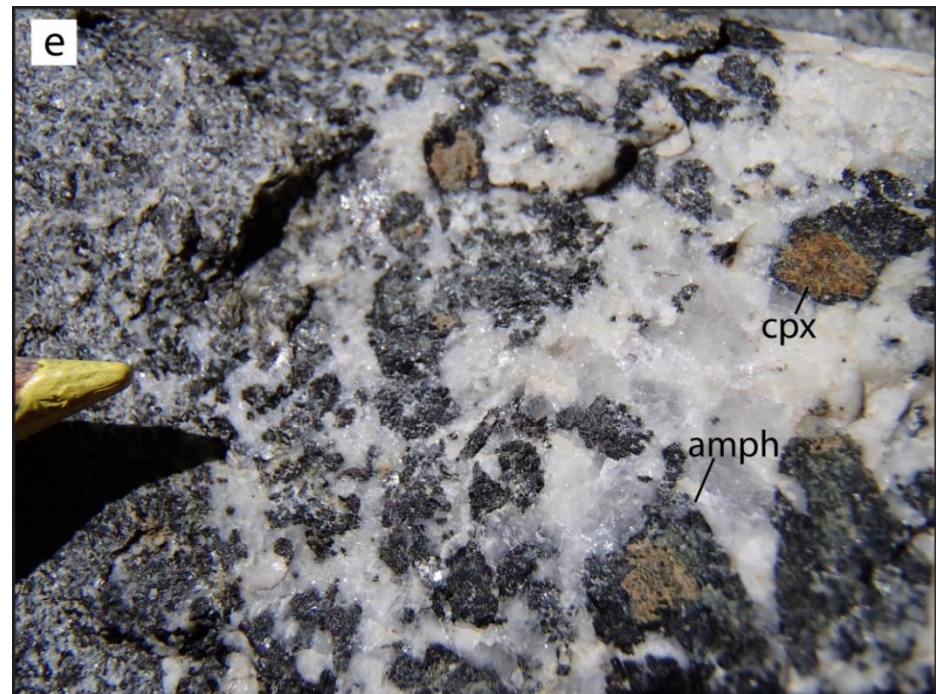
# Permian metamorphism in the Western Alps

Migmatitic biotite-gneiss and amphibolite are found as xenoliths within the Mont Morion granite and constitute its country-rocks. They are the sole occurrence known so far of pre-Permian basement in the Arolla Unit.



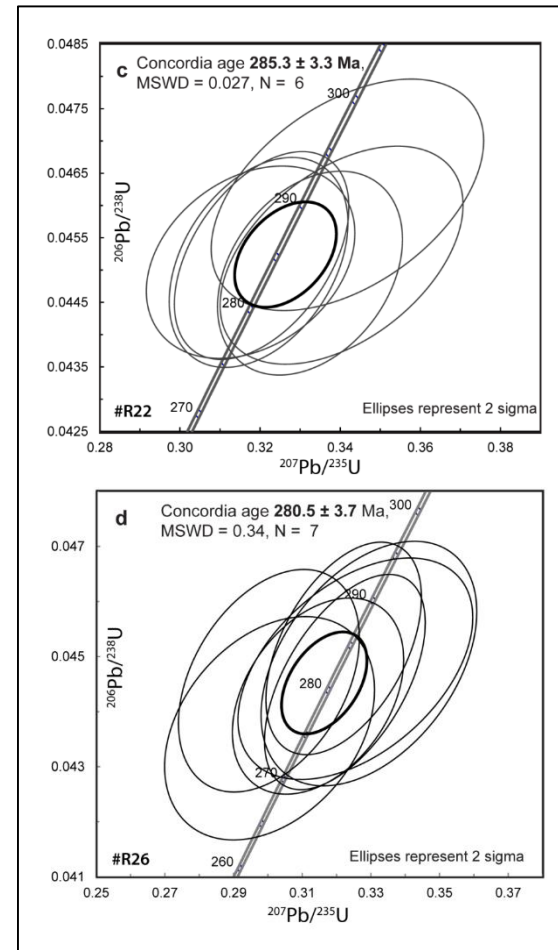
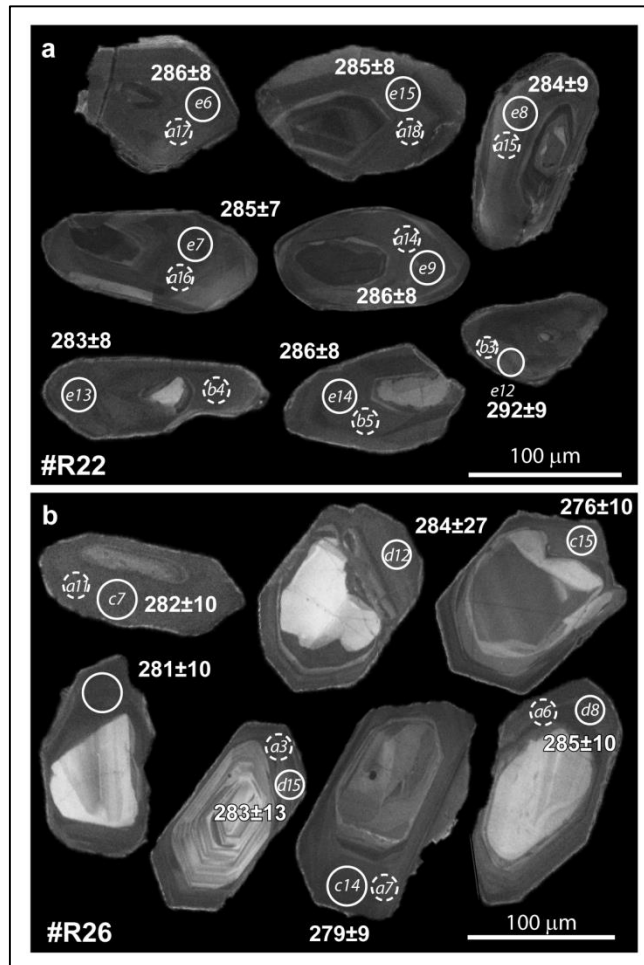
Contact between the migmatitic biotite- gneiss and the Mont Morion biotite-bearing granite: a centimetre-thick selvage of biotite develops at the interface between the granite and the gneiss

