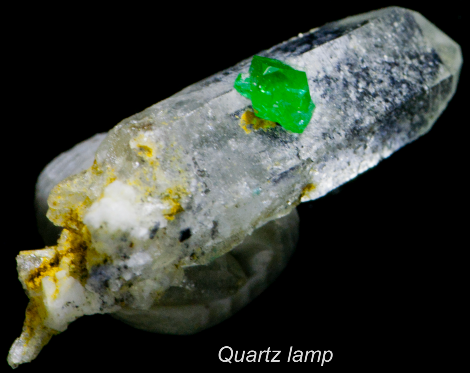
Ion microprobe dating of fissure monazite in the Western Alps: insights from the Argentera Massif and the Piemontais and Briançonnais Zones

Natural light



Quartz lamp

Ricchi E.*

In collaboration with Gnos E., Rubatto D., Whitehouse M.J. and Pettke T.

*emmanuelle.ricchi@unige.ch

EGU2020: Sharing Geoscience Online (#shareEGU20)

Aims of monazite-(Ce) dating

A. Constraining deformation stages along the retrograde path of the exhuming parts of the Alps by new and precise Th-U-Pb crystallization ages

B. Comparing with existing chronological data to further constrain cooling history and deformation stages in the Alps

Monazite-(Ce) dating

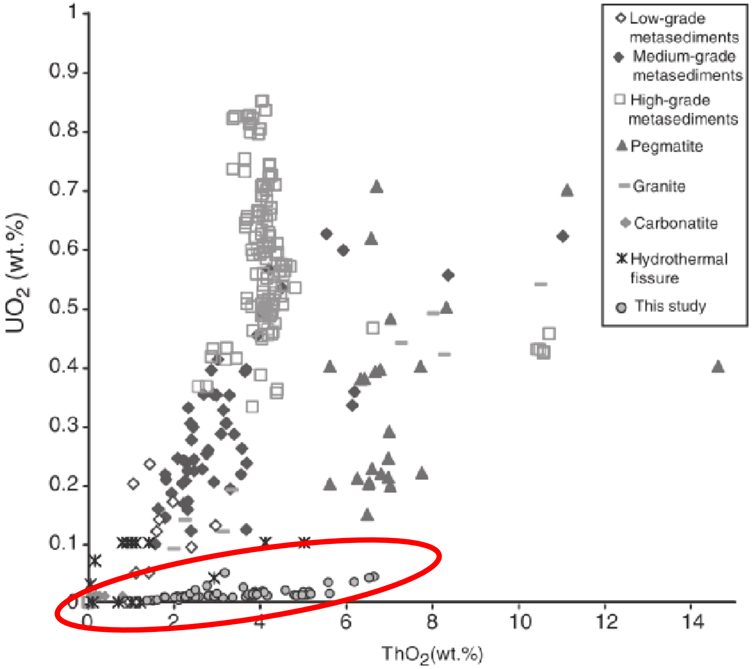
- Reliably dated with the **Th/Pb system**

- **Negligible diffusion of Pb and Th**

- **No Pb incorporation** during crystallization

- Th-Pb chronometer can be disturbed or reset only by **dissolution/precipitation process**

- Potential to **record several tectonic events**



(Janots et al., 2012)

- Reliably dated with the **Th/Pb system**

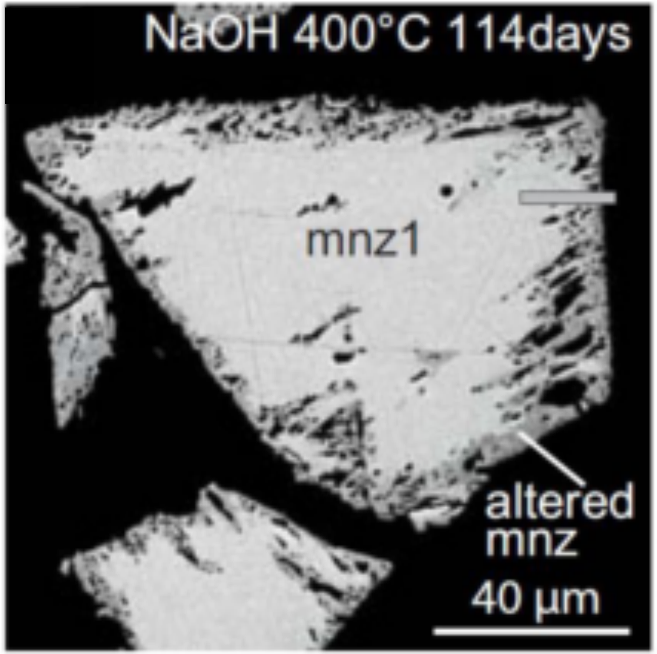
- **Negligible diffusion of Pb and Th**

- **No Pb incorporation** during crystallization

- Th-Pb chronometer can be disturbed or reset only by **dissolution/precipitation process**

