Les Alpes sont -elles un orogène de type alpin ?

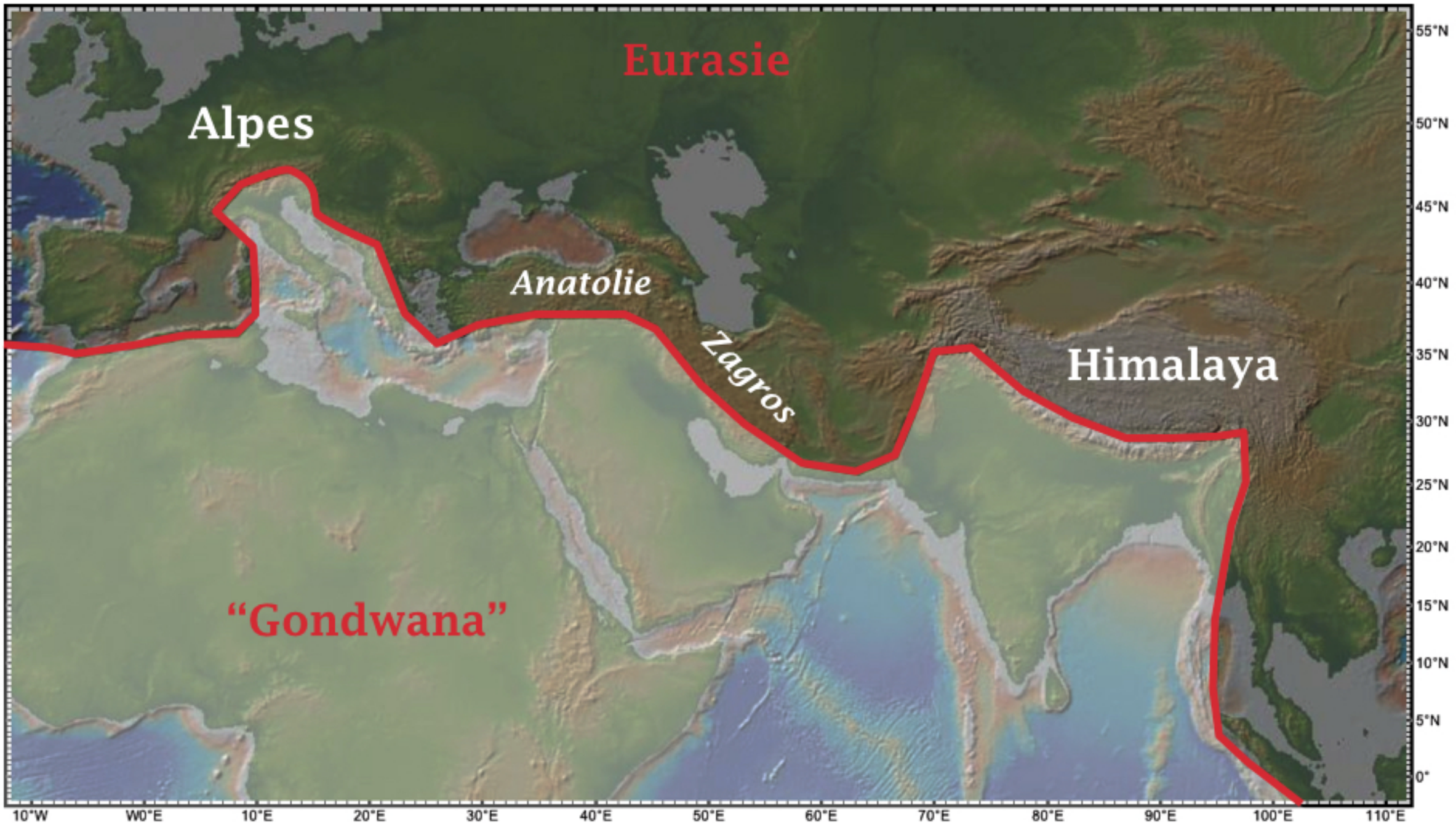
Romain Bousquet

Christian-Albrecht-Universität zur Kiel, Allemagne

Christian Robert

ENS Paris

Ludewig-Meyn-Str.10 - 24118 Kiel (Allemagne) / bousquet@min.uni-kiel.de


Eurasie
Alpes
Anatolie
Zagros
Himalaya
"Gondwana"
55°N
50°N
45°N
40°N
35°N
30°N
25°N
20°N
15°N
10°N
5°N
0°
10°W
W0°E
10°E
20°E
30°E
40°E
50°E
60°E
70°E
80°E
90°E
100°E
110°E

Horace - Bénédict de Saussure

connu pour avoir réalisé et surtout médiatisé **la 2ème ascension du Mt Blanc** avec le guide Jacques Balmat en 1787.

Réalisa **de nombreux voyages** ou expéditions à travers les sommets et les cols alpins, dont il tira de **nombreuses observations et résultats scientifiques** botaniques, physiques et géologiques.

Le tout fut publié dans quatre livres intitulés ***Voyages dans les Alpes***

Son nom est associé à plusieurs domaines naturalistes :
Saussurea est un genre d'environ 300 espèces de plantes alpines
Saussiritisation des feldspaths magmatiques

Découvertes faites dans les Alpes

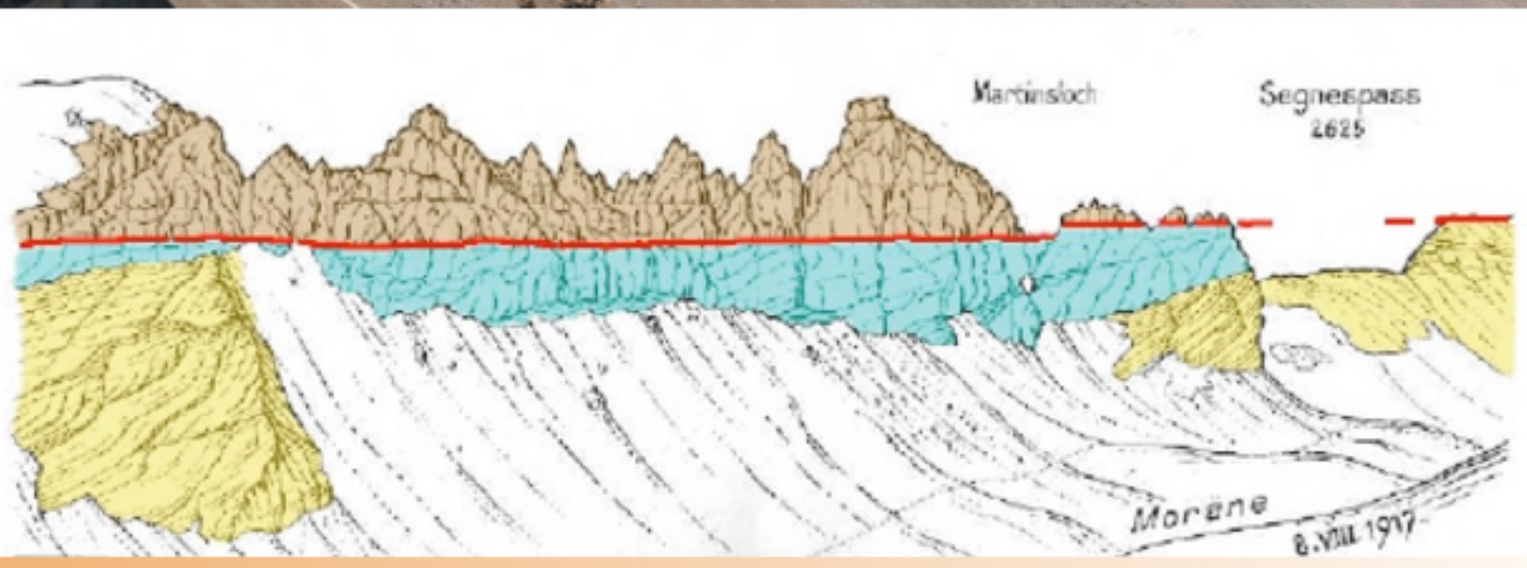
Une des découvertes pétrologiques majeures fut la première description des **éclogites** par **l'Abbé René Haüy (1822)**

*« J'ai donné à cette roche le nom d'éclogite, qui signifie **choix, élection** parce que ses composants, n'étant pas de ceux qui existent communément plusieurs ensembles dans les roches primitives, comme le feldspath, le mica, l'amphibole, semblent s'être choisis pour faire bande à part. Cette roche se trouve en Carinthie, dans le Sau-Alpe, et en Styrie ».*

Découvertes faites dans les Alpes

Une des découvertes pétrologiques majeures fut la première description des **éclogites** par **l'Abbé René Haüy (1822)**

Le chevauchement de Glaris

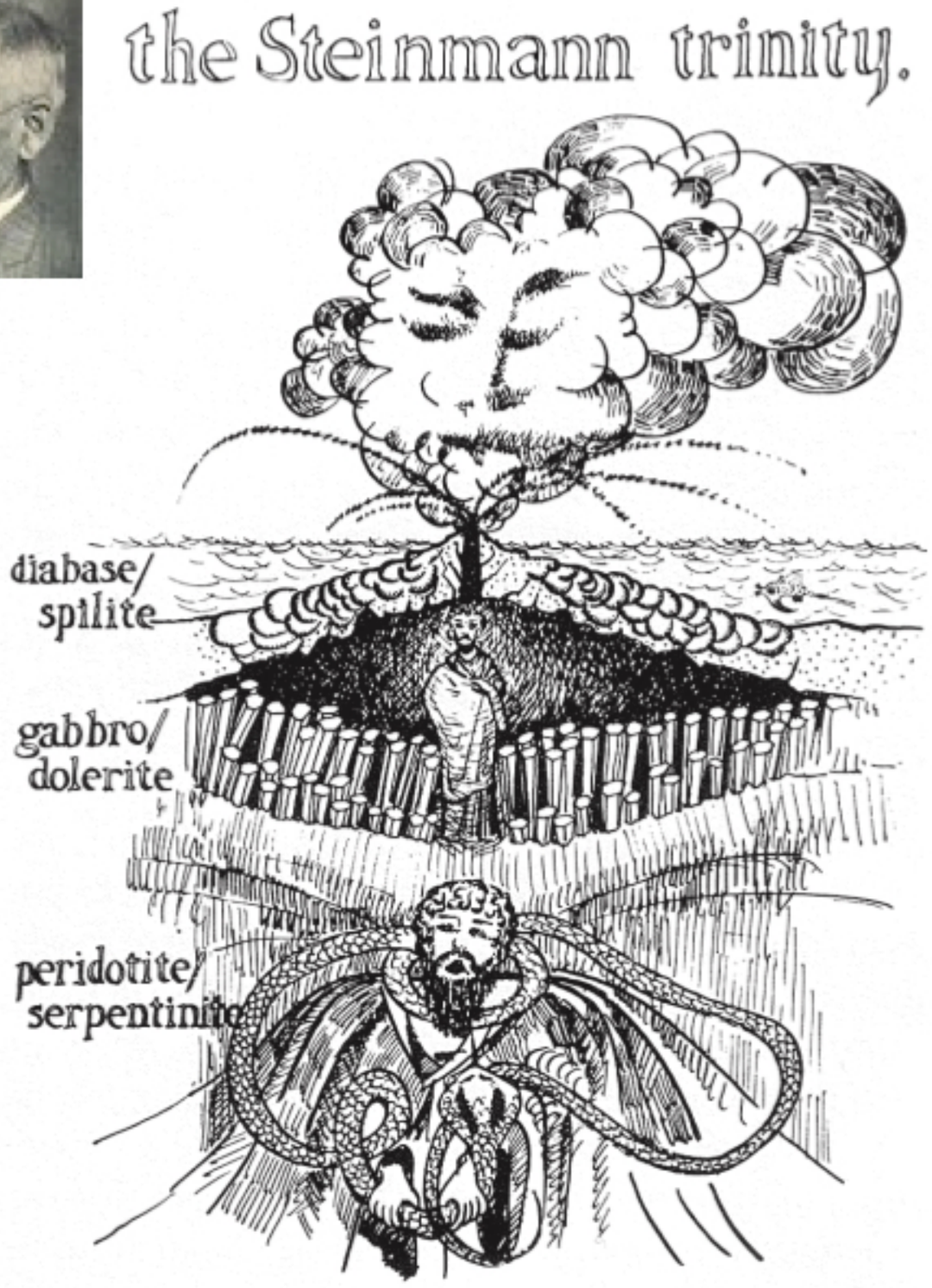


Découvertes faites dans les Alpes

Alexandre Brongniard
1770 –1847

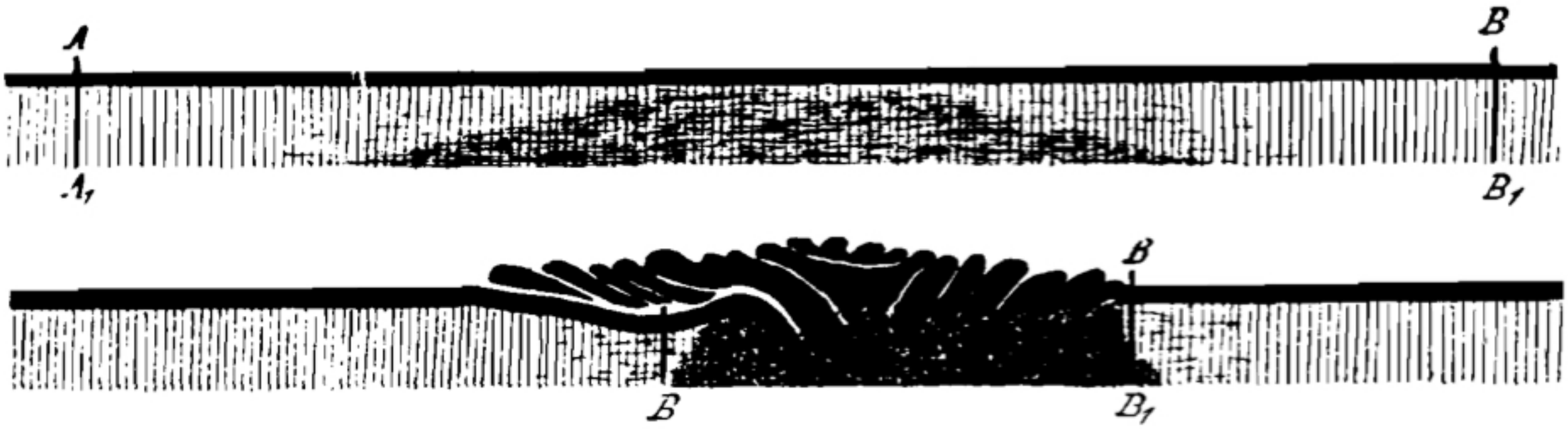
Ophiolites =
serpentine + diabase

Gustav Steinmann 1927



Die Verschluckung

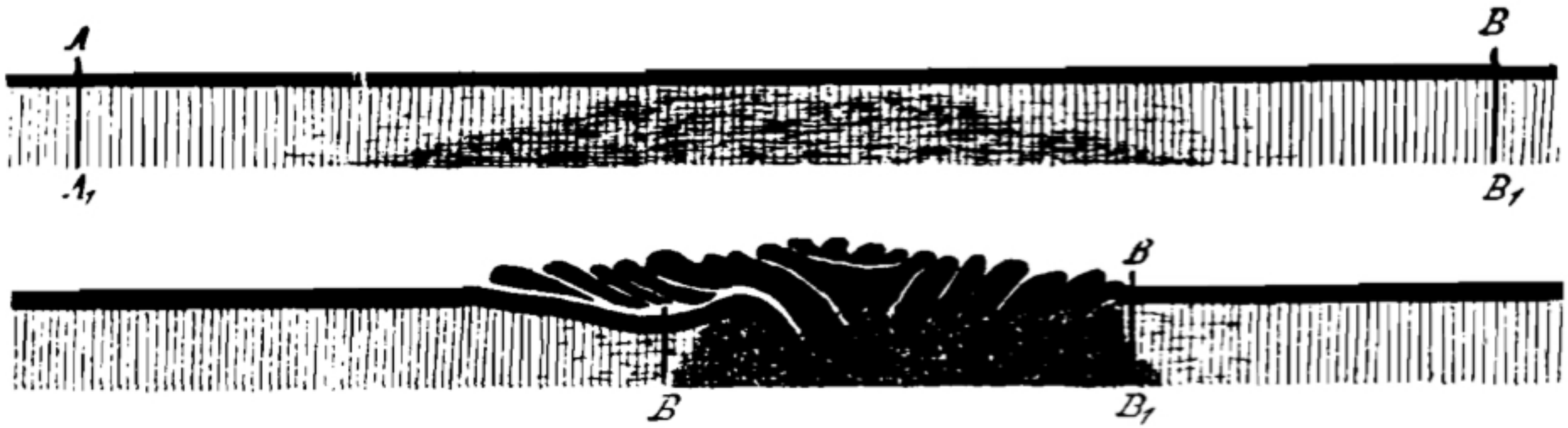
Otto Ampferer, 1905



Die Verschluckung

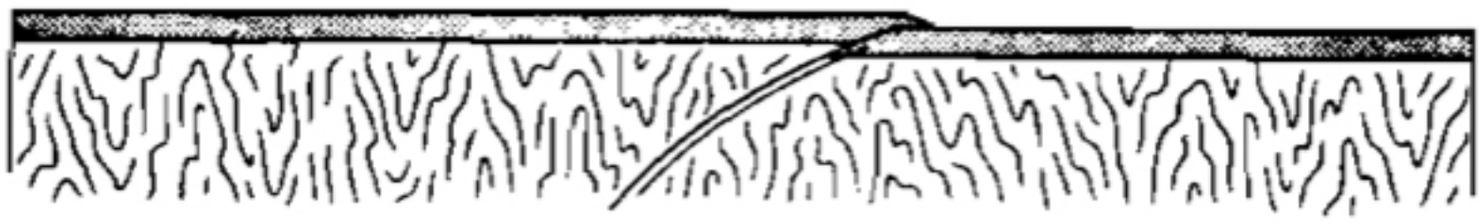
Otto Ampferer, 1905

Mattauer et al. (1978)



Acception définitive du nom et de la notion en 1970 *(White et al.)*

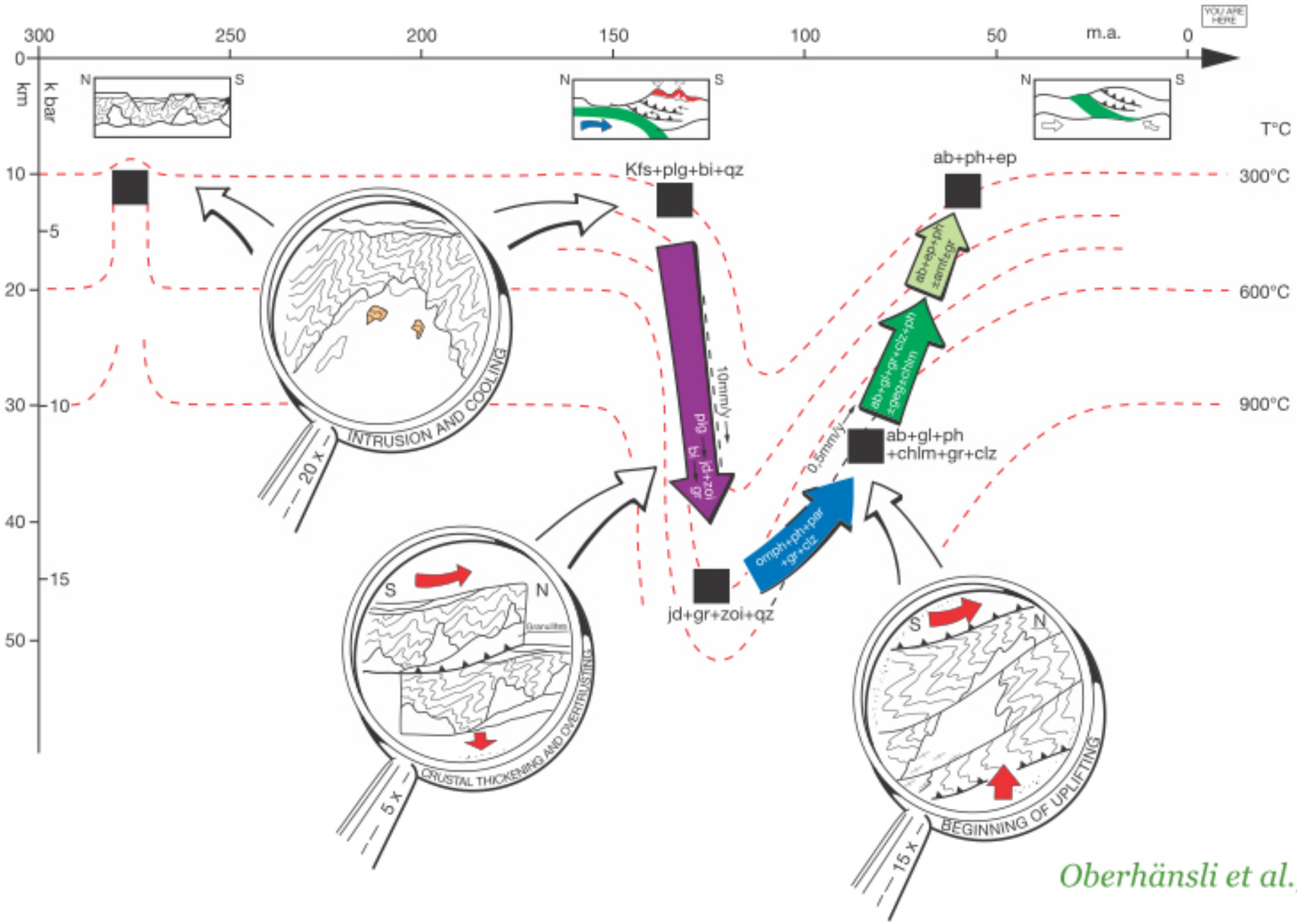
André Amstutz, 1951



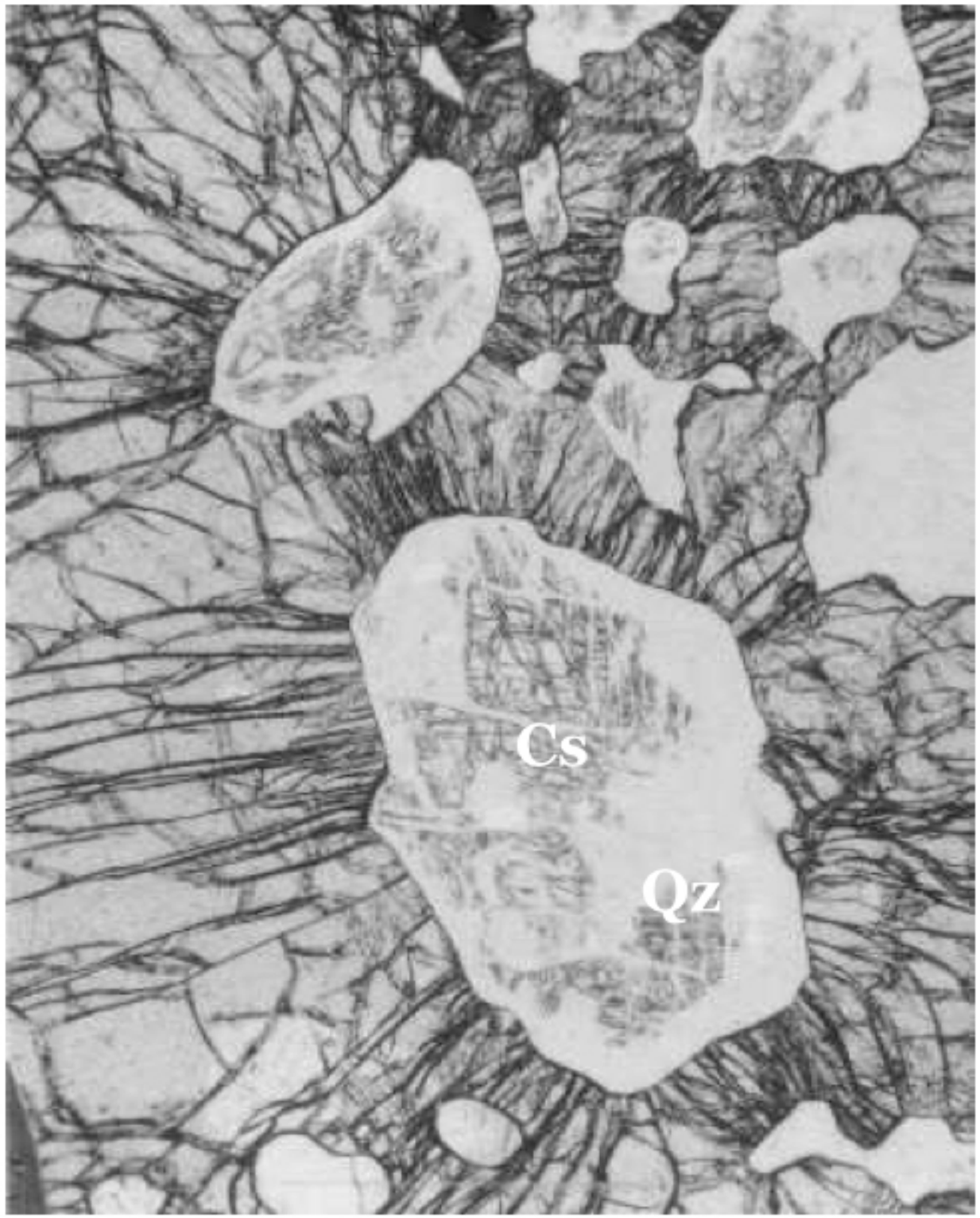
Découvertes faites dans les Alpes

Avant même la découverte de la coesite, les géologues alpins ont compris la nécessité de la subduction continentale

Dal Piaz et al., 1972
Oberhänsli et al., 1983



Oberhänsli et al., 1983



Chopin, 1984

La découverte de la coesite en 1984

d'abord par **C. Chopin** dans les Alpes
et ensuite en Norvège par **D. Smith**.

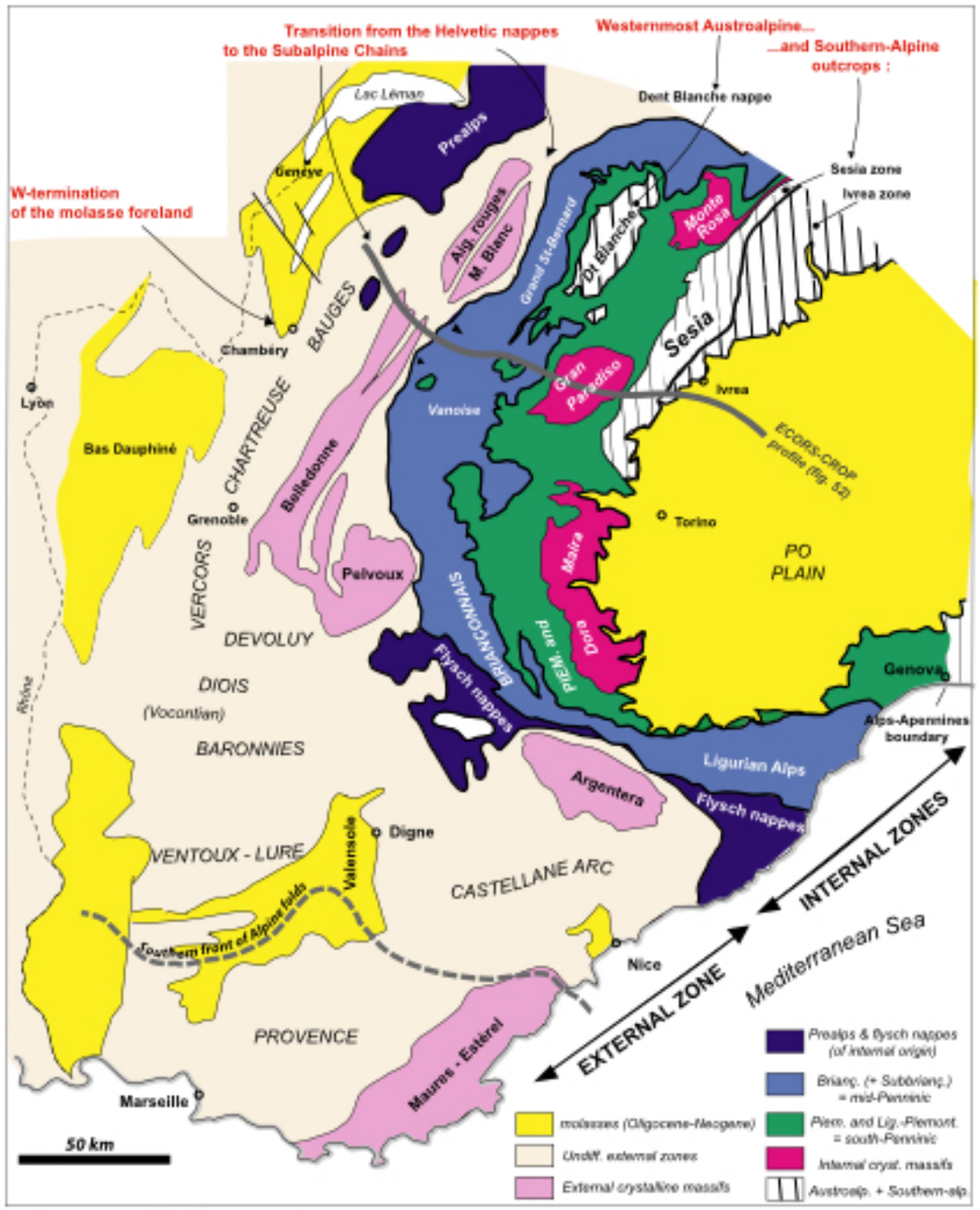
International Geology Review
2010, iFirst article, 1–19

Taylor & Francis
Taylor & Francis Group

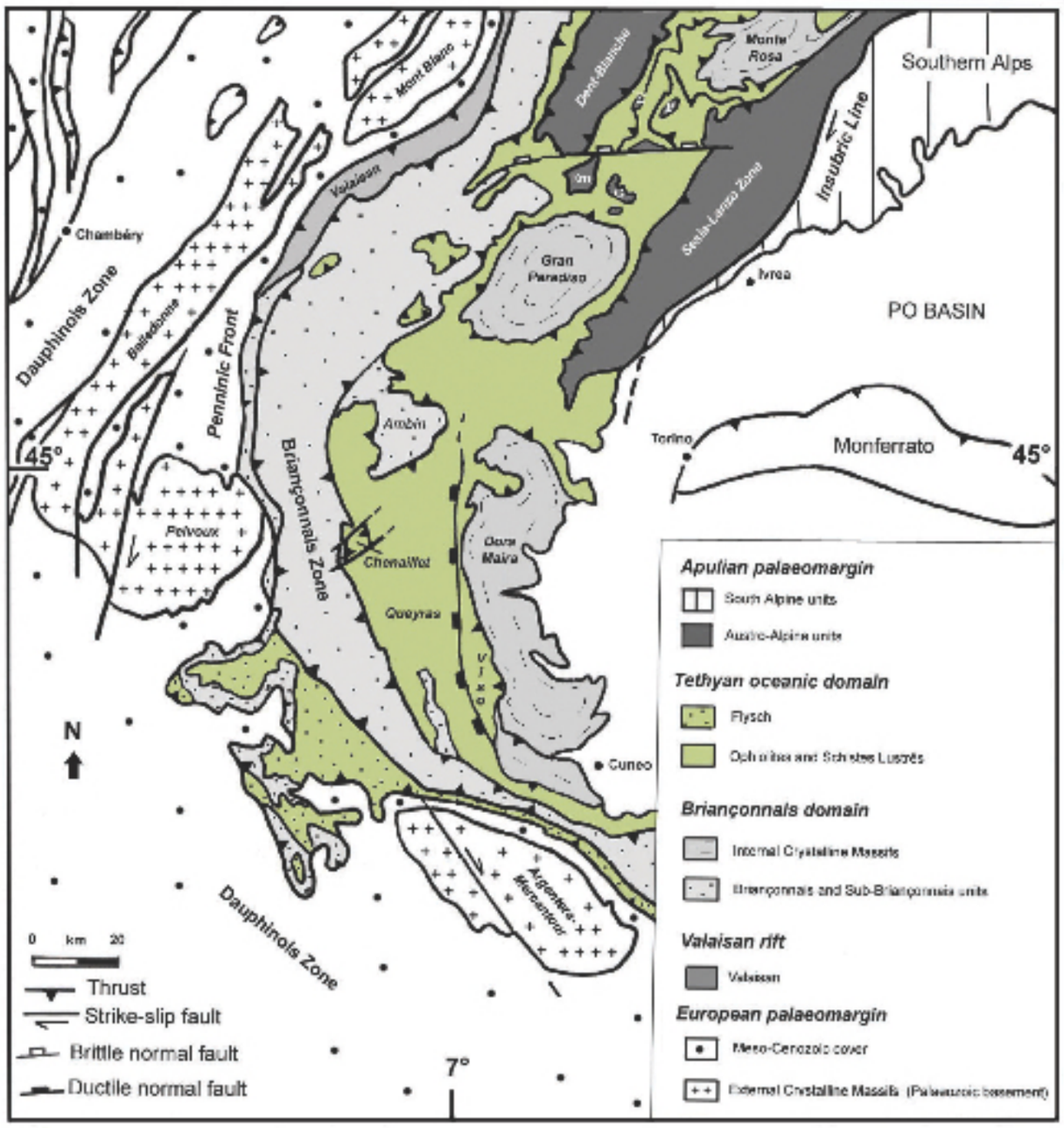
Subduction zone metamorphism – pioneering contributions from the Alps

W.G. Ernst*

Les Alpes, un orogène bien connu



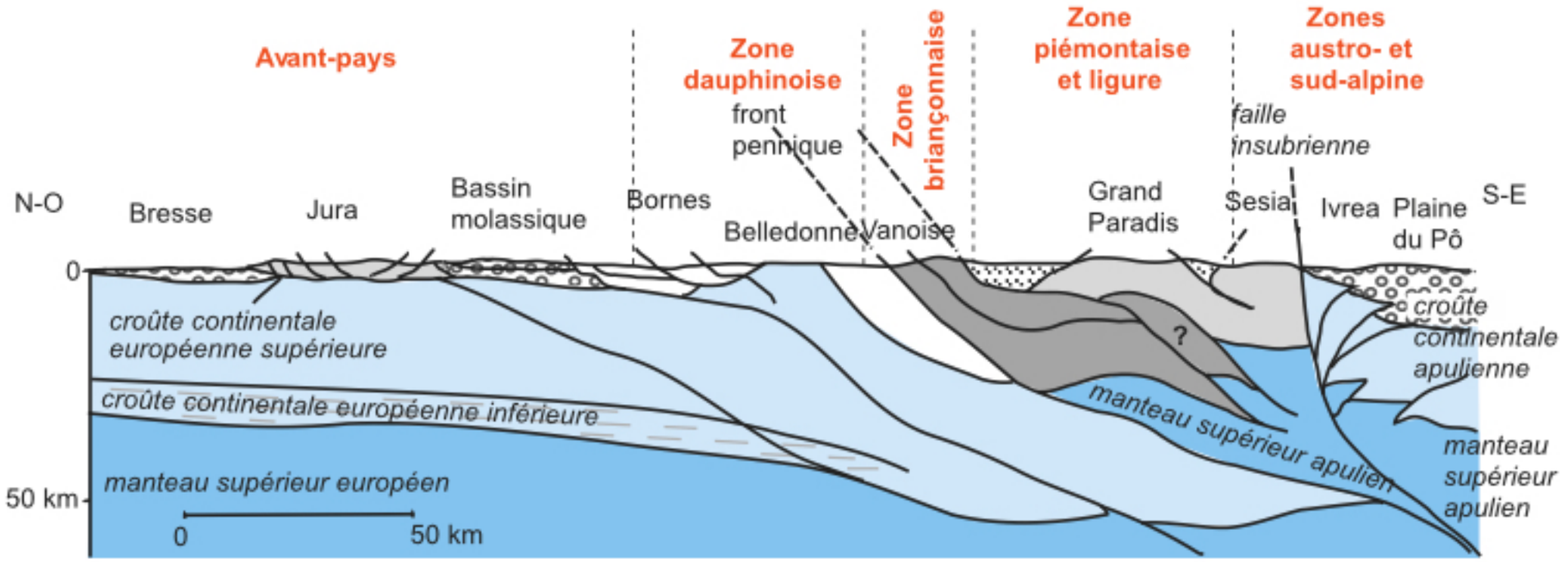
Agard & Lemoine, 2001



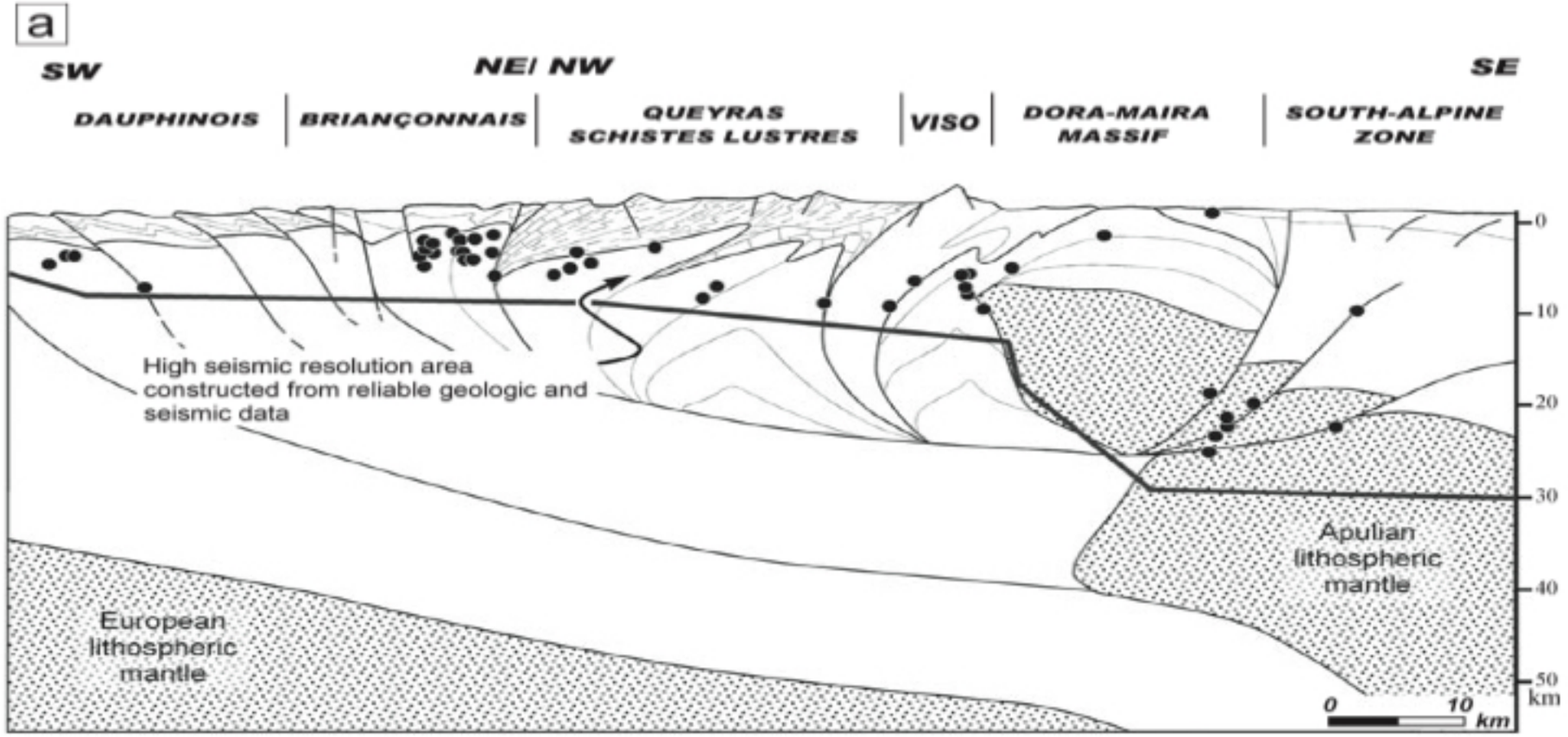
Lardeaux, 2014

Huchon et al., 2005

Les Alpes, une structure bien connue



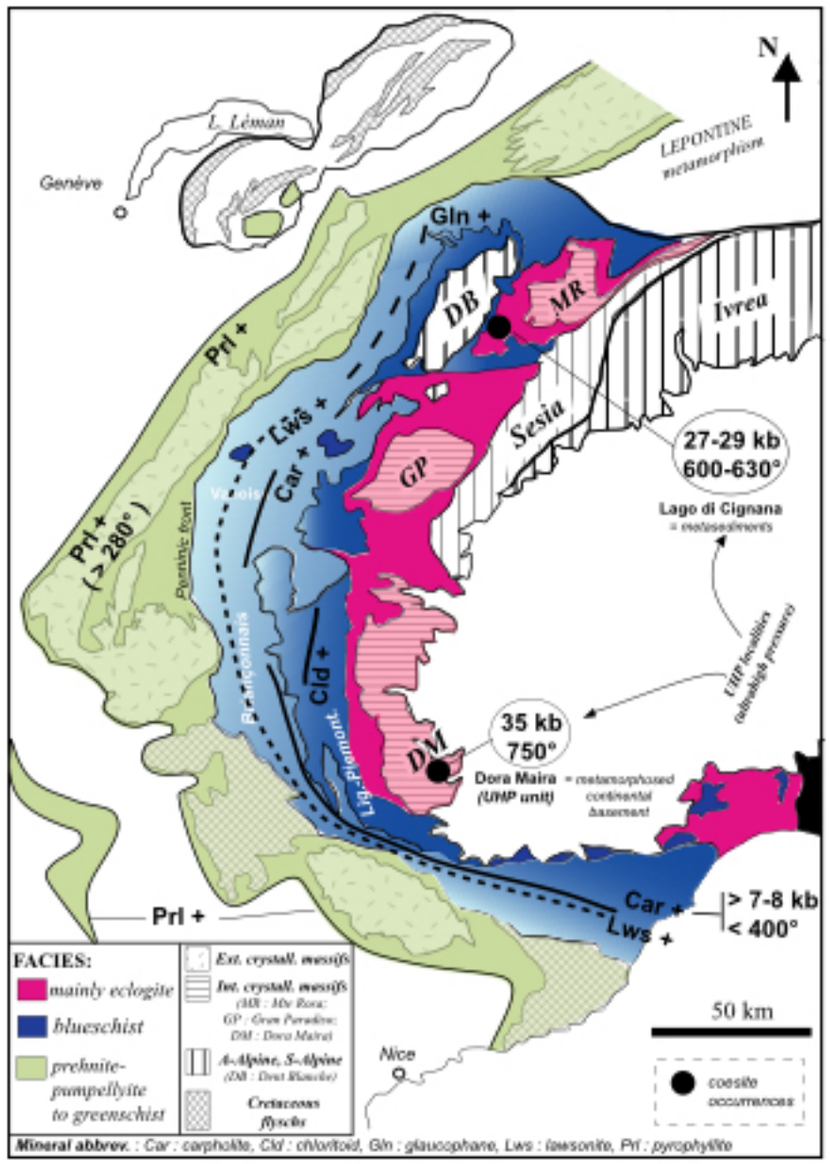
Pécru et al., 2008



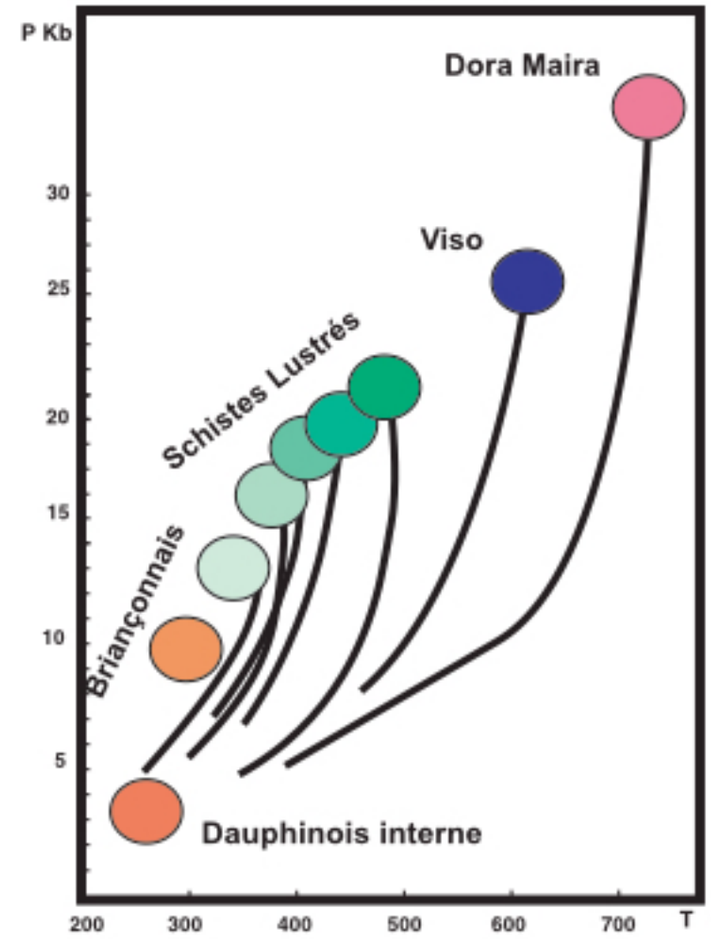
Lardeaux et al., 2006

Les Alpes, un métamorphisme bien décrit

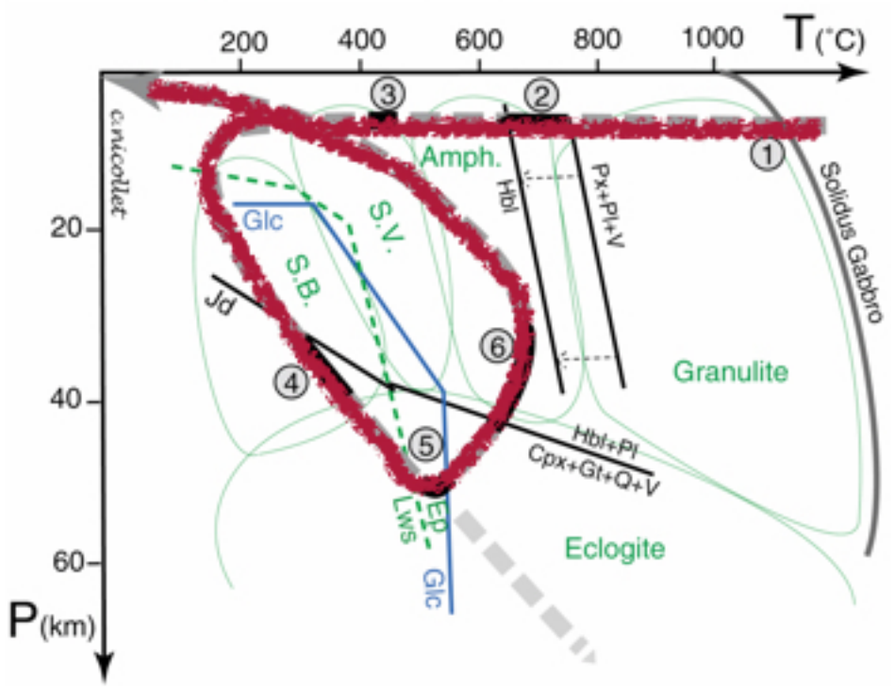
Ernst, 1971



Agard & Lemoine, 2001



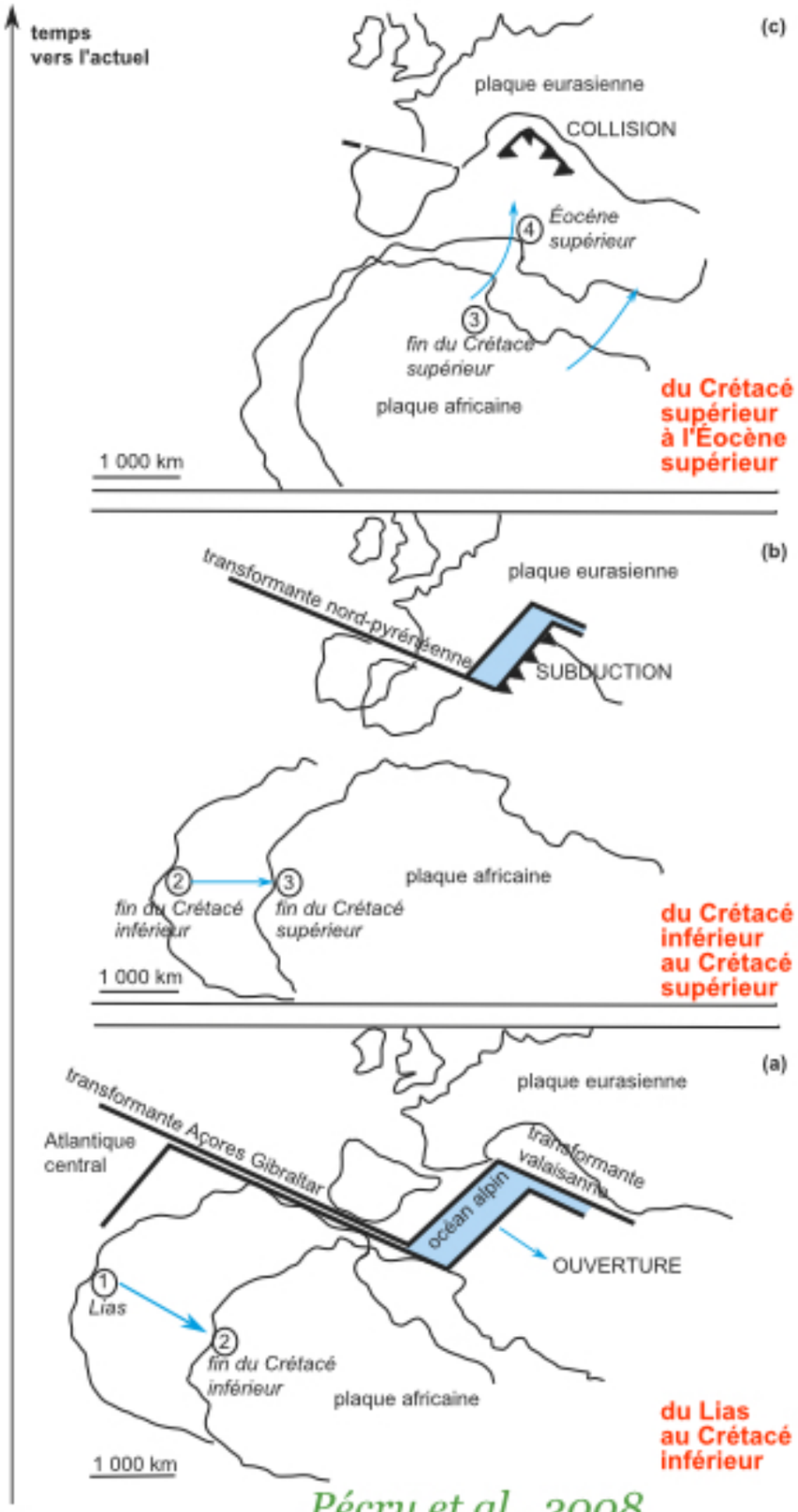
Huchon et al., 2005



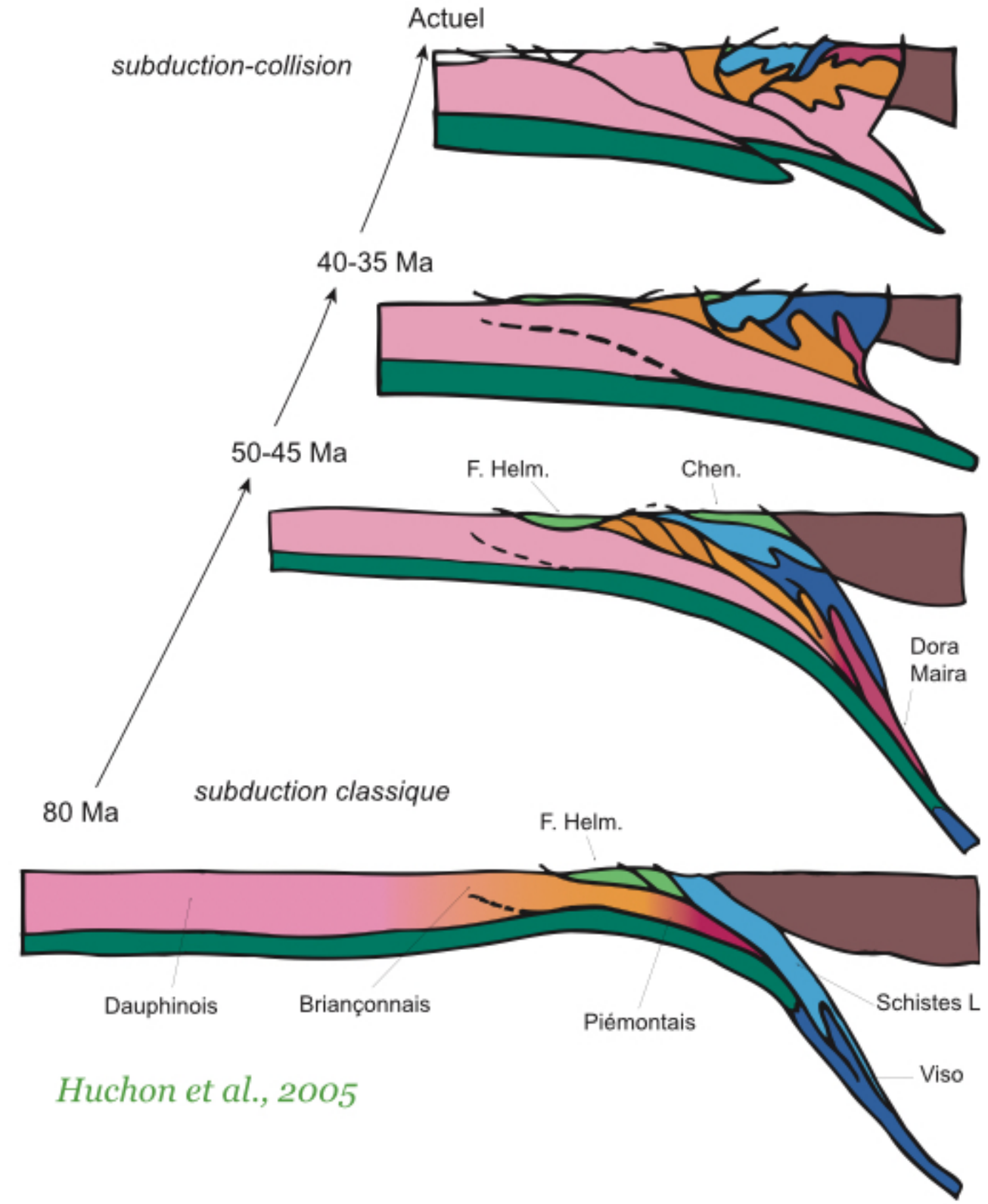
C. Nicollet

Le métamorphisme augmente progressivement
de l'ouest *(zones externes)*
vers l'est *(zones internes)*