Coarse-grained leucosome consisting of clinopyroxene (rimmed by amphibole), plagioclase and quartz in a partially melted amphibolite.



# Permian metamorphism in the Western Alps

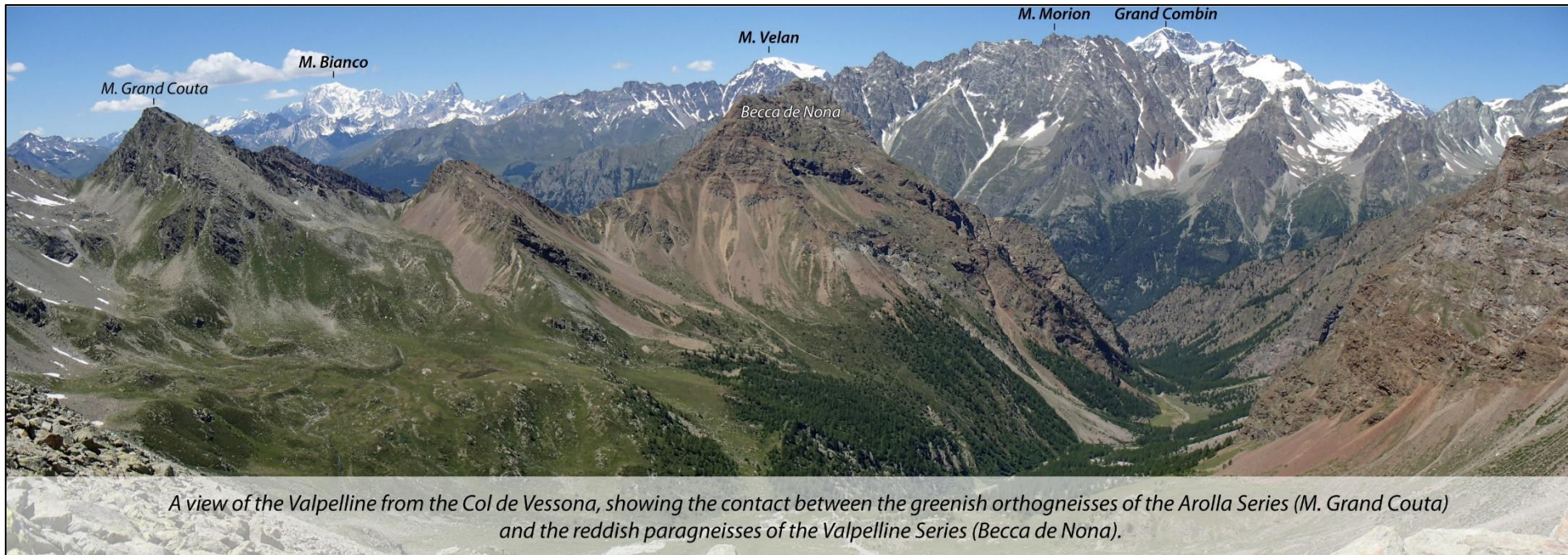
Migmatitic biotite-gneiss zircon has metamorphic overgrowths that yield U–Pb ages of  $285 \pm 3$  Ma and  $281 \pm 4$  Ma, and are thus contemporaneous with the intrusion of the Mont Morion granite.