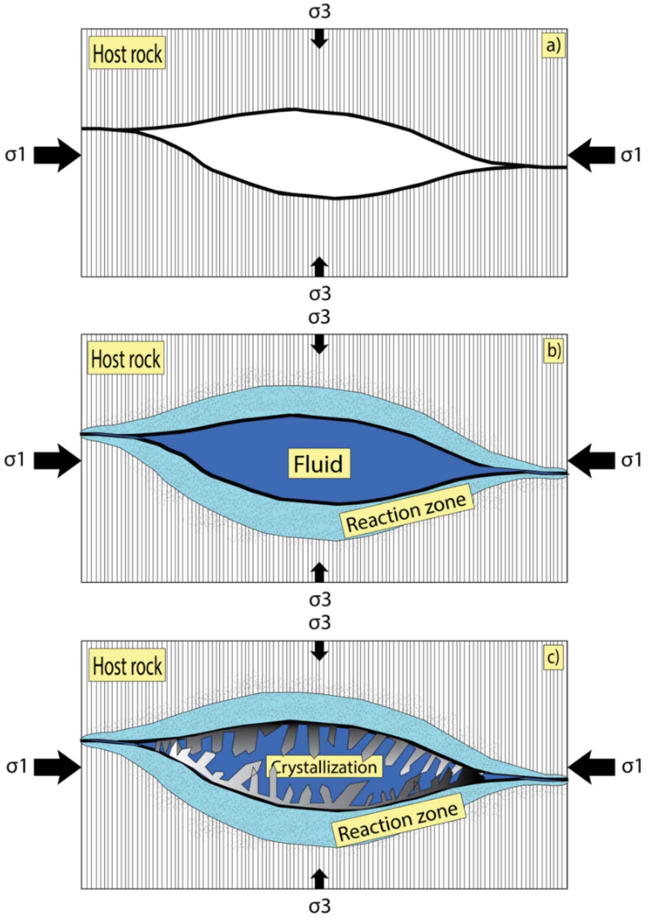
- Potential to **record several tectonic events**

Experimental alteration



(Grand'Homme et al., 2016)

Alpine fissure formation



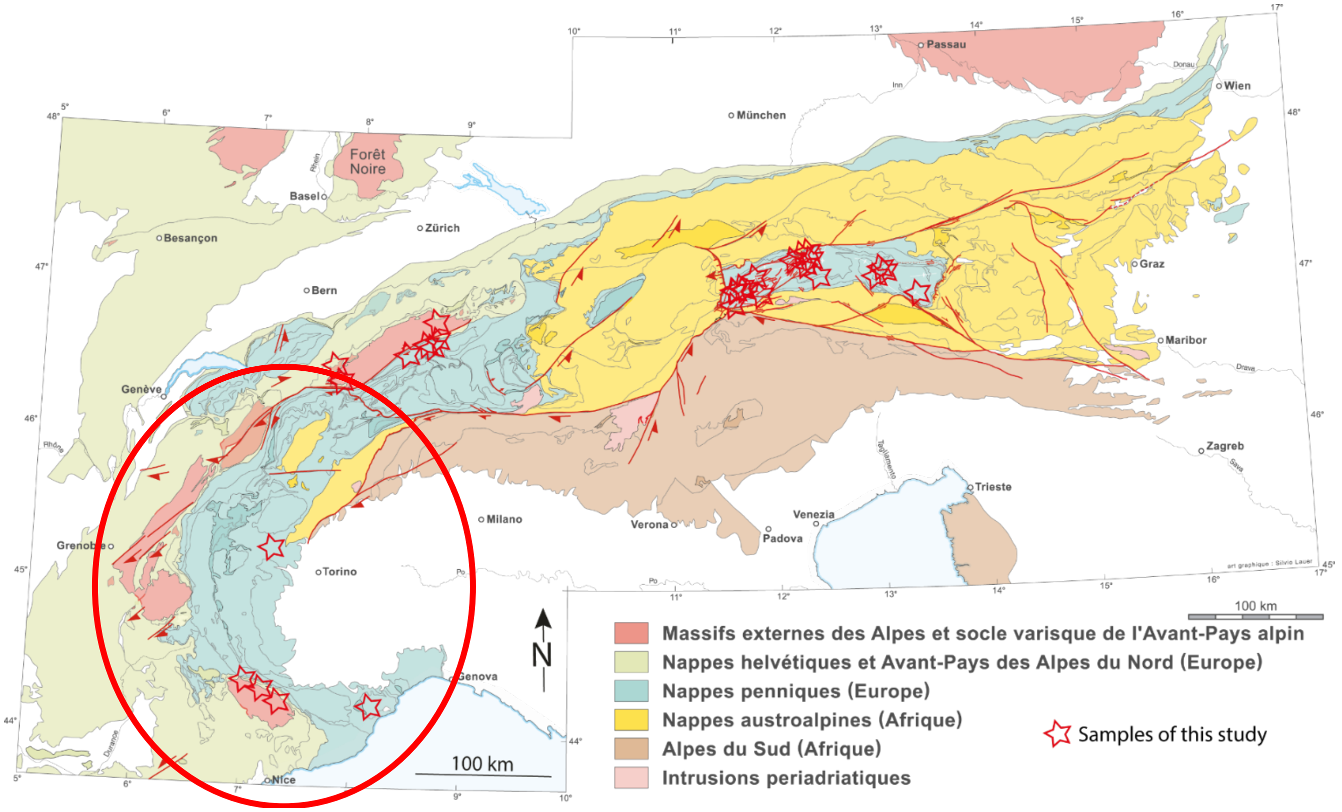
a) Fluid assisted cracking of the rock and fissure formation perpendicular to the foliation and lineation of the host-rock.

b) Fissures are filled by hydrothermal fluid, inducing disequilibrium with the host-rock, resulting in dissolution of the minerals from the host-rock wall.

c) Precipitation of hydrothermal minerals in the fissure during re-equilibration.