Le Alpes, une évolution bien définie



Pécru et al., 2008



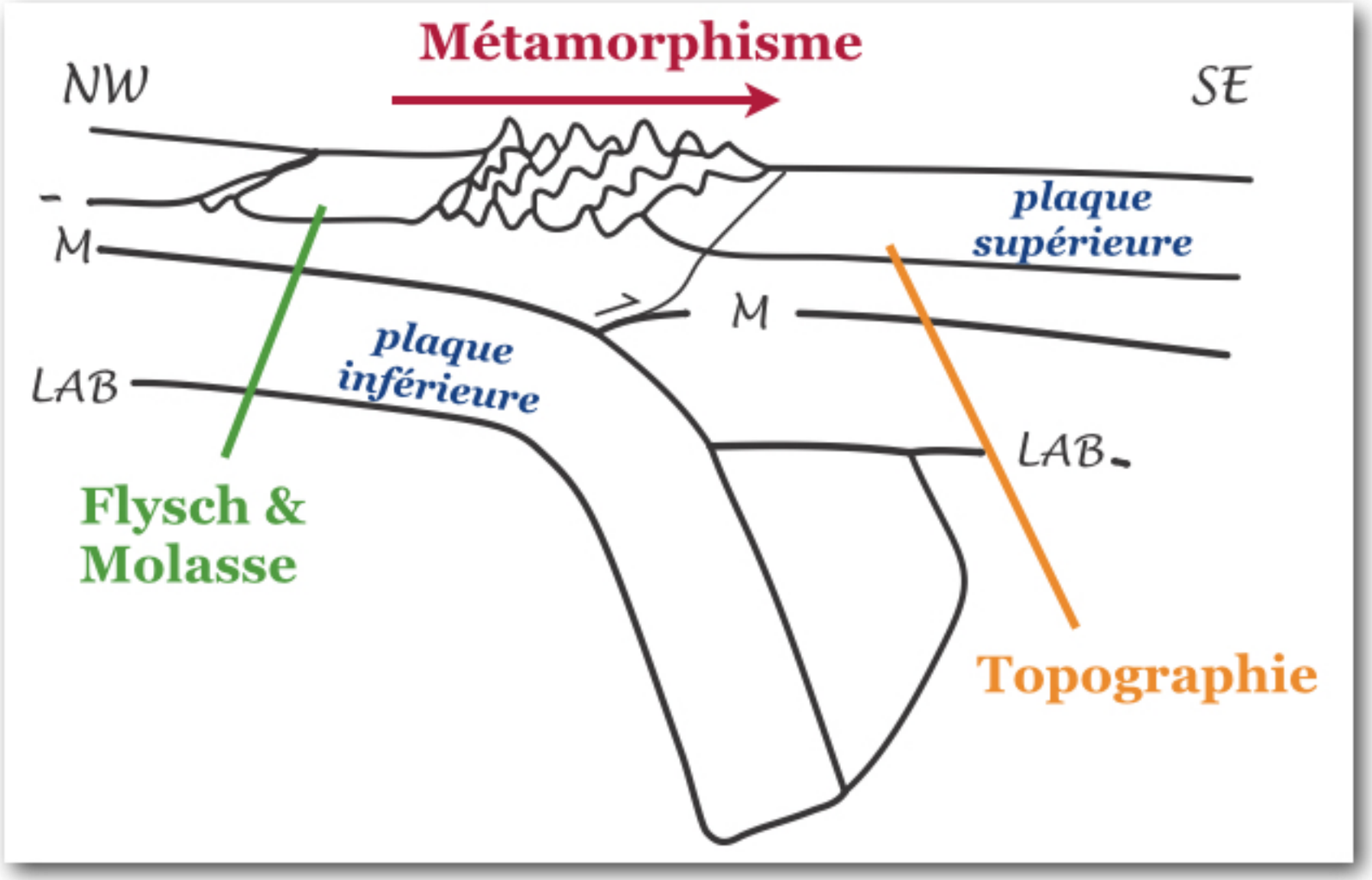
Huchon et al., 2005

Les Alpes *(occidentales)* une chaîne de collision parfaite

Un océan "parfait" entre deux continents
(cf. Le Chenaillet)

Une subduction presque parfaite: métamorphisme HP qui augmente d'W en E
(il manque le volcanisme)

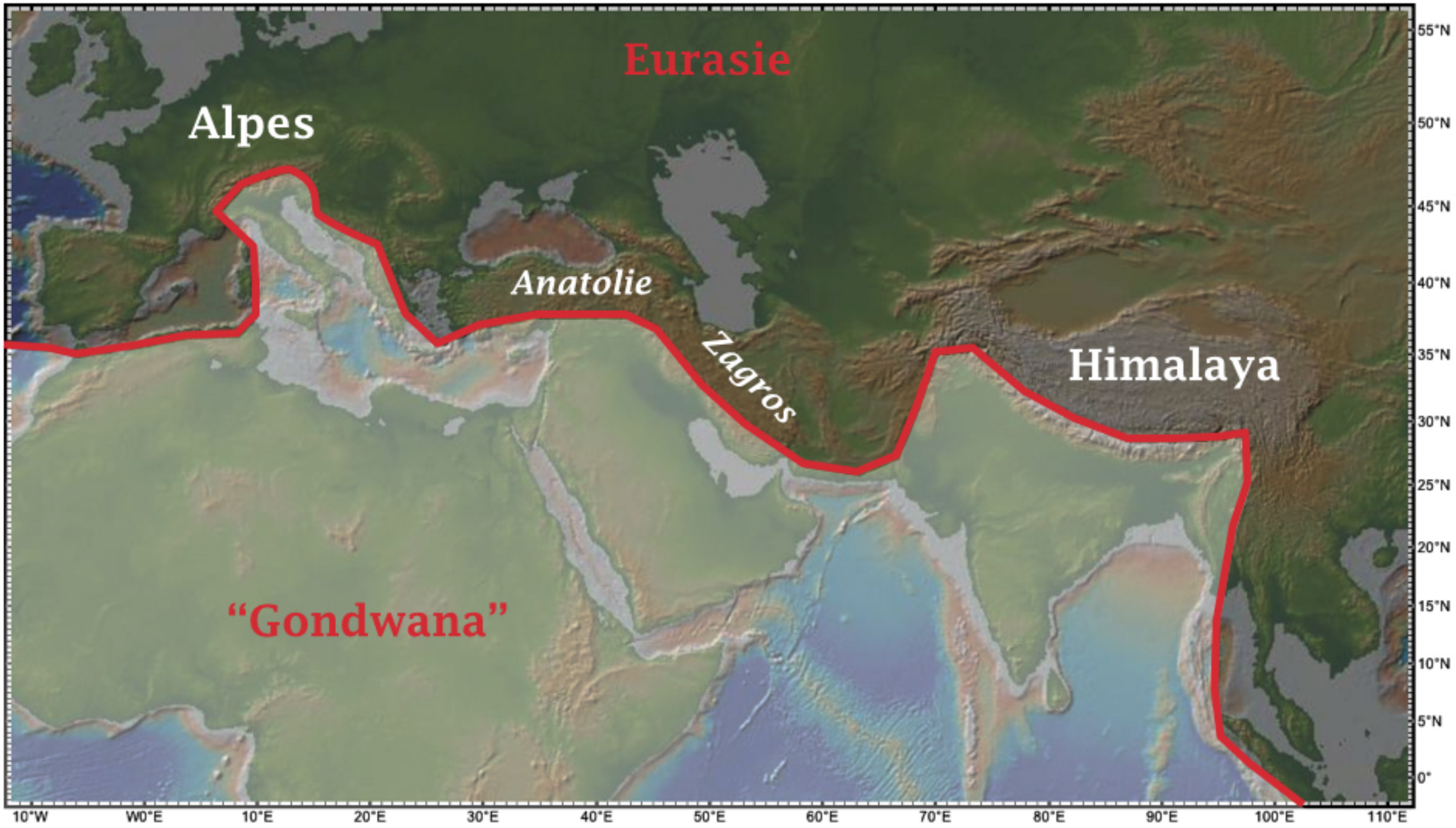
Une collision entre deux continents



- ✓Sait-on tout des Alpes aujourd'hui?
- ✓Pourquoi les modèles n'ont-ils pas évolué depuis 40 ans?
- ✓Peut-on comprendre les Alpes aujourd'hui en ne regardant que les Alpes occidentales?

Mais que sont vraiment les Alpes ?

Les Alpes différentes des autres chaînes



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Subduction zone metamorphism – pioneering contributions from the Alps

W.G. Ernst*

versus

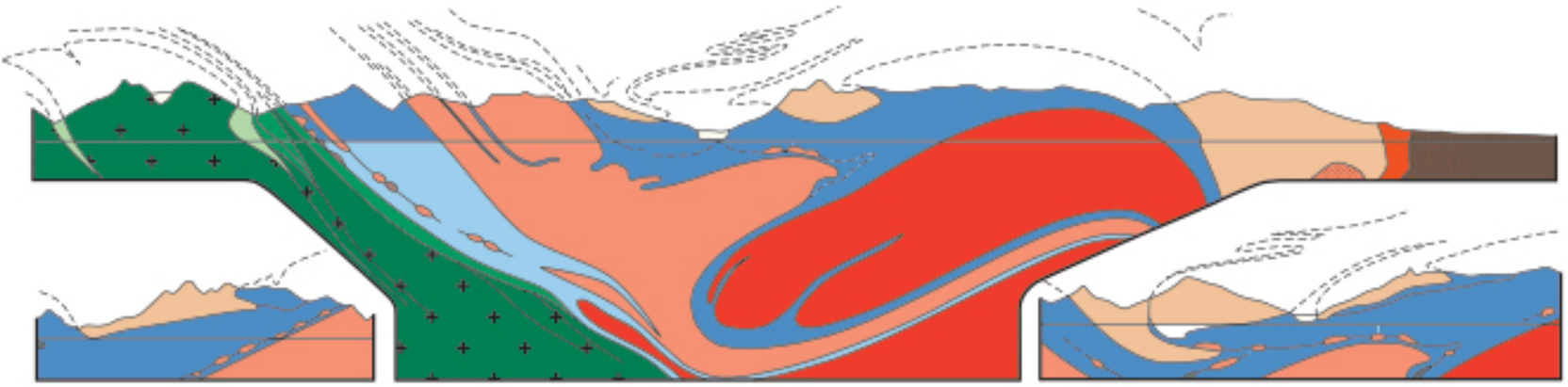
Int J Earth Sciences (Geol Rundsch) (2001) 90:477–483
DOI 10.1007/s005310000175

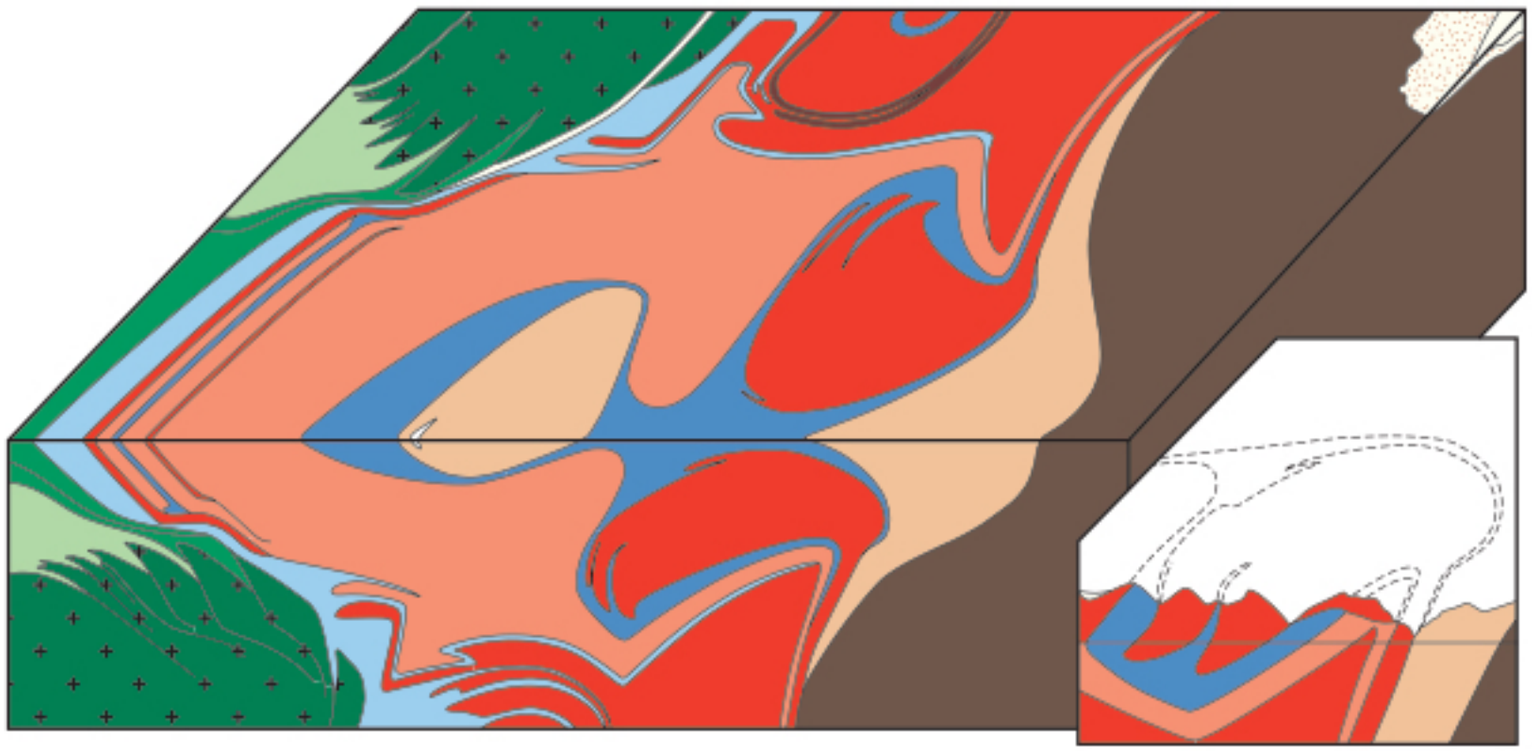
ORIGINAL PAPER

R. Trümpy

Why plate tectonics was not invented in the Alps

Les Alpes une chaîne cylindrique ?





Emile Argand, années 20

P. Niggli : la chaleur provient de la formation de la chaîne elle-même. (*Alpine Metamorphose und alpine Gebirgsbildung, 1970*)

la déformation synchrone de la croissance des minéraux HT

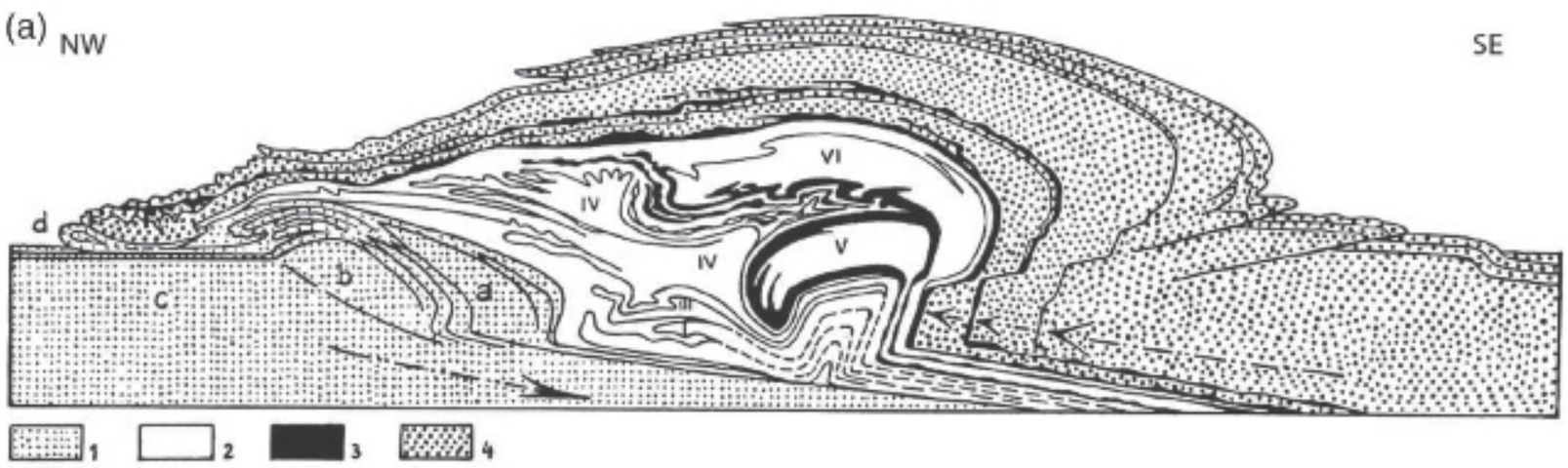


Abb. 1. Schematisches Sammelprofil durch die Alpen nach E. ARGAND, aus L. W. COLLET, 1935, Fig. 62.
1. Vorland oder „Eurasien" 2. Penninische Decken 3. Basische Gesteine 4. Ostalpen (inkl. Südalpen)

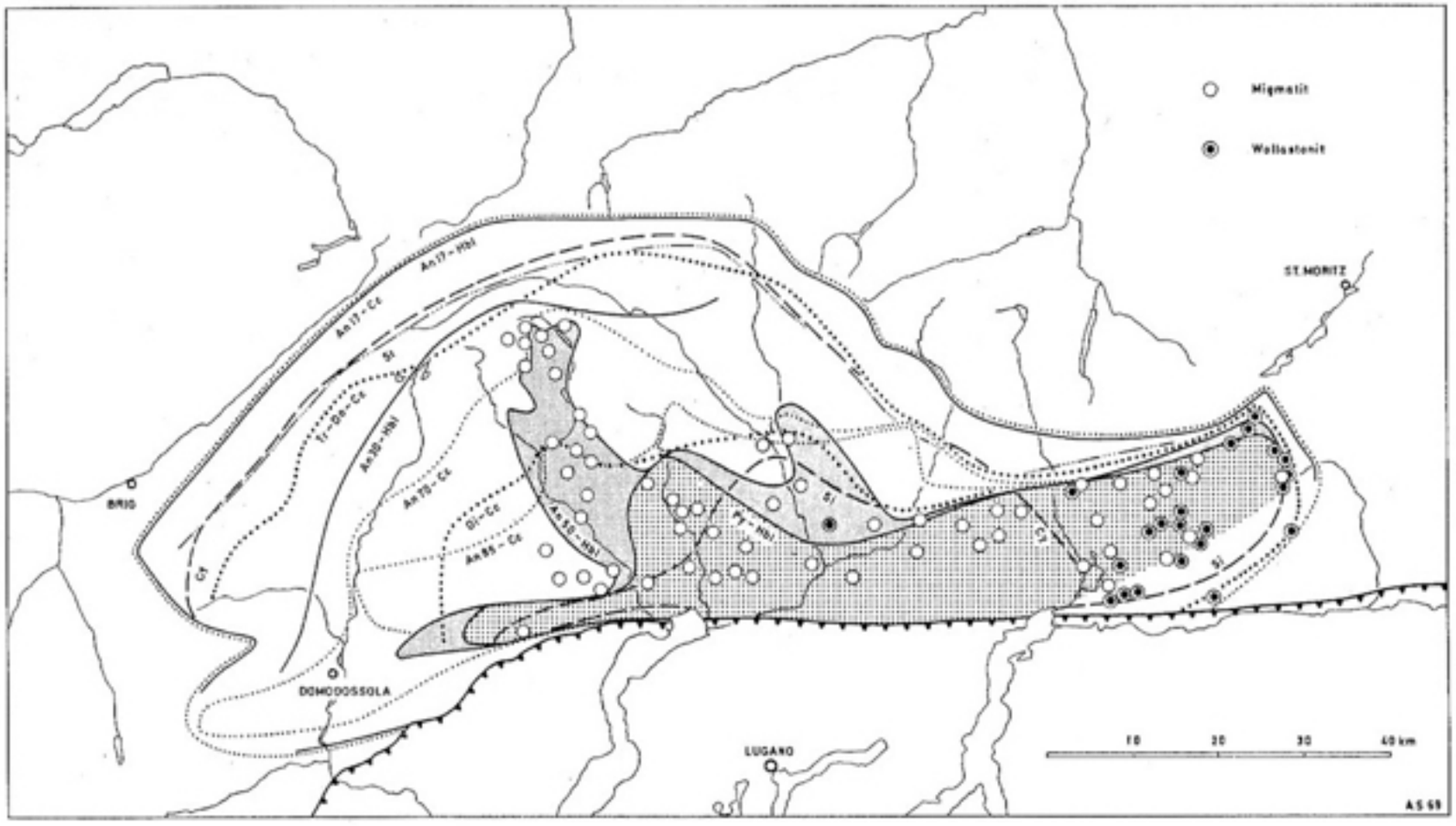
Controverses alpines

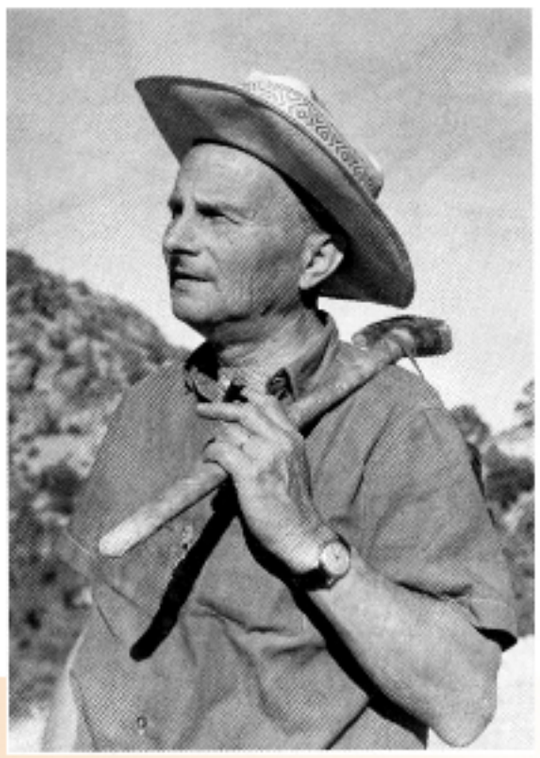
P. Niggli : la chaleur provient de la formation de la chaîne elle-même. (*Alpine Metamorphose und alpine Gebirgsbildung, 1970*)

la déformation synchrone de la croissance des minéraux HT

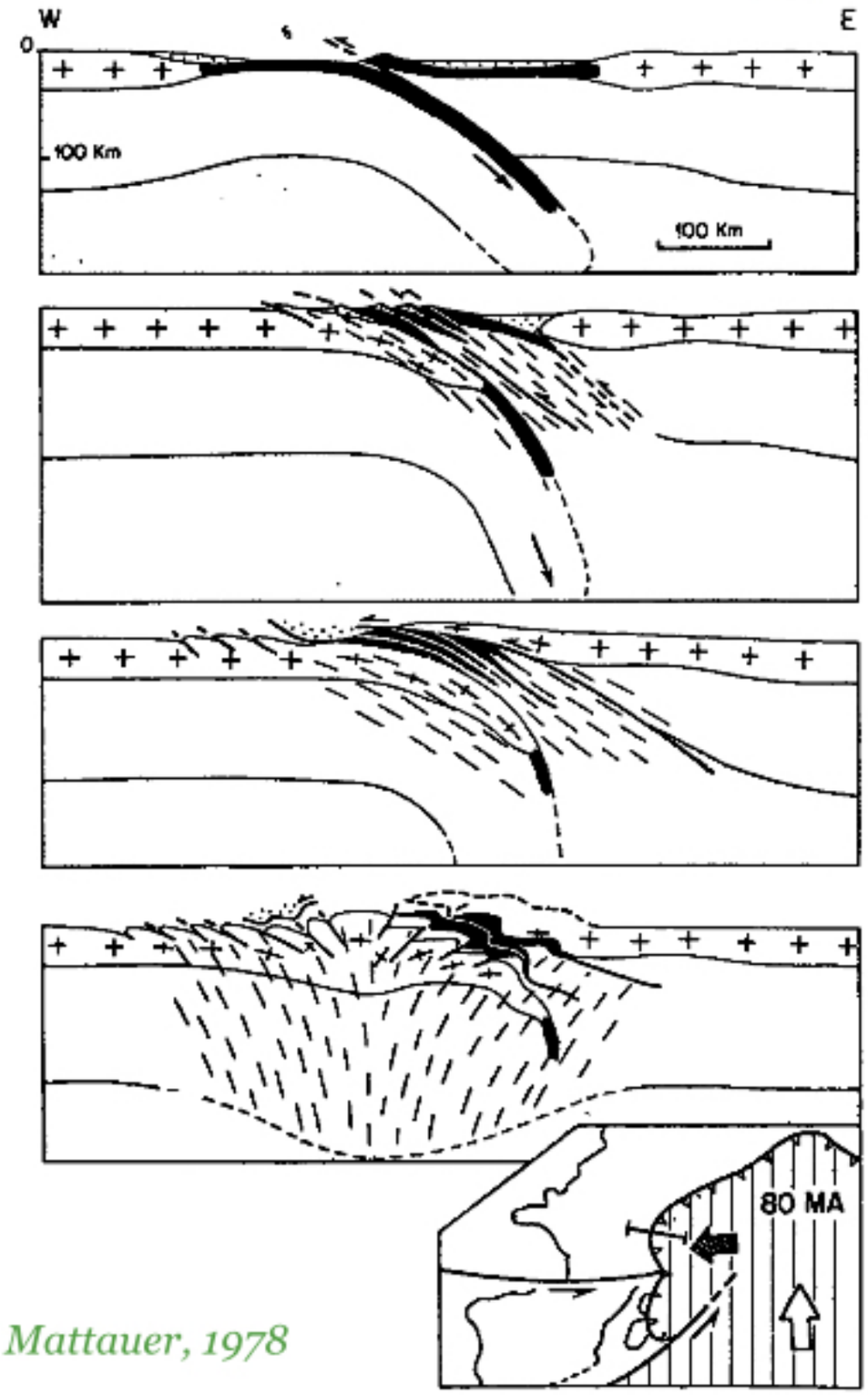
E. Wenk : la chaleur provient des granites et de l'anatexie (*Alpine Metamorphose und alpine Gebirgsbildung, 1970*)