# Permian metamorphism in the Western Alps

The Valpelline Unit (Dent Blanche) is a slice of Permian lower crust derived from the Adriatic continent. It is made of a suite of pelitic, carbonate and mafic protoliths with high-grade amphibolite to granulite facies metamorphism (ca. 7-8 kbar, 800-850°C). The pre-Alpine structures in the Valpelline Unit are well preserved (along strike, for at least 10 km; across strike, for about 1-2 km).



*A view of the Valpelline from the Col de Vessona, showing the contact between the greenish orthogneisses of the Arolla Series (M. Grand Couta) and the reddish paragneisses of the Valpelline Series (Becca de Nona).*



# Permian metamorphism in the Western Alps

The Valpelline Unit (Dent Blanche) preserves field evidence of partial melting.



Partially melted meta-pelite displays granoblastic aggregates of quartz, K-feldspar, plagioclase, garnet, sillimanite, and biotite.

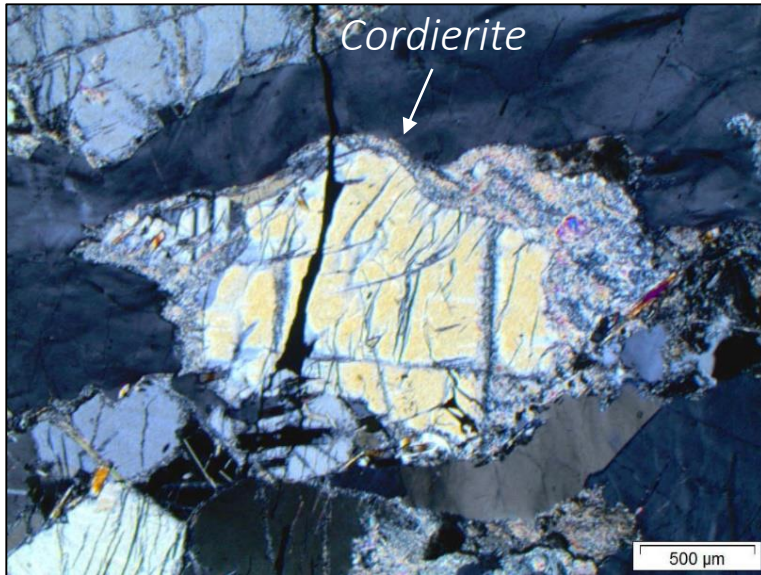
Idioblastic garnet porphyroblasts in a leucosome within an amphibolite. Garnet occurs in most cases inside the leucosomes (quartz-plagioclase), suggesting that it precipitates during partial melting as a peritectic phase (e.g.  $Pl + Amp + Qtz = Liq + Grt$ ).





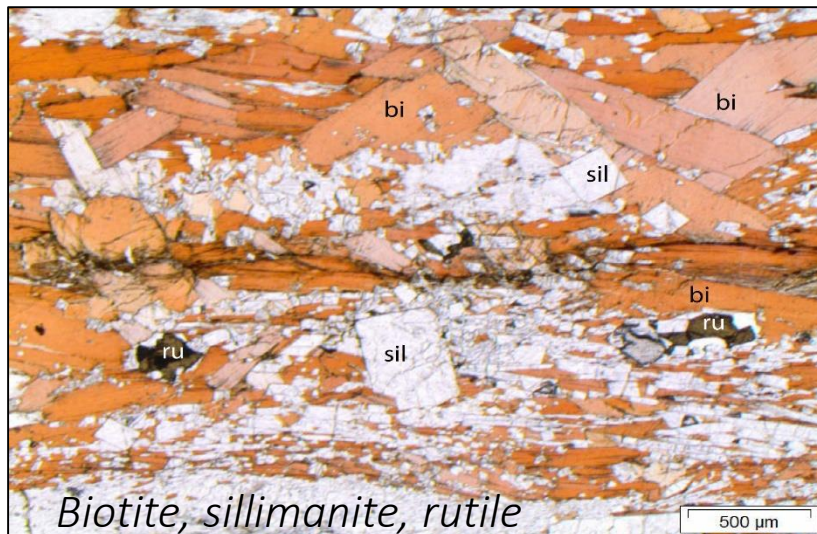
# Permian metamorphism in the Western Alps

The Valpelline Unit (Dent Blanche) preserves microscopic evidence of HT metamorphism.