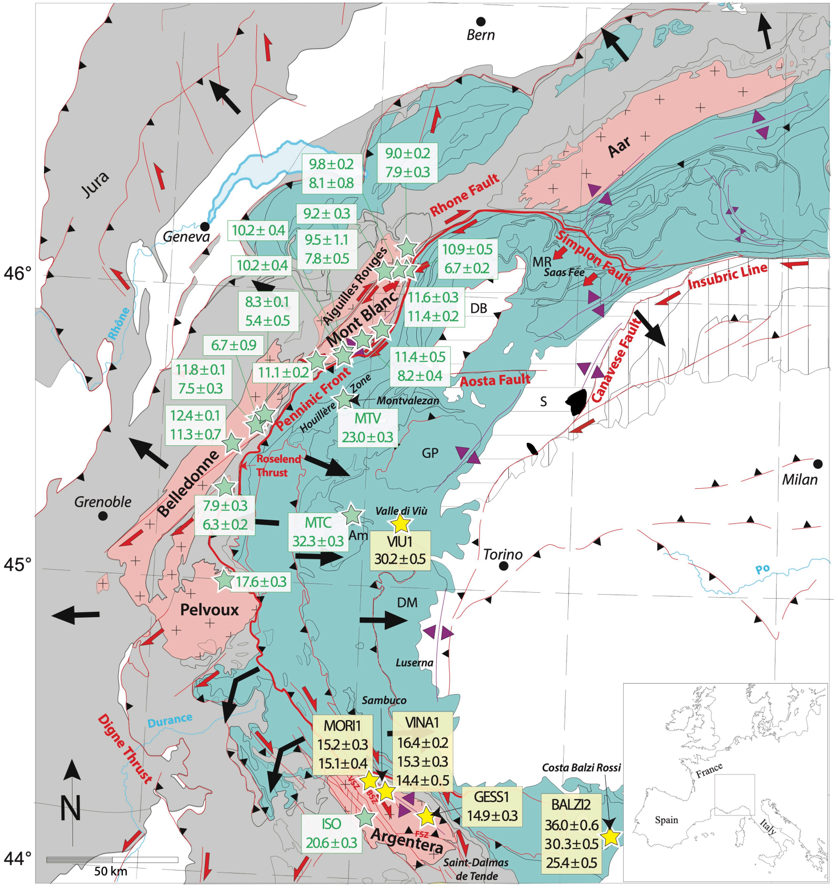
➢ This is a cyclic process due to repeated chemical disequilibrium between fluid and host rock potentially triggered by deformation, leading to the formation of strongly zoned minerals.

Study area



Modified after Schmid et al. (2004). Fault data from Bousquet et al. (2012), Steck et al. (2013), Schneider et al. (2013).

Study area – The western Alps



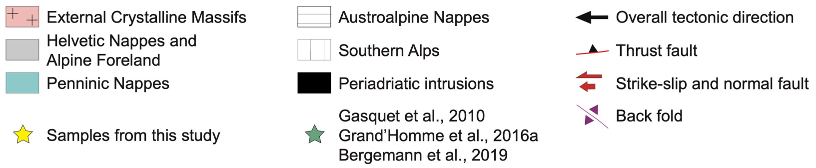
Modified after Bergemann et al. (2018), Steck et al. (2013), Sanchez et al. (2011), Schmid et al. (2004, 2017).

Tectonic map of the study area modified after Schmid et al. (2004), Sanchez et al. (2011a), Steck et al. (2013) and Bergemann et al. (2019).