la croissance des minéraux HT est ultérieure à la déformation

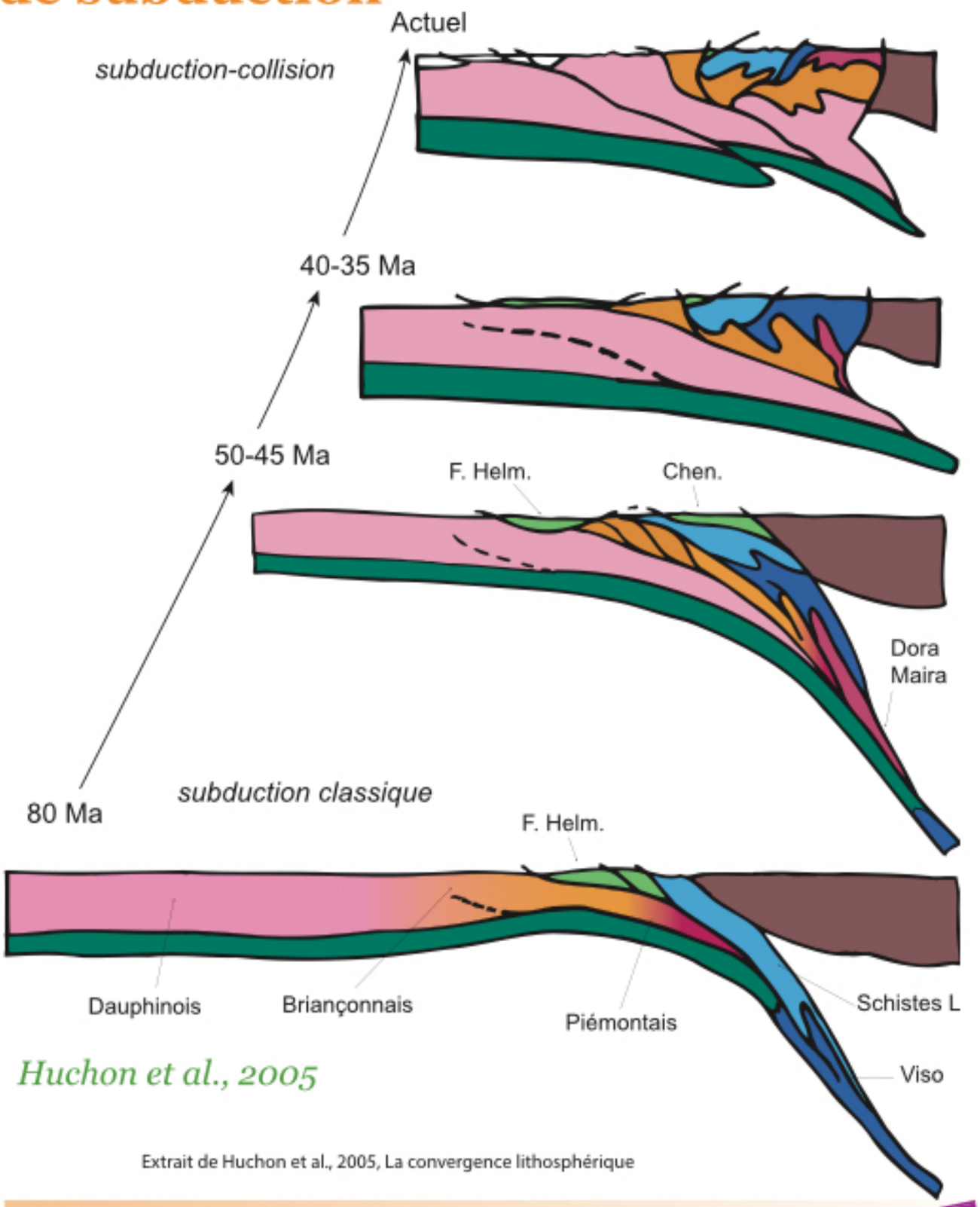




Type et âge de subduction



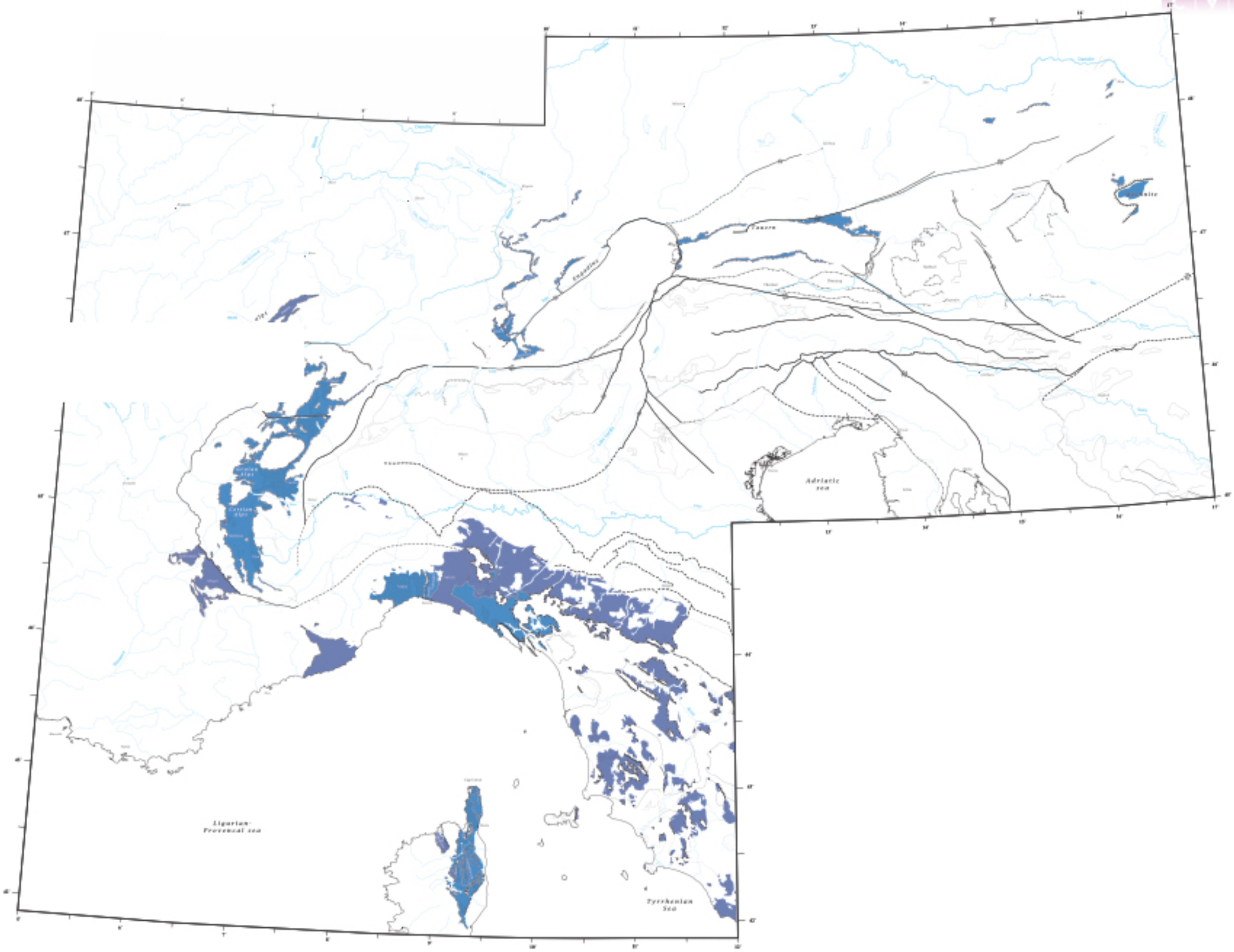
Mattauer, 1978



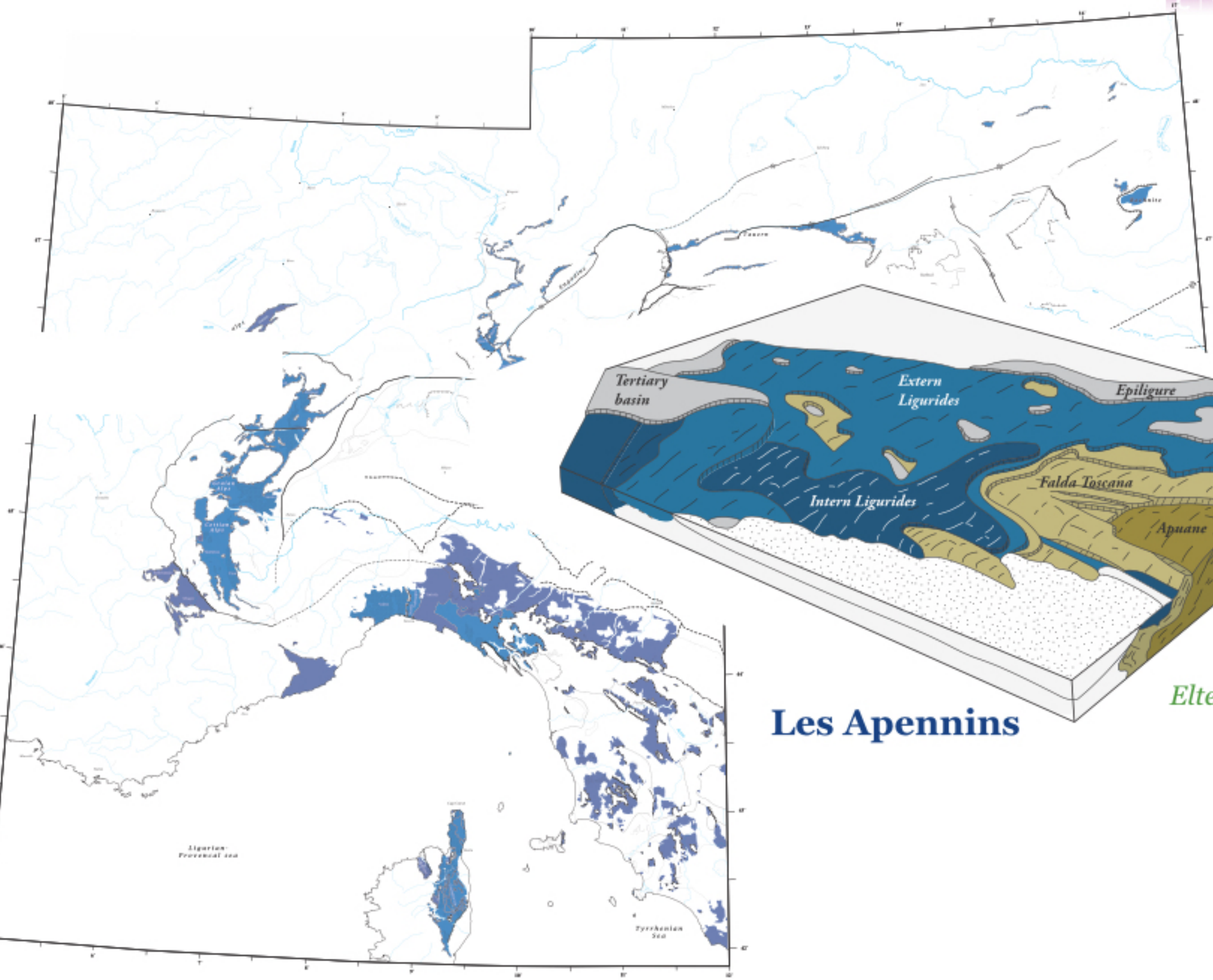
Huchon et al., 2005

Extrait de Huchon et al., 2005, La convergence lithosphérique

Océan liguro-piémontais



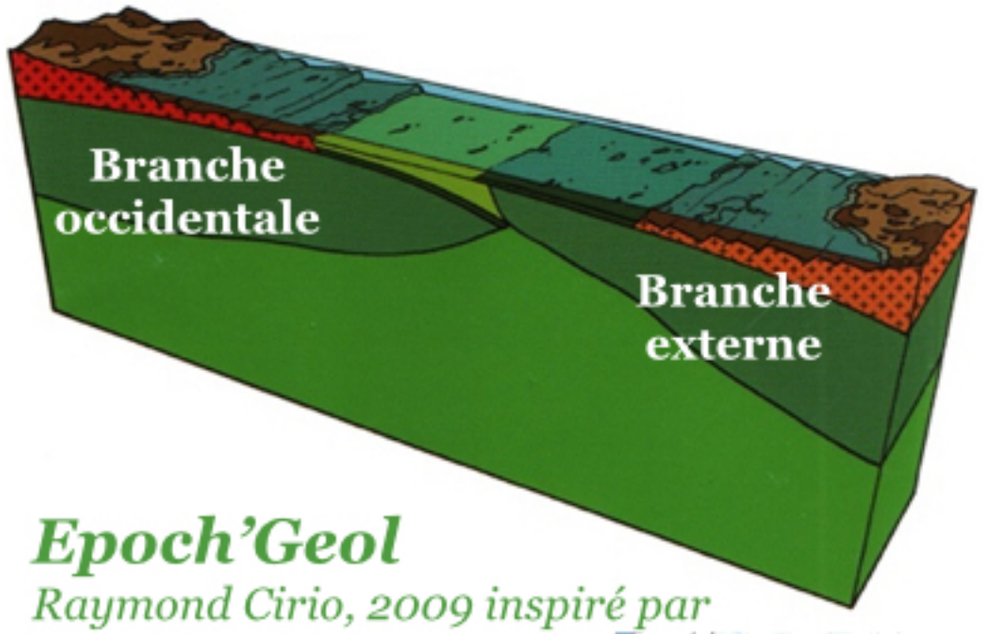
Océan liguro-piémontais



Elter, 1972

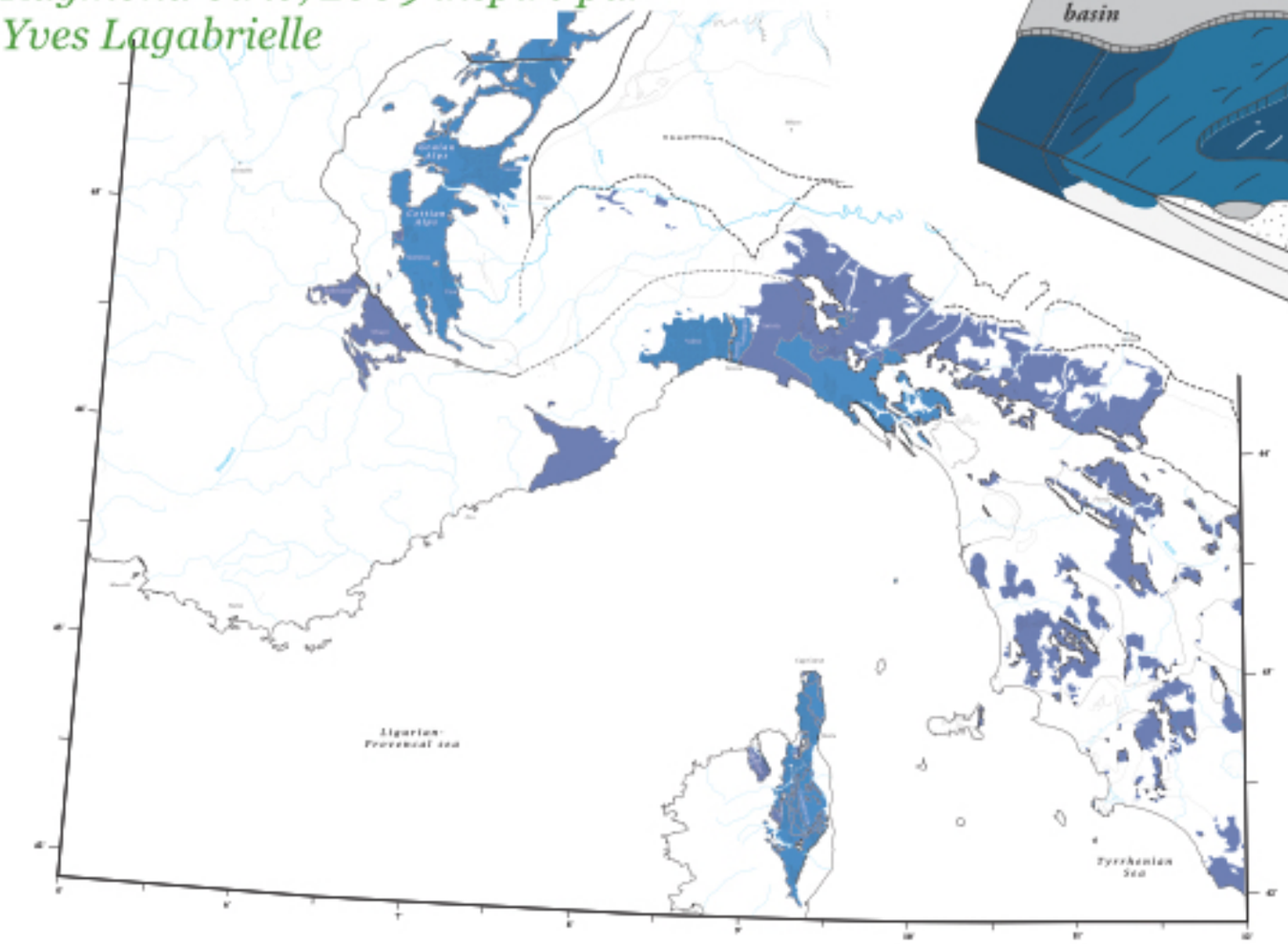
Les Apennins

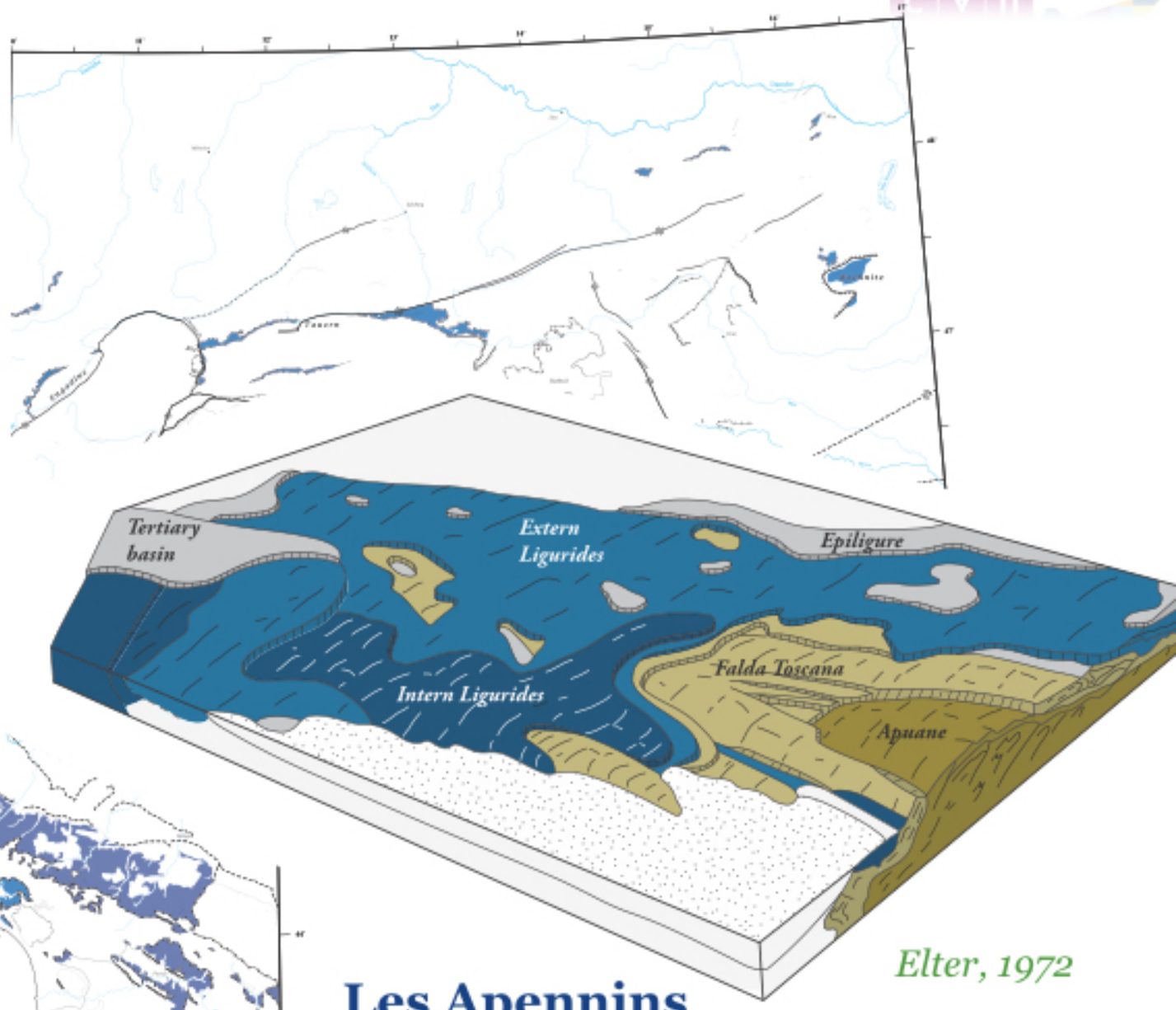
Océan liguro-piémontais



Epoch'Geol

Raymond Cirio, 2009 inspiré par Yves Lagabrielle

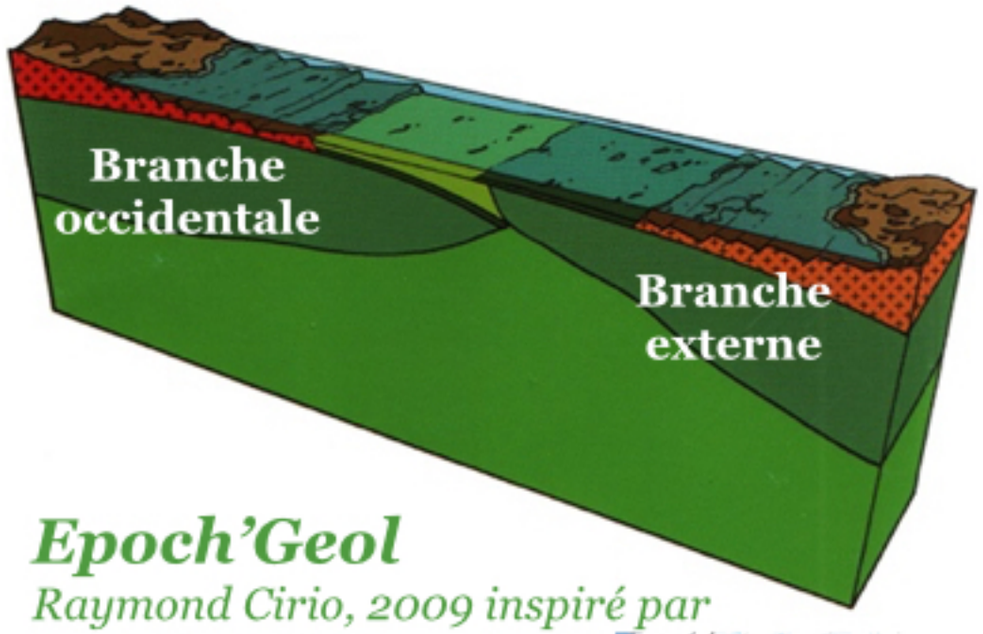




Elter, 1972

Les Apennins

Océan liguro-piémontais



Epoch'Geol

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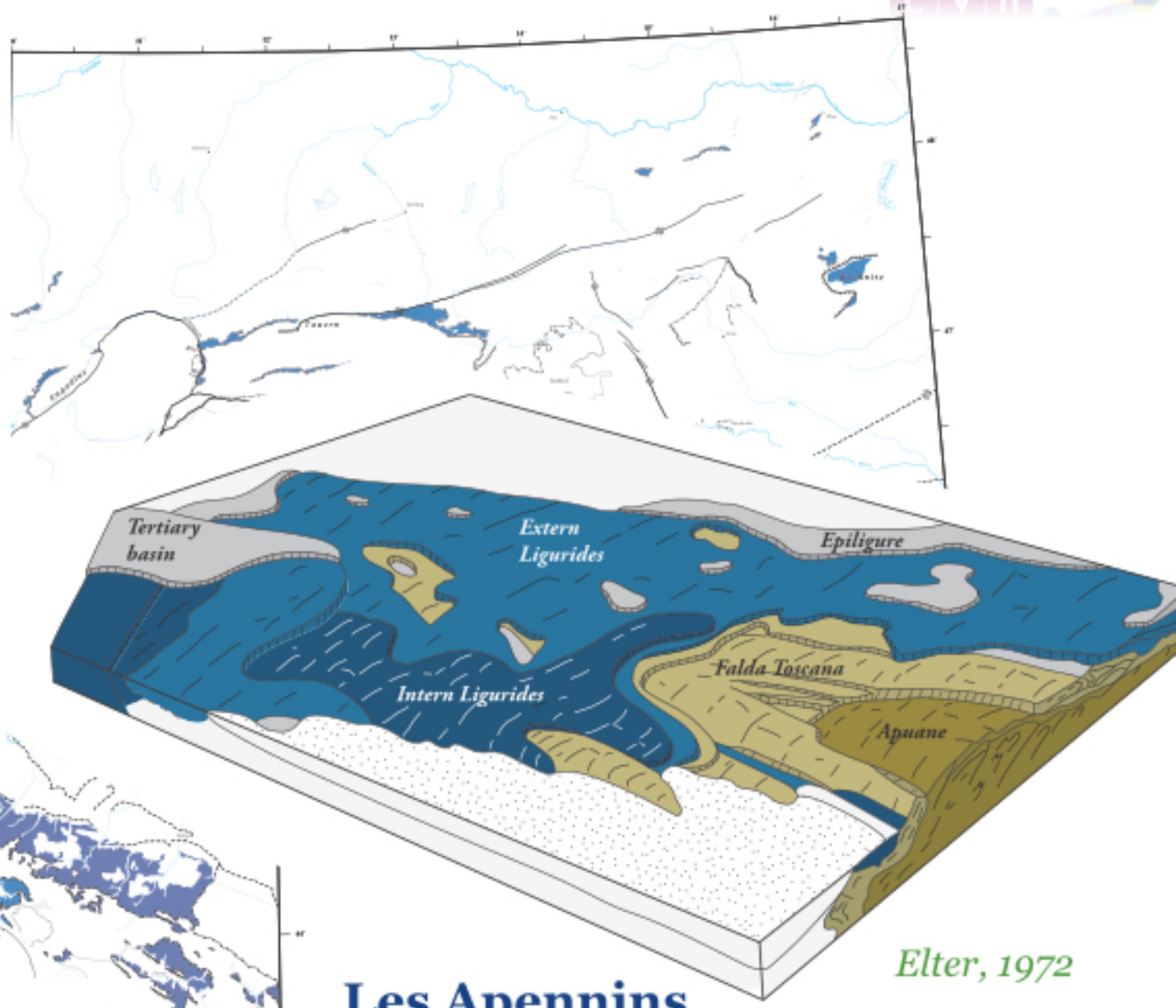
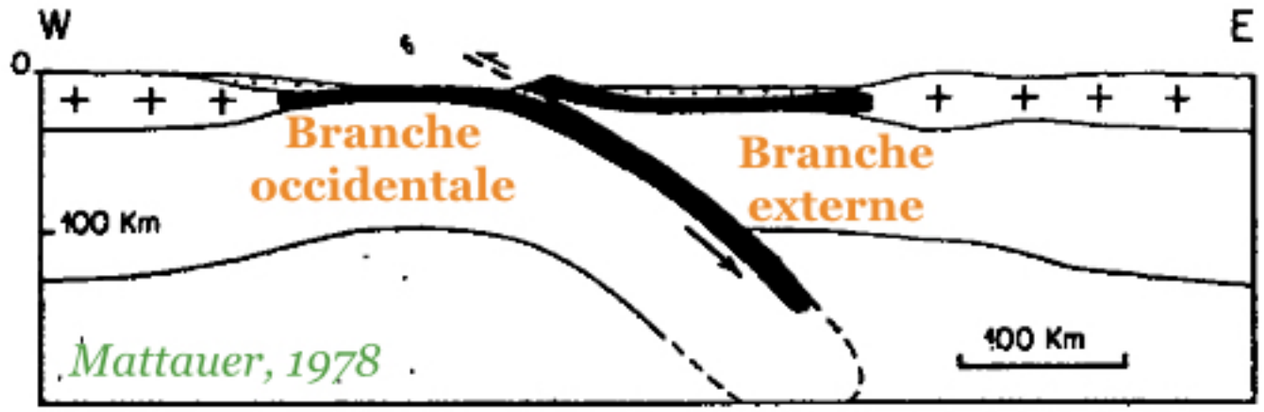


Elter, 1972

Les Apennins

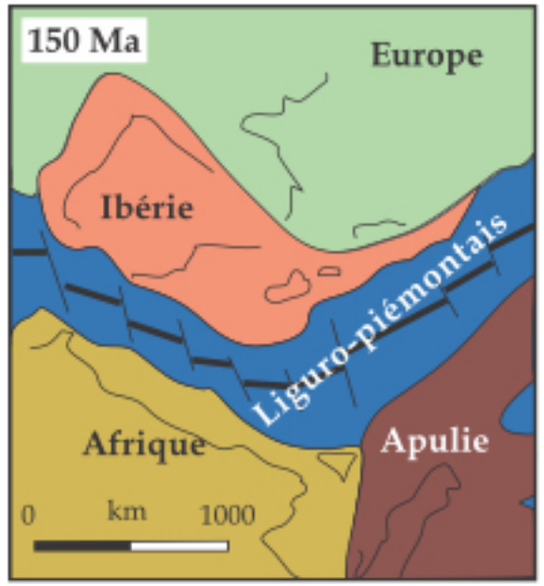


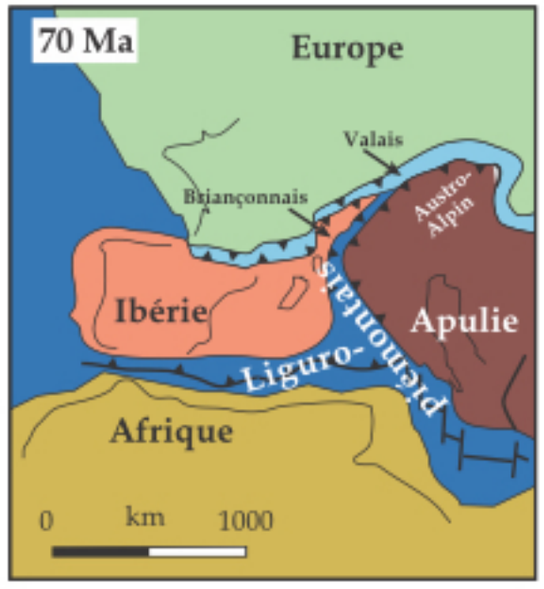
Mattauer, 1978

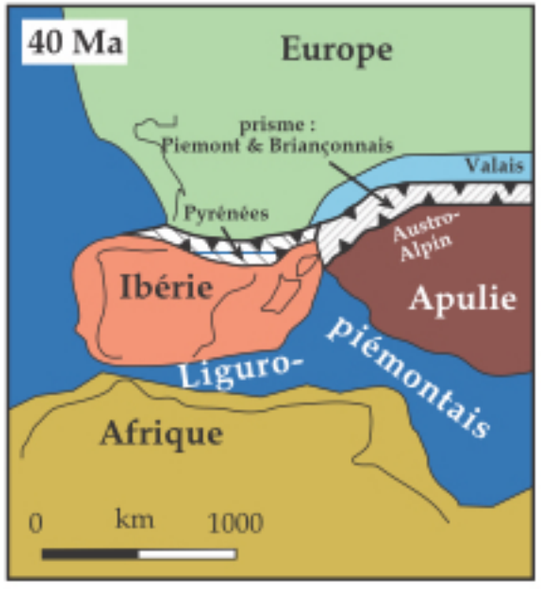
Combien d'océans?

1 océan

Dercourt et al., 1986





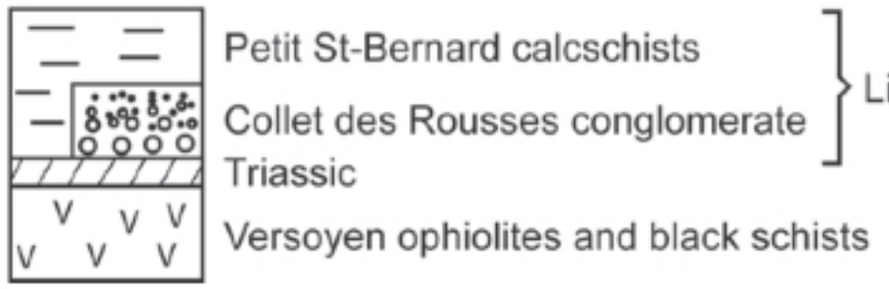


2 océans

Stampfli, 1992

L'océan valaisan (????) au niveau du col du Petit St Bernard

Géochronologie des roches vertes du Versoyen
=> Permien



Masson et al., 2008

L'océan valaisan (????) au niveau du col du Petit St Bernard

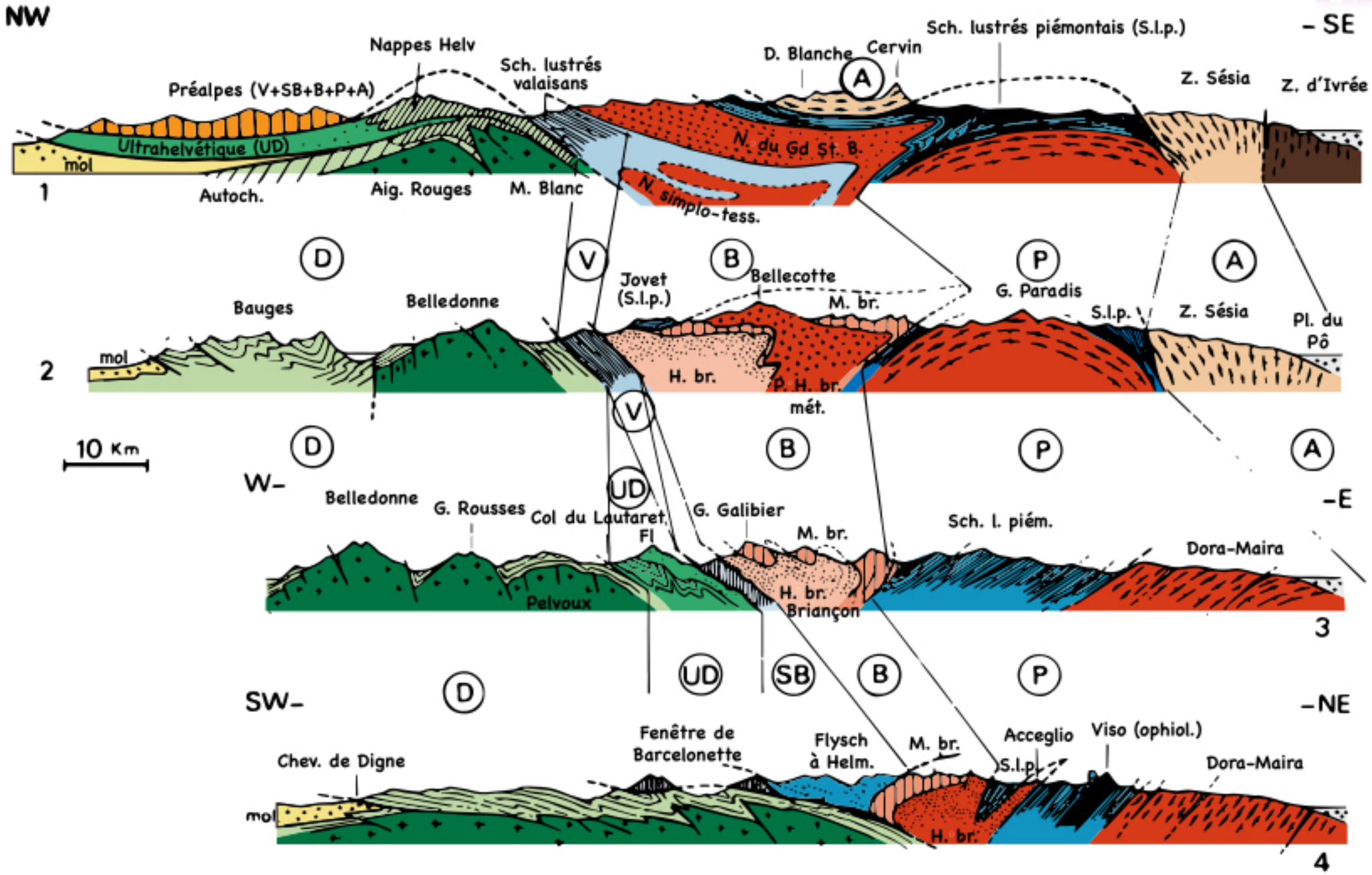
Géochronologie des roches vertes du Versoyen
=> Permien

Masson et al., 2008

Observations de terrain
=> Sill dans le Jurassique & le Crétacé

Debelmas, 2001

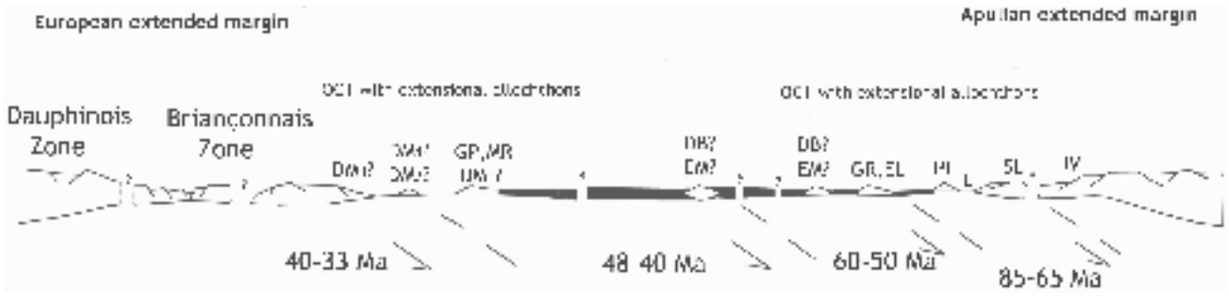
Controverses alpines

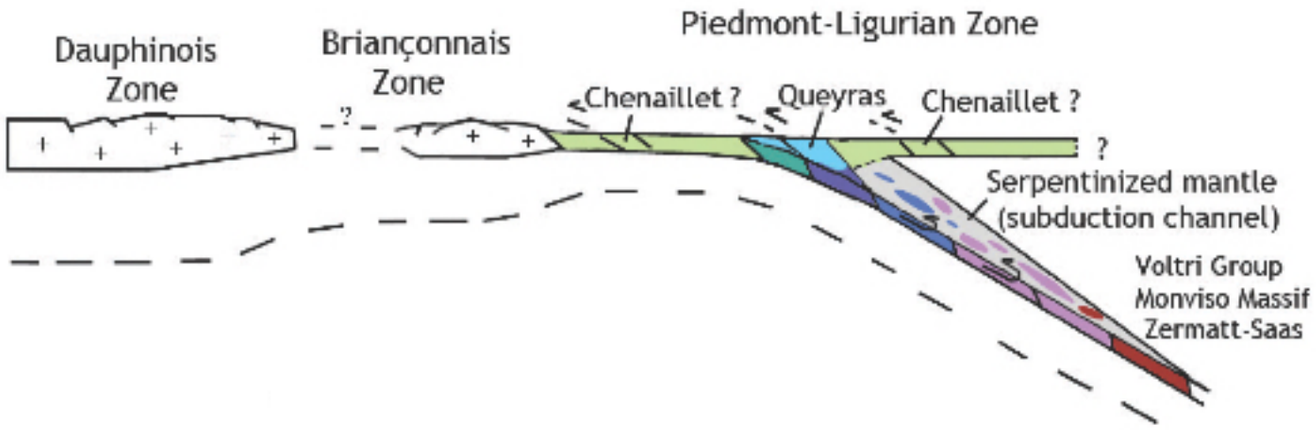


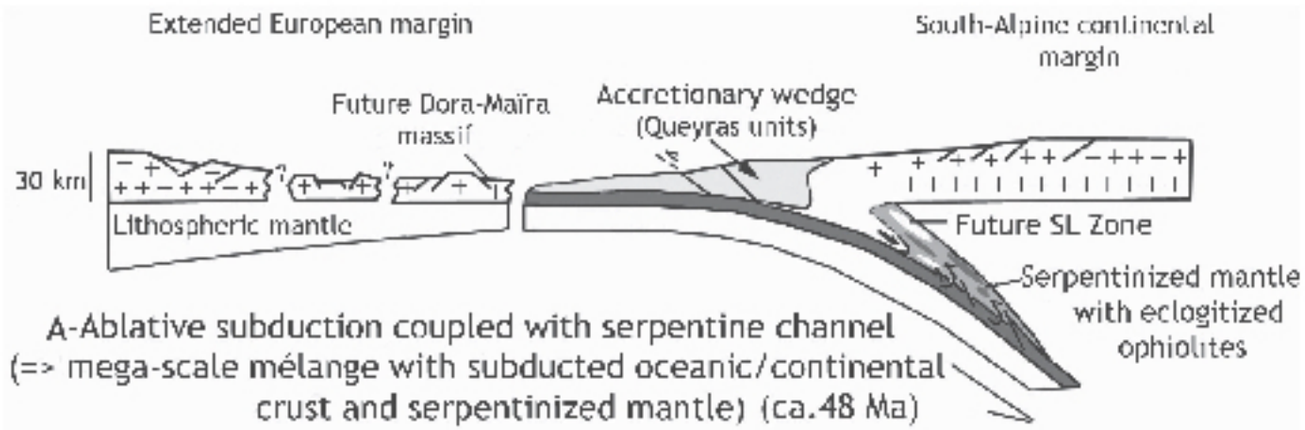
Coupes simplifiées au Travers des Alpes Franco-Italiennes
D : Zone Dauphinoise – UD : Zone ultradauphinoise – V : Zone valaisanne – SB : Zone subbriançonnaise – B : Zone briançonnaise – P : Zone piémontaise – A : Austro-alpin.
H. Br. Permo-houiler briançonnais – M. br. mésozoïque briançonnais – S. l. p. Schistes lustrés piémontais

Debelmas, 1973

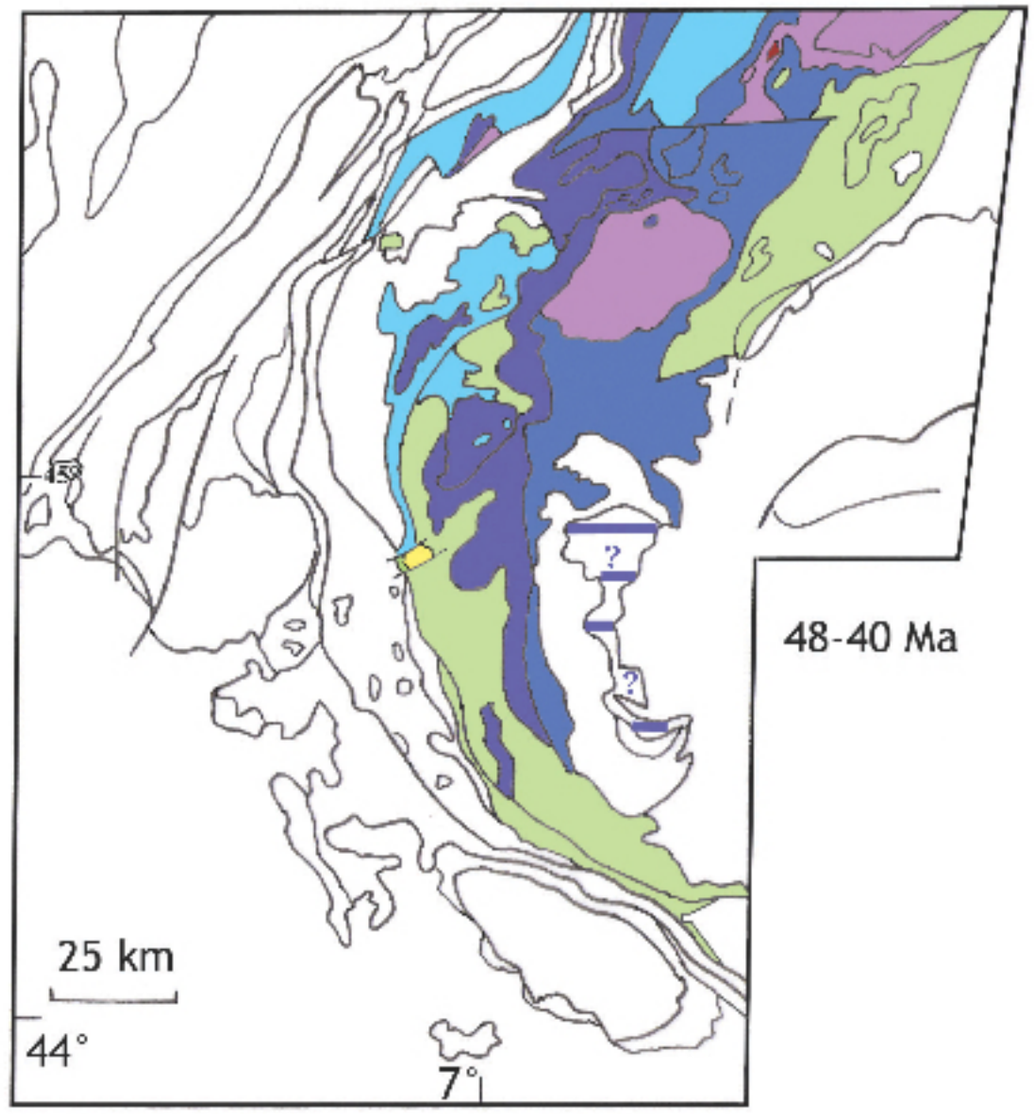
Controverses alpines





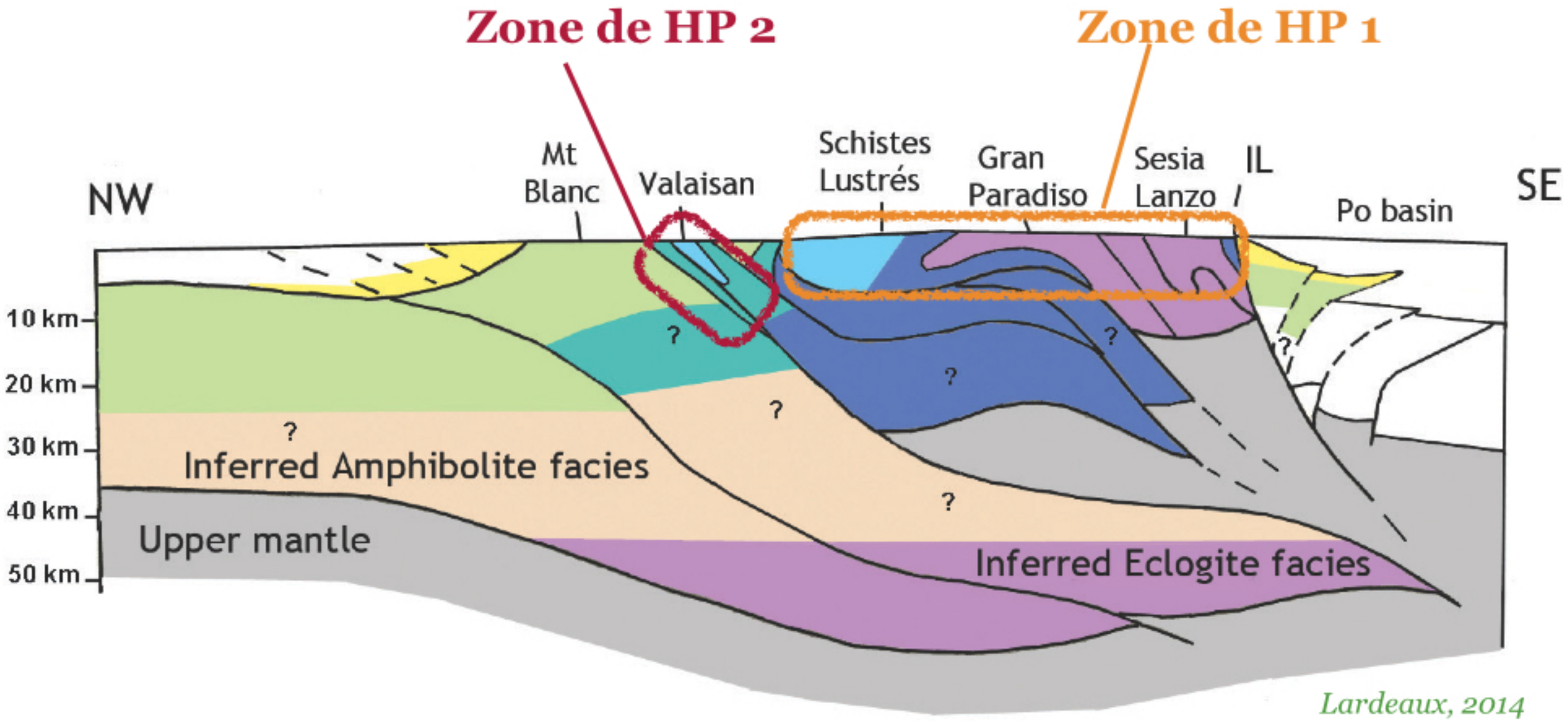


Une carte métamorphique avec **2 zones de HP**



Un modèle avec **1 zone de subduction !**

Lardeaux, 2014

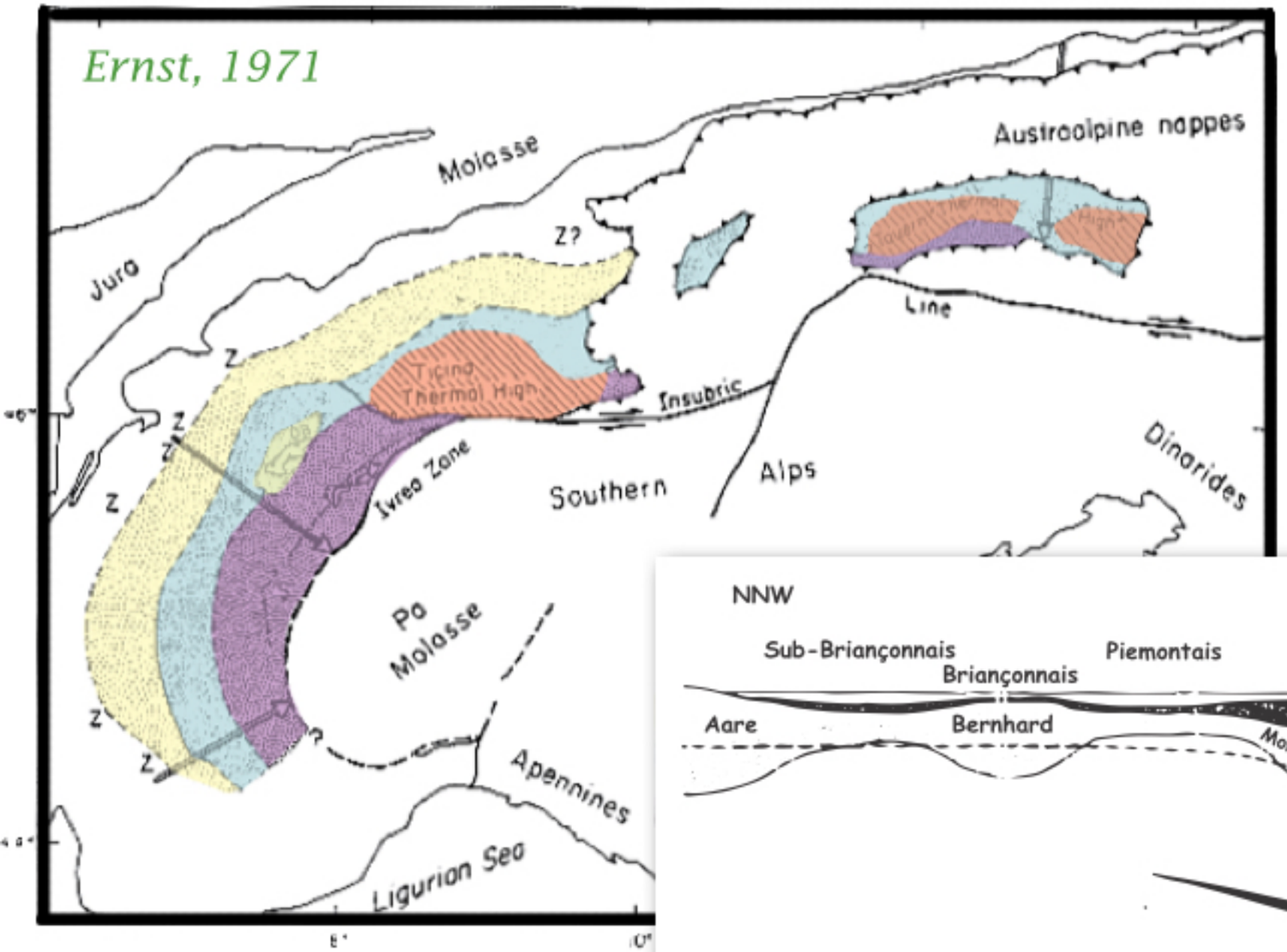


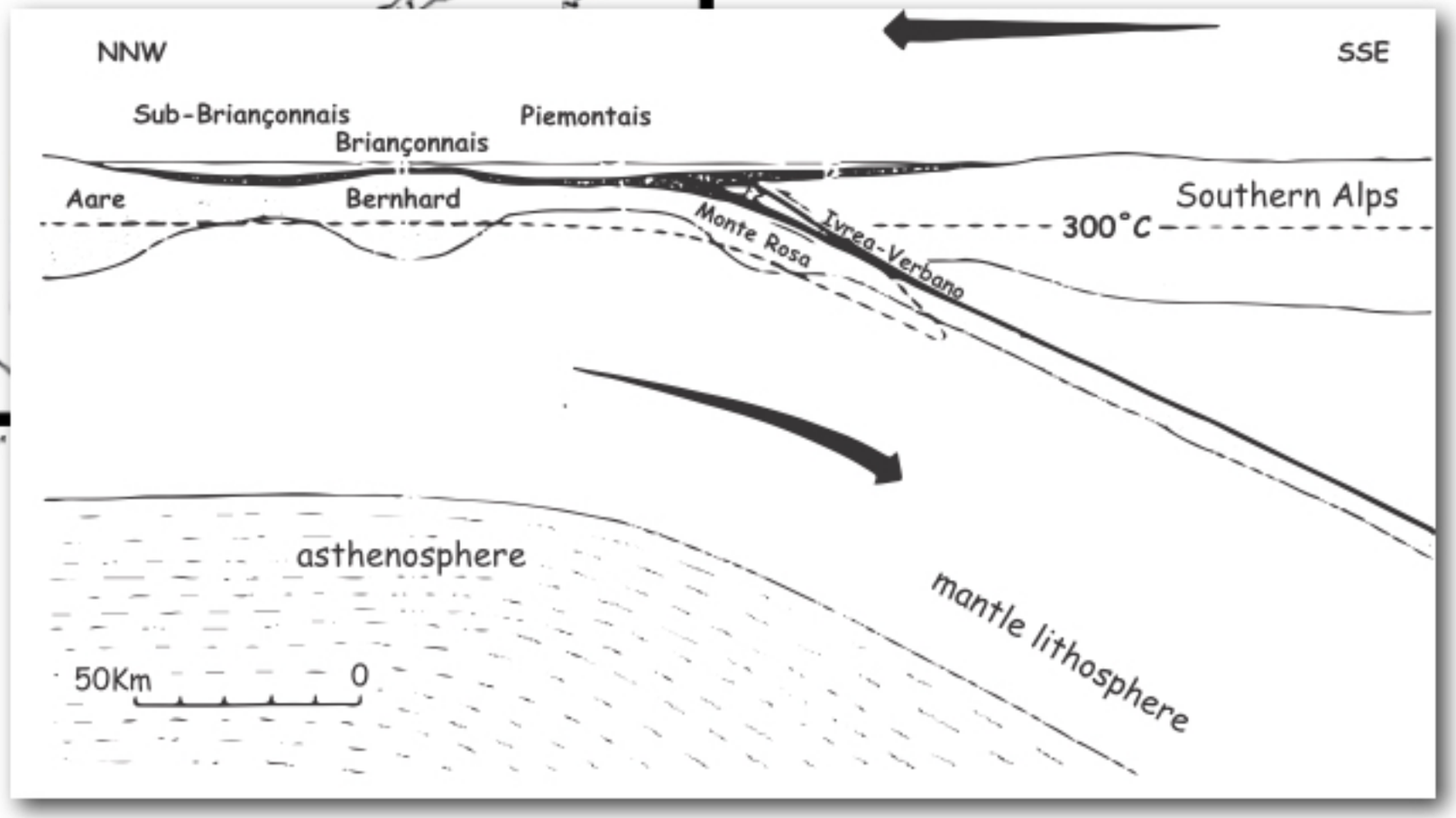
Lardeaux, 2014

Peut-on faire de la HP sans subduction ?

Un orogène de type alpin : qu'est-ce ?

Ernst, 1971

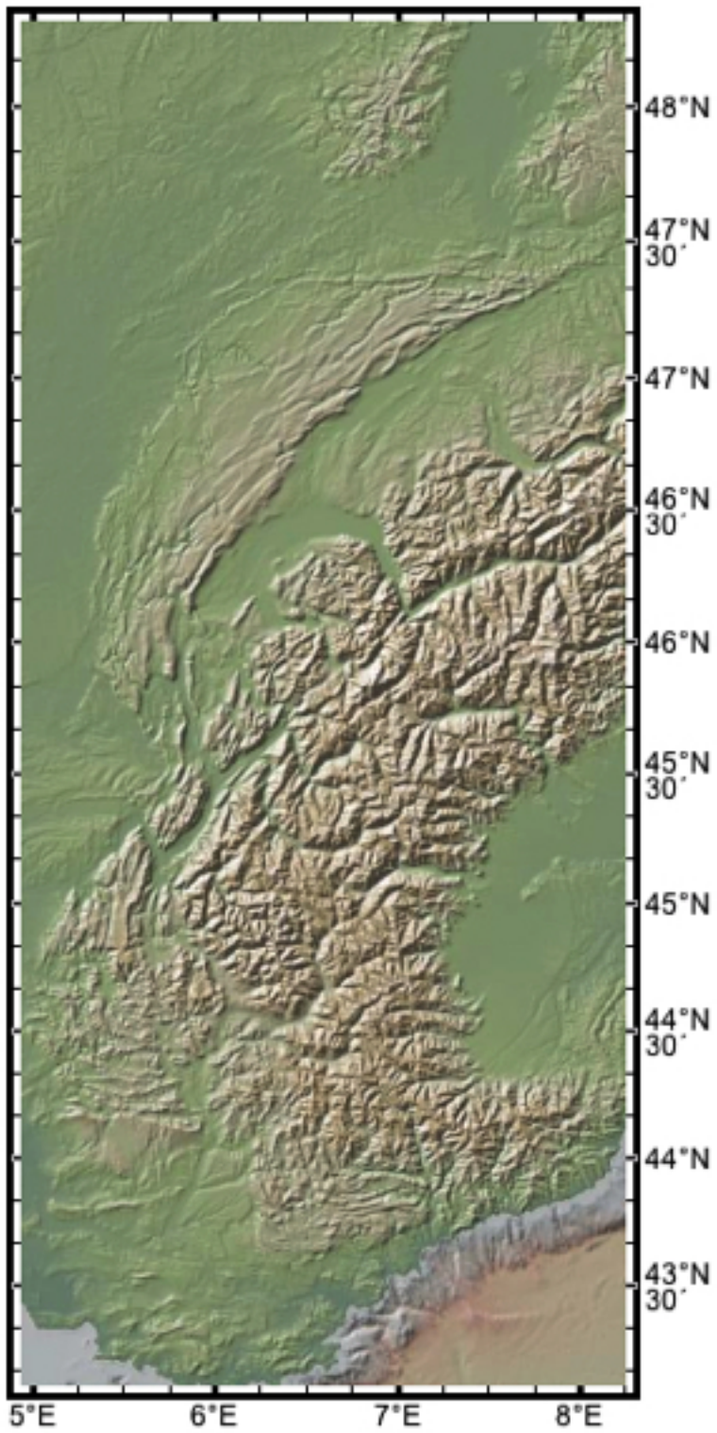




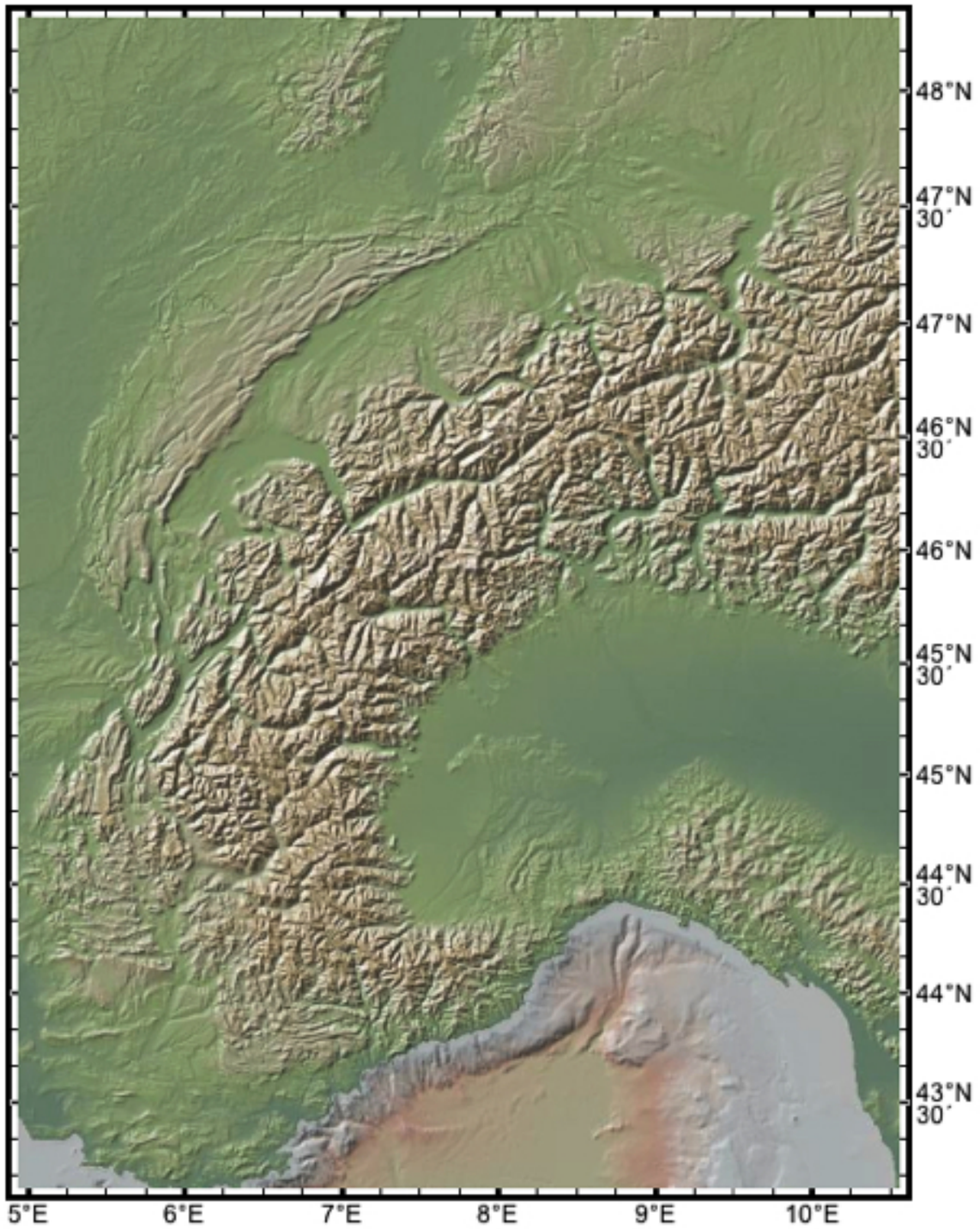
Ernst, 1973

Vue générale des Alpes avec le Jura, le bassin molassique

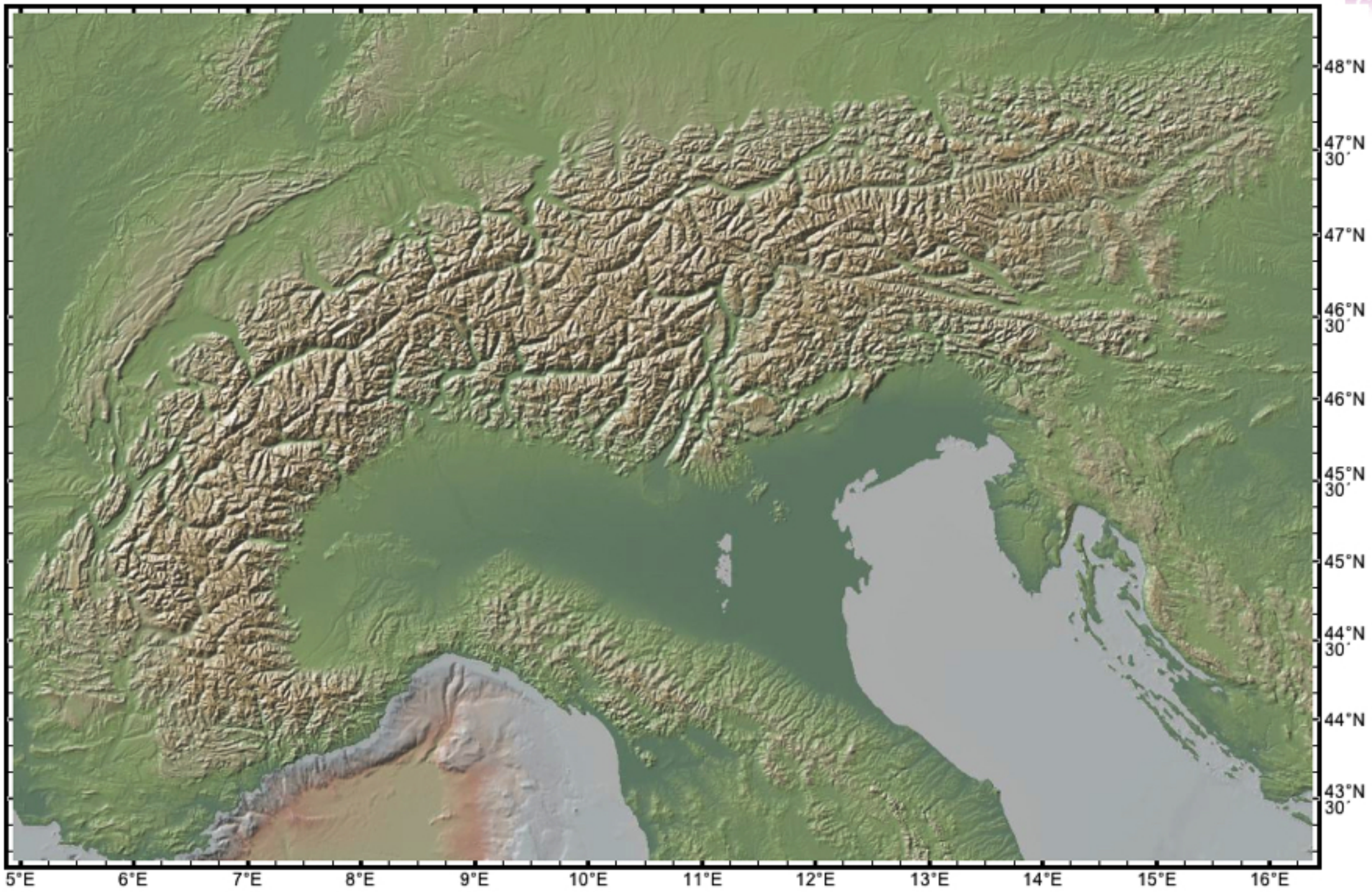
Que sont les Alpes ? *Les Alpes géologiques traditionnelles*