Coexisting cordierite and orthoclase

Spinel inclusions in idioblastic sillimanite

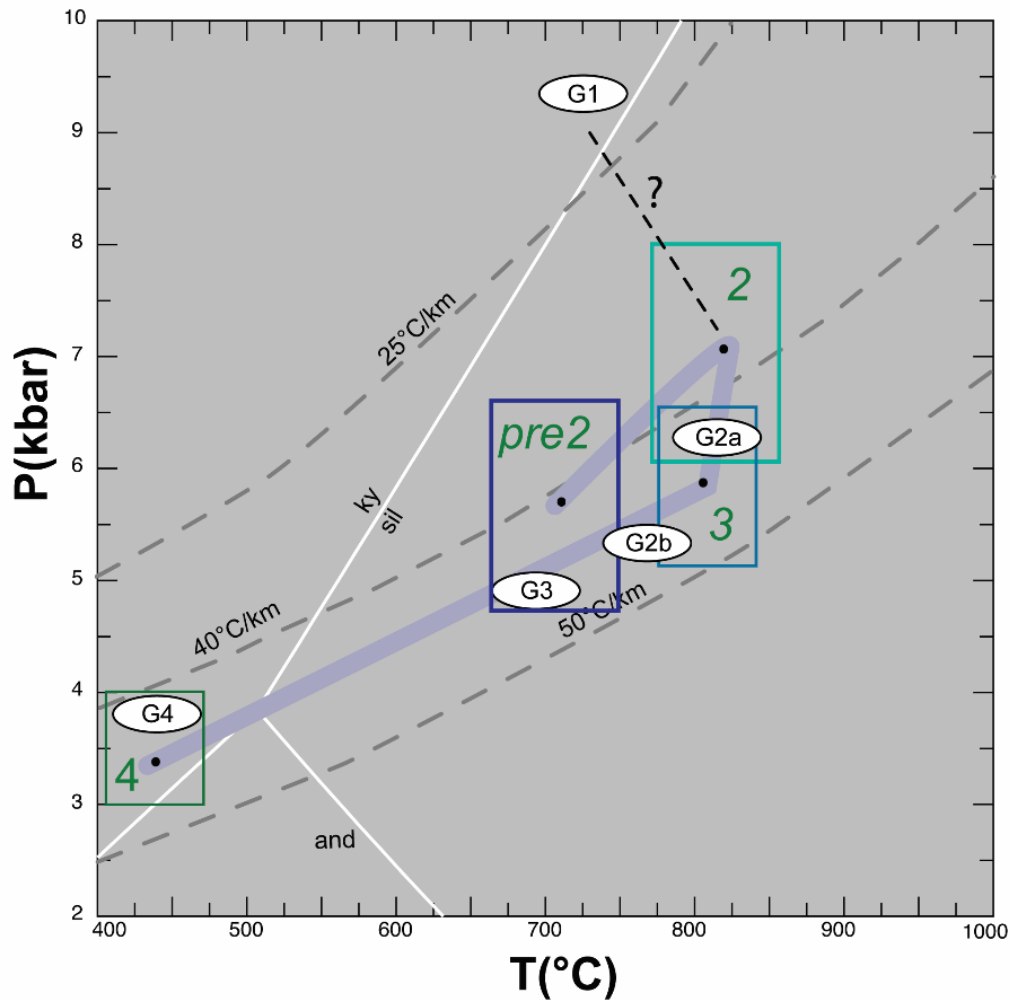


Foliation defined by biotite, sillimanite and rutile in a metapelite



# Permian metamorphism in the Western Alps

P-T path for the Valpelline Unit (Dent Blanche).