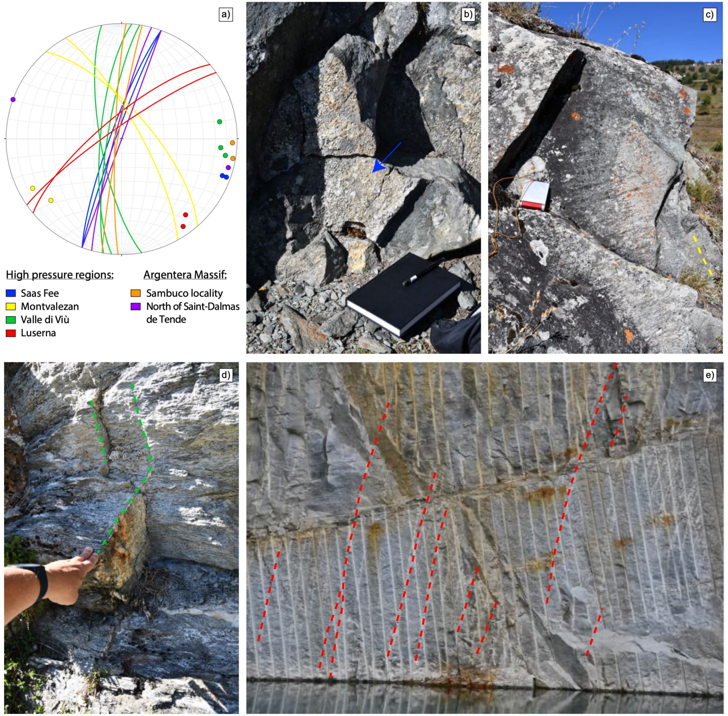
Stars correspond to **monazite samples** from **this study (yellow)** and from Gasquet et al. (2010), Grand'Homme et al. (2016a) and Bergemann et al. (2019) **(green stars).**

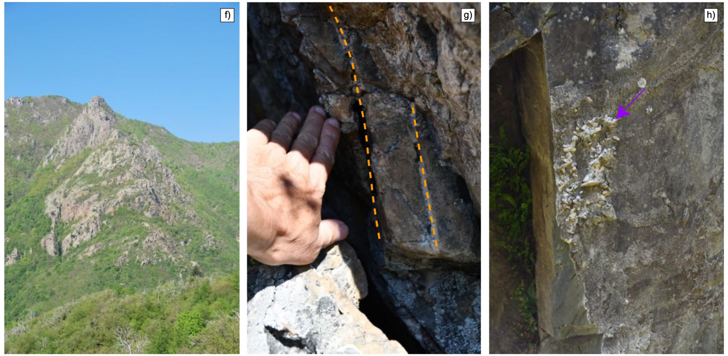
Weighted mean age of fissure monazite growth domains are indicated.

The internal domains are labelled as follow: MR: Monte Rosa, DB: Dent Blanche, S: Sesia, GP: Grand Paradiso, Am: Ambin, DM: Dora Maira



Study area – The western Alps





a Stereographic projection of planes and their poles of subvertical Alpine fissure in the western Alps. Localities are indicated in Fig. 1. Fissures in high pressure regions and in the Argentera Massif are presented in b-f and g-h, respectively.

b NNE (N020) striking vertical fissure in amphibolite facies metabasalt of the Zermatt-Saas high-pressure zone. At the locality of Mittaghorn, Saas Fee, Switzerland, the vertical fissure shown contains crystals of albite (pericline), quartz and chlorite (the wall of the fissure is indicated by the blue arrow).

c Subvertical, SSE (N145) striking fissure in Permo-Carboniferous metaconglomerates at Montvalezan, Savoie, France (yellow-dashed lines), associated with strike-slip faulting (note horizontal lineation). The fissure is located in greenschist-facies overprinted blueschist facies rocks.

d N (N000) striking, subvertical fissures (green-dashed lines) in greenschist facies overprinted eclogite facies metasedimentary rocks at Margone, Val di Viù, Piedmont, Italy. Sample VIU1 is from this area.

e Meta-granitoid rocks at Montoso, Piedmont, exploited as "Pietra di Luserna". The steeply oriented, NE (N050) striking fissures (indicated by red-dashed lines) cutting the horizontal foliation caused bleaching (dissolution of biotite) in the adjacent host rock. Fissure monazite has been reported from these quarries (Finello et al. 2007).

f Permian metarhyolites and metasedimentary rocks forming the mountains of Costa Balzi Rossi, Magliolo, Liguria, Italy. The dated monazite sample BALZI1 is from fissures located in metarhyolites.

g Vertical N-S (N005) striking fissures (indicated by orange-dashed lines) at the locality Sambuco, Valle di Stura, Argentera Massif. Although monazite has not been reported from this locality, monazites from Vinadio (VINA1) and Moriglione (MORI1) in Valle Stura are from fissures of similar orientation.

h NNE (N020) striking fissure in metamorphic Permian siltstones of the Argentera Massif, France, ca. 1.5 km north of Saint-Dalmas de Tende, showing milky quartz crystals on fissure wall (violet arrow)

Example of fissures in the western Alps

Results and Discussion

Chemical, **textural**, and **geochronological information** for the 5 fissure monazite grains analysed in this study.