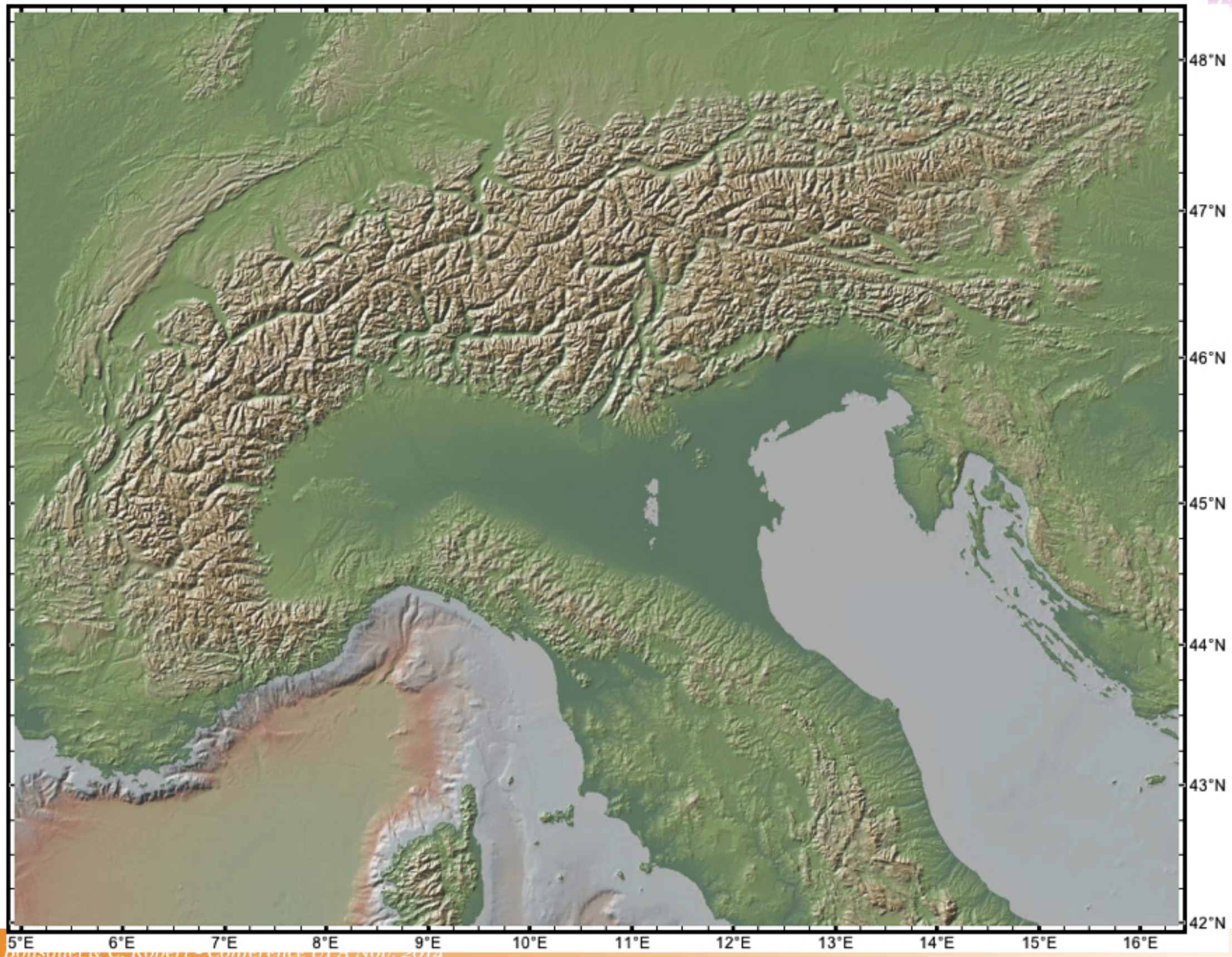
Que sont les Alpes ? *Les Alpes "skiables"*



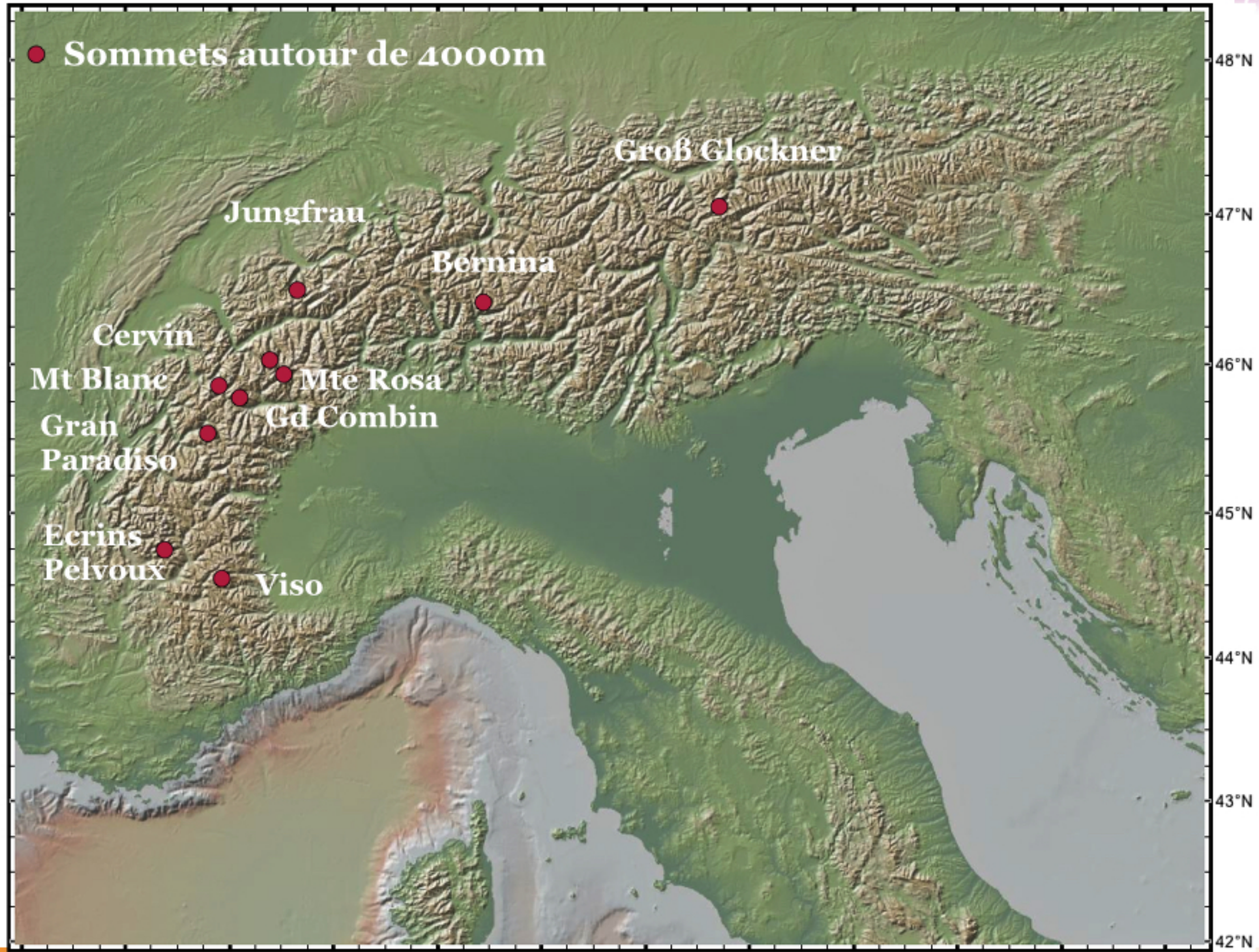
Que sont les Alpes ? *La topographie*



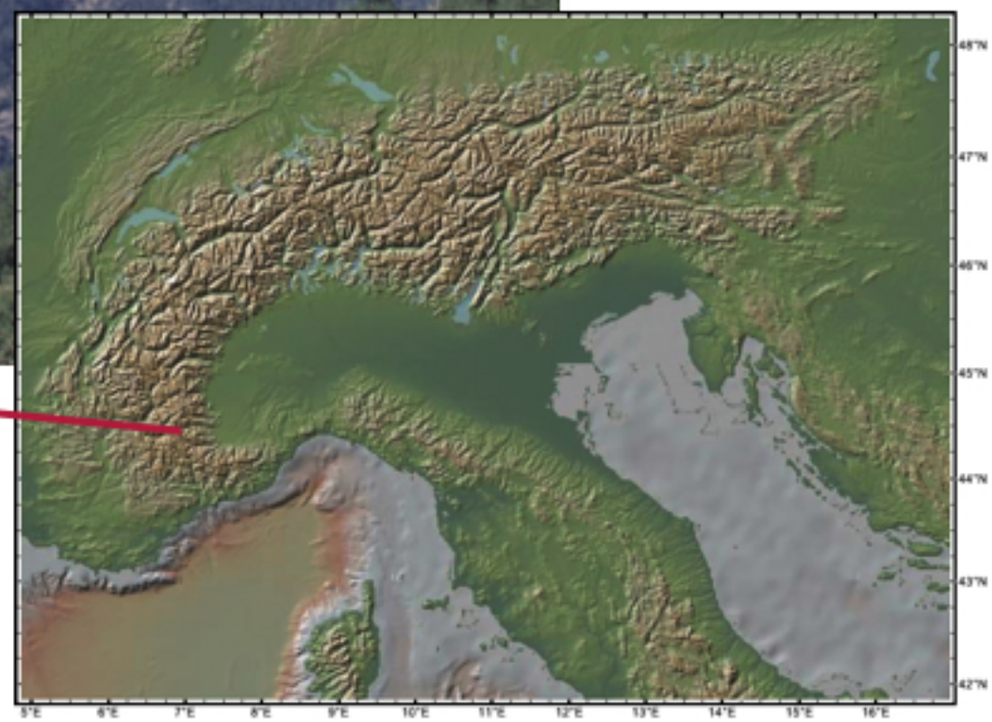
Que sont les Alpes ? *La géodynamique*



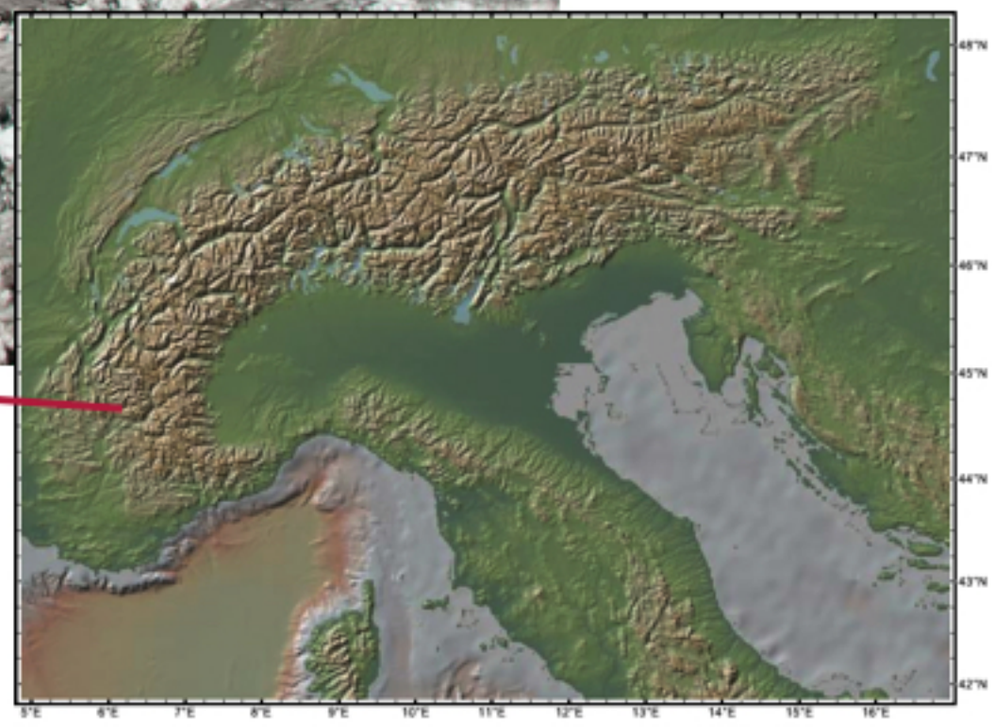
Les hauts sommets alpins



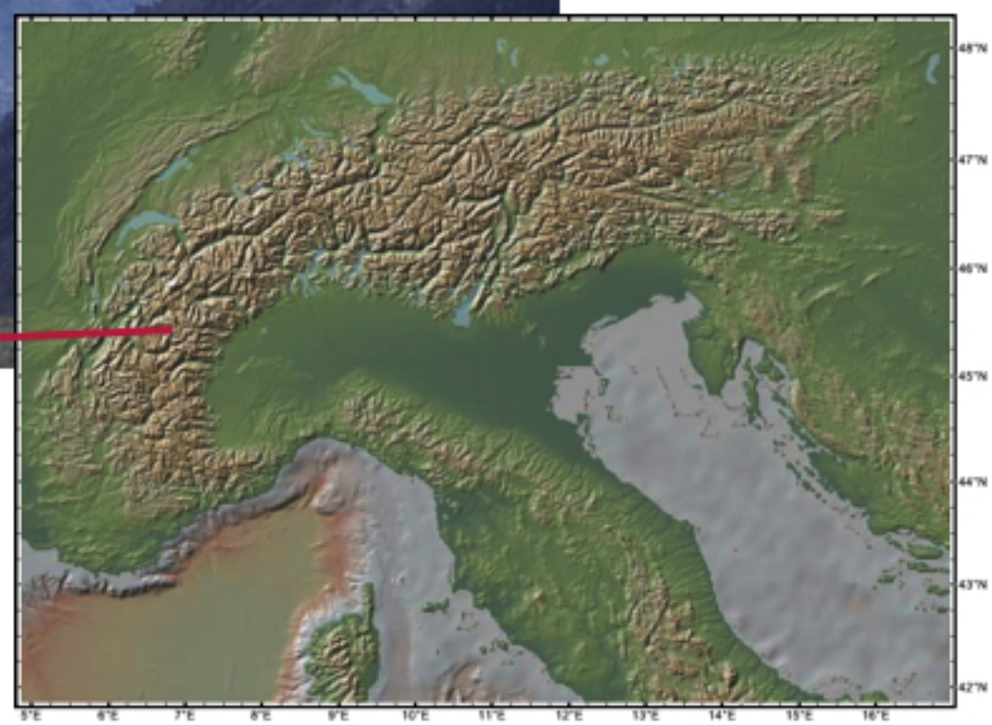
Le Mont Viso (3965 m)



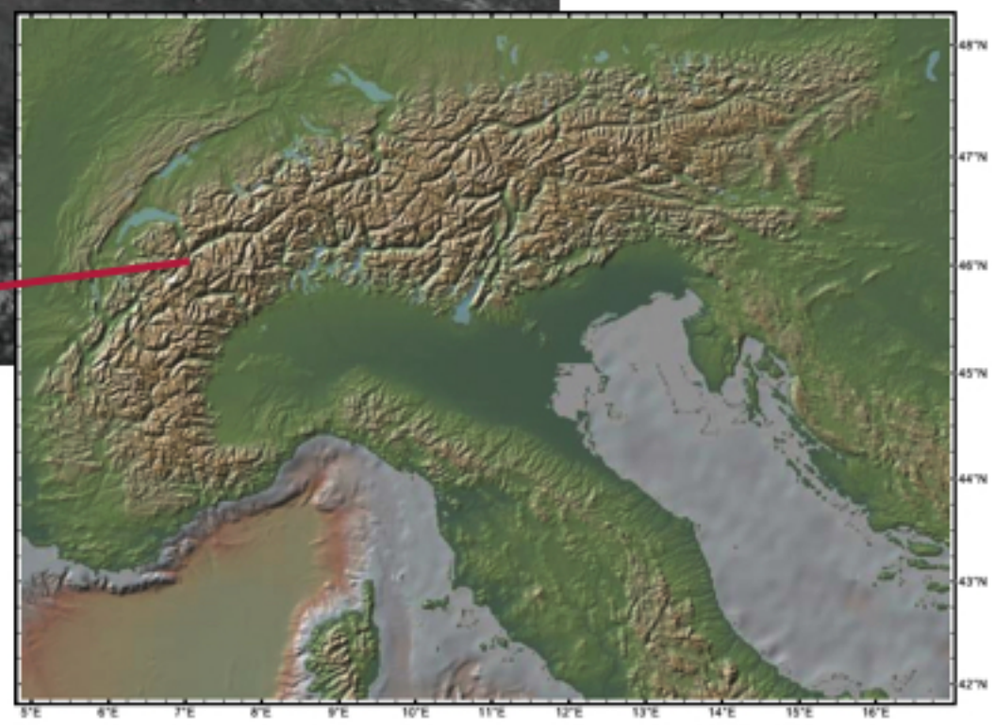
Écrins (4103 m) & Pelvoux (3946 m)



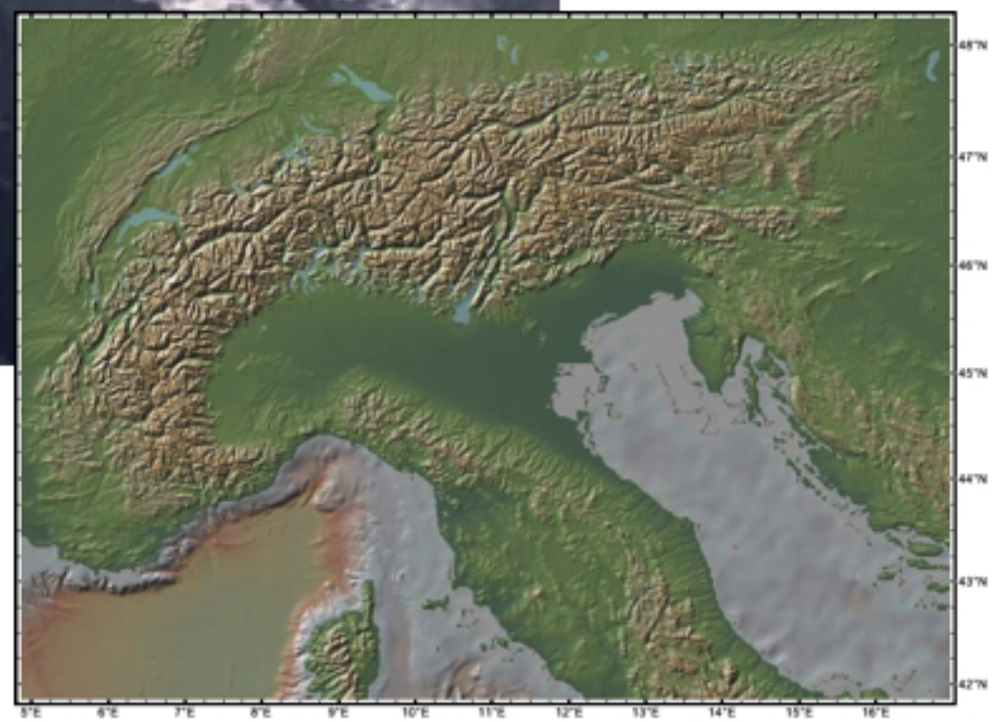
Grand Paradis (4061 m)



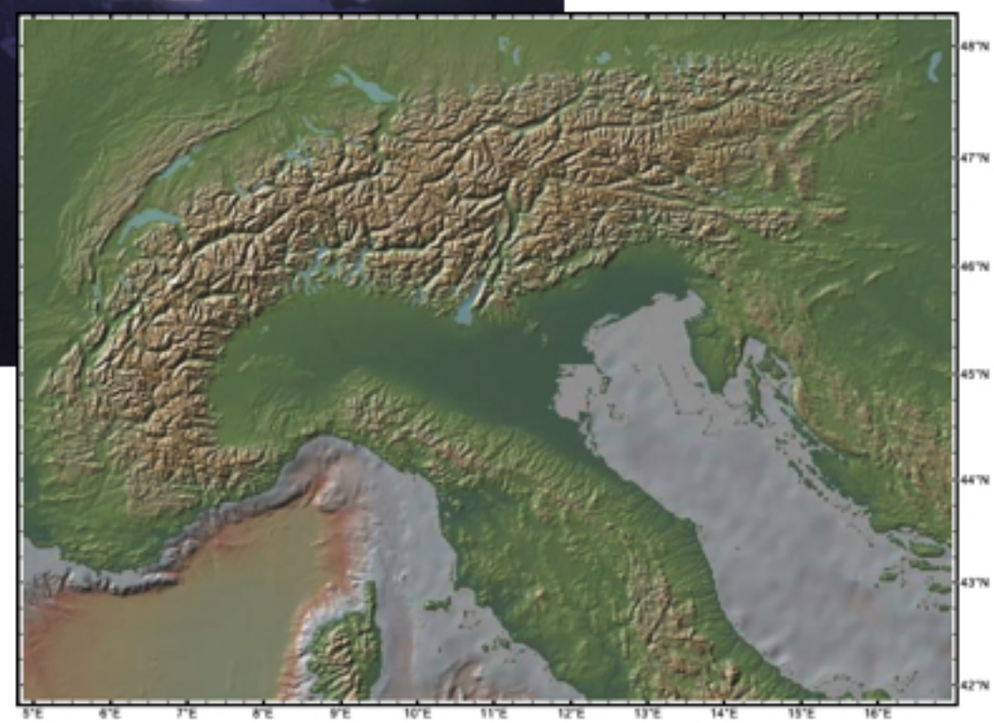
Grand Combin (4317 m)



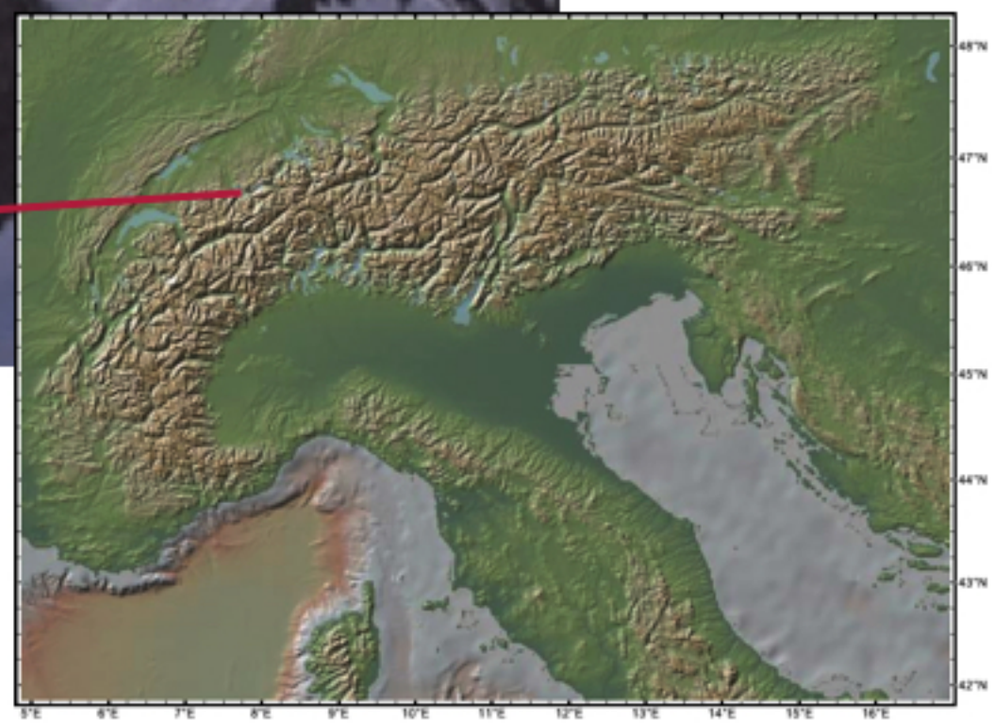
Mont Blanc (4807 m)



Cervin (4477 m)

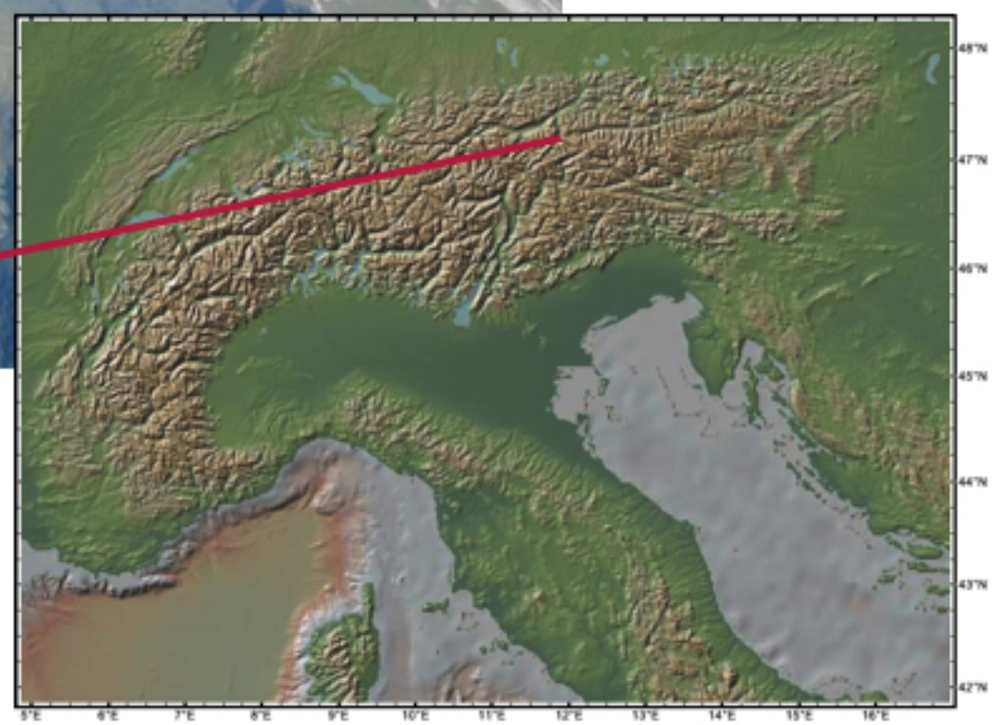


Junfrau (4168 m)

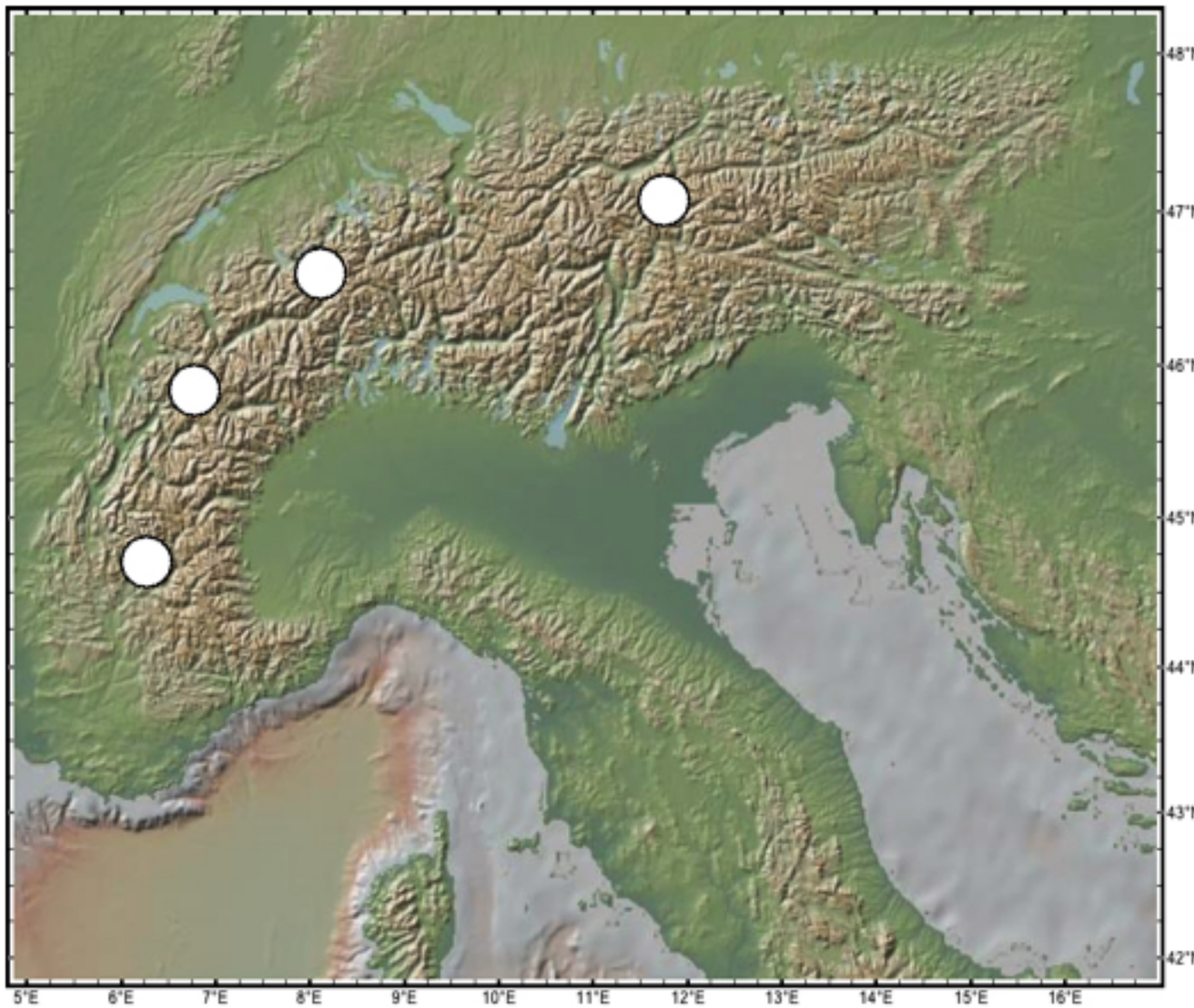


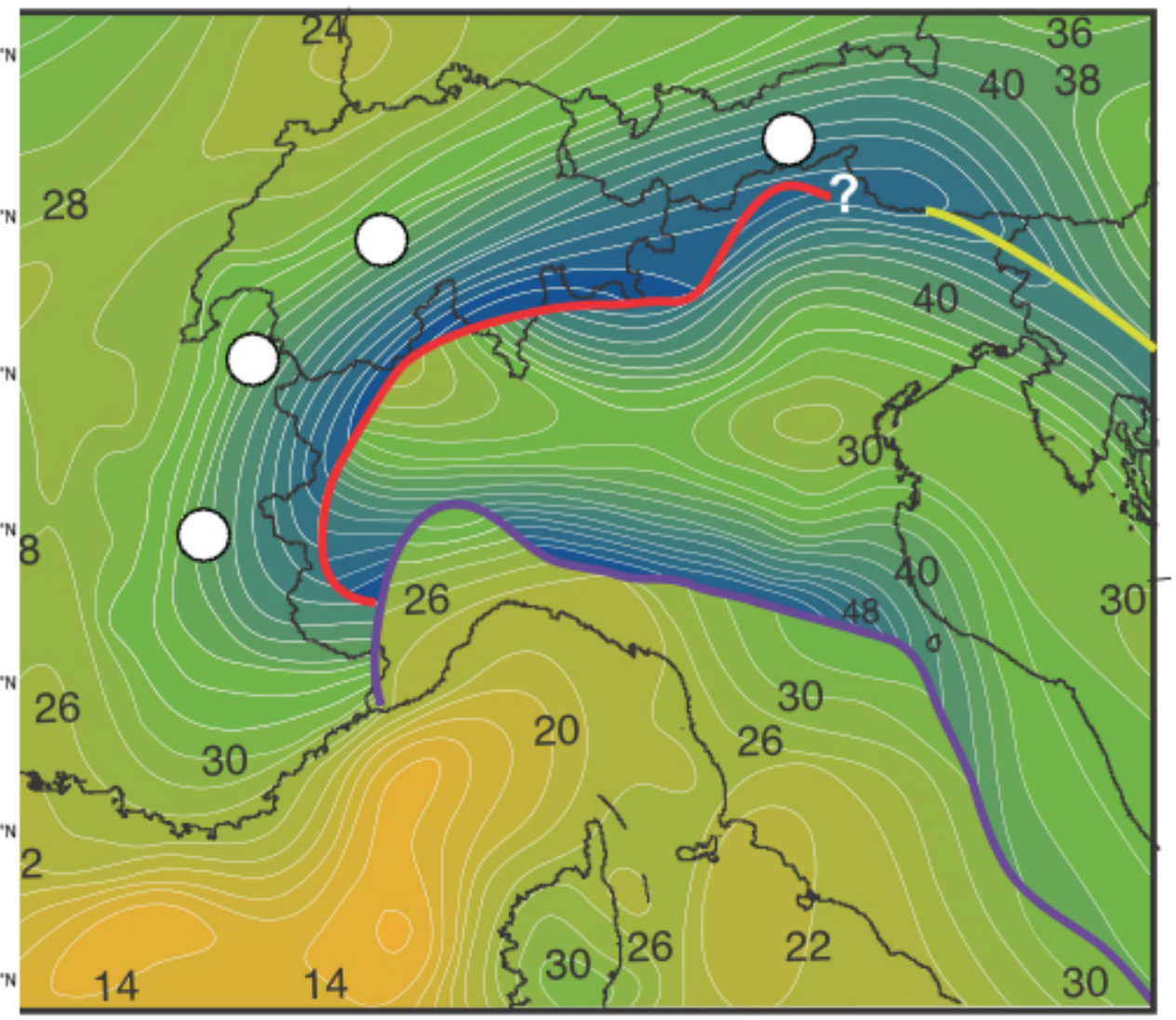
Bernina (4049 m)

Groß Glockner (3798 m)



Relief & profondeur du Moho



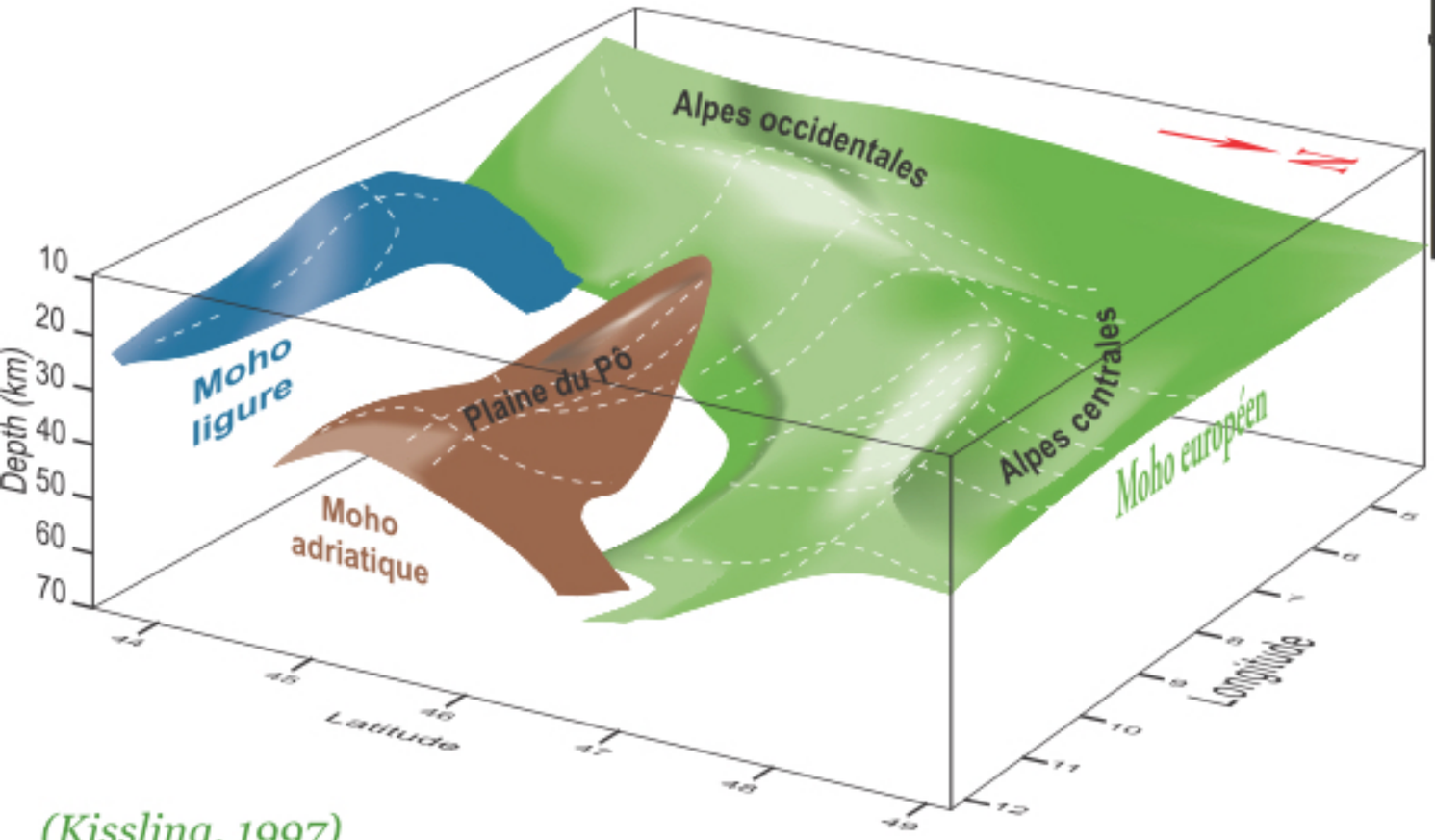


Relief

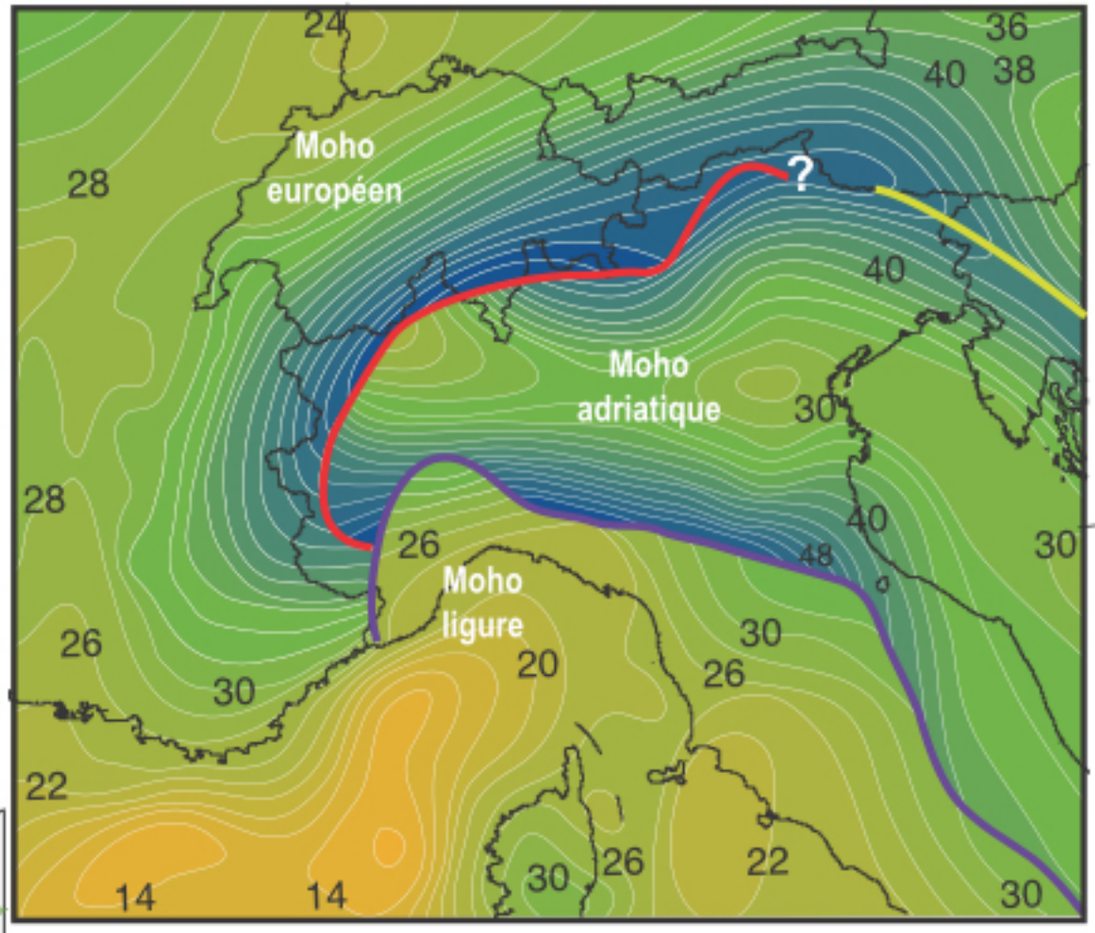
Profondeur du Moho

- *Highest topographic point (~4000m)*

Structure profonde des Alpes

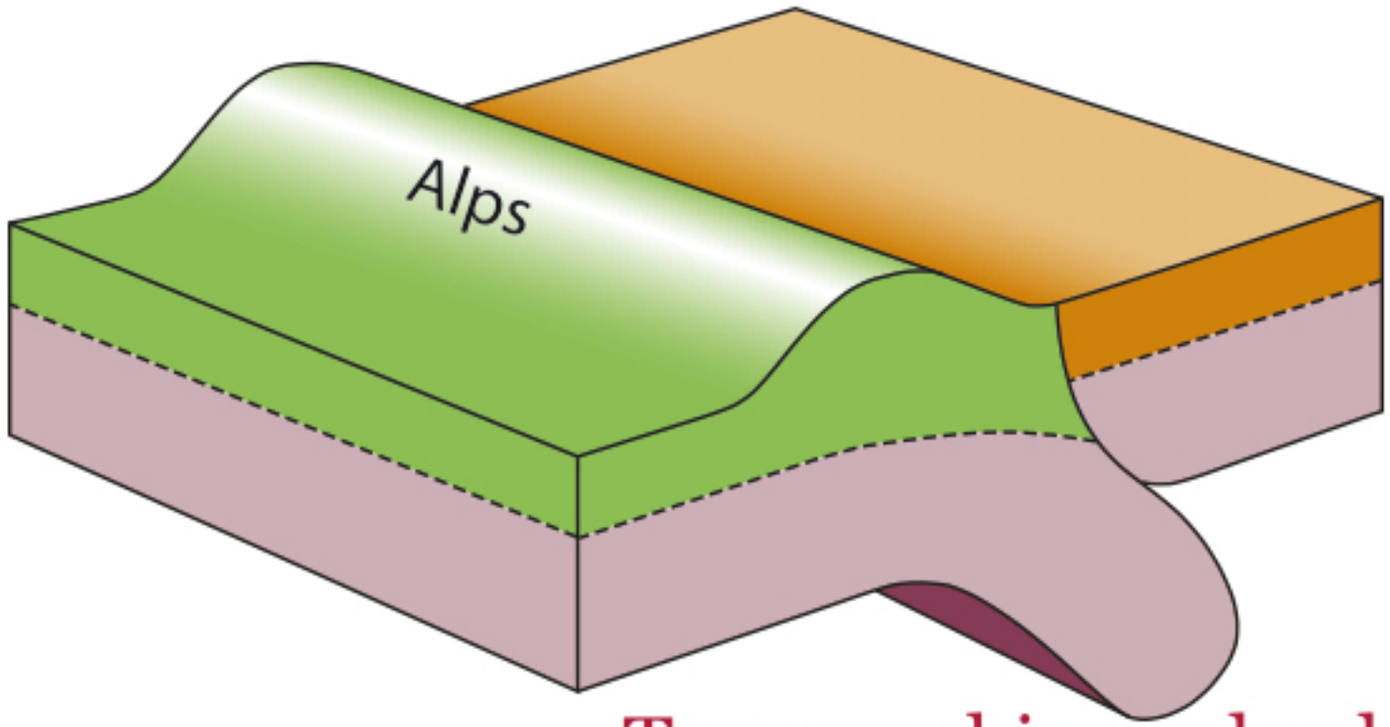


(Kissling, 1997)