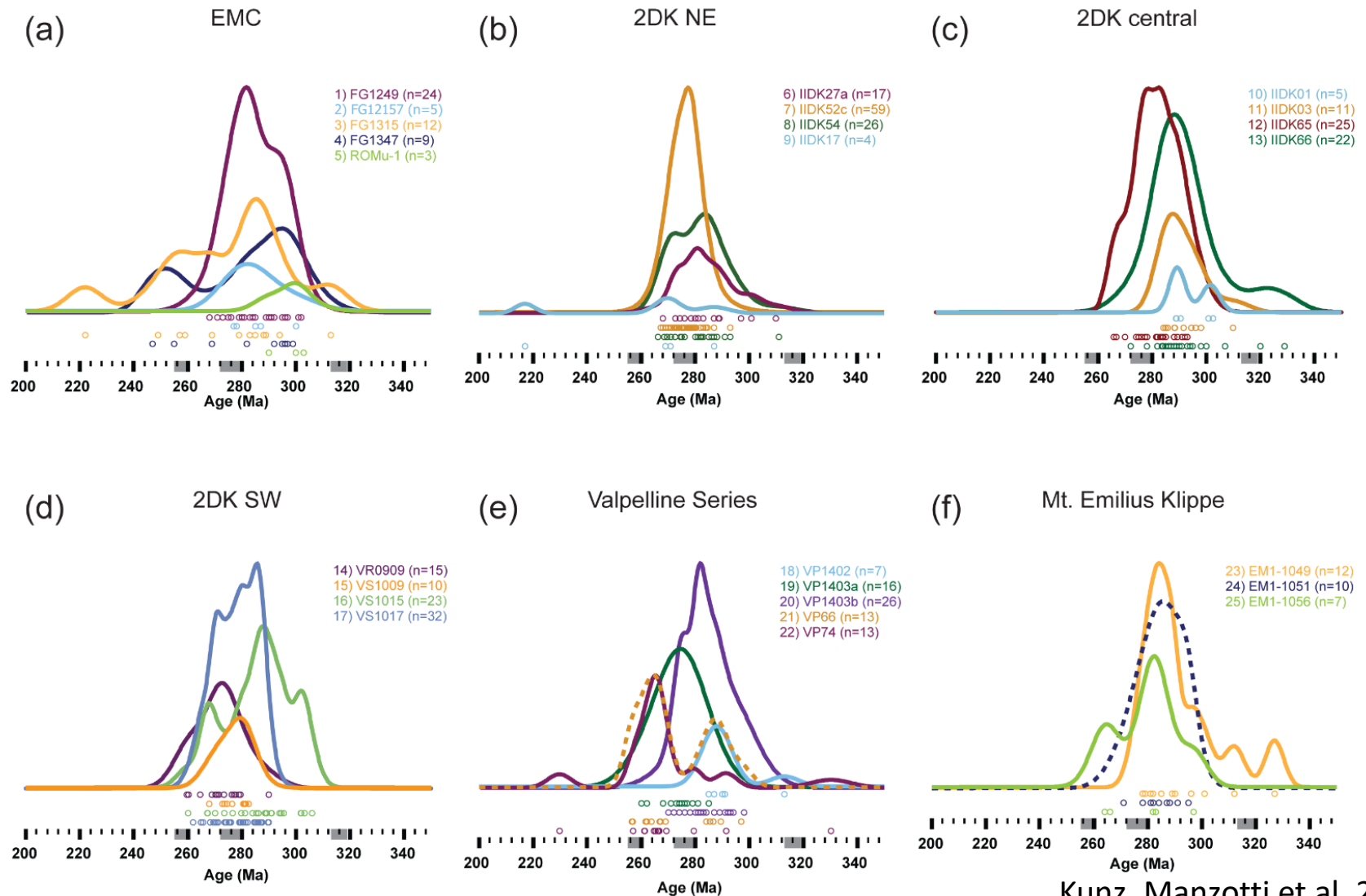


The peak metamorphism has been estimated at about ~7-8 kbar, 800-850 °C. Relict kyanite (G1, Gardien 1994) has been rarely found.

Following cooling and exhumation of the Valpelline Unit, a local mineral-chemical re-equilibration under greenschist facies (~4 kbar, 450 °C) is observed, but its age is uncertain.