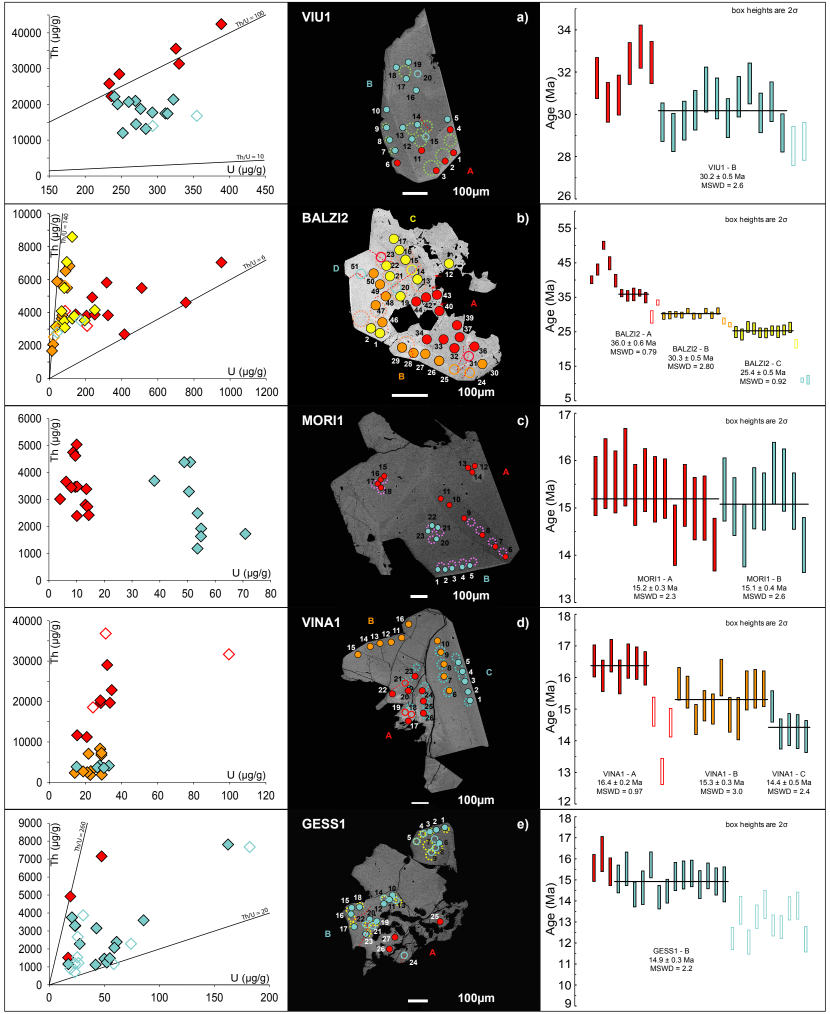
Colour-filled and open-dashed circles on BSE images, respectively, correspond to ion probe and LA-ICP-MS spot locations.

The defined growth domains (A, B, C…) are indicated on BSE images with a distinct colour code (red, orange, blue …) and referred to as groups in the table below.

Spot ages considered in the weighted mean age calculations are indicated by colour-filled bars whereas spot ages only considered in the age range are indicated by open bars (bar length representing the spot age plus its 2 σ uncertainty).

Table 4 Summary of fissure monazite growth domains weighted mean ages and spot age ranges

Sample domain	Figure	Zoning of the grains	Weighted mean domain $^{208}Pb/^{232}Th$ ages (Ma, ± 1σ)	MSWD	Number of analyses	Spot $^{208}Pb/^{232}Th$ age range of entire grain (Ma, ± 1σ)
VIU1 - B	3a	Regular	30.2 ± 0.5	2.6	12	33.2 ± 0.5 - 28.5 ± 0.5
BALZI2 - A	3b	Patchy border	36.0 ± 0.6	0.79	5	50.1 ± 0.6 - 11.2 ± 0.6
BALZI2 - B			30.3 ± 0.5	2.80	10	
BALZI2 - C			25.4 ± 0.5	0.92	10	
MORI1 - A	3c	Regular	15.2 ± 0.3	2.3	13	15.9 ± 0.4 - 14.2 ± 0.3
MORI1 - B			15.1 ± 0.4	2.6	9	
VINA1 - A	3d	Regular	16.4 ± 0.2	0.97	7	16.7 ± 0.3 - 13.0 ± 0.2
VINA1 - B			15.3 ± 0.3	3.0	11	
VINA1 - C			14.4 ± 0.5	2.4	5	
GESS1 - B	3e	Patchy border	14.9 ± 0.3	2.2	14	16.2 ± 0.4 - 12.1 ± 0.3