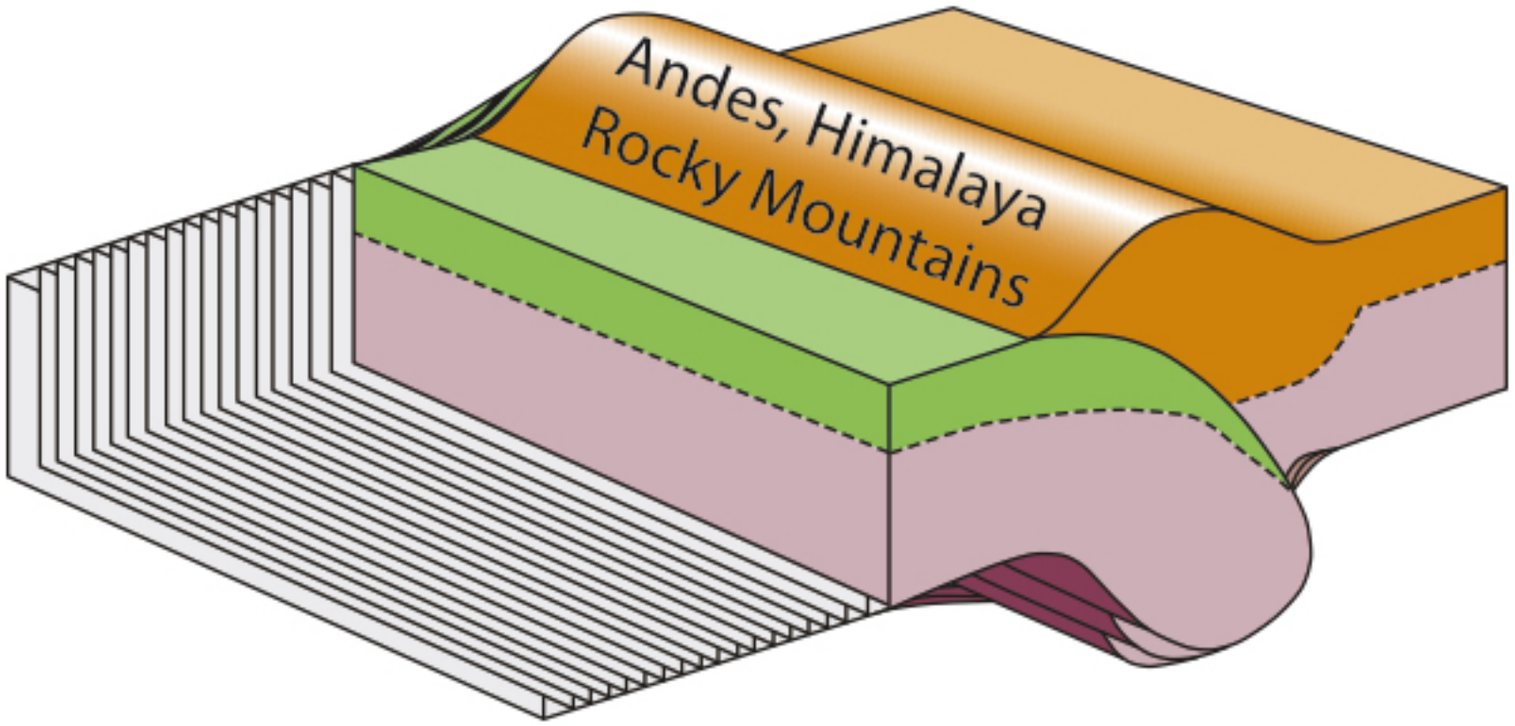


Relief des Alpes

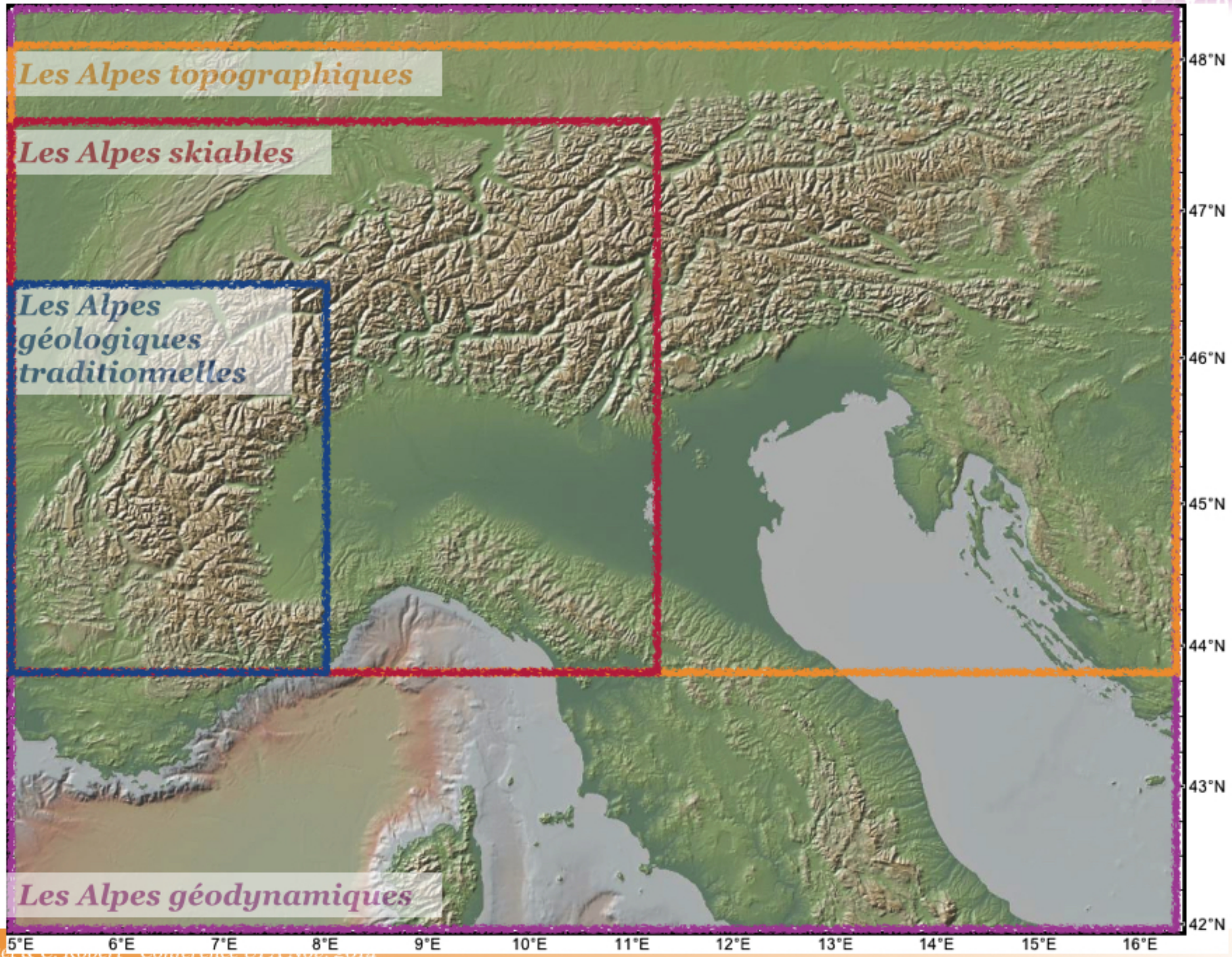
Topographie sur la plaque inférieure



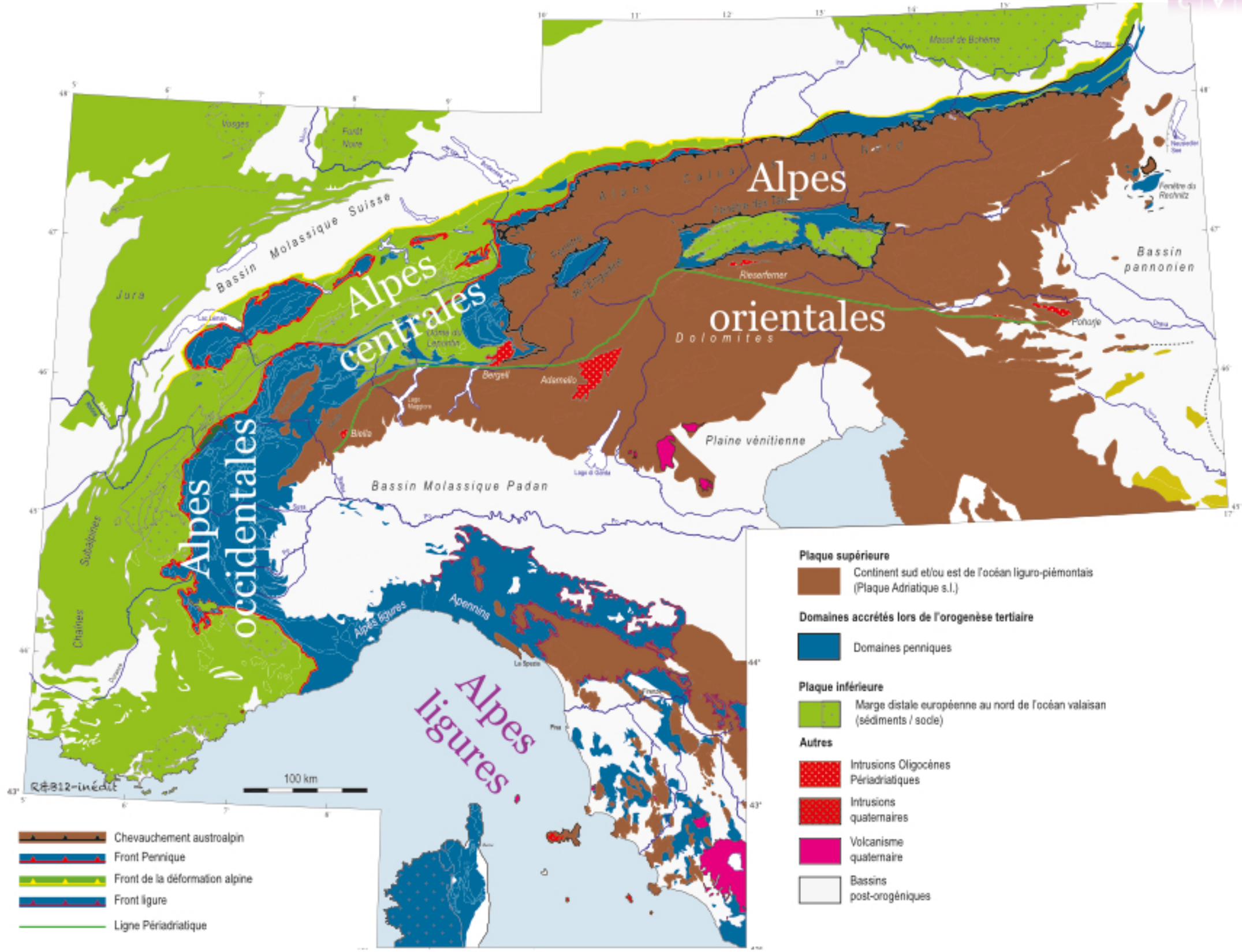
Topographie sur la plaque supérieure



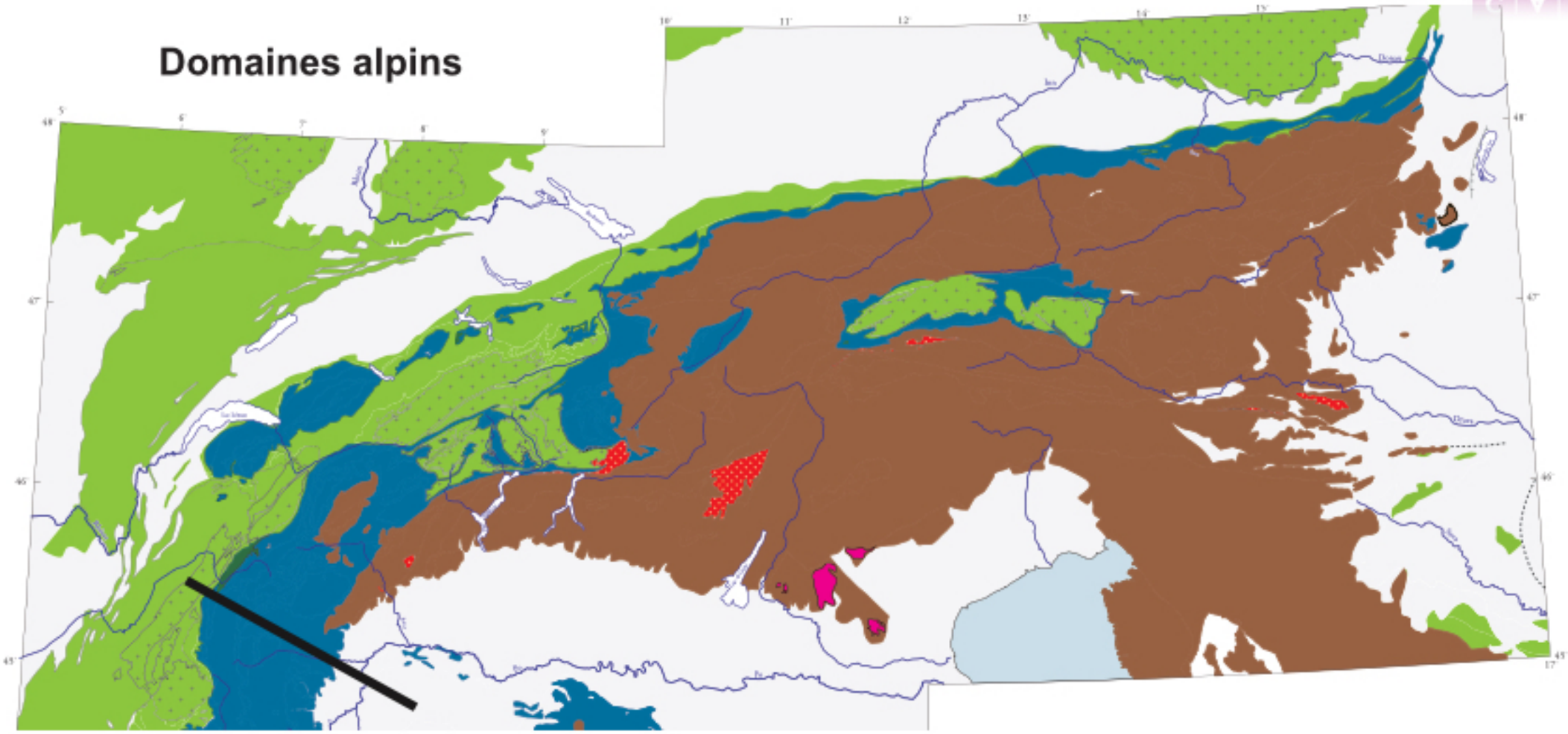
Que sont les Alpes ?

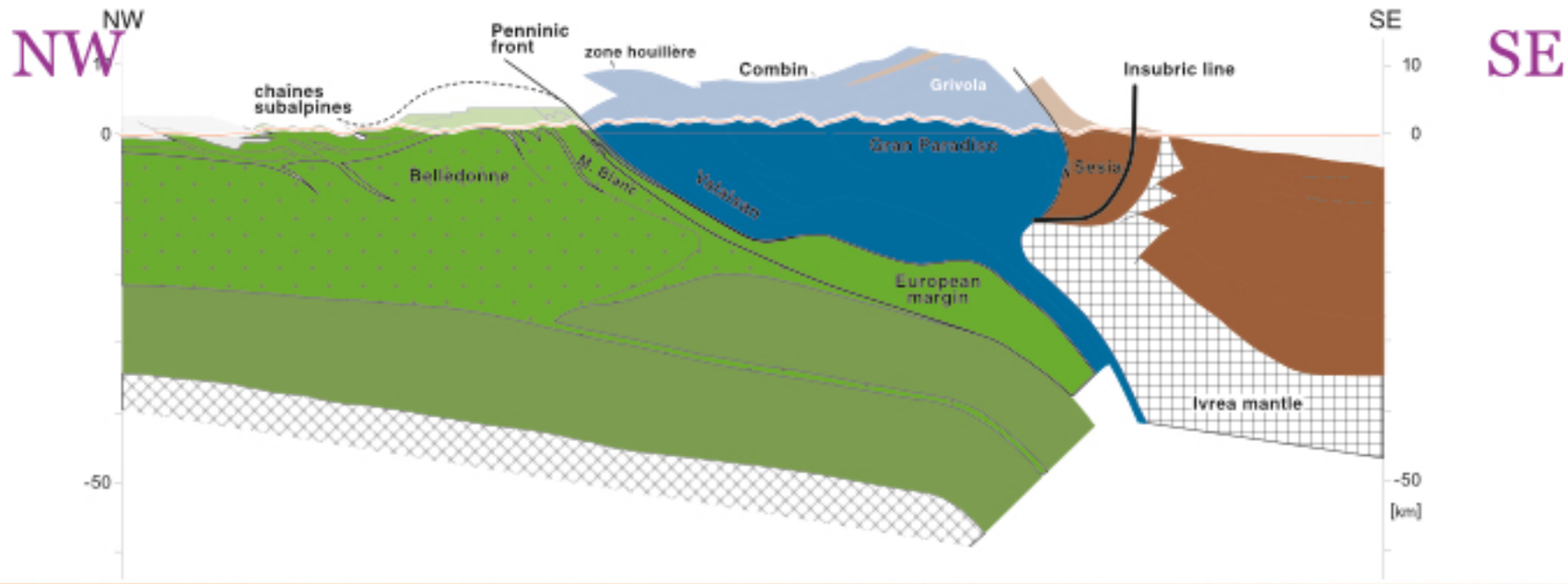


Le puzzle alpin : simple

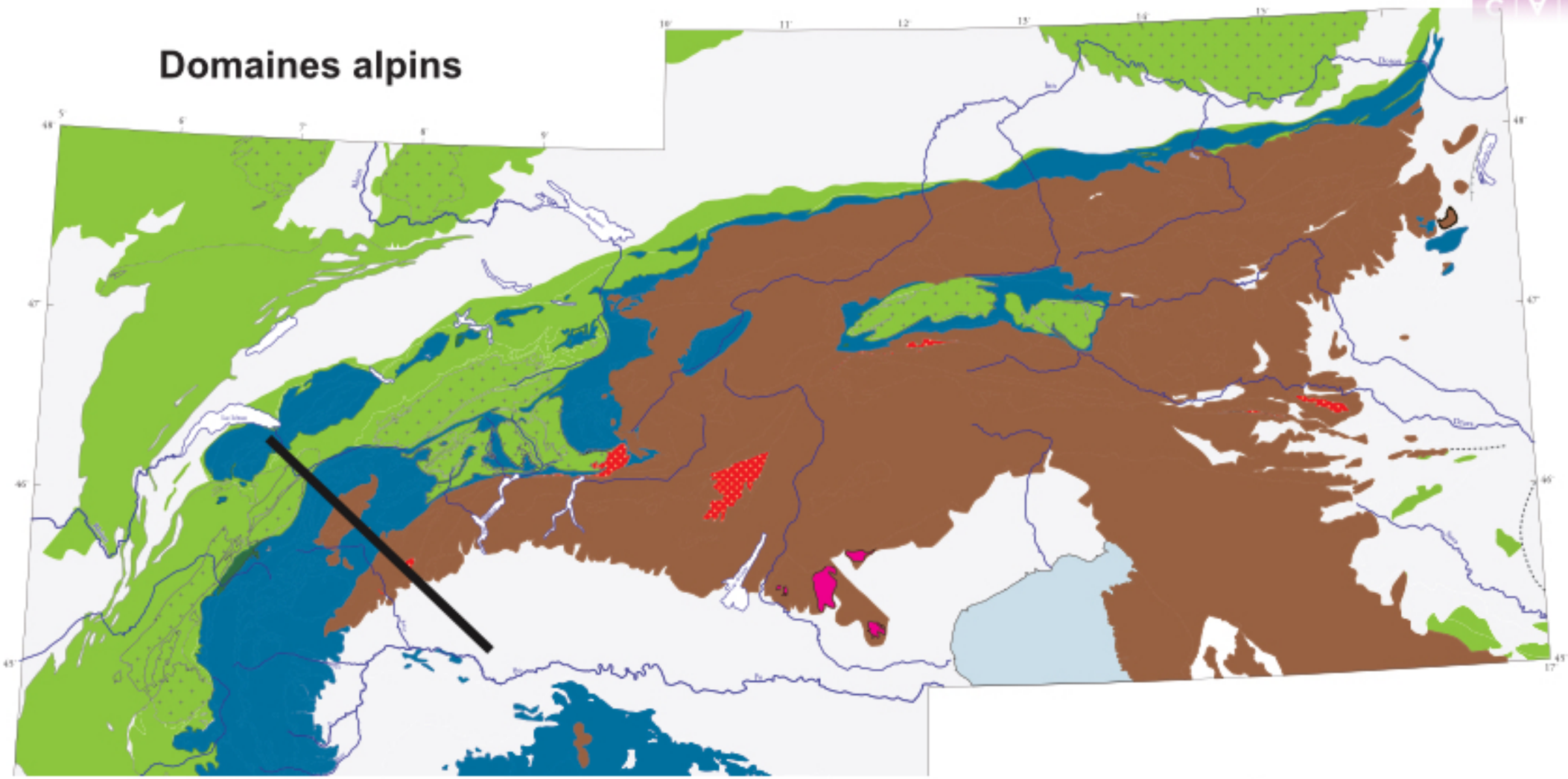


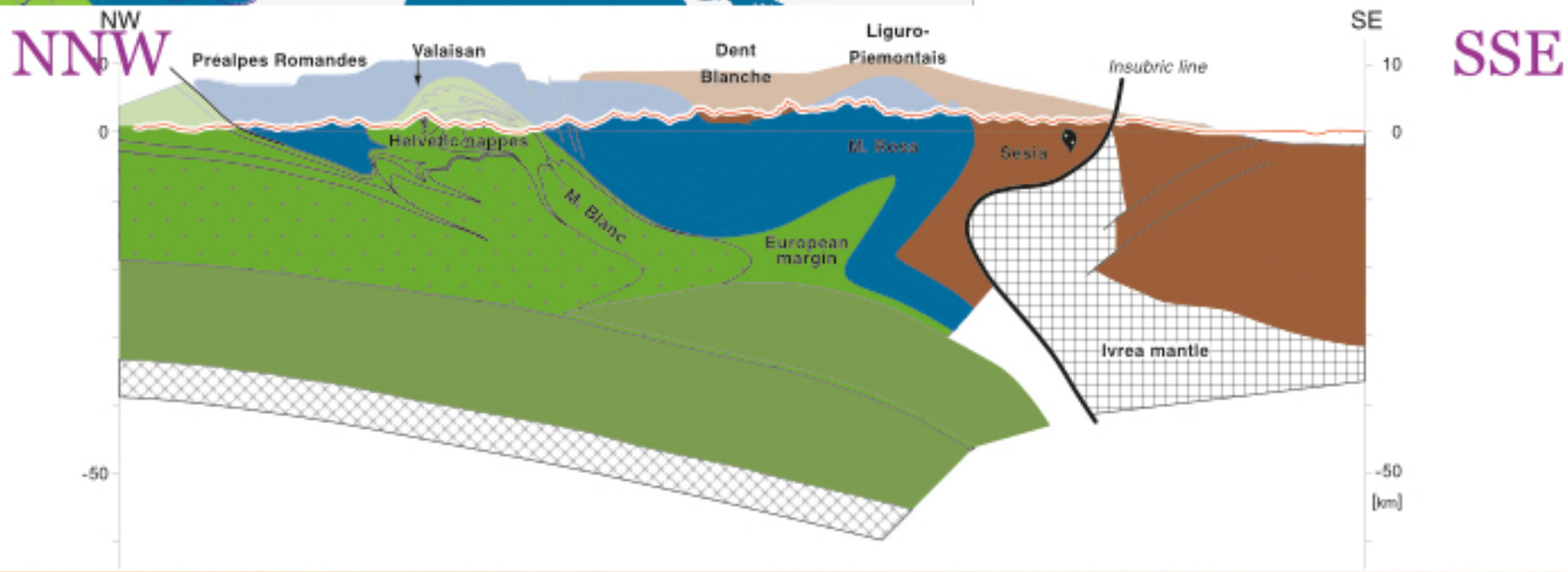
Le puzzle alpin : simple



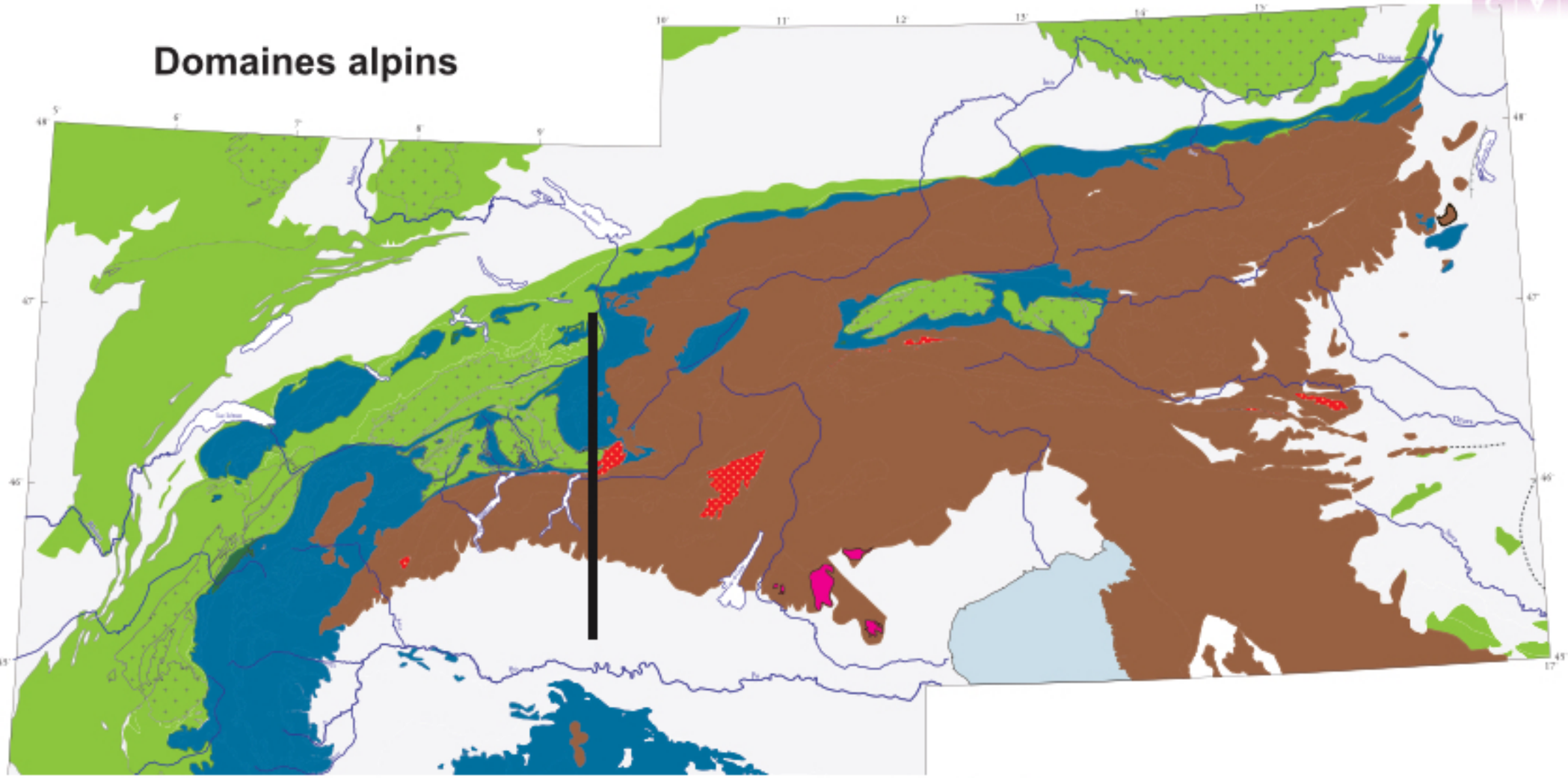


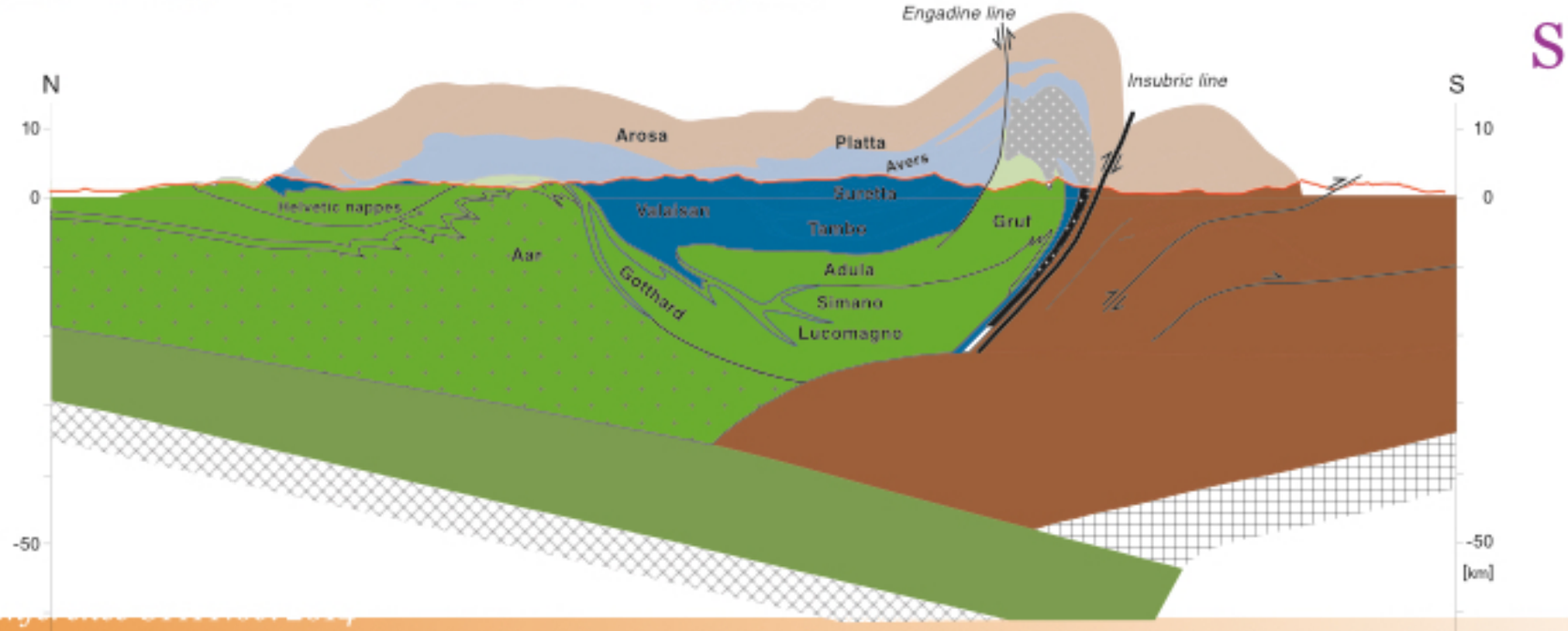
Le puzzle alpin : simple



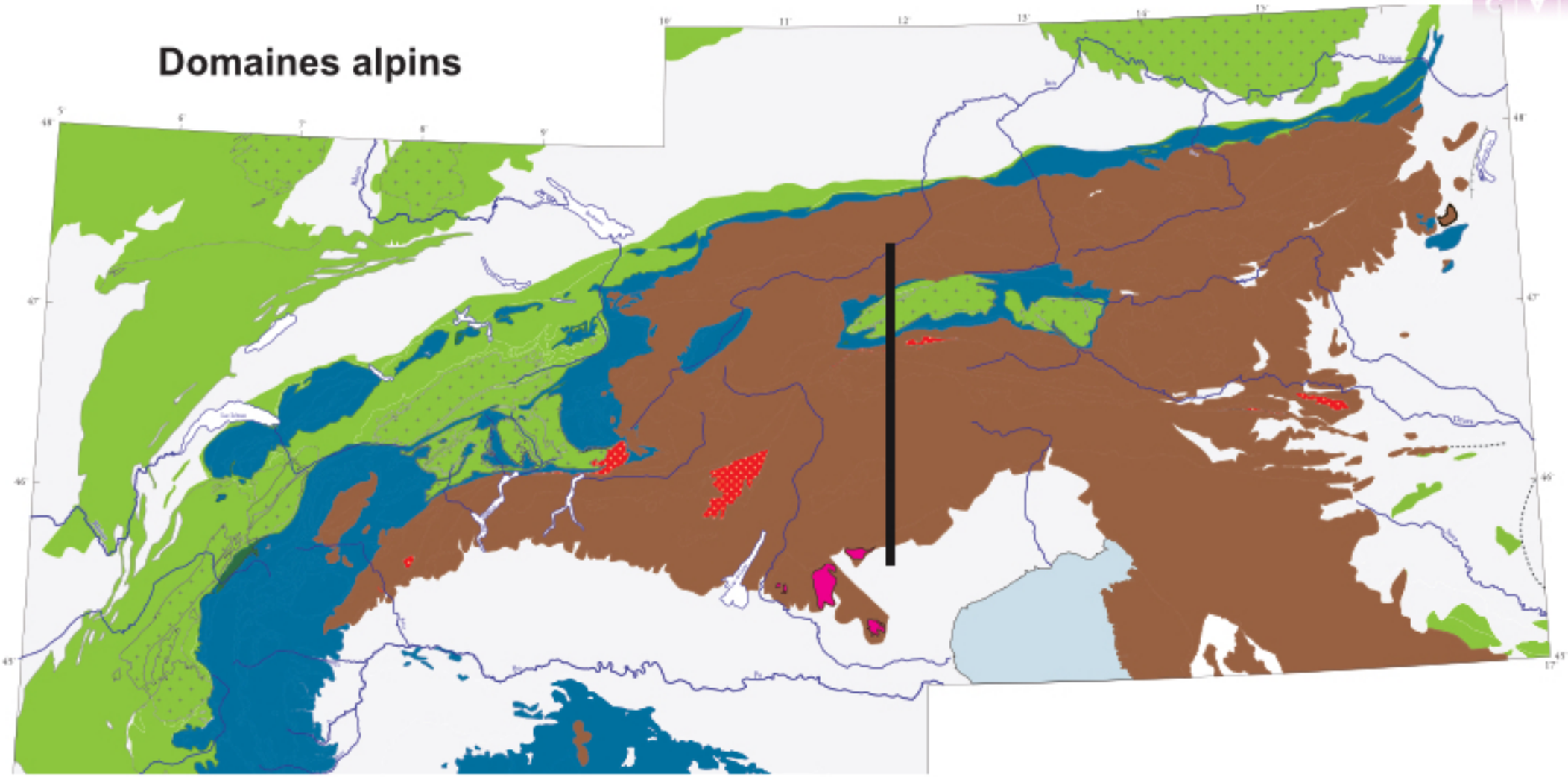


Le puzzle alpin : simple

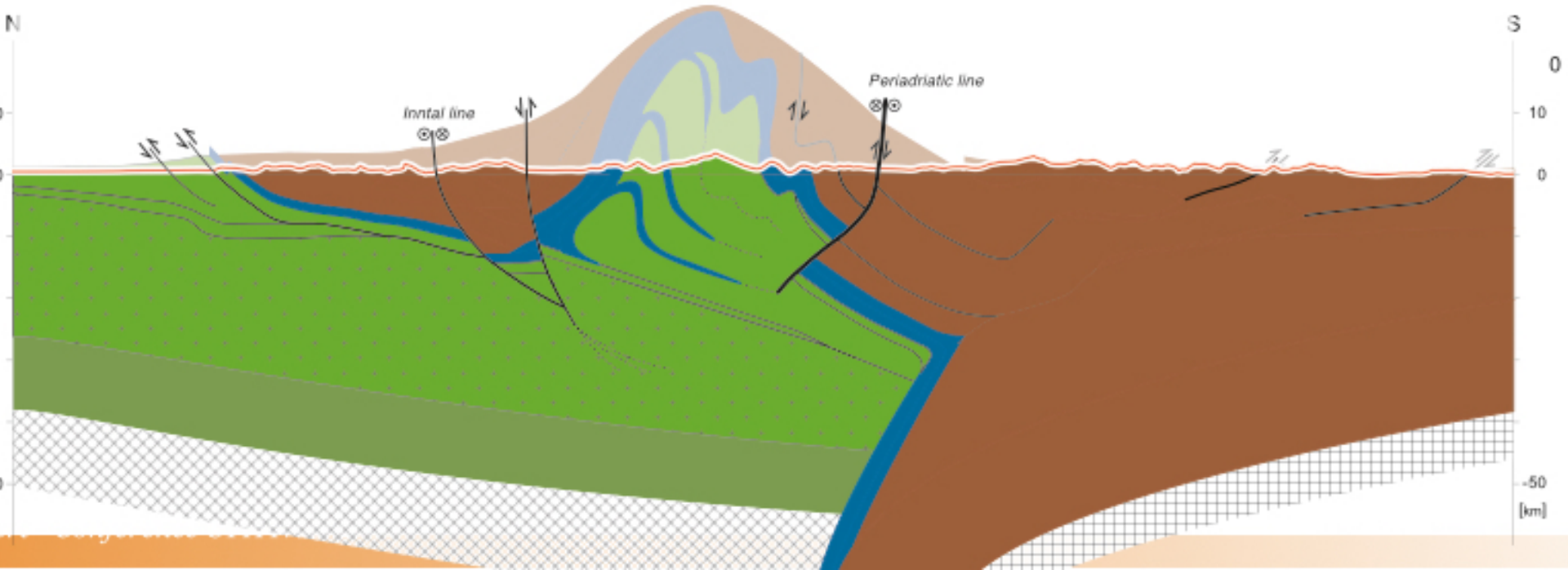




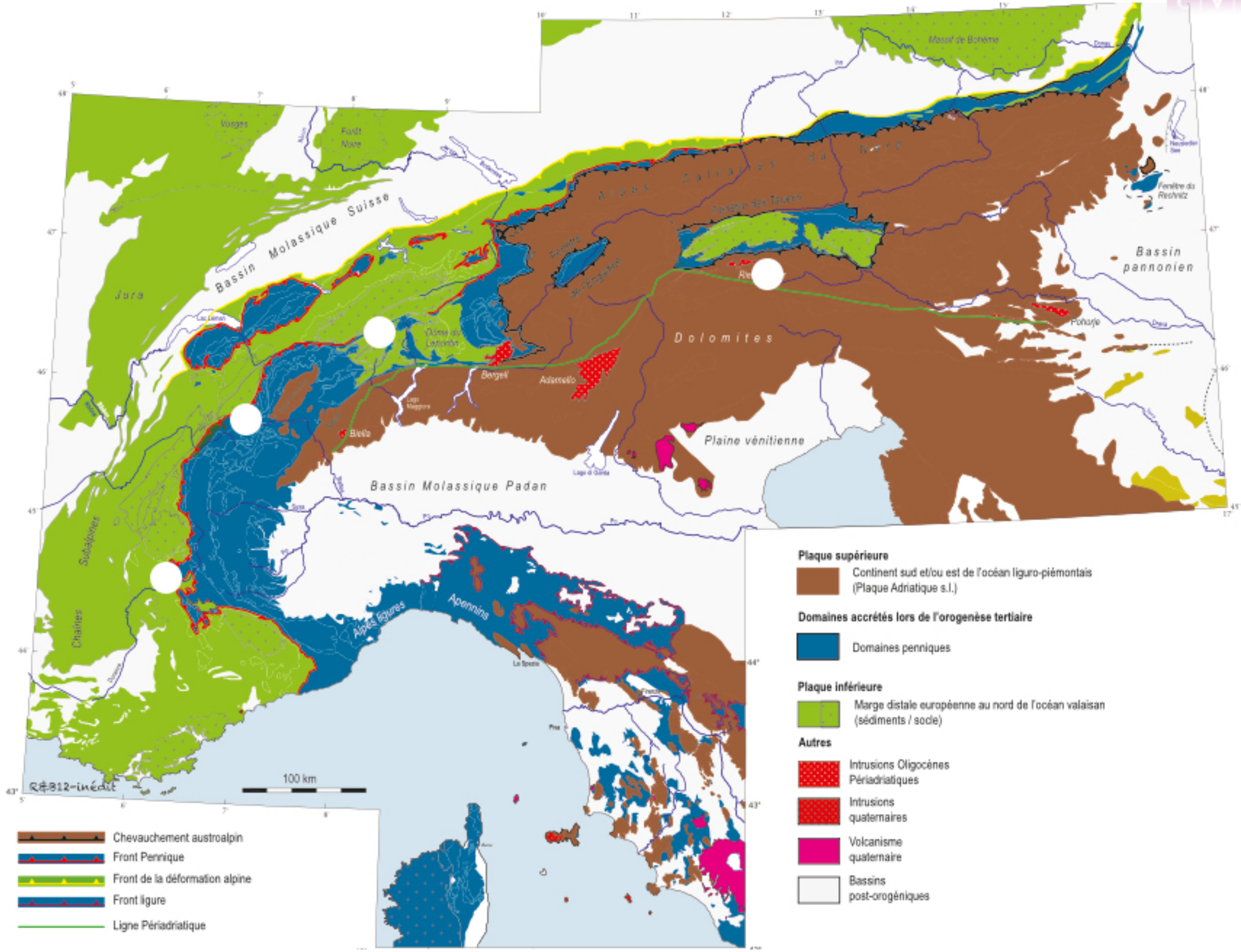
Le puzzle alpin : simple



Profil N

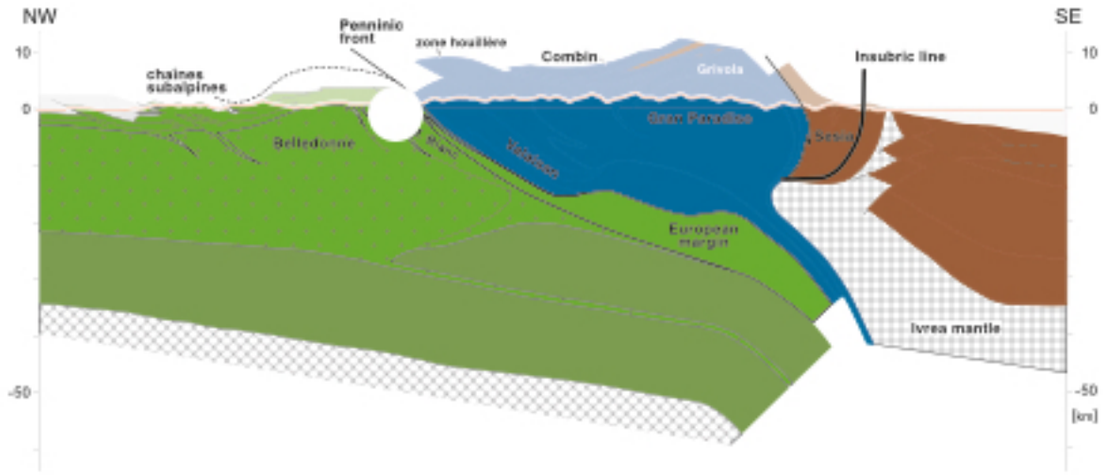


Le puzzle alpin : simple

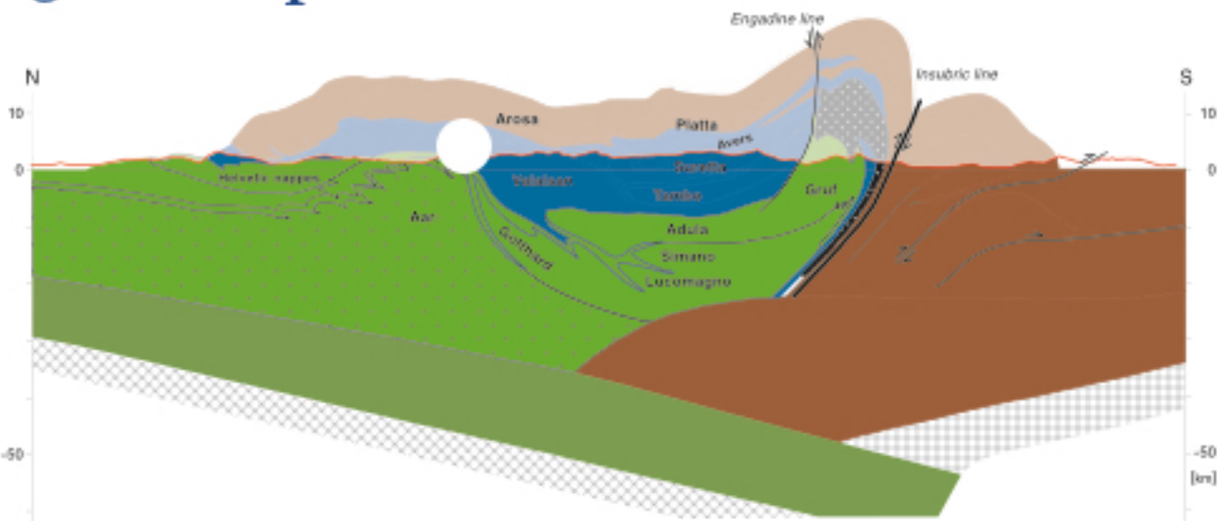


La structure profonde des Alpes varie progressivement d'est en ouest

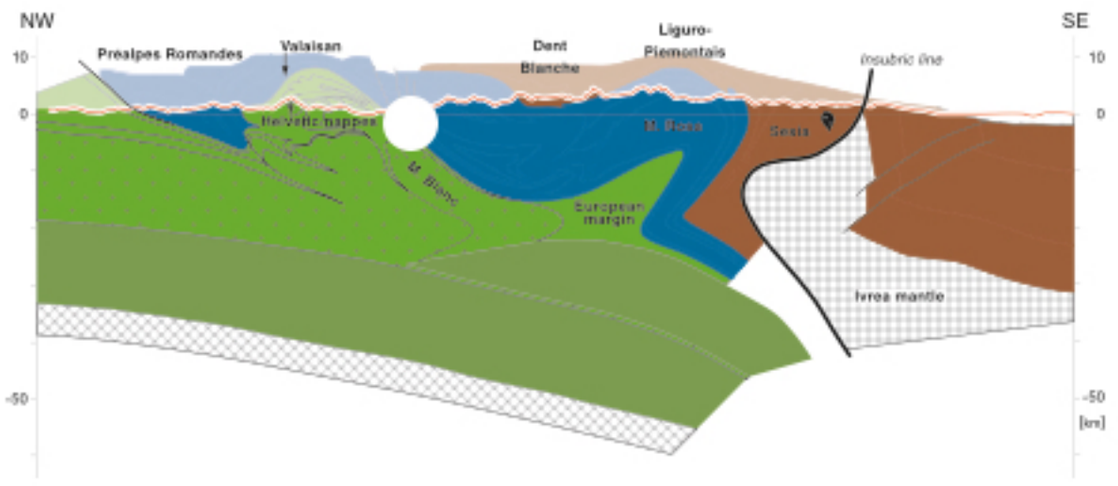
1-Les Alpes occidentales



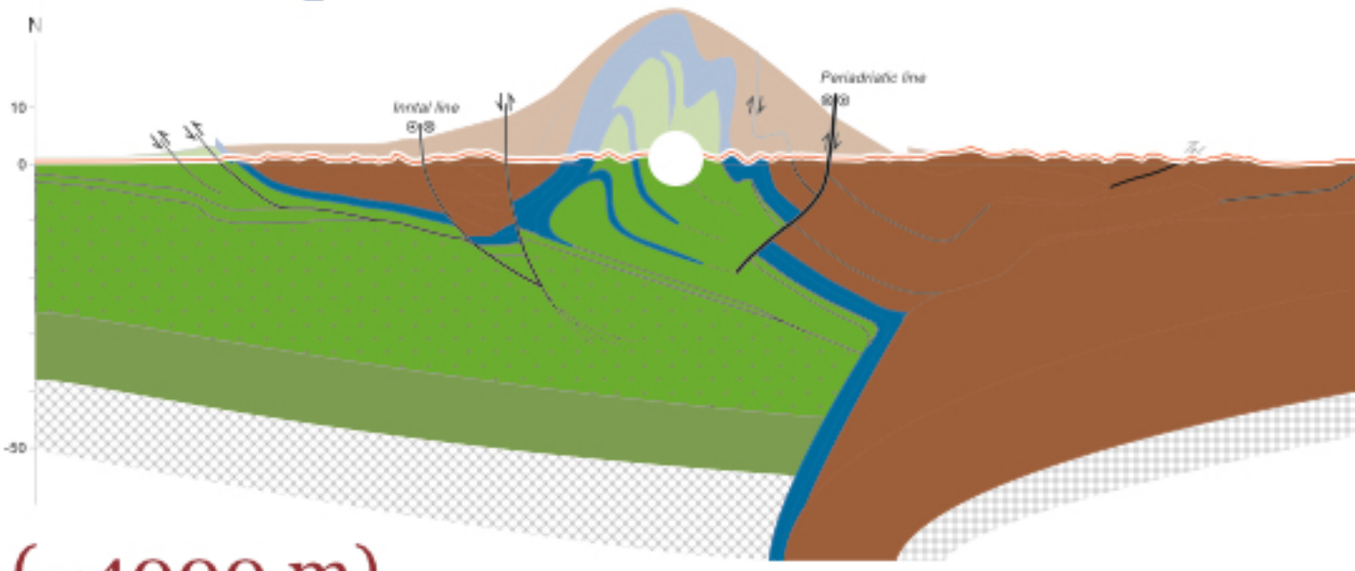
3-Les Alpes centrales



2-Les Alpes occidentales (nord)