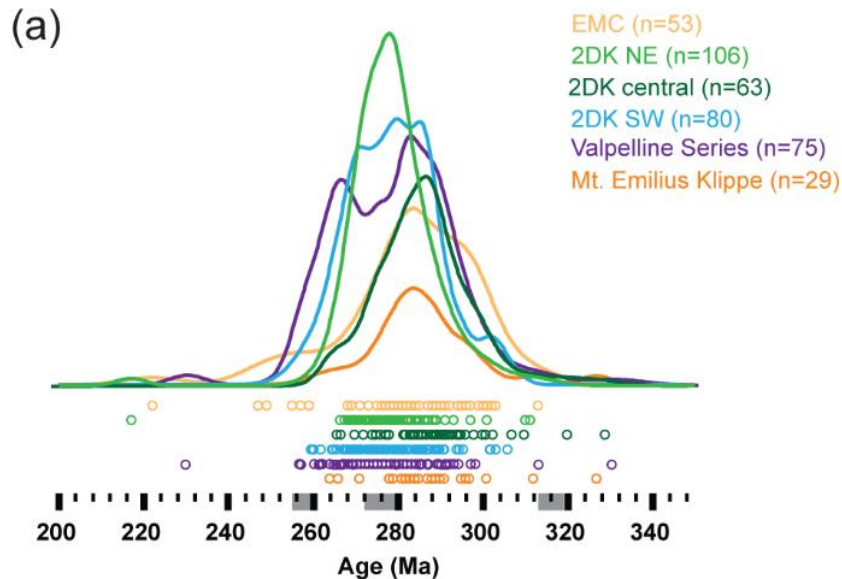
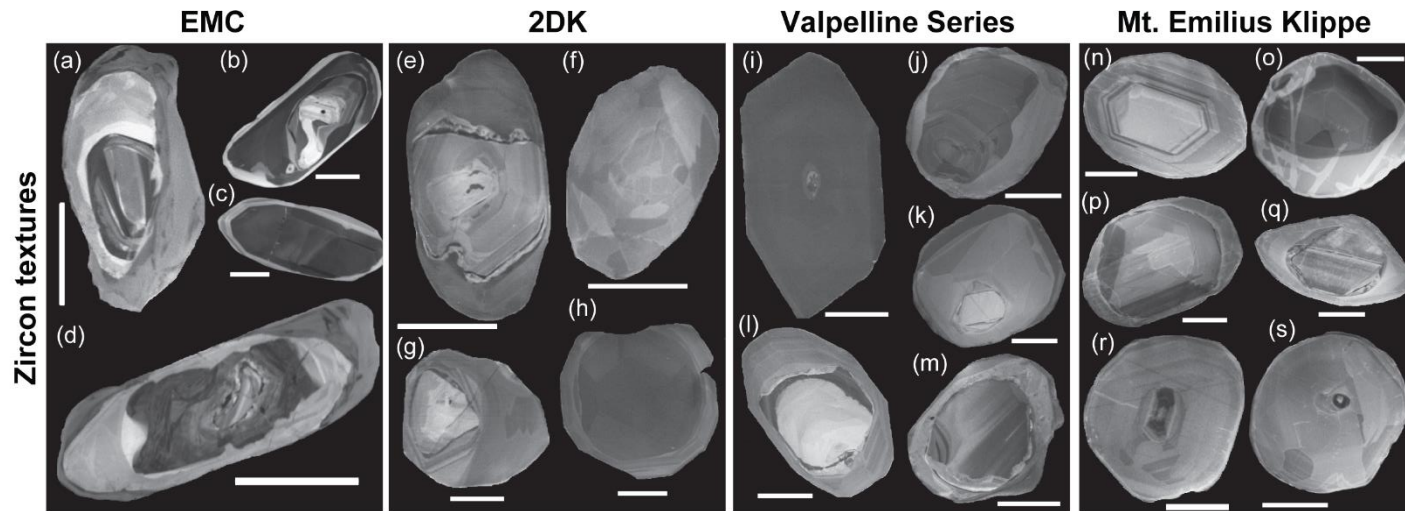
# Permian metamorphism in the Western Alps

U/Pb ages of metamorphic zircon from several Adria-derived continental units now situated in the Western Alps, defining a range between **~286** and **~266 Ma**. Two ages groups have been identified at **290-280 Ma** and **276-266 Ma** respectively.