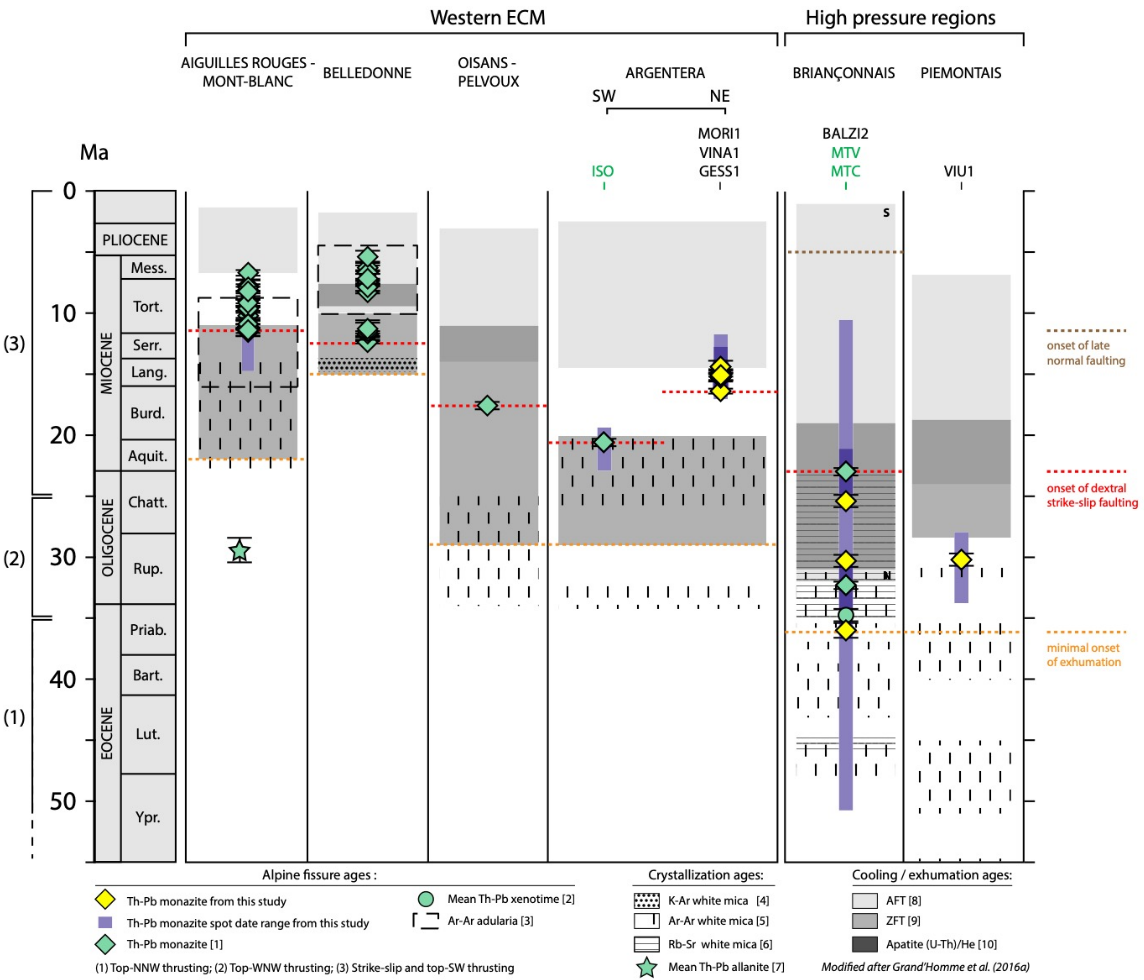
Results – Fissure monazite ages

(1) Top-NNW thrusting (>35 Ma):

The oldest ages recorded by fissure monazite found in the Briançonnais Zone at **~36 Ma** (BALZI2 sample), are related to **exhumation along the PF during top-NNW thrusting in sinistral transpression.**

(2) Top-WNW thrusting (35 – 25 Ma):

This first exhumation episode was **overprinted by subsequent top-WNW thrusting** recorded between **~32 – 30 Ma** by fissure monazites from the Briançonnais and Piémontais zones (BALZI2, MTC and VIU1 grains).



Discussion – Fissure monazite ages

Summary of fissure monazite ages from this study compared to published crystallization and cooling ages.

(3) Strike slip and top-SW thrusting (25 – 0 Ma):