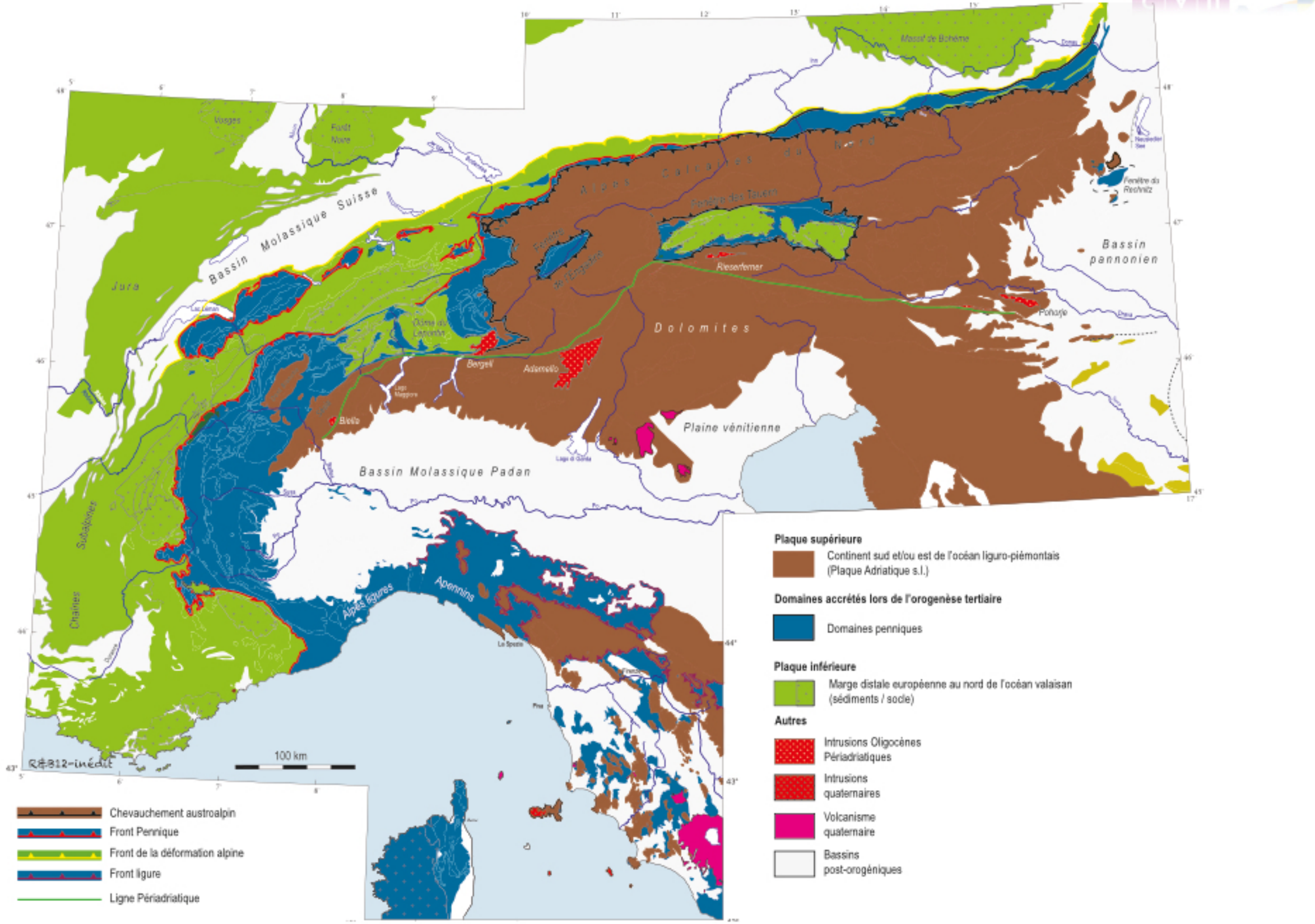


4-Les Alpes orientales

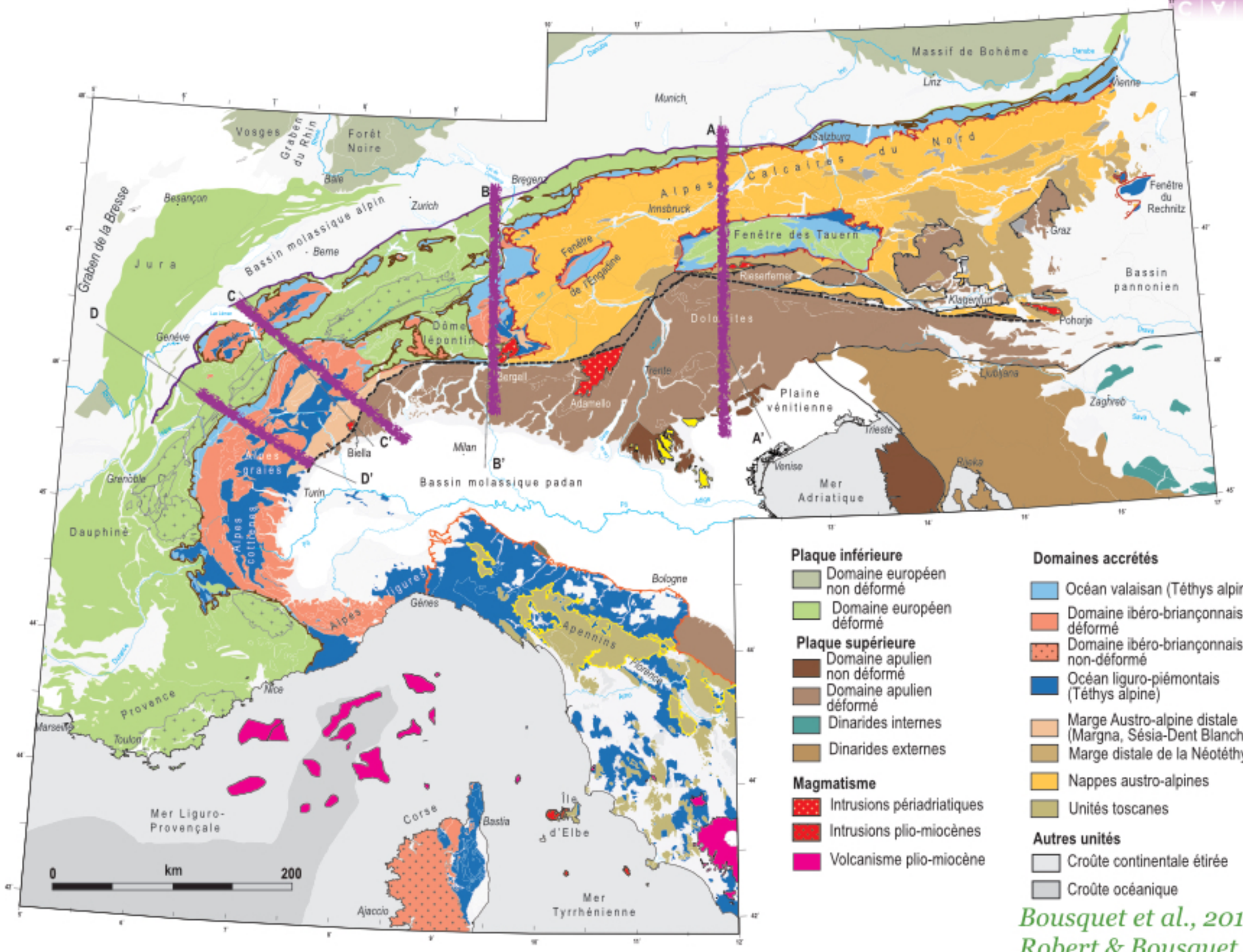


- Maximum topographique (~4000 m)

Le puzzle alpin : simple



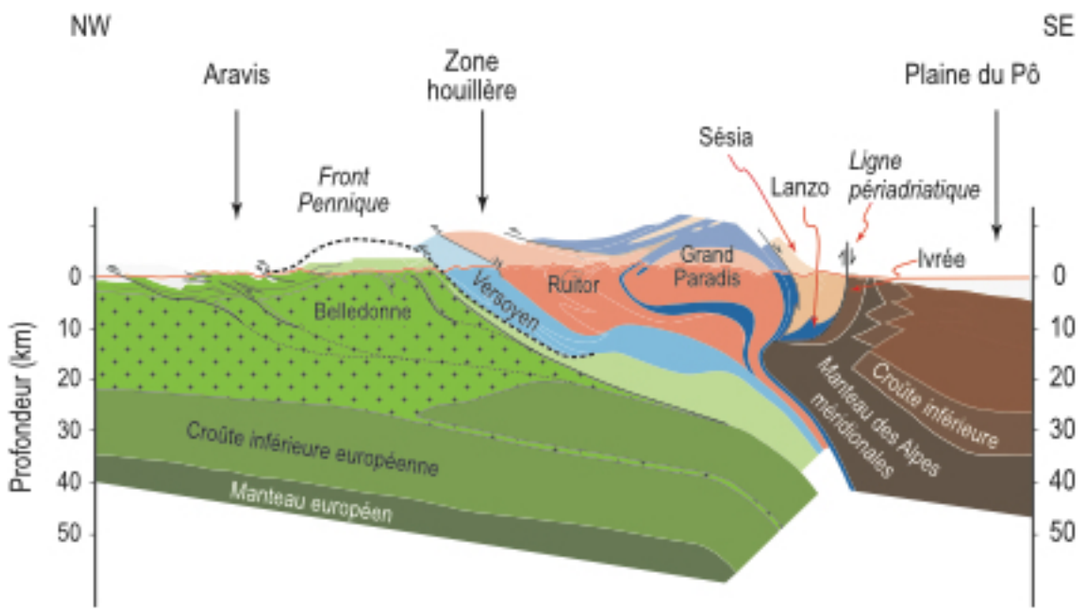
Le puzzle alpin… un peu moins simple



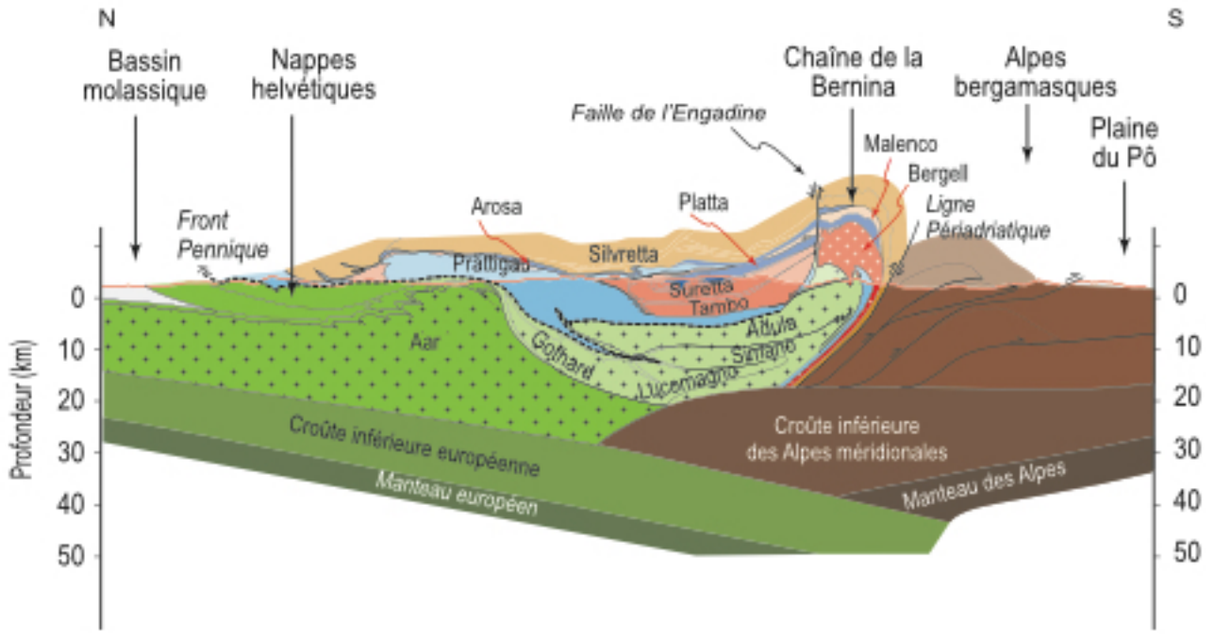
Bousquet et al., 2012
Robert & Bousquet, 2013

La structure des Alpes varie d'Ouest en Est

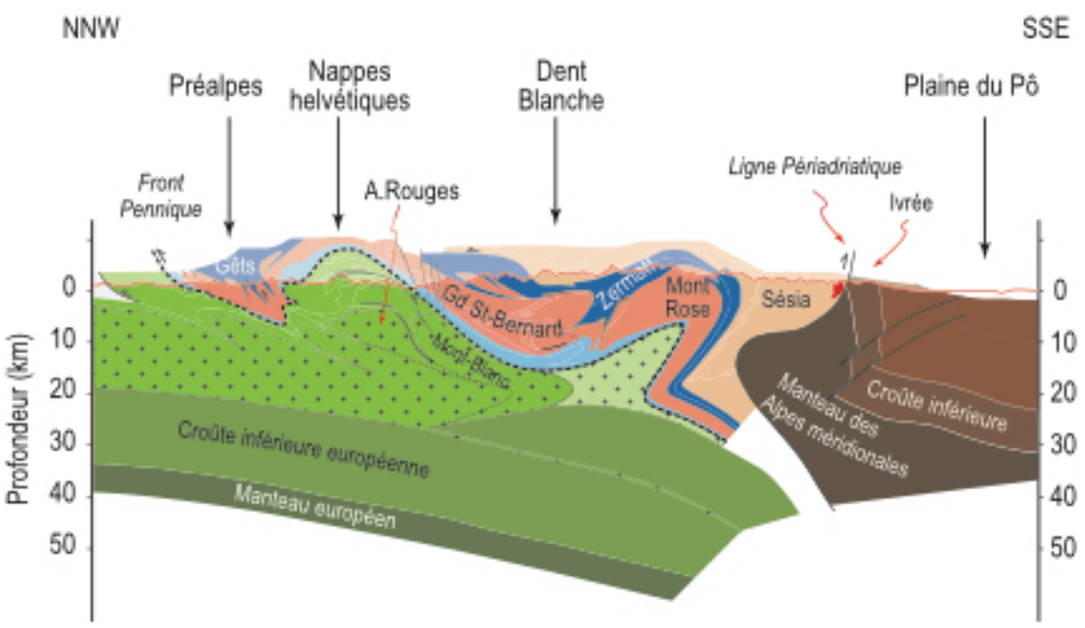
Profil ECORS-CROP



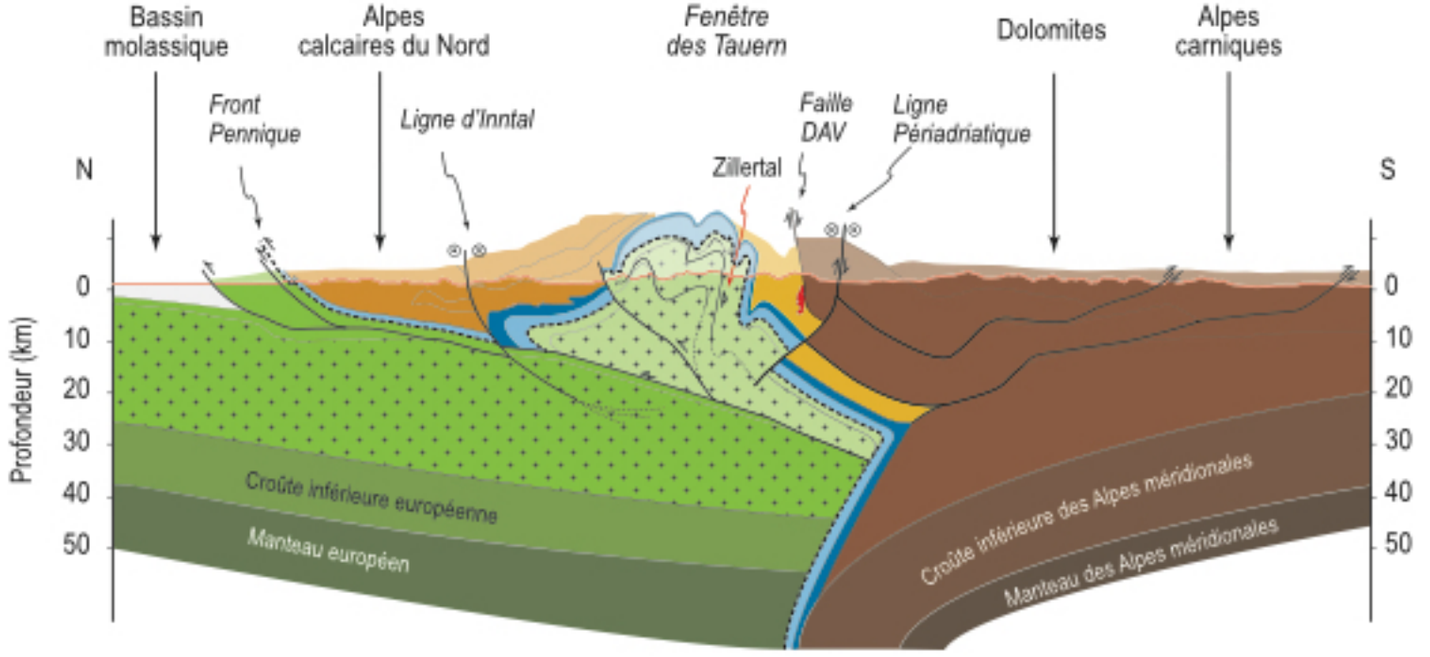
Profil NFP20-West



Profil NFP20-East

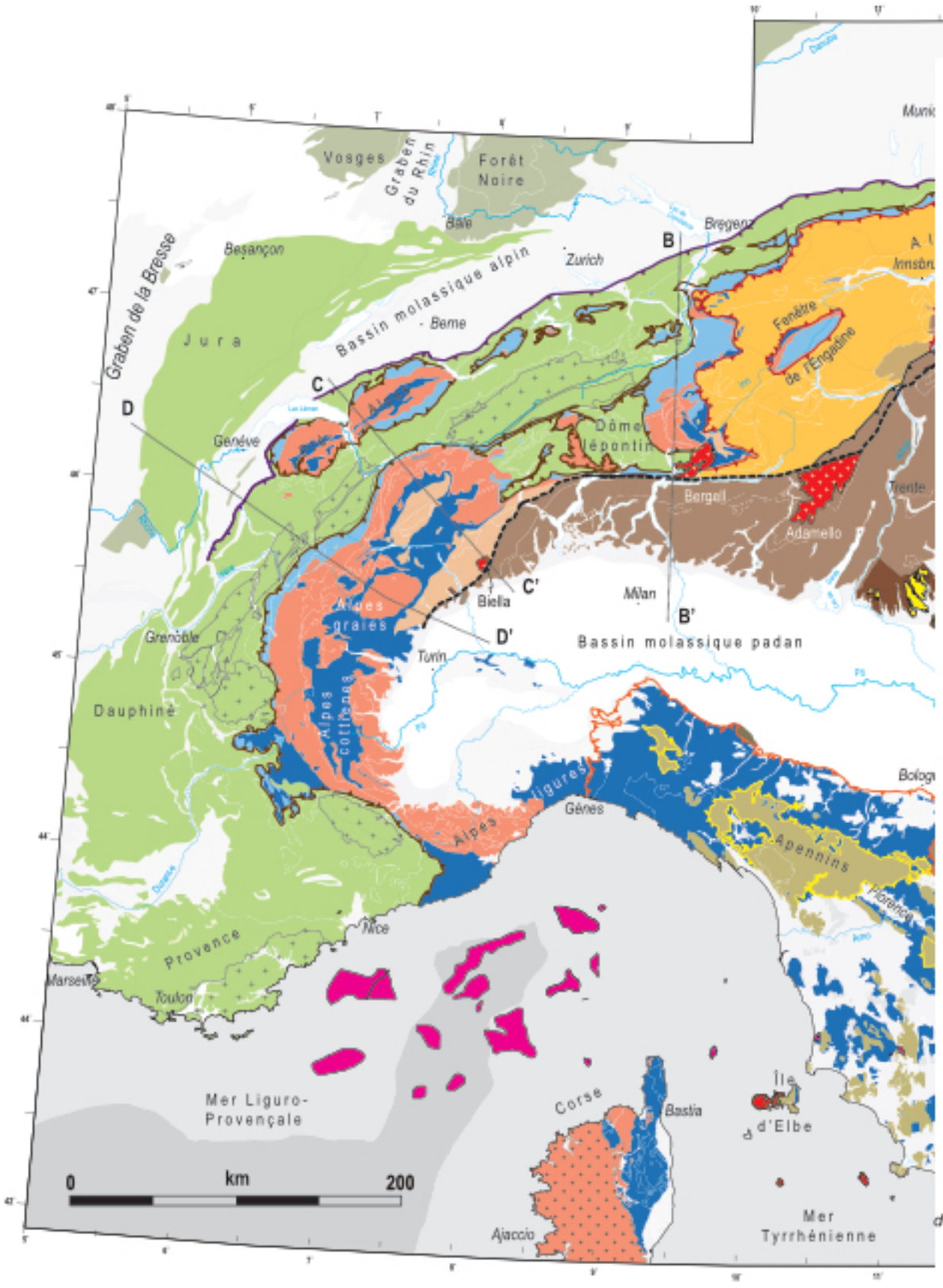


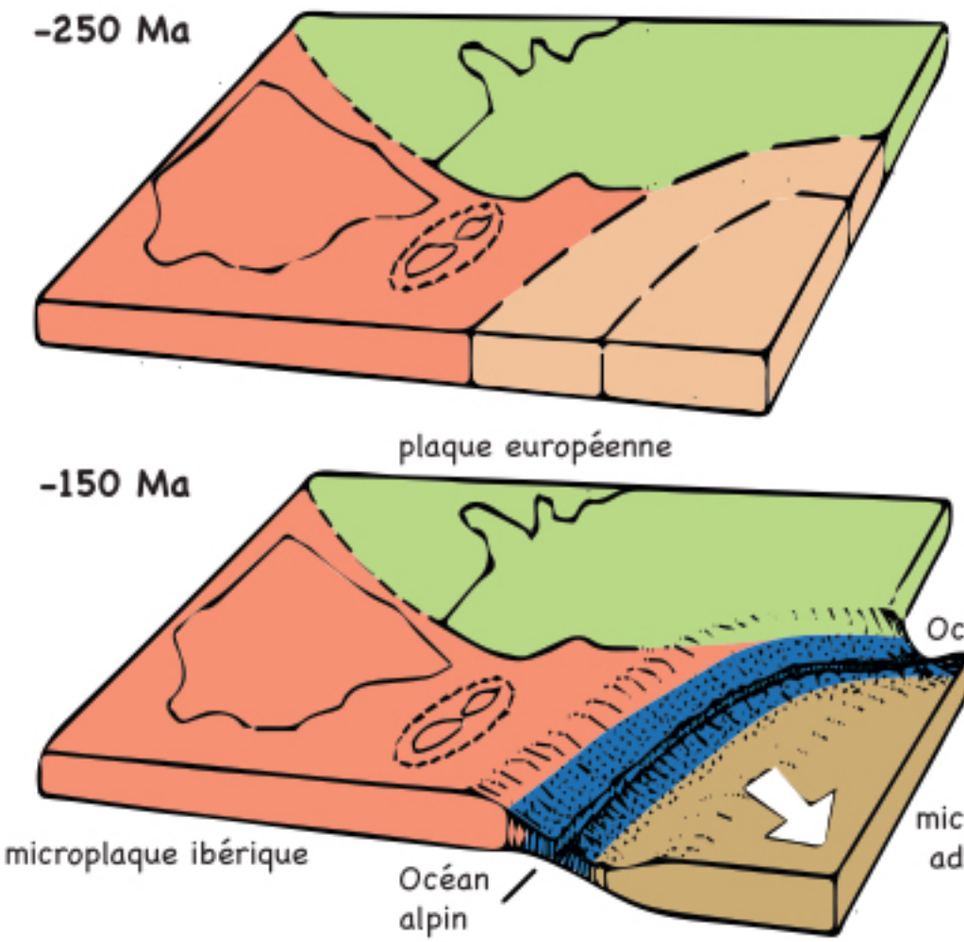
Profil TRANSALP

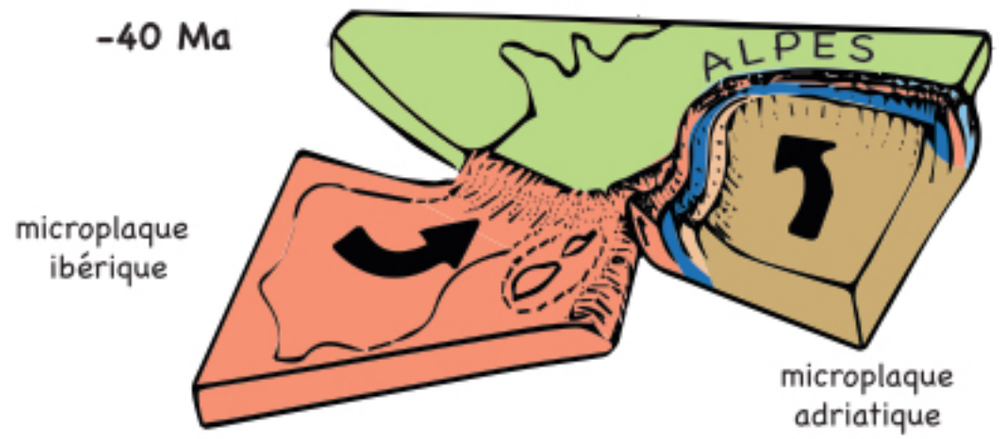


Bousquet et al., 2012
Robert & Bousquet, 2013

La structure des Alpes..... un certain puzzle



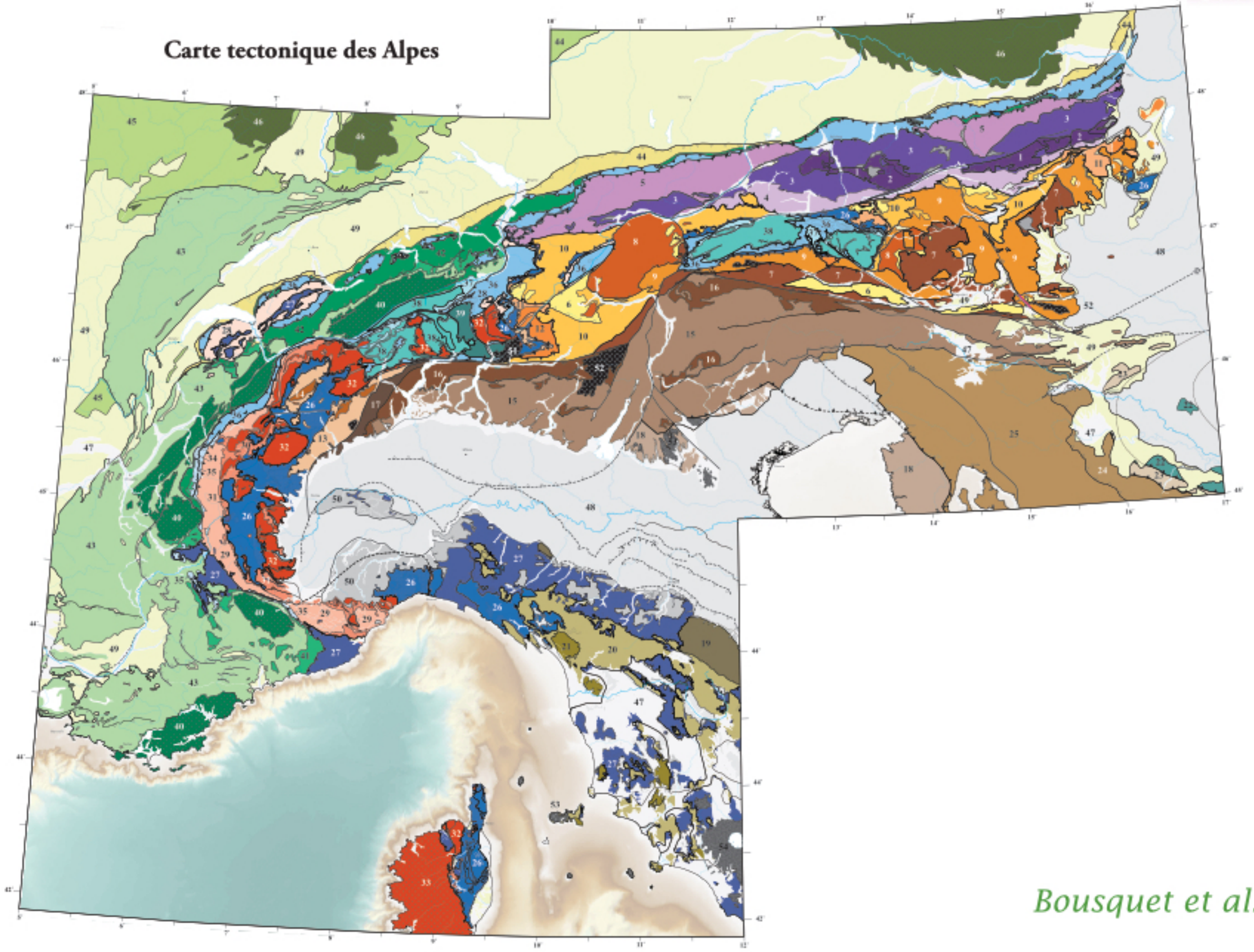




d'après M. Mattauer "Monts et merveilles"

Mattauer, 1978

Le puzzle alpin… vraiment compliqué !



Bousquet et al., 2012

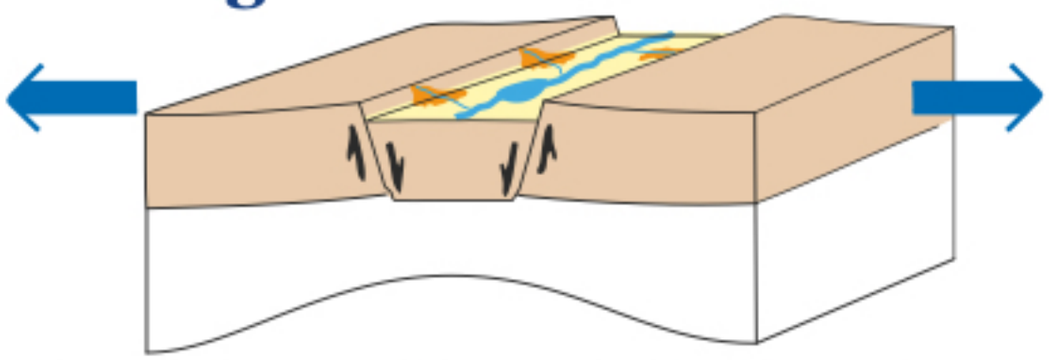
Structure des Alpes centrales

Bloc diagramme des Alpes Centrales

Vaduz
Luzern
Zernez
Thun
Tirano
MOLASSE
HELVETICS
AAR
GOTTHARD
AUSTROALPINE
Prättigau
Tonals
Grava
Adula
Tambo
Suretta
Avers
Châtel St Denis
PRÉALPES
Simme
Niesen
Brig
Leventine
Simano
Antigorio
Maggia
TONALE LINE
Sion
Rhone - Simplon Line
Siviez - Mischabel
Mont Fort
DENT BLANCHE
Mt. Rosa
Locarno
IVREA
AIG. ROUGES
Mt. BLANC
Pontis
Aosta Line
SESIA
MOLASSE
European Crust
MOHO
Adriatic Crust
MOHO
CANAVESE SUTURE
PIEMONT SUTURE
VALAIS SUTURE
100km
R&B,12

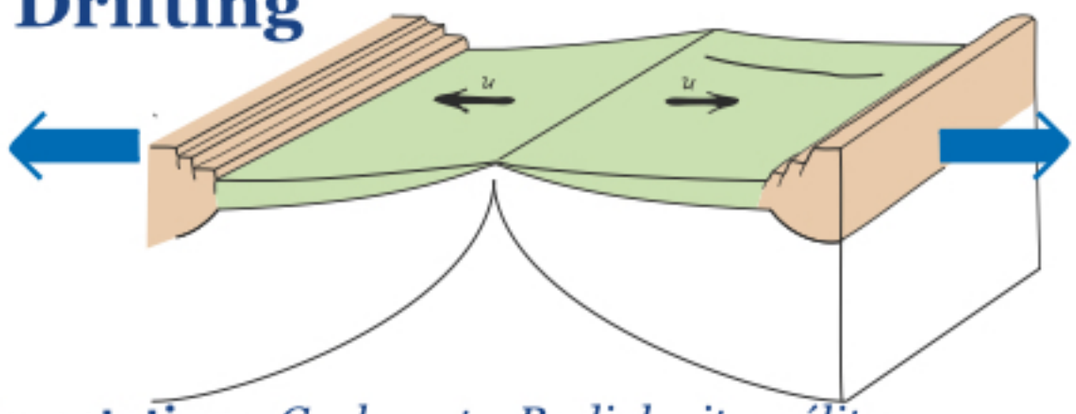
Caractéristiques du Cycle de Wilson

Rifting



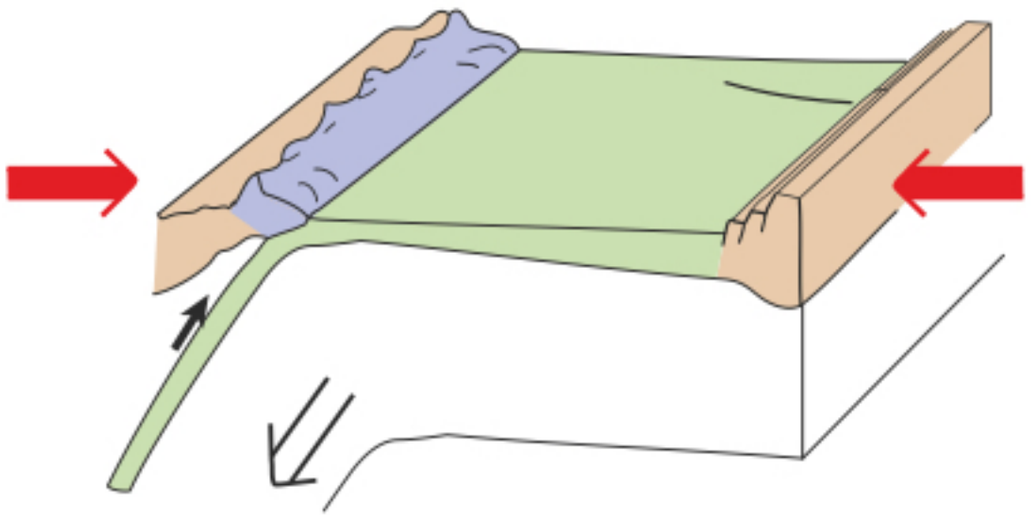
Sédimentation : *Brèches, Dolomite, Évaporite*
Tectonique : *Extension (Failles normales)*
Métamorphisme : *Abukuma (HT-LP)*
Magmatisme : *sous-placage magmatique, rhyolites*

Drifting



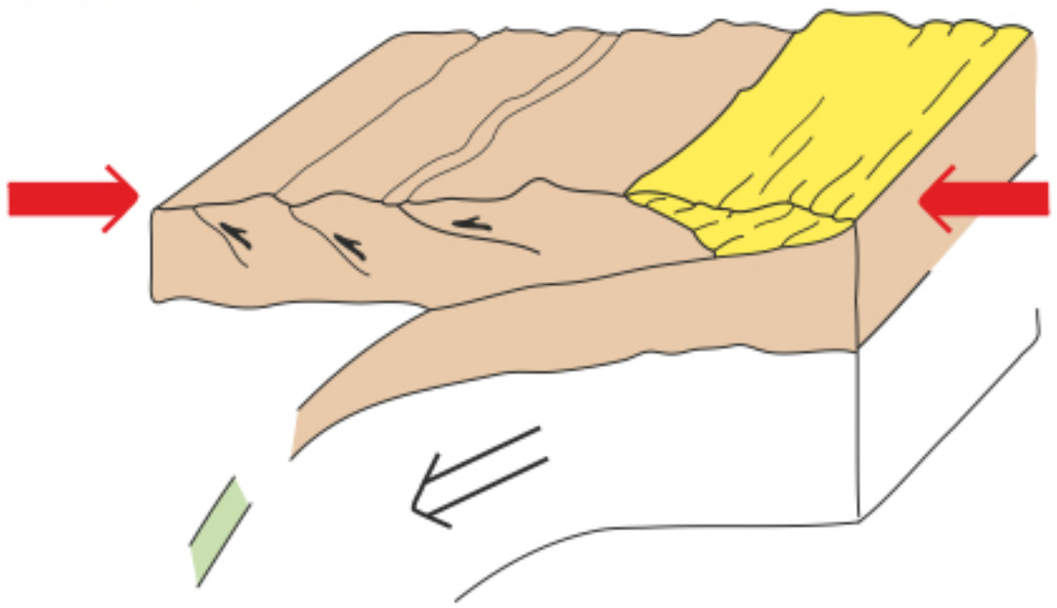
Sédimentation : *Carbonate, Radiolarite, pélites*
Tectonique : *Extension au niveai de la ride*
Métamorphisme : *Hydrothermalisme*
Magmatisme : *Tholéite (MORB)*

Subduction



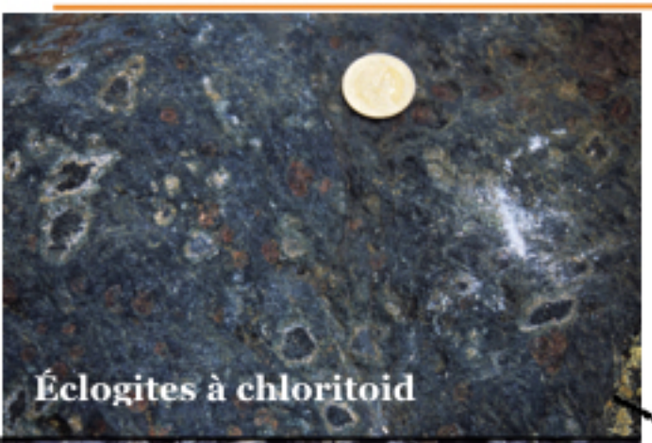
Sédimentation : *Flysch*
Tectonique : *Compression (chevauchements)*
Métamorphisme : *Franciscain (BT-HP)*
Magmatisme : *calco-alcalin*

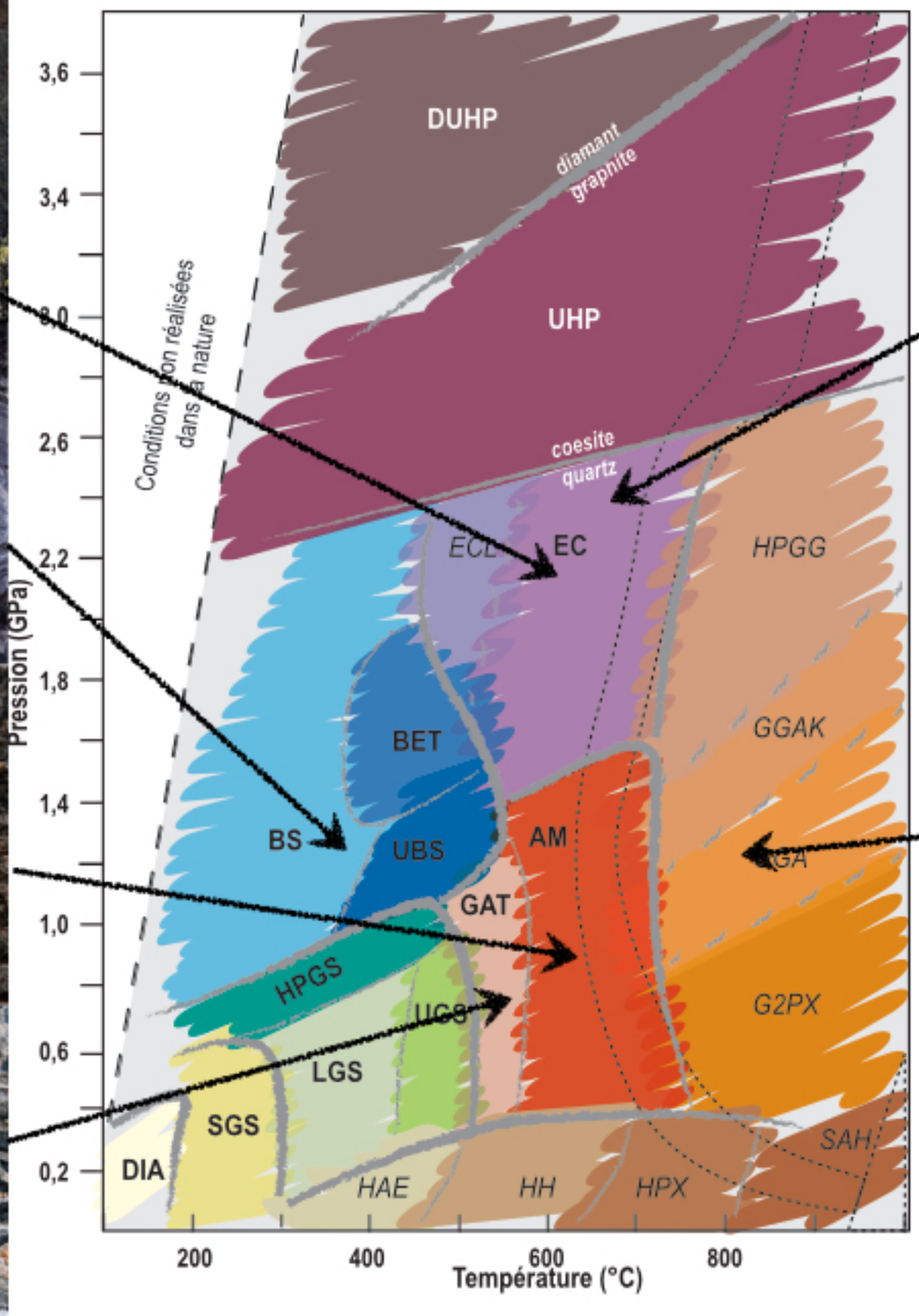
Collision

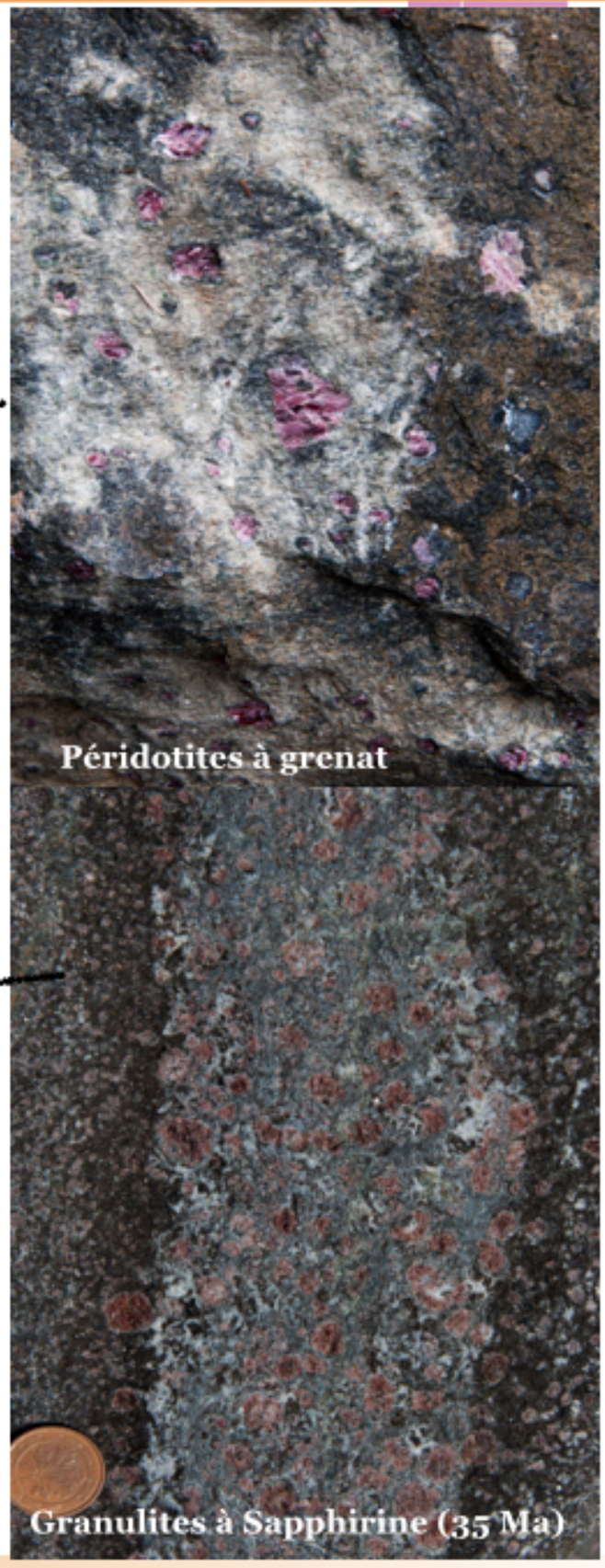


Sédimentation : *Molasse (conglomérats)*
Tectonique : *Compression, rétrochevauchement, rétroplis*
Métamorphisme : *Barrovien (MT-MP)*
Magmatisme : *leucogranites, anatexie*

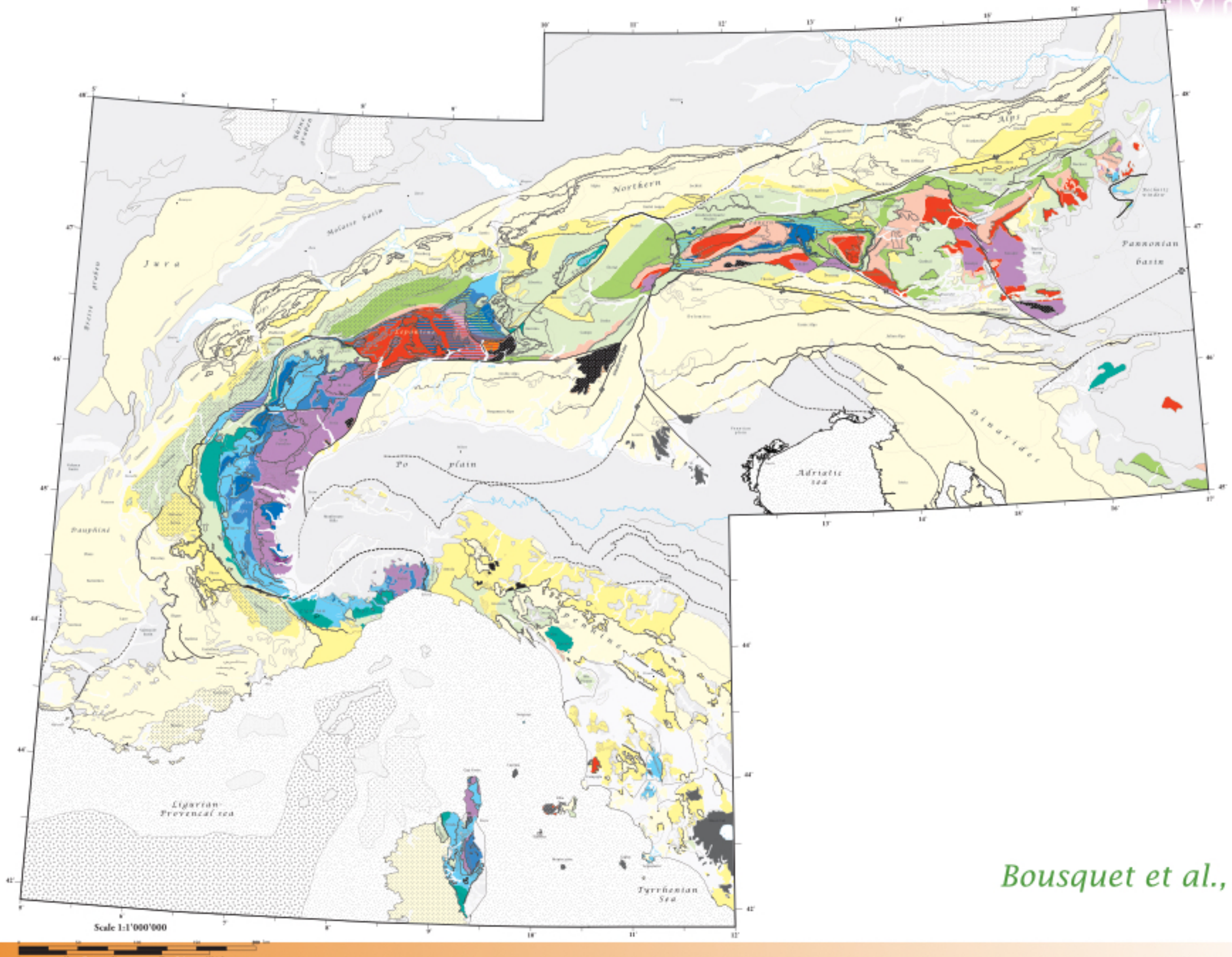
Le métamorphisme alpin est TRÈS diversifié