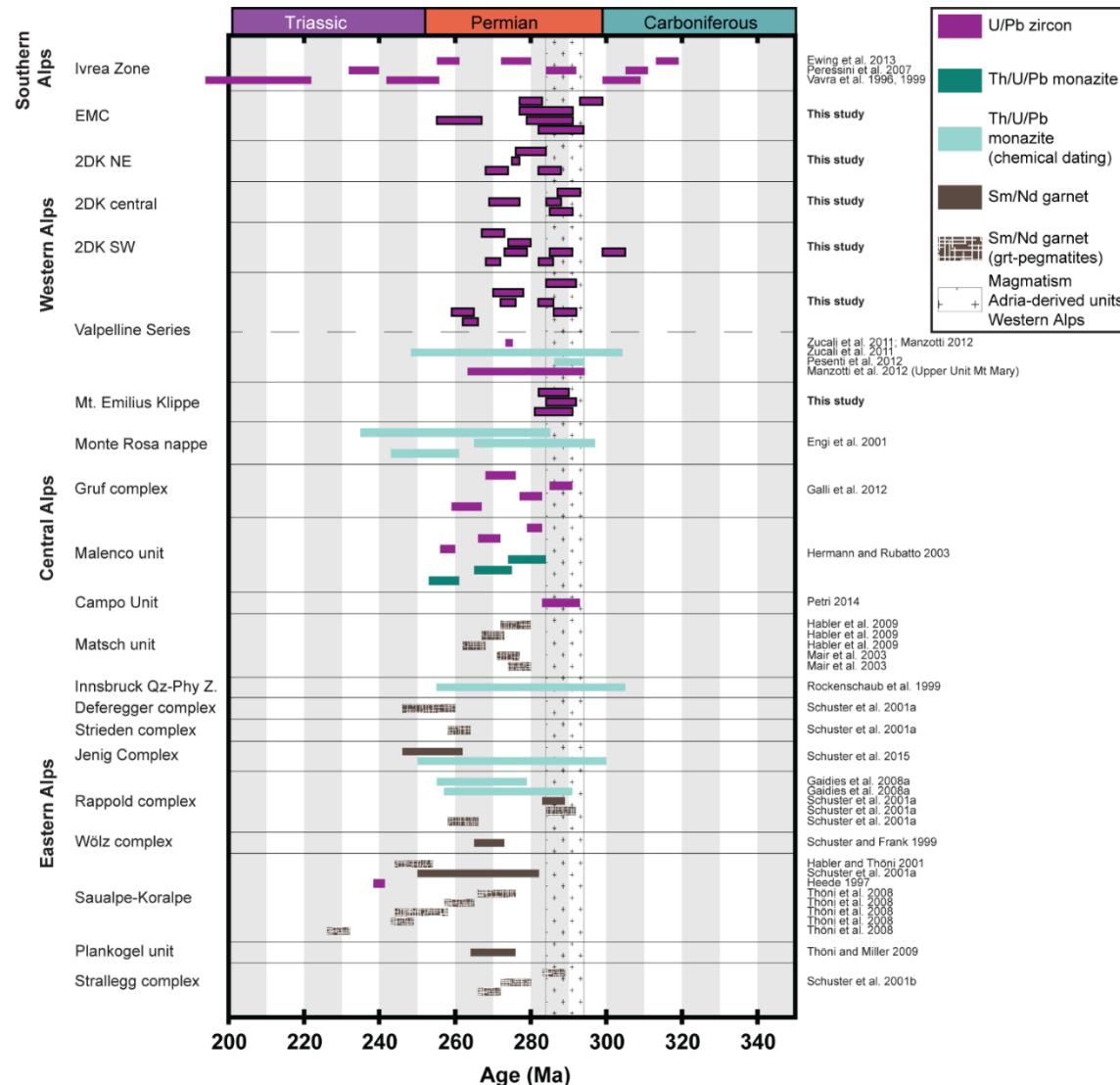
# Permian metamorphism in the Western Alps



- The Adria-derived units show little evidence of the oldest age generation found in the Ivrea Zone ( $316 \pm 3$  Ma).
- The first age group (286–283 Ma) is only present as a partially resolved age peak ( $\sim 285$  Ma) in the Ivrea Zone (Ewing et al. 2013).
- The second age group (277–266 Ma) overlaps with the intermediate Ivrea age of  $276 \pm 4$  Ma.

# Permian metamorphism in the Alps

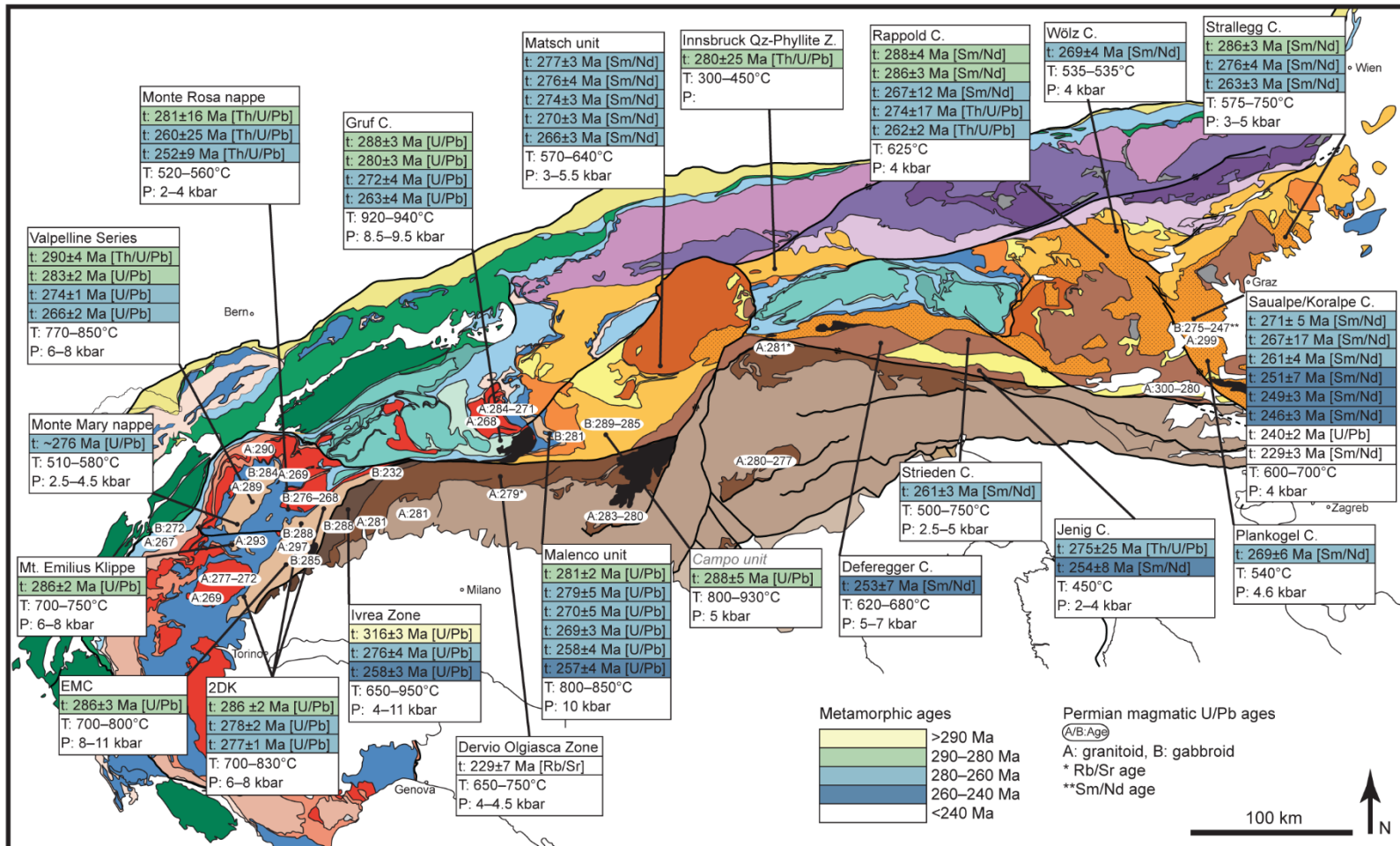
U/Pb ages from this study are similar to Permian ages reported for the Ivrea Zone in the Southern Alps and Austroalpine units in the Central and Eastern Alps.