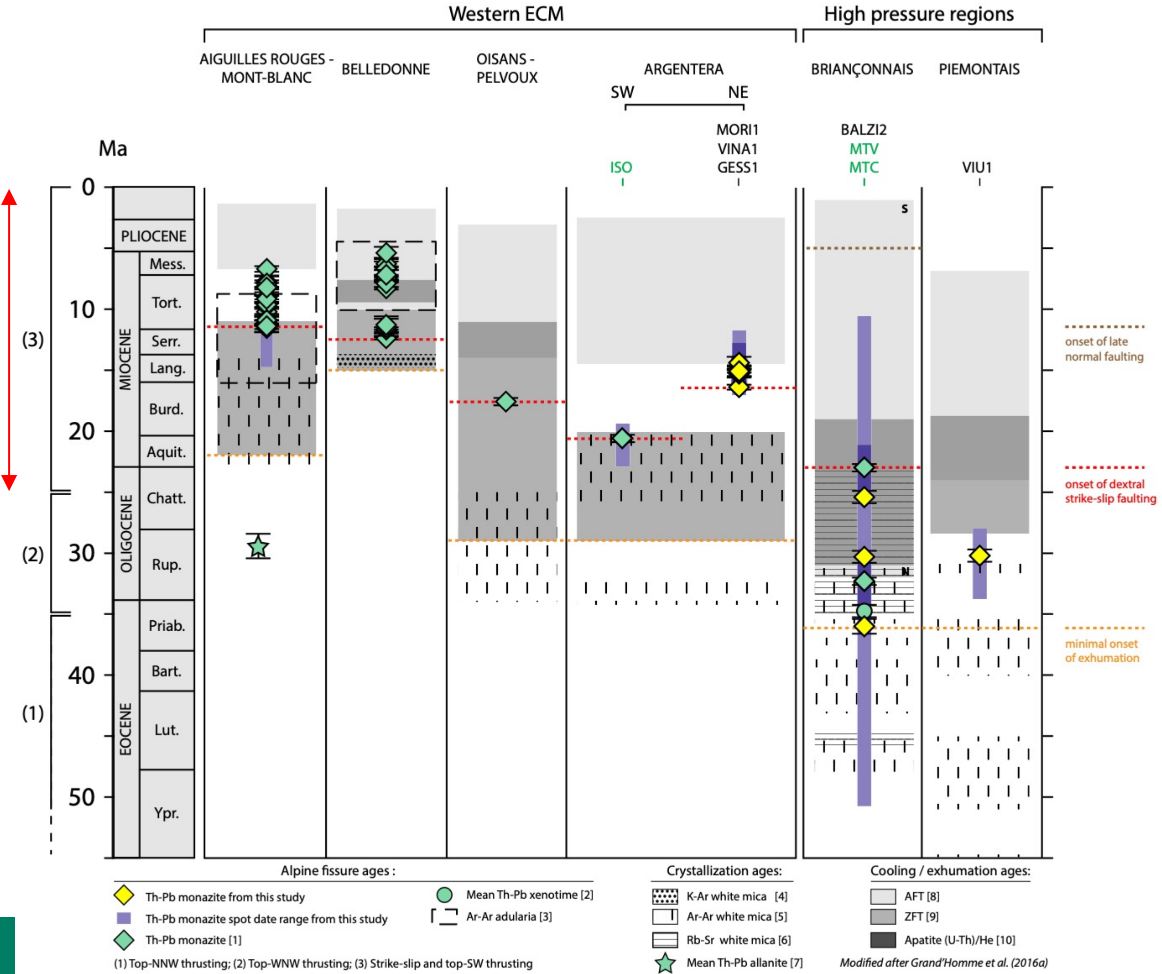
During top-SW thrusting, fissure monazite crystallization is recorded in association with strike-slip faulting in the Briançonnais Zone Houillère at **~23 Ma** (MTV grain), likely related to the **progressive opening of the Liguro-Provençal Basin.**

Later, at **~20.6 Ma** (ISO grain), fissure monazite from a fault zone located in the south-western border of the Argentera Massif is attributed to the **onset of the anticlockwise rotation of the Corsica-Sardinia Block.**

To the contrary, monazite crystallization recorded **at ~16 – 14 Ma** (MORI1, VINA1 and GESS1 grains) in a fault zone of the north-eastern Argentera Massif likely constrains the **end of the Corsica-Sardinia block rotation**. Contemporaneous with this rotation, deformation during the **exhumation of the Pelvoux Massif** is recorded at **~17.6 Ma**.

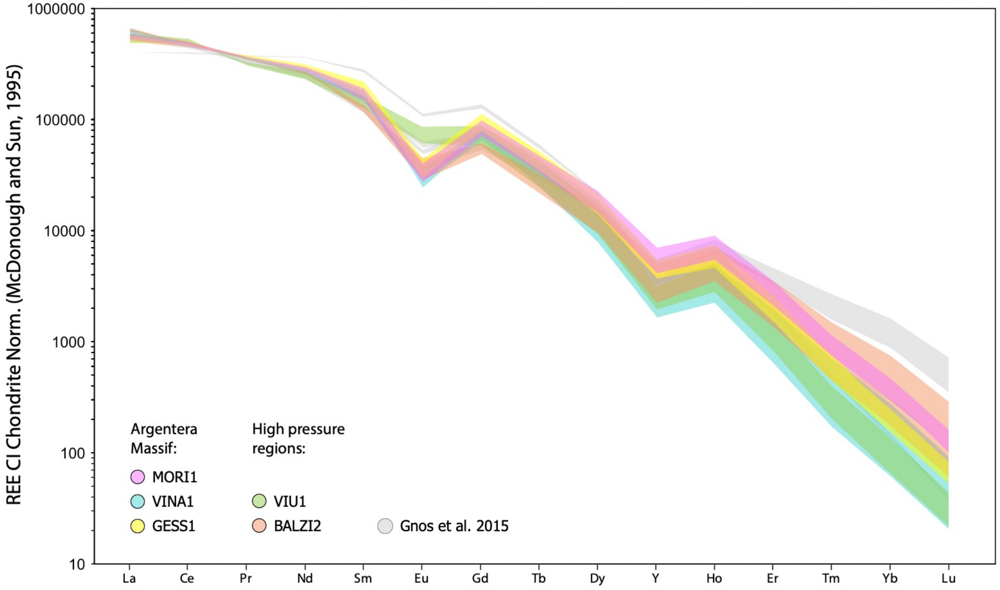
Finally, **successively younger episodes of dextral strike-slip** are recorded at **~12 – 11** and **~8 – 5 Ma** in the Belledonne Massif and at **~12 – 7 Ma** in the Mont-Blanc and Aiguilles Rouges massifs.

The observed fissure monazite age rejuvenation toward the northern External Crystalline Massifs (ECM) of the western Alps is interpreted as marking the progressive and episodic (re)-activation of dextral strike-slip movements along and through the internal part of the ECM.