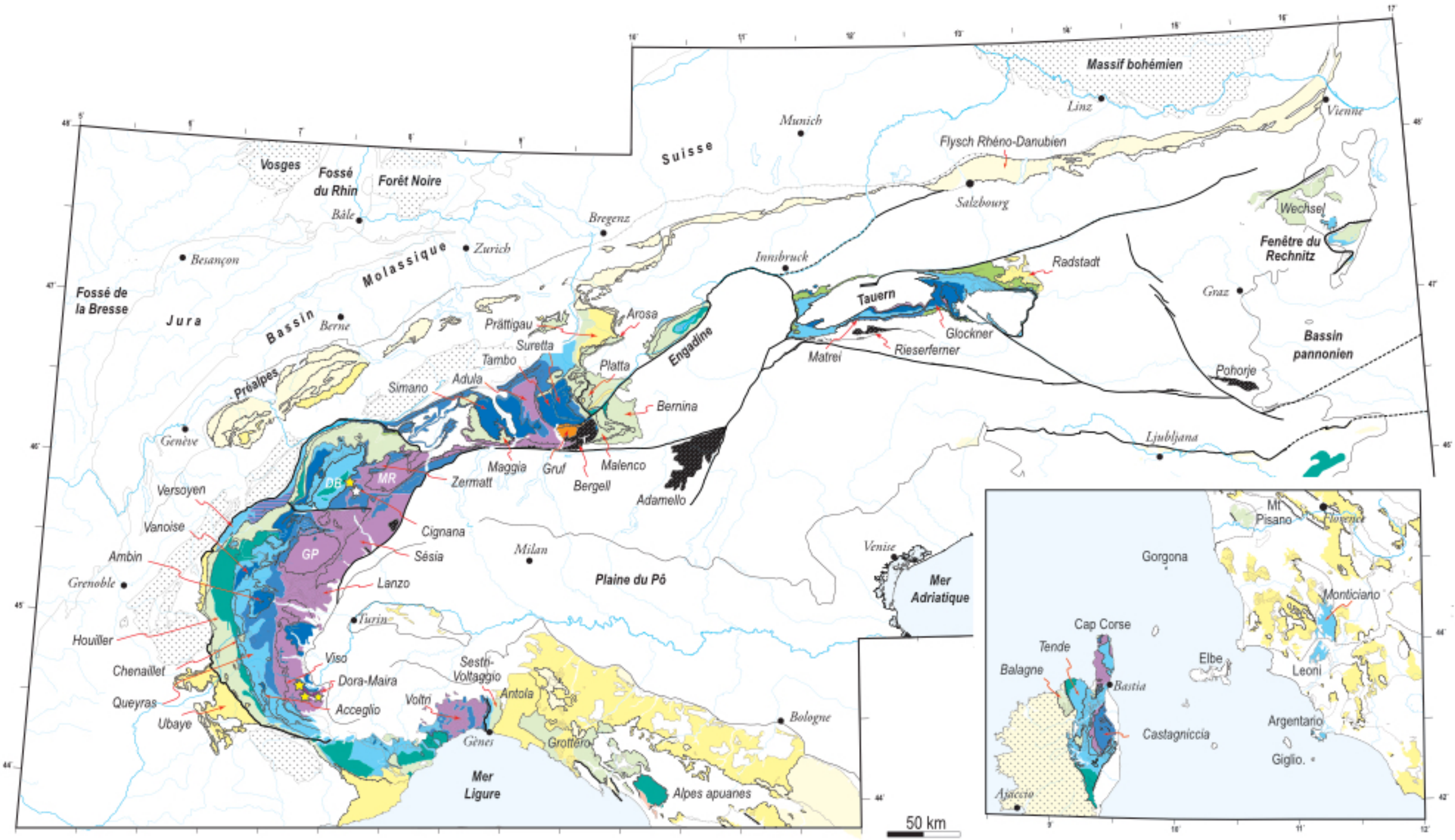


Structure métamorphique des Alpes



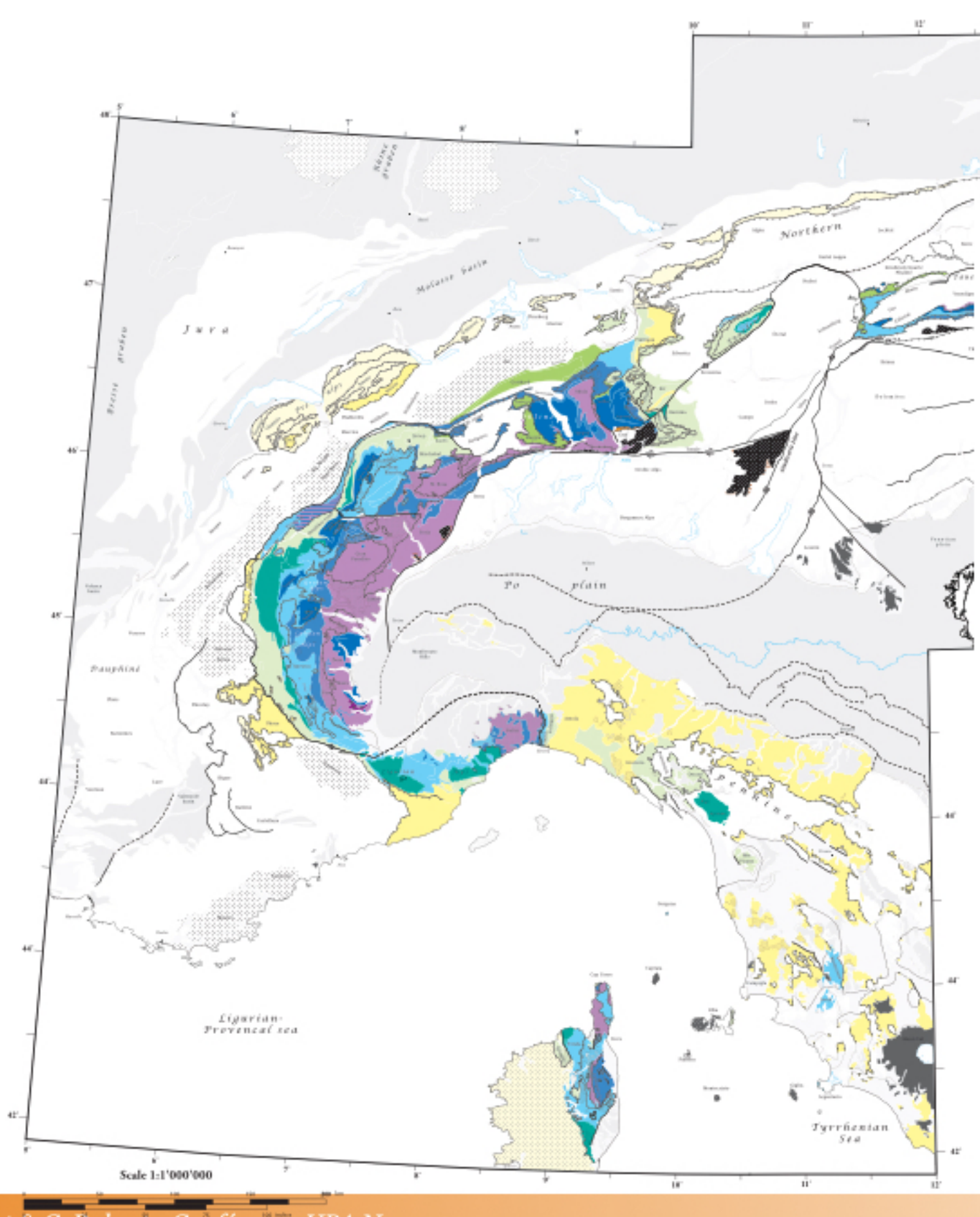
Bousquet et al., 2012

Le métamorphisme de subduction au Tertiaire

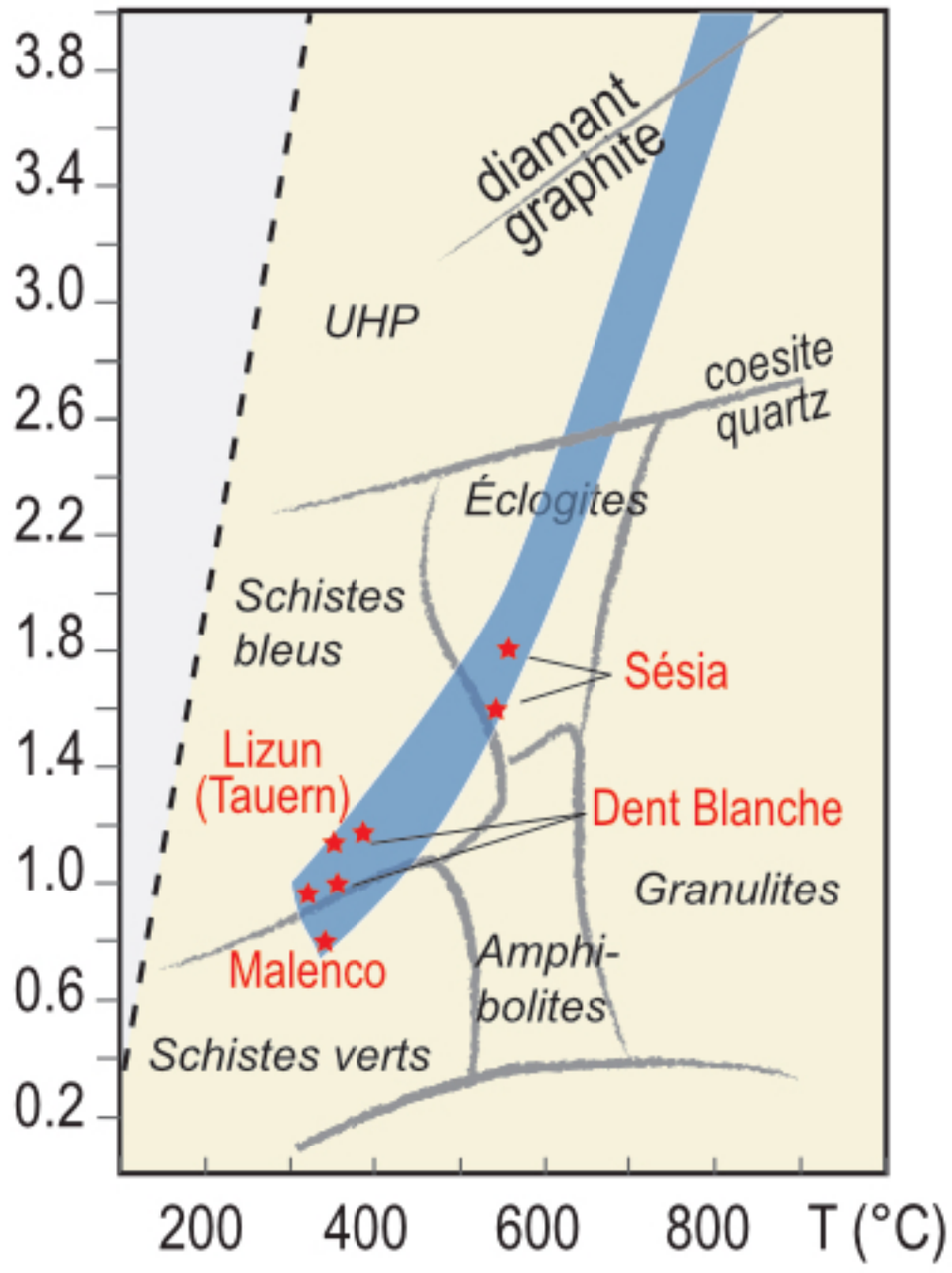


Bousquet et al., 2012
Robert & Bousquet, 2013

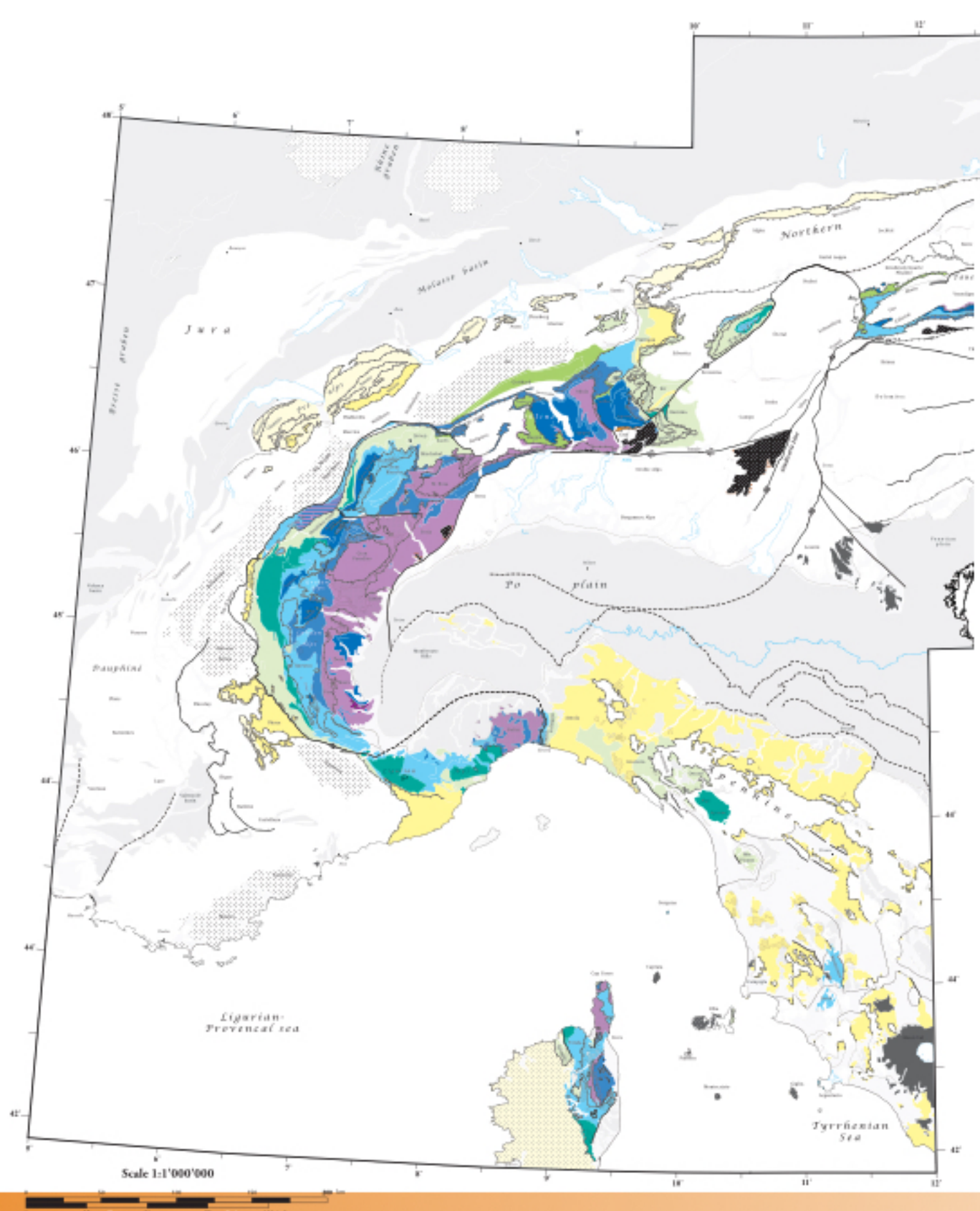
Processus métamorphiques au Tertiaire



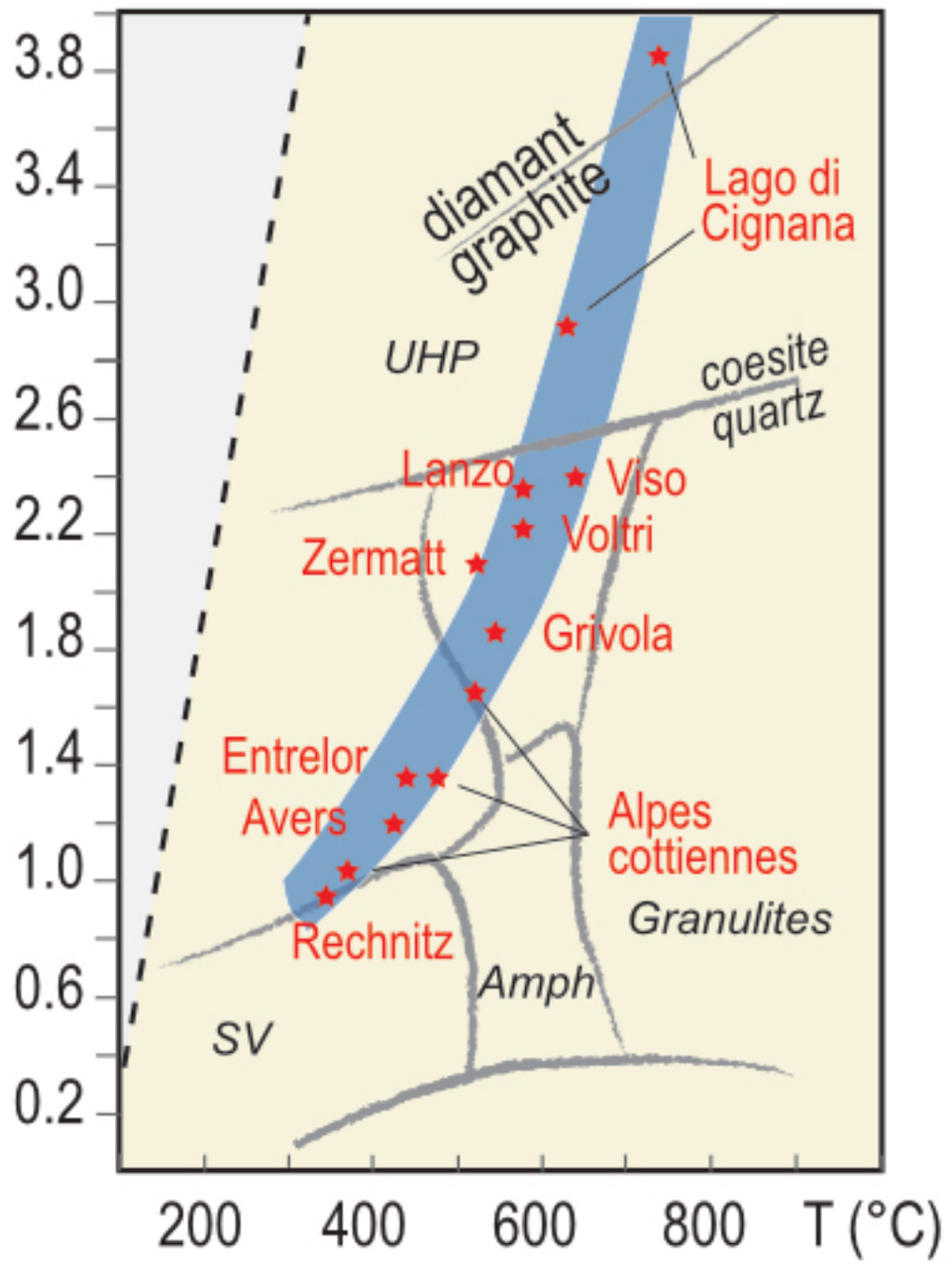
A. Austro-alpin inférieur



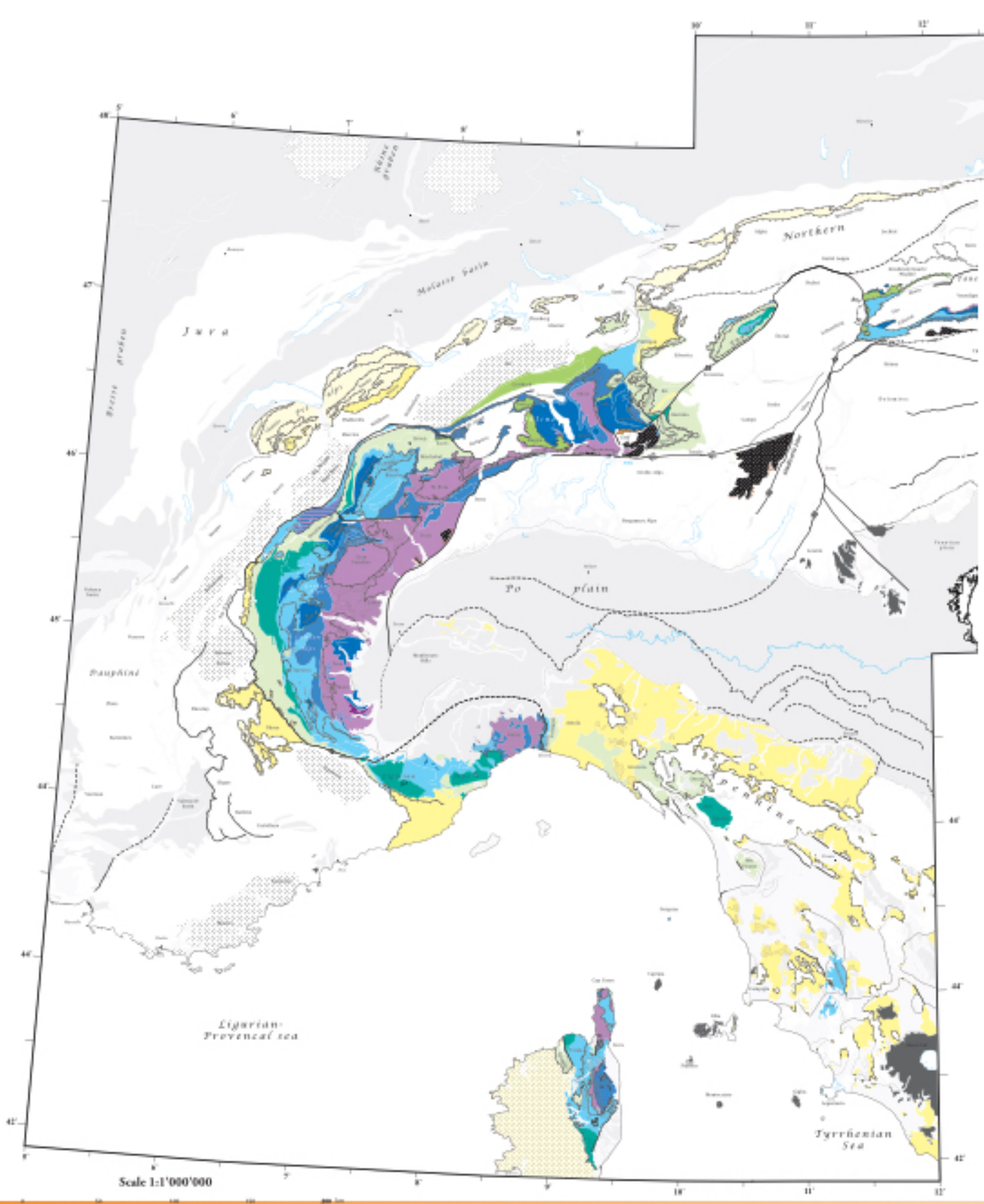
Processus métamorphiques au Tertiaire



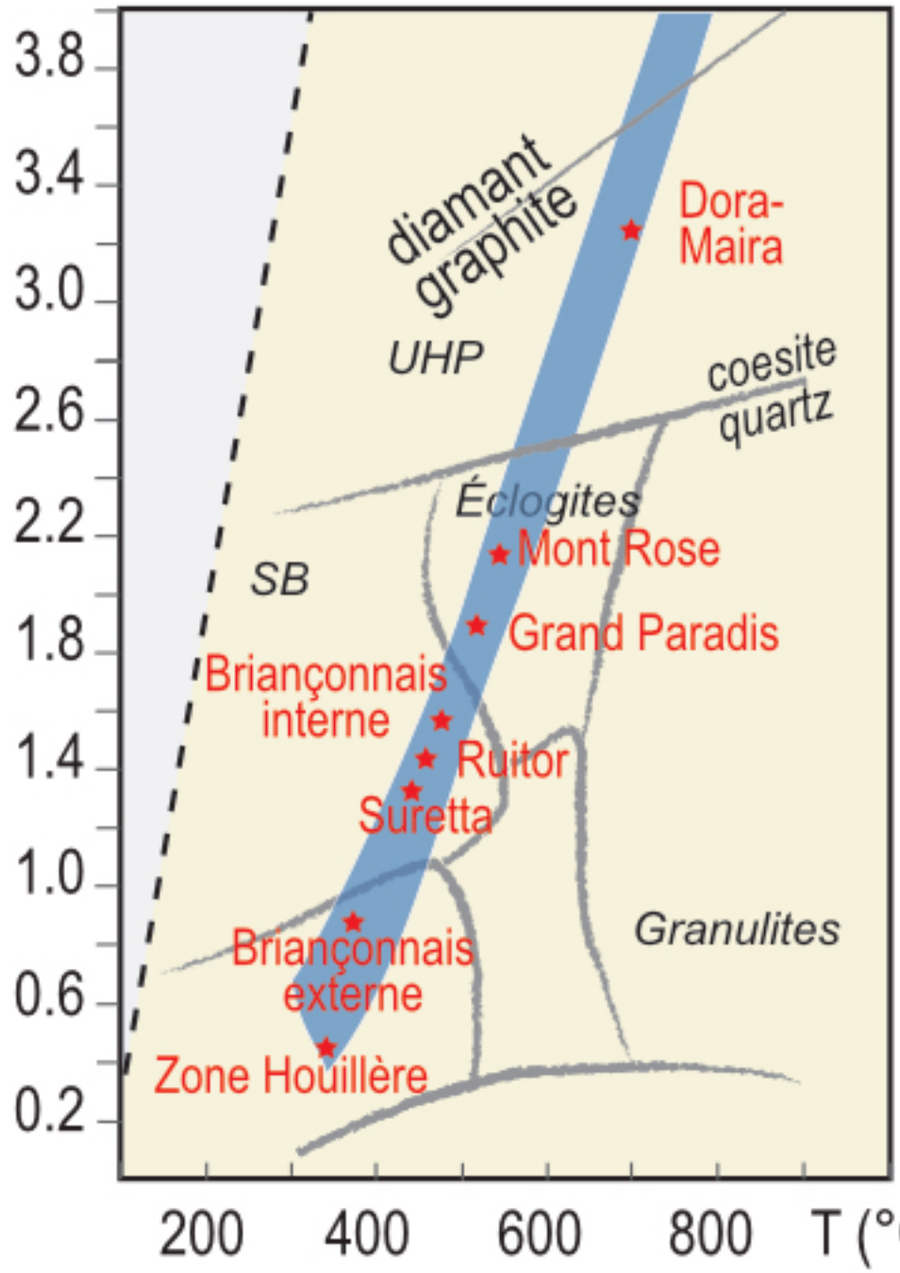
B. Liguro-piémontais



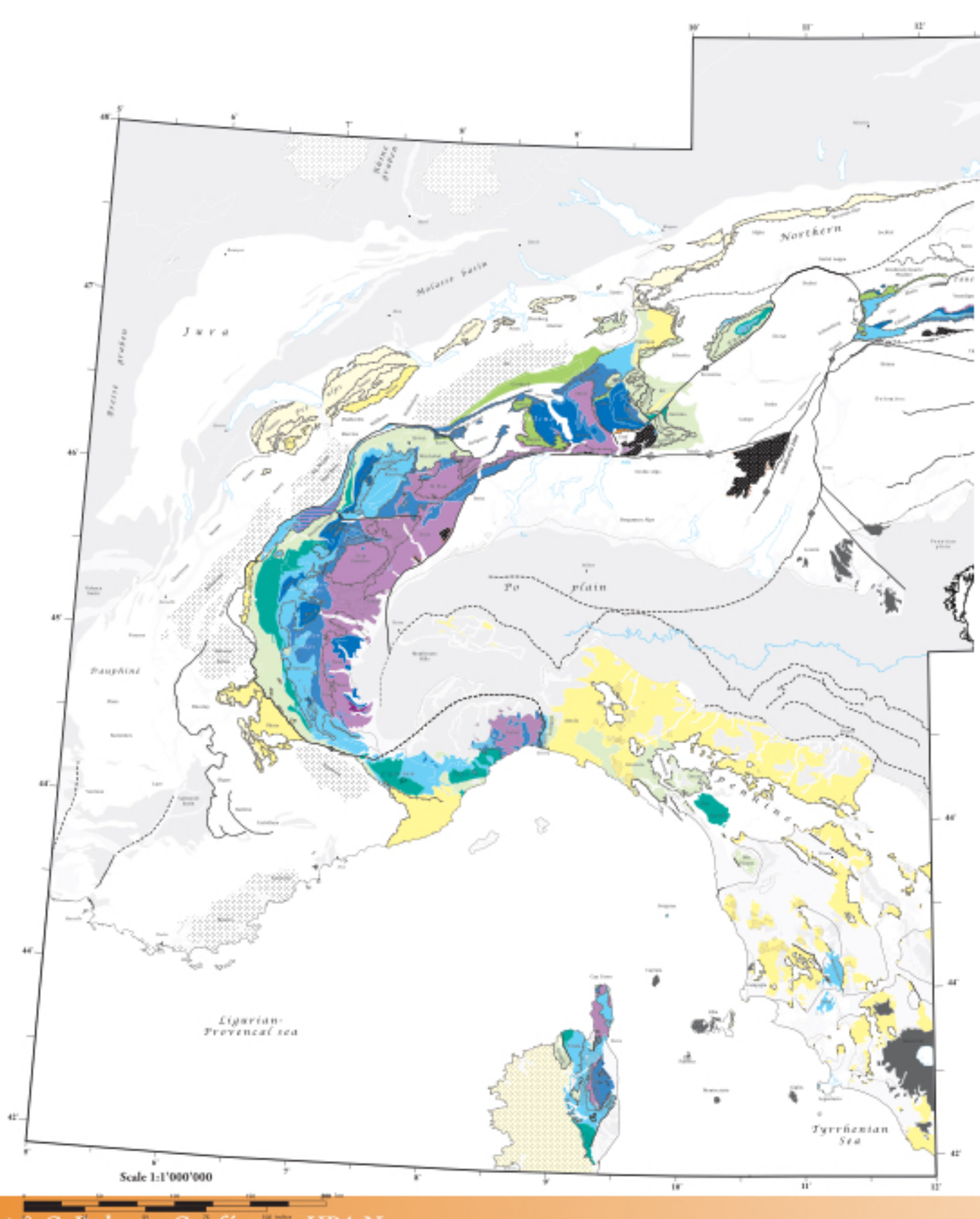
Processus métamorphiques au Tertiaire

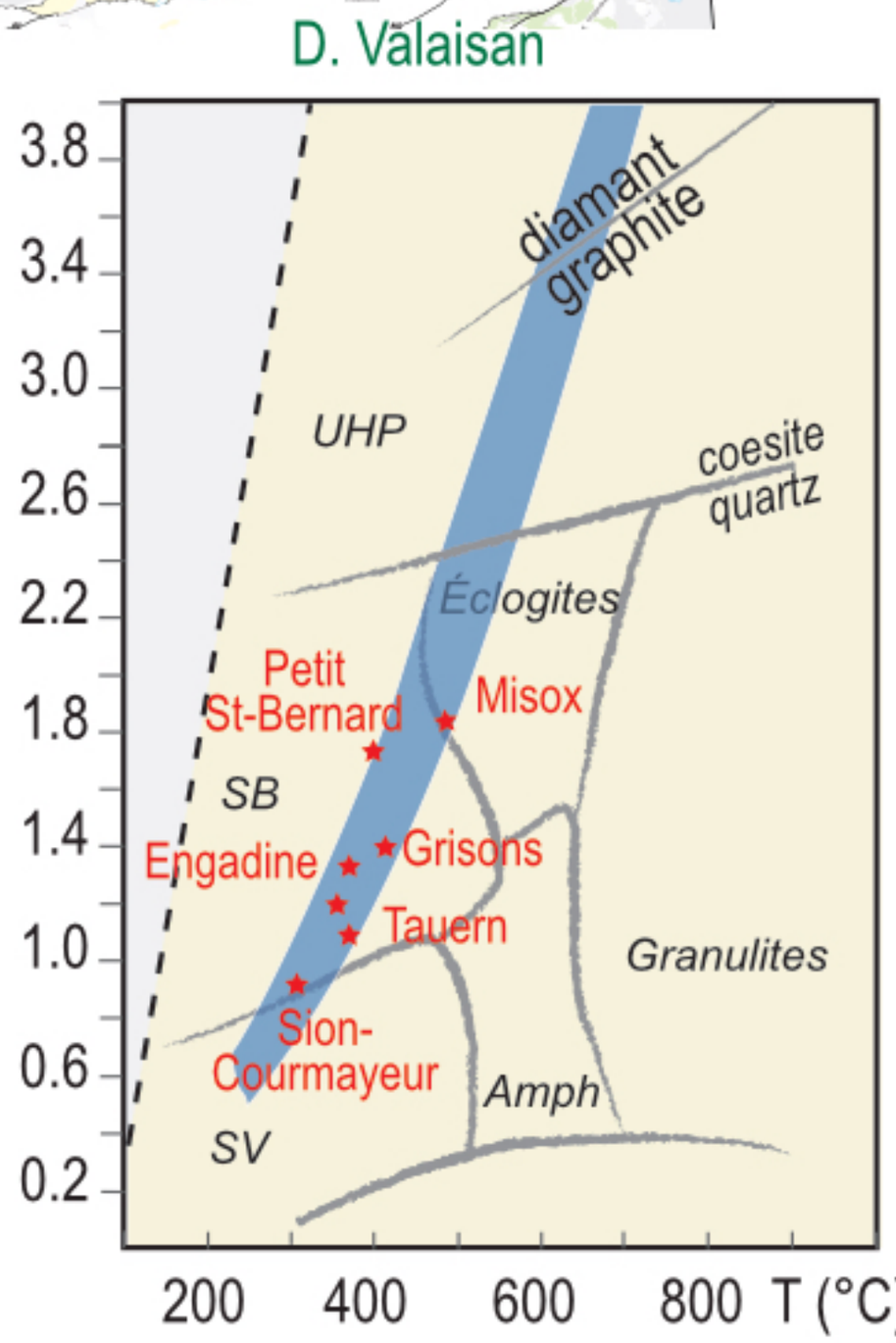


C. Briançonnais

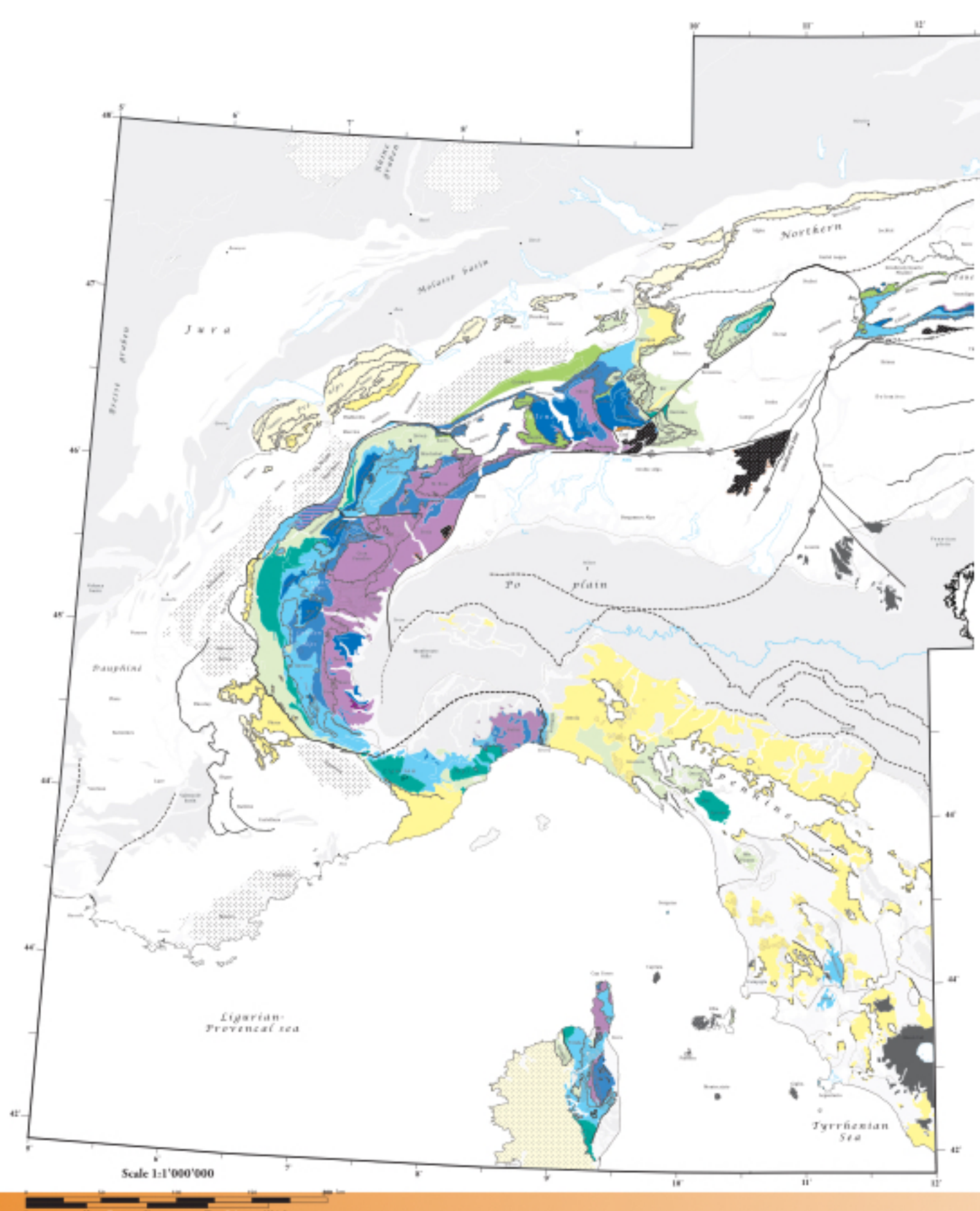


Processus métamorphiques au Tertiaire

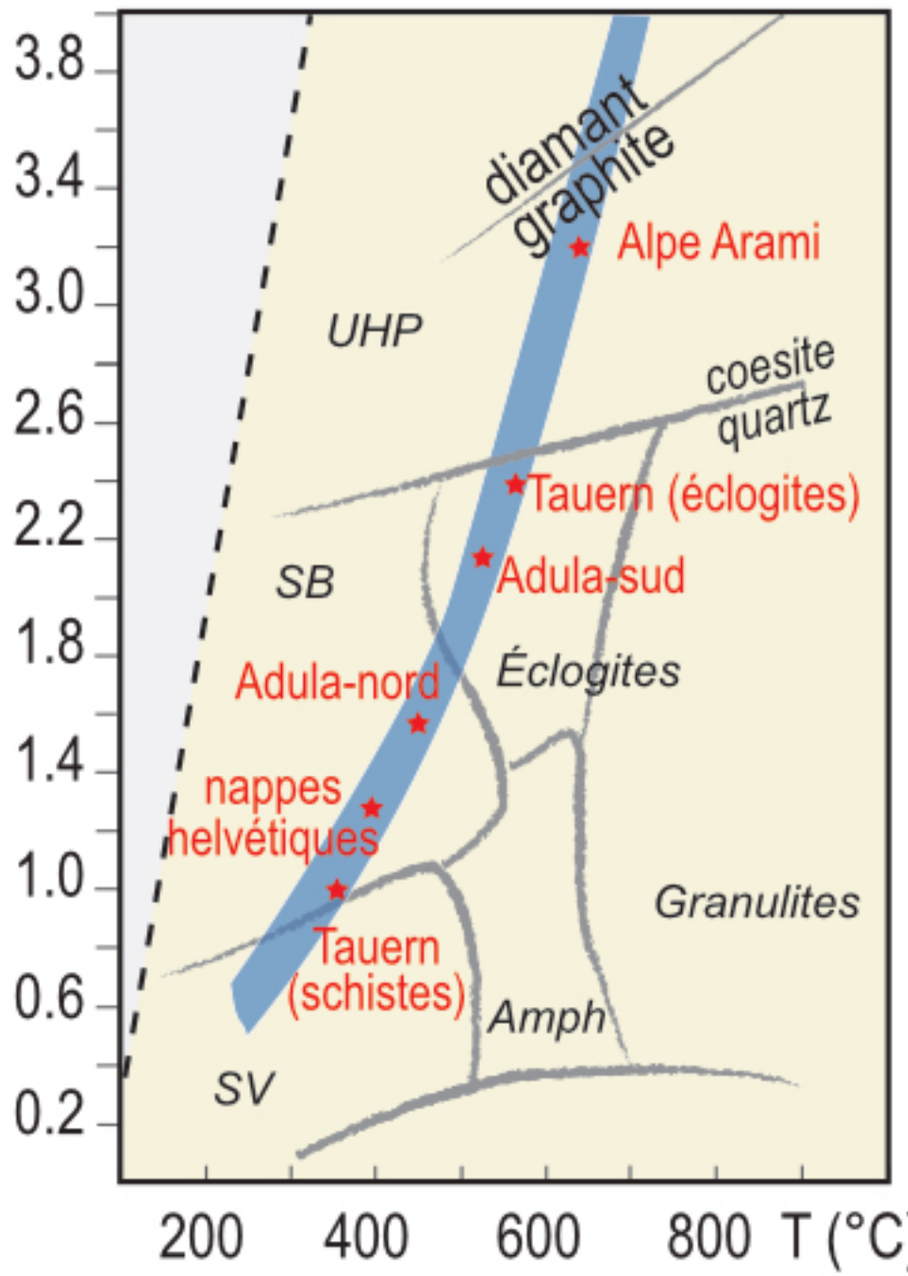




Processus métamorphiques au Tertiaire



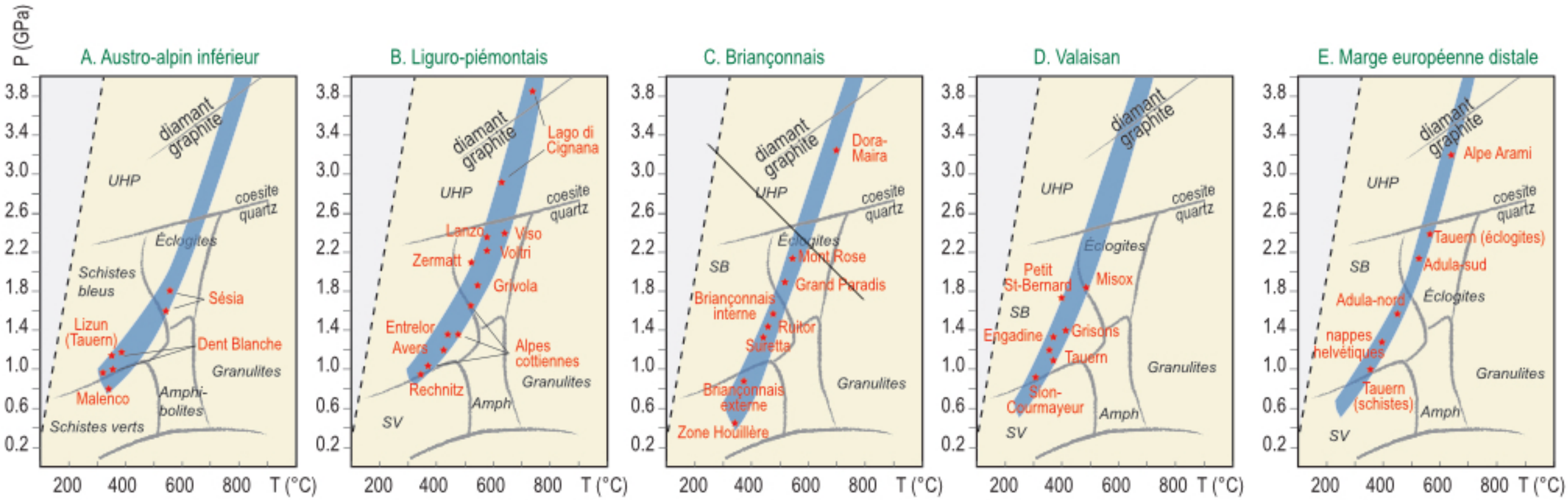
E. Marge européenne distale



Le métamorphisme de subduction

Age de l'épisode de HP

70-65 Ma — *55-50 Ma* — *48-42 Ma* — *40-37 Ma* — *38-35 Ma*



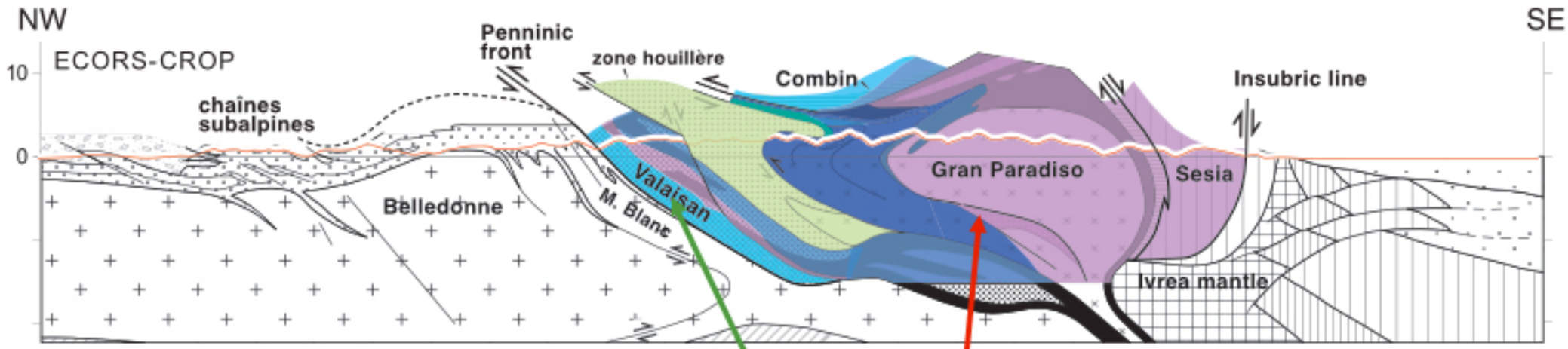
Gradient géothermique de la subduction

15-12°C/km — *12-10°C/km* — *7,5°C/km* — *10°C/km*

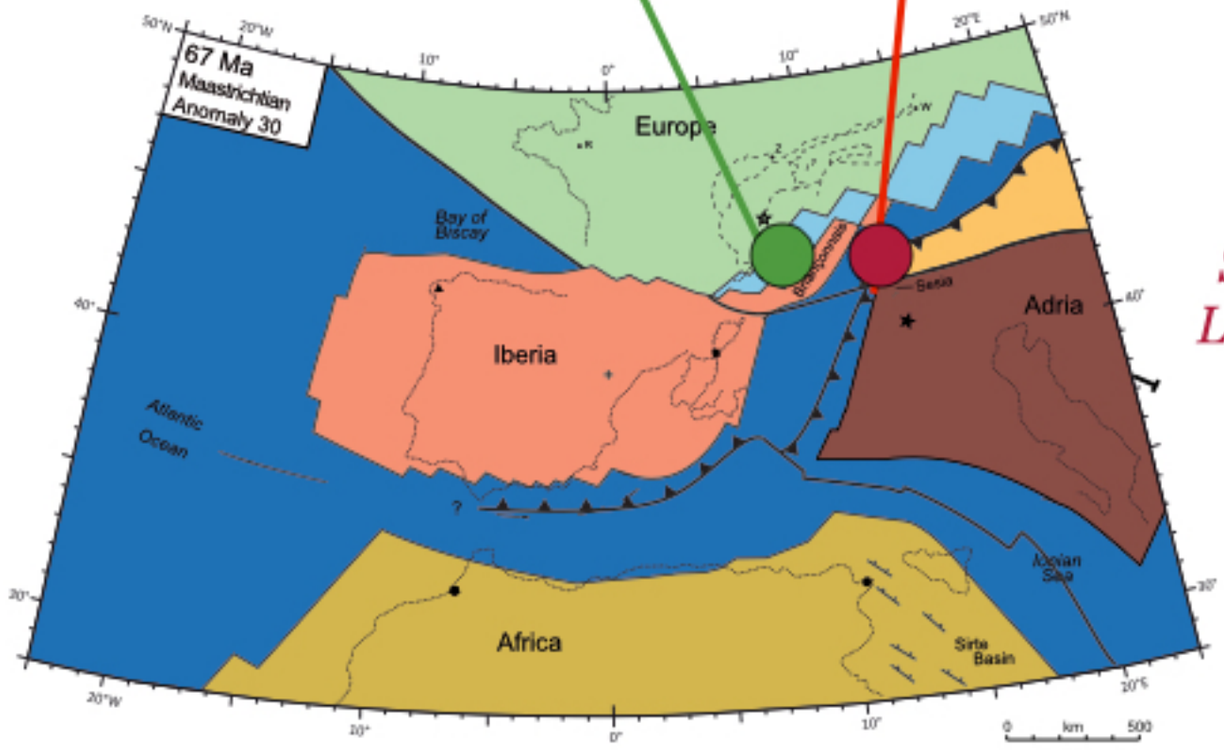
Vitesse de subduction

15 mm/an — *13,5 mm/an* — *≥5,5 mm/an* — *~ 4 mm/an*

Processus de subduction



Bousquet et al., 2008
Geol. Soc. London Sp Pub



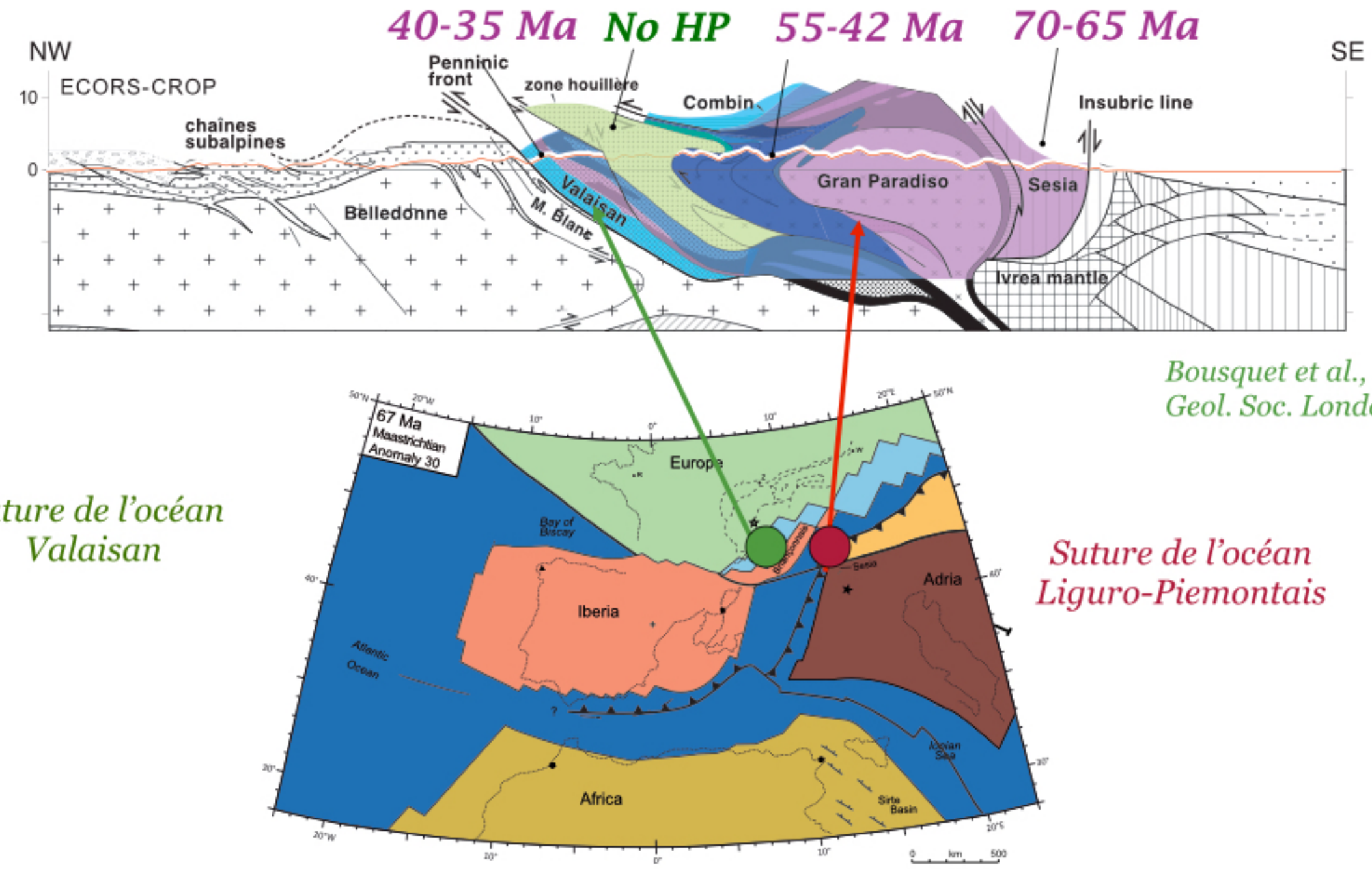
Suture de l'océan Valaisan

Suture de l'océan Liguro-Piemontais

Des **processus de subduction continus** (accrétion d'océans et de terranes)
de ~70 Ma à 35 Ma avec une **exhumation continue et syn-subduction** des roches de HP