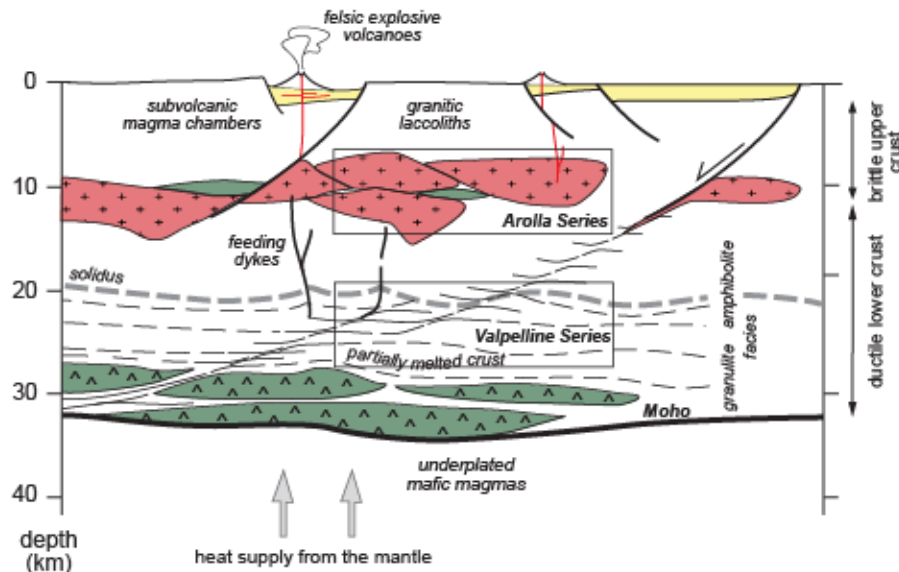
# Permian high thermal regime in the Alps

Tectonic overview map of the Alps with ages of Permian magmatism and  $P$ – $T$ – $t$  conditions from rocks that experienced Permian HT metamorphism.



# Conclusions

- The Adria-derived units in the Western Alps record the high heat flow that affected the Adriatic margin in Permian times. This high thermal regime is linked to extensive partial melting, with migmatites and pegmatite dykes at lower crustal levels (e.g. Valpelline Series, IIDK), and acid and basic intrusions at the higher levels (e.g. granitoids and gabbros forming the Arolla Series, the Gneiss Minuti and the Pillionet).
- Based on the U/Pb zircon age groups, mineral assemblages, and metamorphic conditions, a similar origin of the Adria-derived units and the Kinzigite Formation of the Ivrea Zone is very likely.
- Two zircon age groups (286-283 Ma and 277-266 Ma) have been identified for the timing of the Permian HT metamorphism in the Western Alps. The first metamorphic age group (290-280 Ma) is essentially coeval with the Permian magmatic ages. The second age group is present in several units (Valpelline Series, NE, and SW 2DK).





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