Summary of fissure monazite ages from this study compared to published crystallization and cooling ages.

Discussion – Fissure monazite ages



Chondrite-normalised REE element patterns of studied fissure monazites

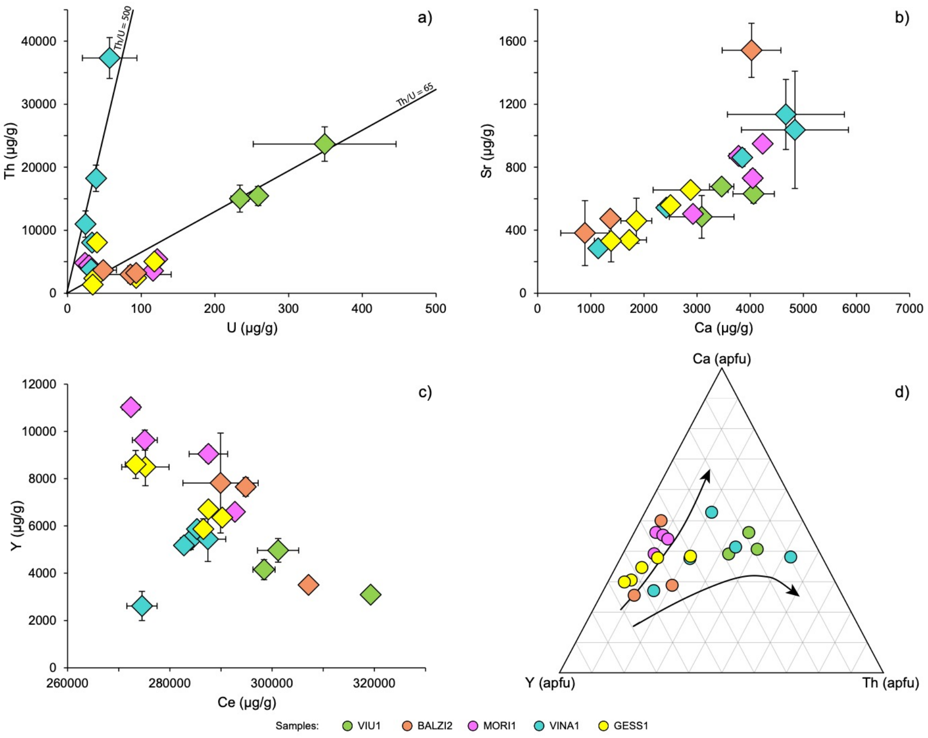
Trace element analyses of fissure monazite show a **negative Eu anomaly**, most likely resulting from co-crystallisation of albite. The difference in negative Eu/Eu* is interpreted to be inherited from the host rock and is **distinct in VIU1** (Piémontais Zone) compared to the other grains.

a) As described by Gnos et al. (2015), the **high Th/U content** of **VINA1** grain likely attest for a **more oxidizing environment of crystallization.**

b) Sr and Ca correlation indicates **dissolution of host-rock plagioclase or carbonate as a source** (Gnos et al., 2015). Samples from the Argentera Massif (MORI1, VINA1 and GESS1) have nearly identical Sr and Ca contents (average Sr/Ca = 0.22), suggesting a similar source for these elements compared to the samples from the high-pressure regions.

c) An **increase in Ce correlated with a decrease in Y** suggests that **more monazite or allanite was dissolved with respect to xenotime in the host rock.**

d) An **increase in cheralite component (Ca+Th replacing 2REE)** related to **a decrease of xenotime component (Y)** is observed for grains **VINA1** and **VIU1**.



a – c *Compositional bivariate plots of studied fissure monazites.* ***d*** *Ca-Y-Th triangular diagram (atomic proportions) displaying main cationic variation of monazite from this study*

Conclusions

Fissure monazite ages obtained in this study corroborate previous ages, recording crystallization at **~36 Ma, ~32 – 30 Ma** and, **~25 – 23 Ma** in the **high-pressure regions**, interpreted to be respectively related to **top-NNW, top-WNW** and **top-SW thrusting and associated strike-slip faulting.**

During this latter transpressive phase, younger fissure monazite crystallization is recorded between **~20.6 – 14 Ma** in the **Argentera Massif, in association with dextral strike-slip faulting related to anticlockwise rotation of the Corsica-Sardinia Block.**

Later, orogen-parallel deformation is characterised by the **progressive (re)-activation of dextral-strike slip movements along and through the internal part of the western ECM,** and corresponding fissure monazites display **younger ages in the Belledonne and Mont-Blanc Massifs.**

Trace element concentrations in the investigated fissure monazites suggest a **similar source of Sr and Ca** for the grains from the Argentera Massif, the **REE concentrations** generally indicate **higher amounts of monazite or allanite dissolution from the host-rock** with respect to xenotime and **the extremely high Th/U contents** corroborate previous observations that such monazite domains formed under **strongly oxidizing conditions.**

Conclusions

Thank you for your attention!
Any comment is welcomed.