Processus de subduction

Migration de la subduction avec le temps



Bousquet et al., 2008
Geol. Soc. London Sp Pub

Suture de l'océan Valaisan

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Des **processus de subduction continus** (accrétion d'océans et de terranes)
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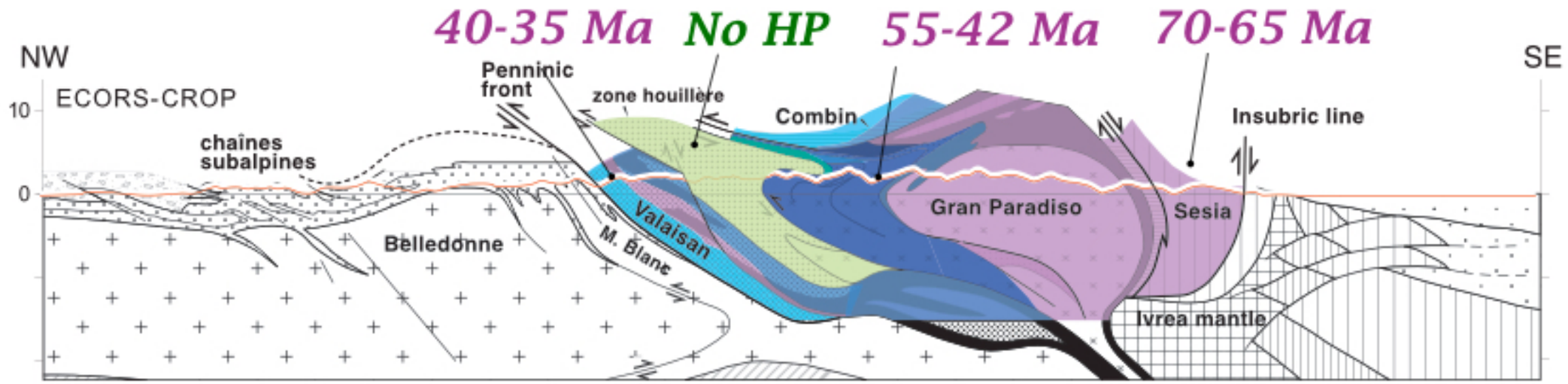
Processus de subduction

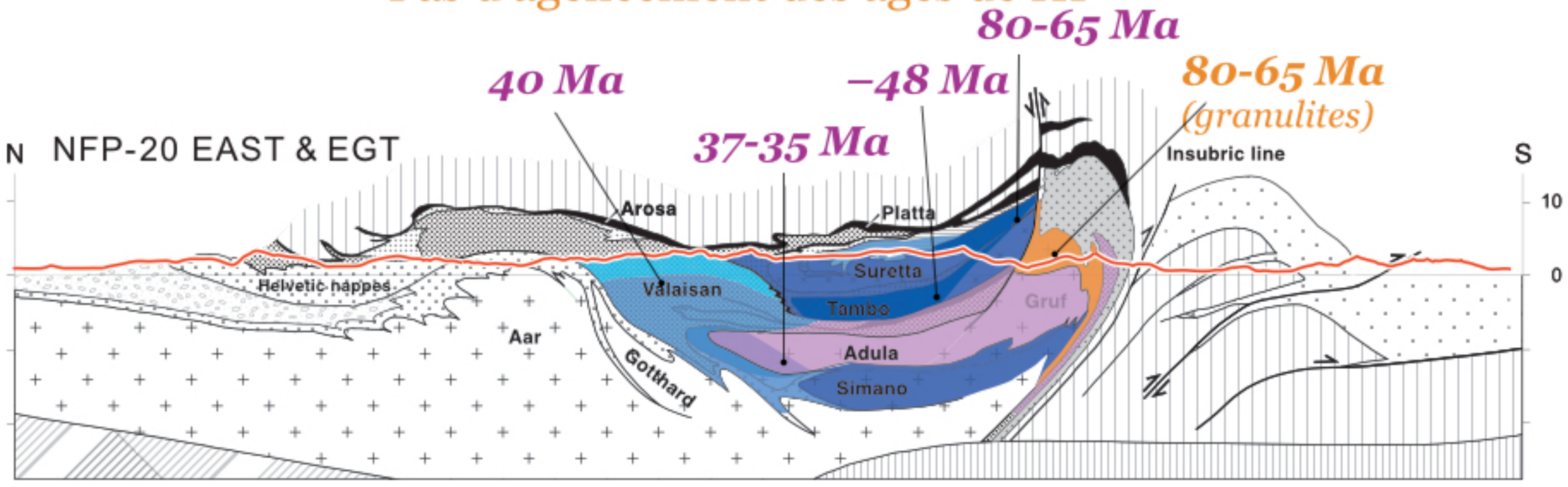
Migration de la subduction avec le temps



Processus de subduction (accrétion de domaines océaniques et de terranes) avec **une exhumation continue** des roches de HP

Bousquet et al., 2008

Pas d'agencement des âges de HP



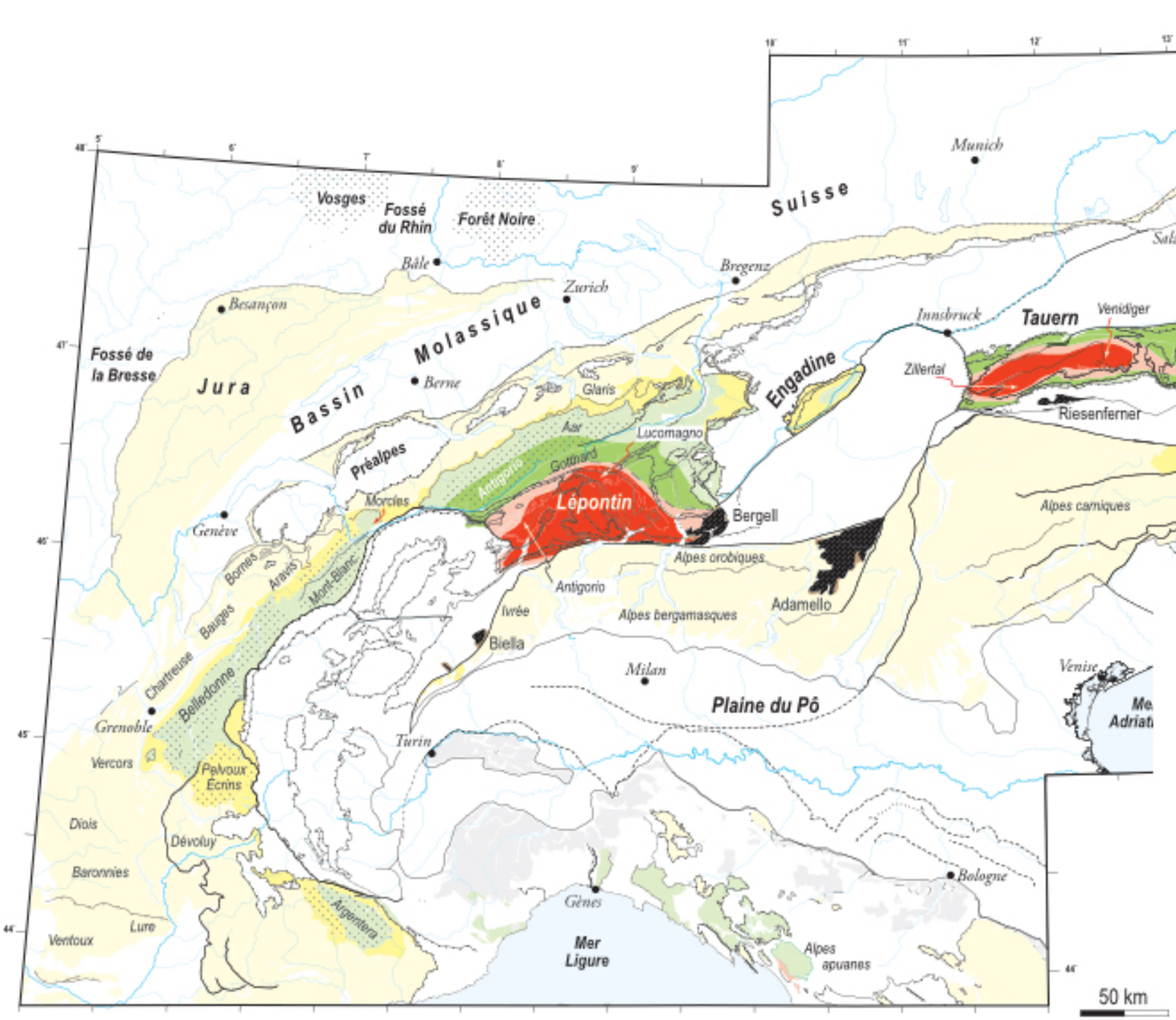
réarrangement des âges a posteriori par l'accrétion au sein d'un prisme orogénique

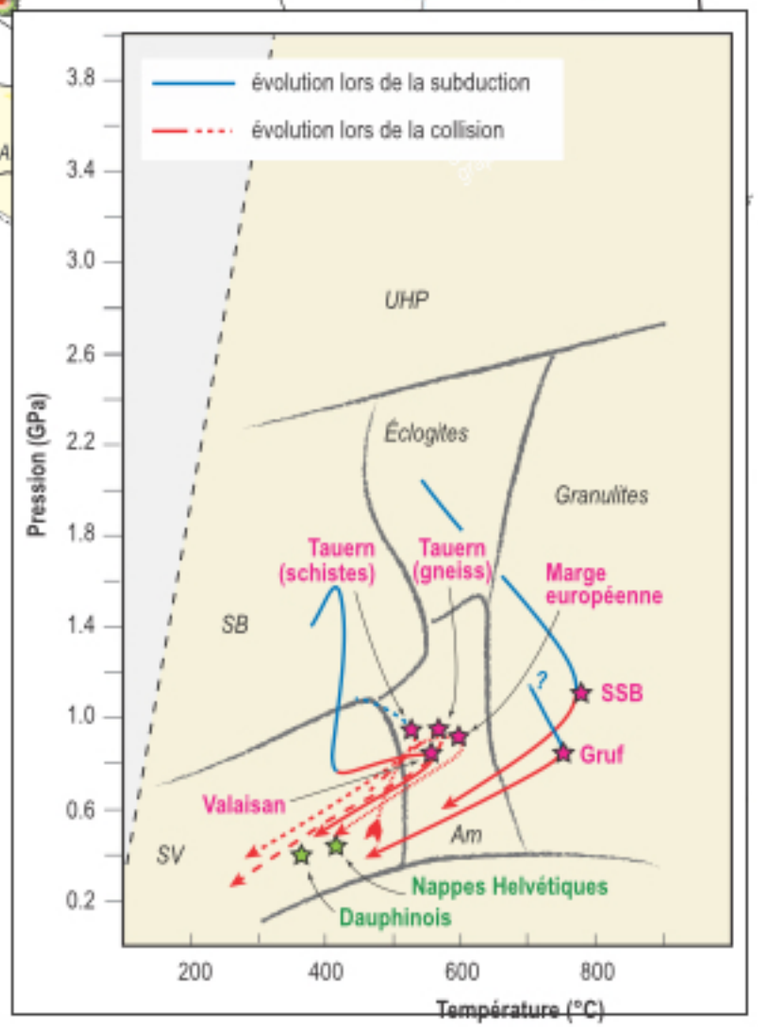
Processus de subduction

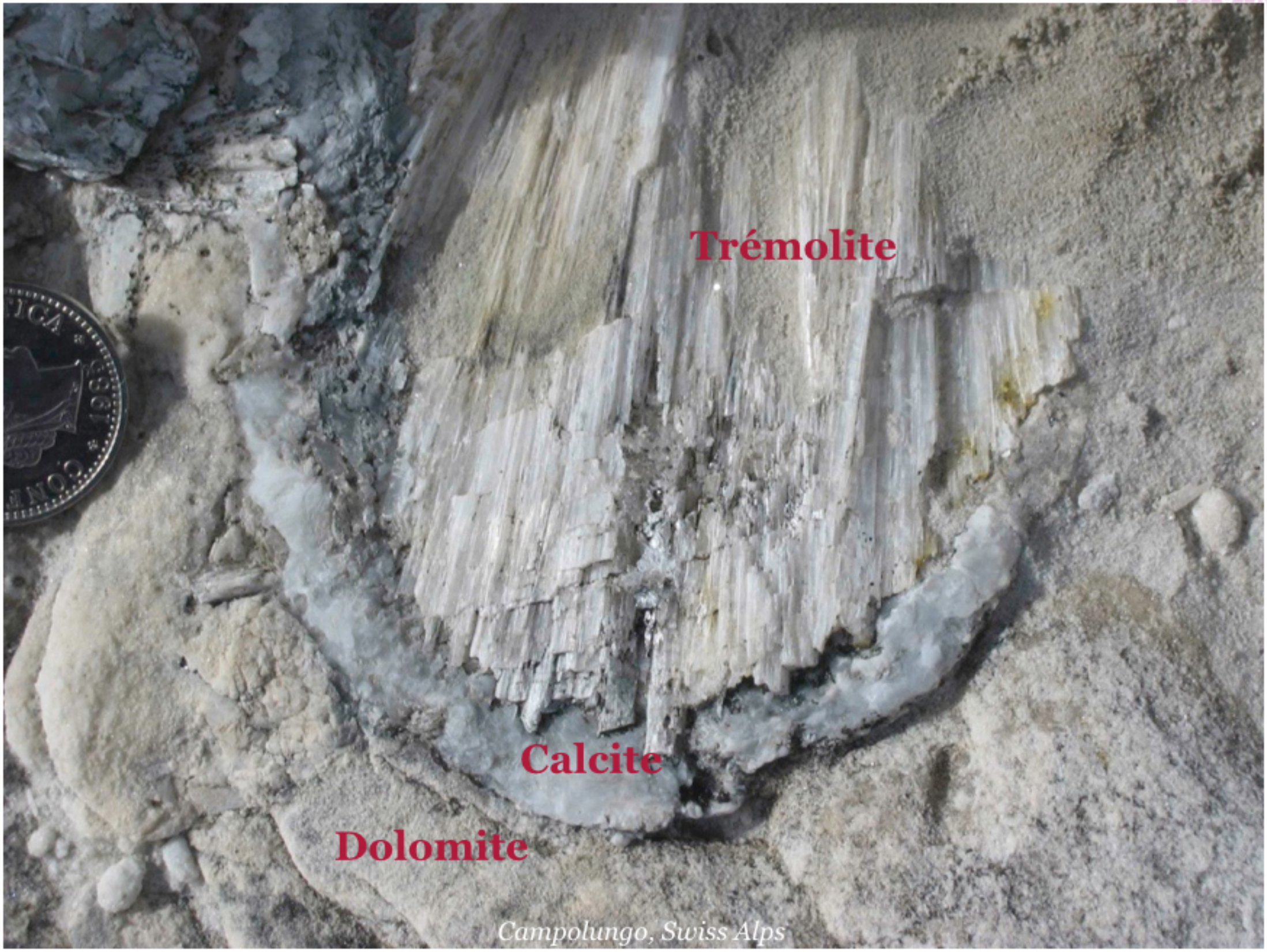
	Age (Ma)	Taux de Convergence (mm/an) *Schmidt et al., 1997*	Gradient de "Subduction" °C/km *after Berger & Bousquet, 2008*	Geodynamique
Paléocène - Eocène inf.	**65 - 50**	**15**	**12-15**	*Débuts de la subduction "alpine" (Austroalpin inférieur & océan ligure)*
Eocène inf. - moyen	**50-40**	**13,5**	**10-12**	*Subduction de l'océan liguro-piémontais & du domaine Briançonnais*
Eocène moyen - sup.	**40-32**	**≥ 5.5**	**7.5-10**	*Subduction de l'océan Valaisan*
Eocène sup. - Miocène inf.	**32-19**	**4,5**	**25-30**	*Collision*
Miocène inf. - aujourd'hui	**19 - 0**	**3**	**???**	*Fin de la collision*

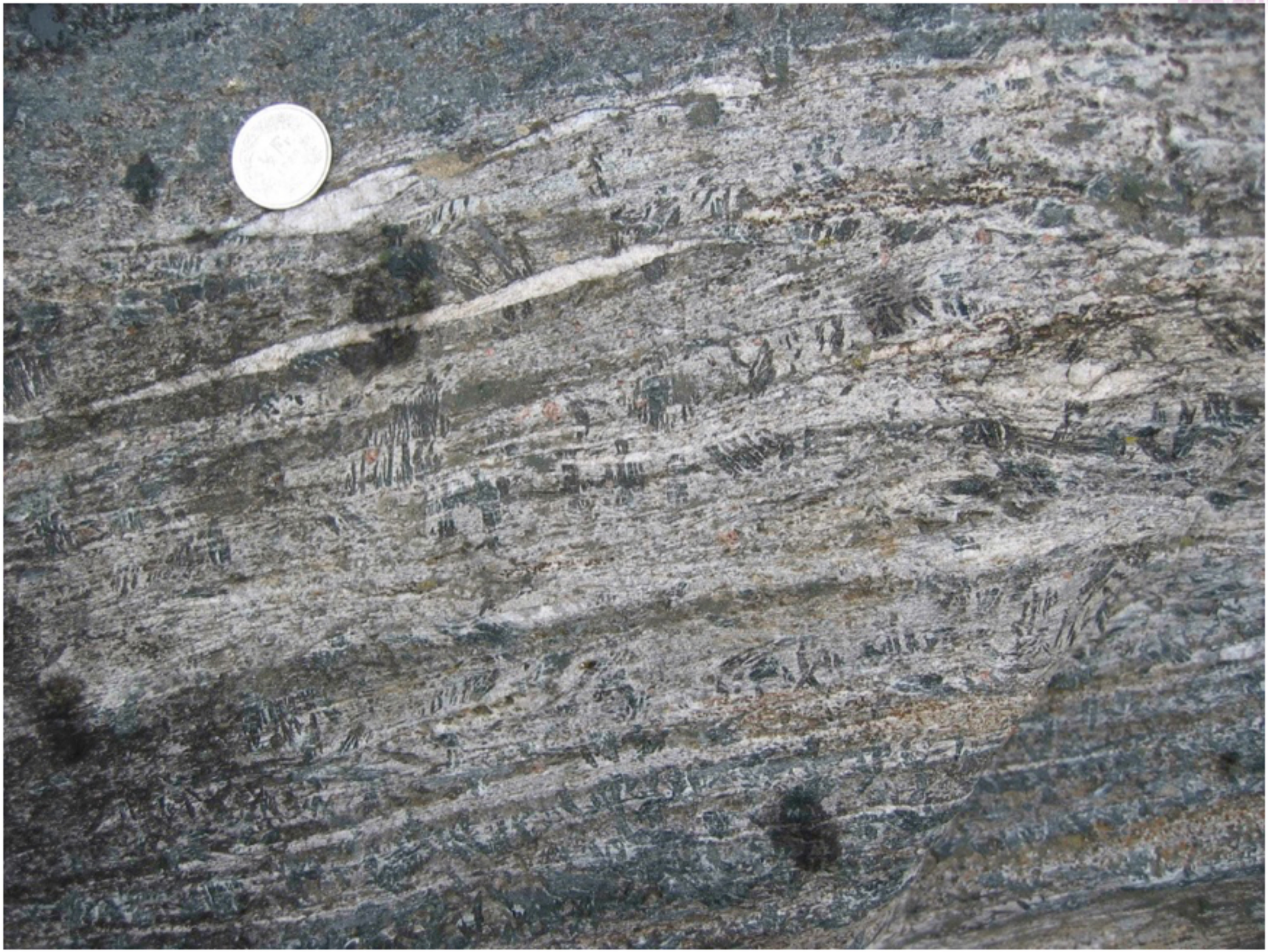
La collision

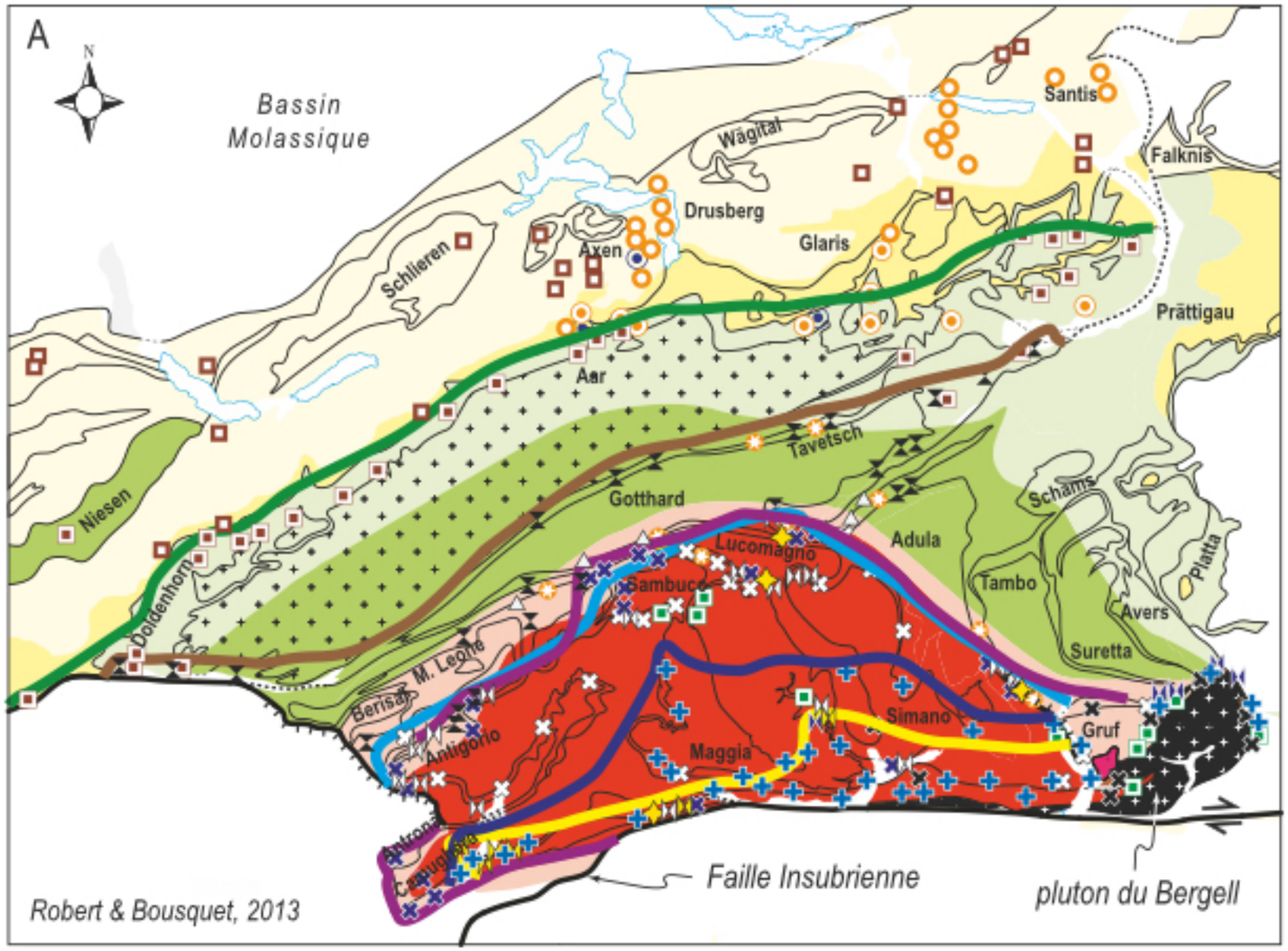
Le métamorphisme de collision

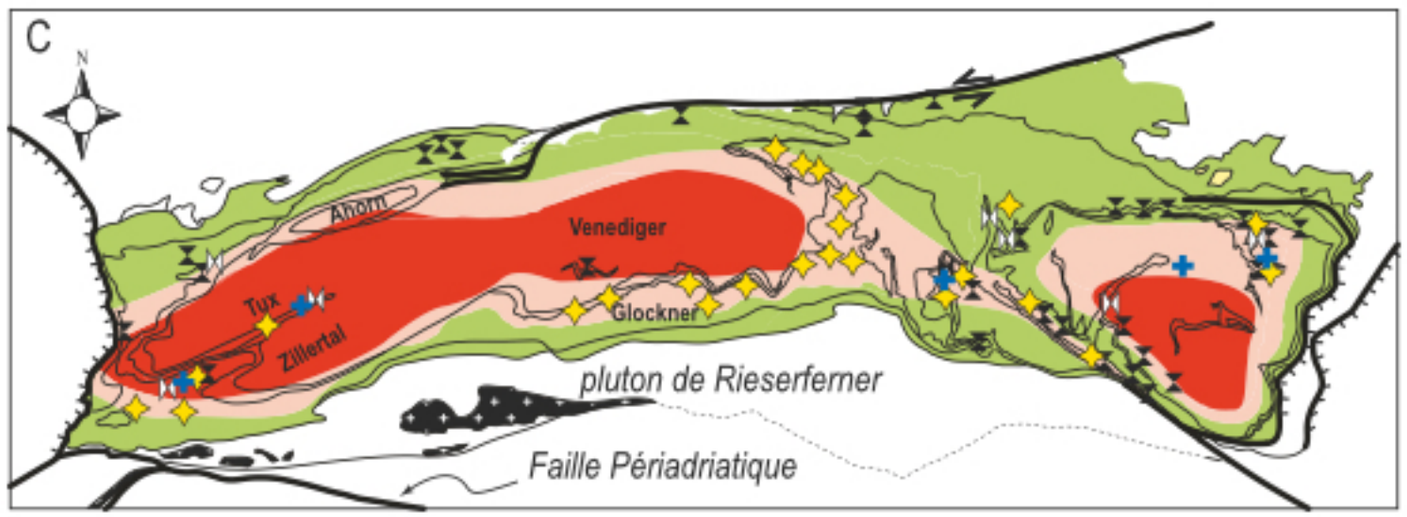


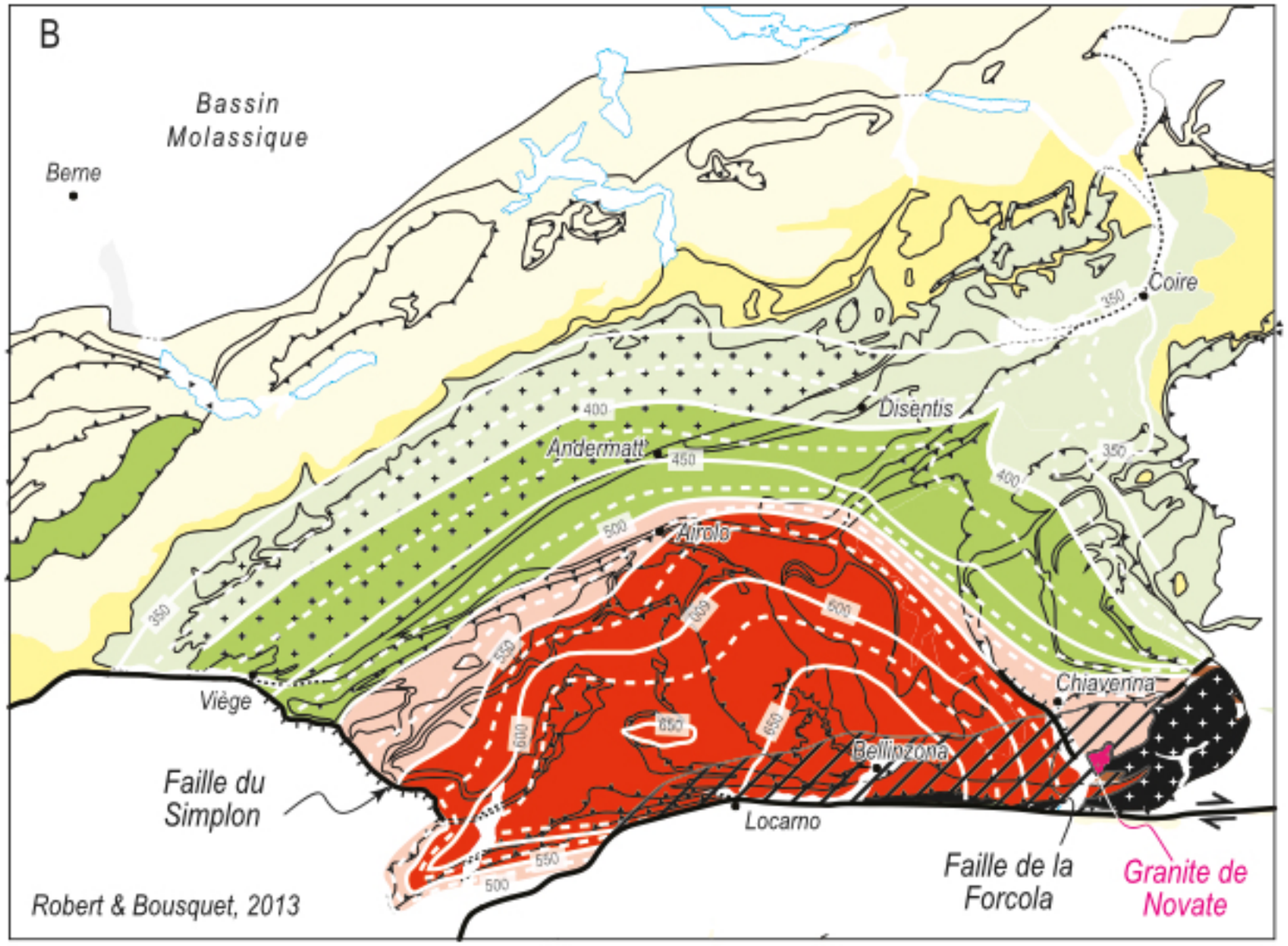


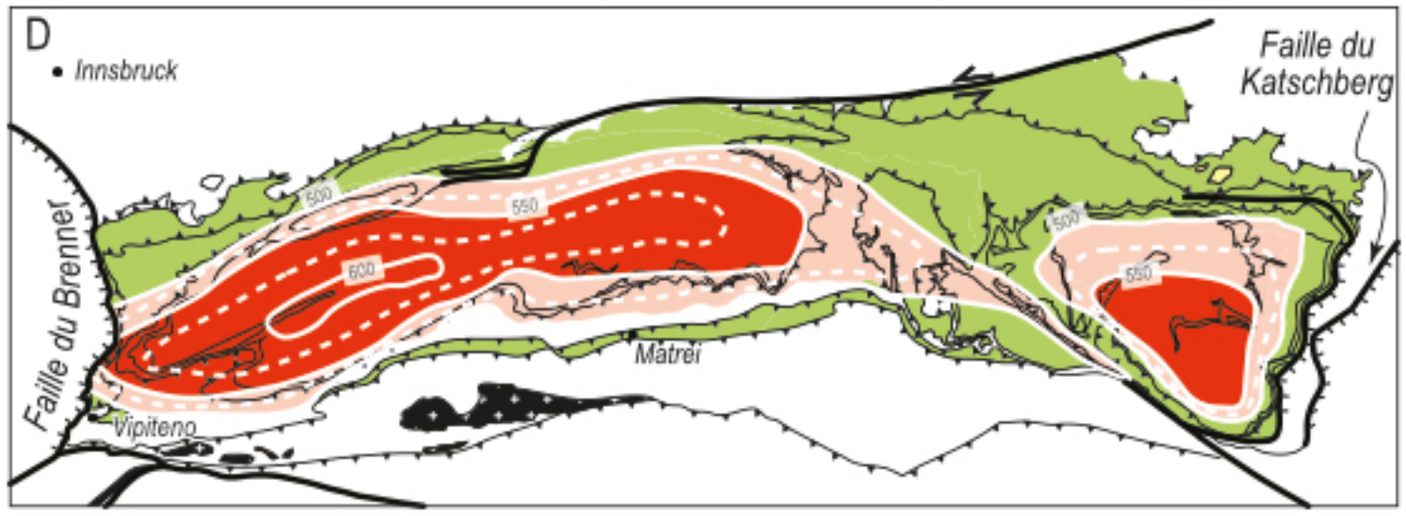

Trémolite
Calcite
Dolomite
Campolungo, Swiss Alps



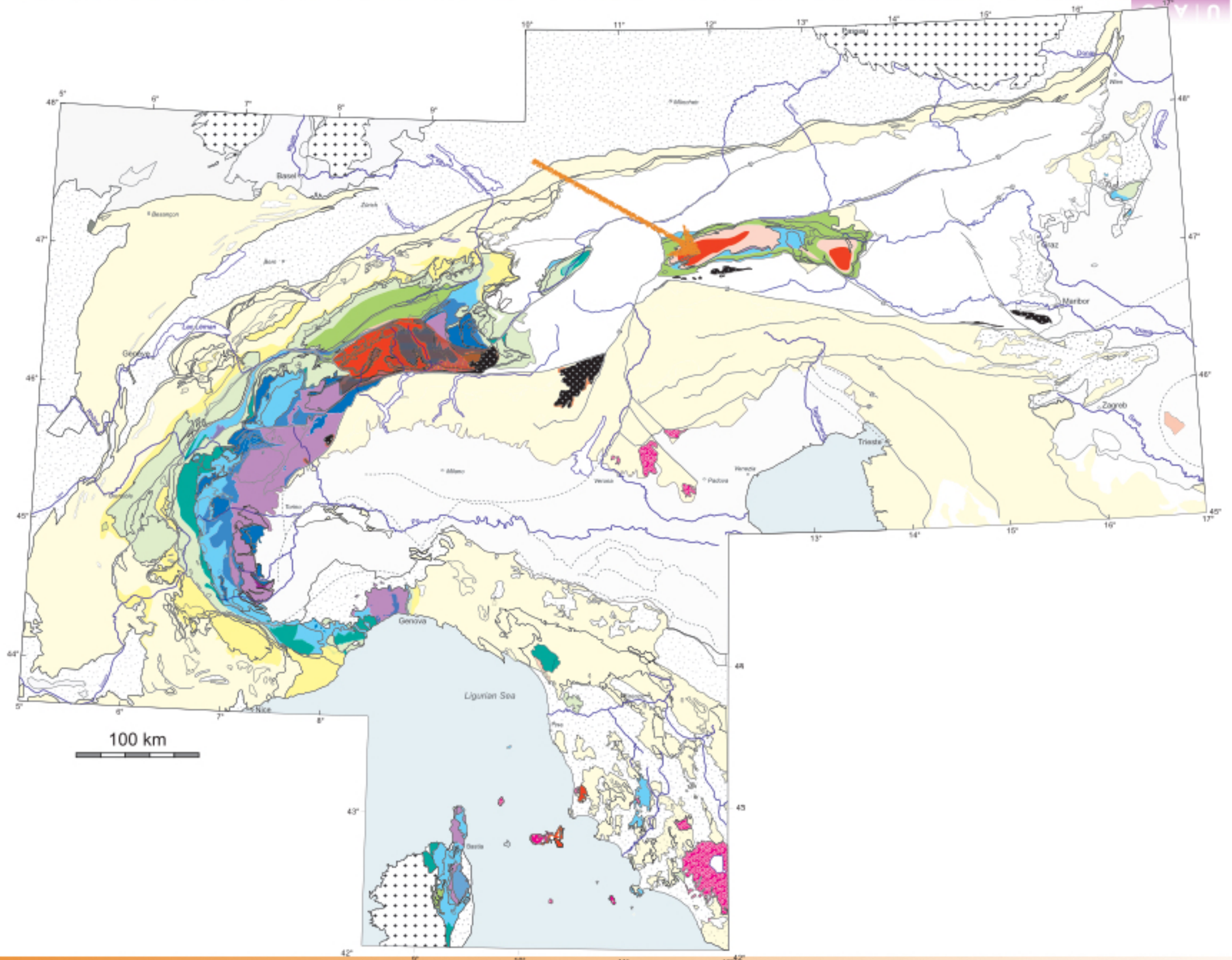

A
N
Bassin
Molassique
Wägital
Santis
Falknis
Drusberg
Glaris
Axen
Schlieren
Prättigau
Aar
Tavetsch
Gotthard
Niesen
Adula
Schams
Lucomagno
Sambuco
Tambo
Platta
Avers
Suretta
Berisal
M. Leone
Simano
Gruf
Antigorio
Maggia
Faille Insubrienne
pluton du Bergell
Robert & Bousquet, 2013


C
N
Ahorn
Venediger
Tux
Glockner
Zillertal
pluton de Rieserferner
Faille Périadriatique

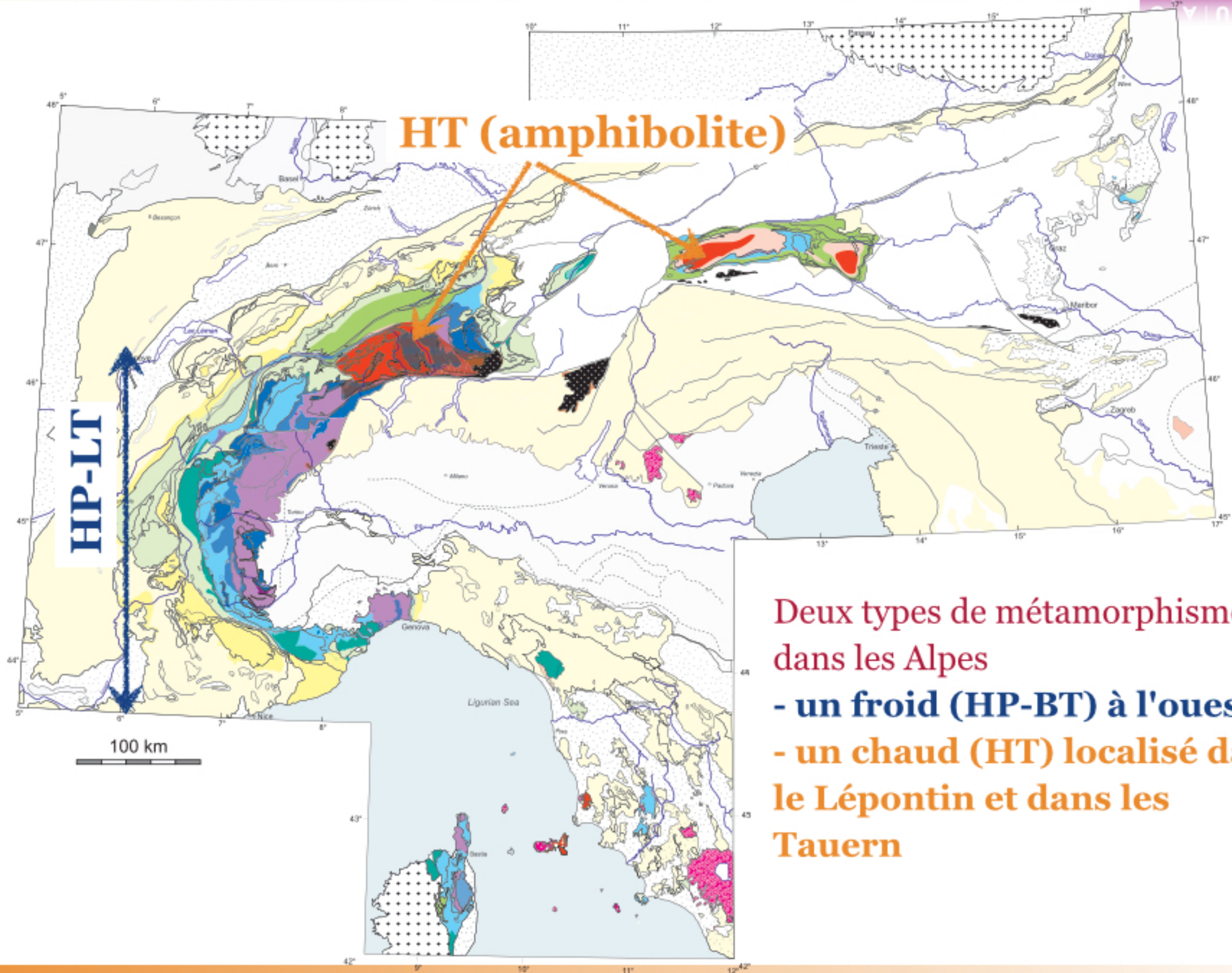

B
Bassin
Molassique
Berne
Coire
Disentis
Andermatt
Airolo
Chiavenna
Bellinzona
Locarno
Viège
Faille du
Simplon
Faille de la
Forcola
Granite de
Novate
Robert & Bousquet, 2013


D
Innsbruck
Faille du
Katschberg
Faille du Brenner
Mâtrei
Vipiteno

Métamorphisme tertiaire dans les Alpes



Métamorphisme tertiaire dans les Alpes



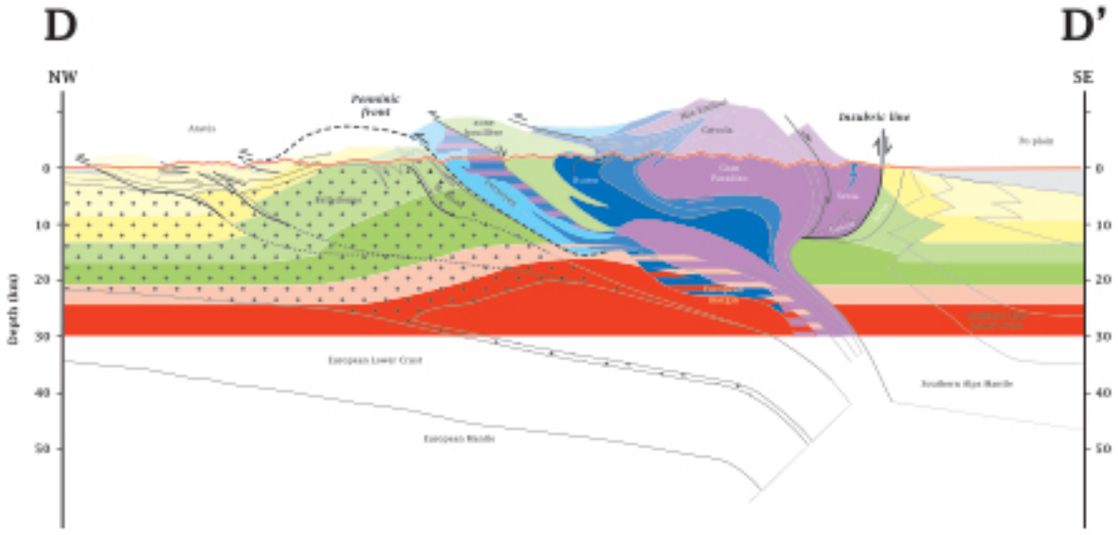
Deux types de métamorphisme dans les Alpes

- un froid (HP-BT) à l'ouest

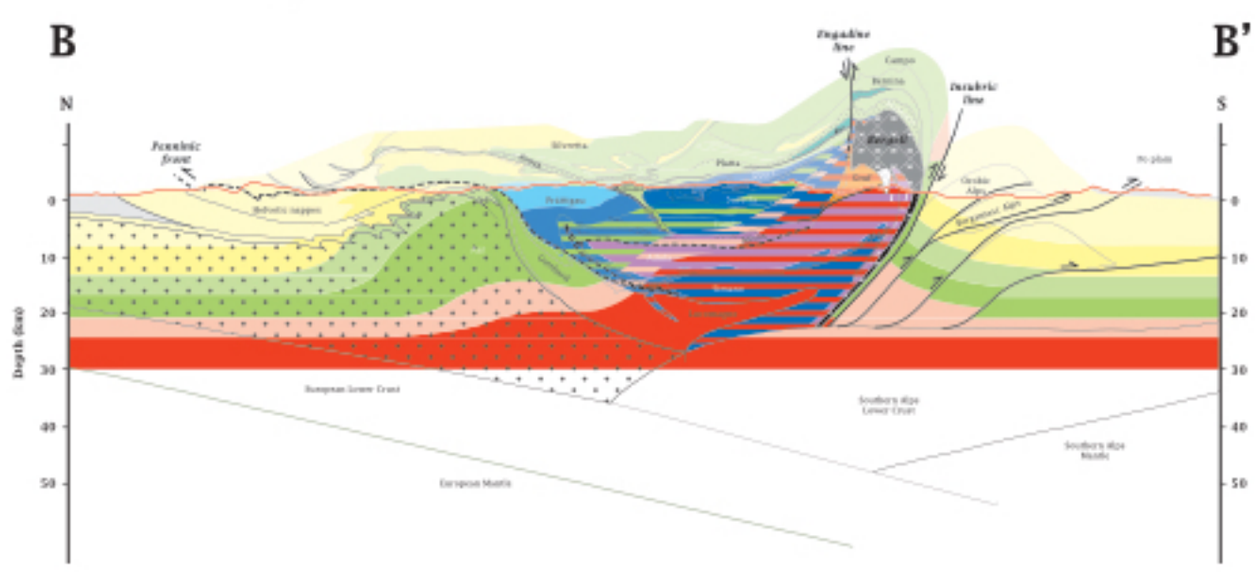
- un chaud (HT) localisé dans le Lépontin et dans les Tauern

Alpine metamorphism, summary

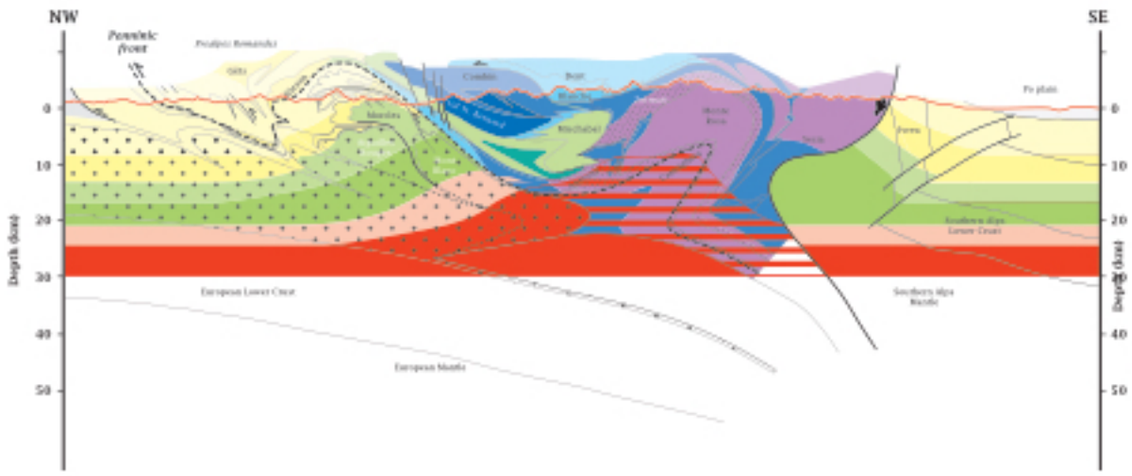
Western Alps : ECORS-CROP



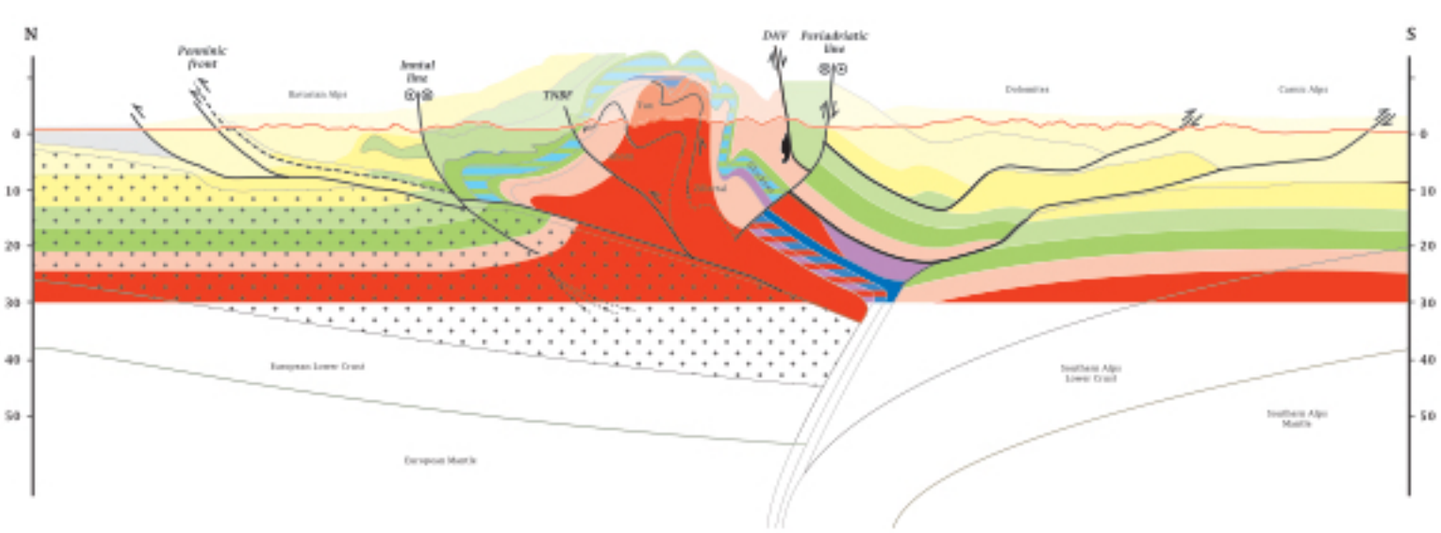
Central Alps : NFP-20 East



Northwestern Alps : NFP-20 West

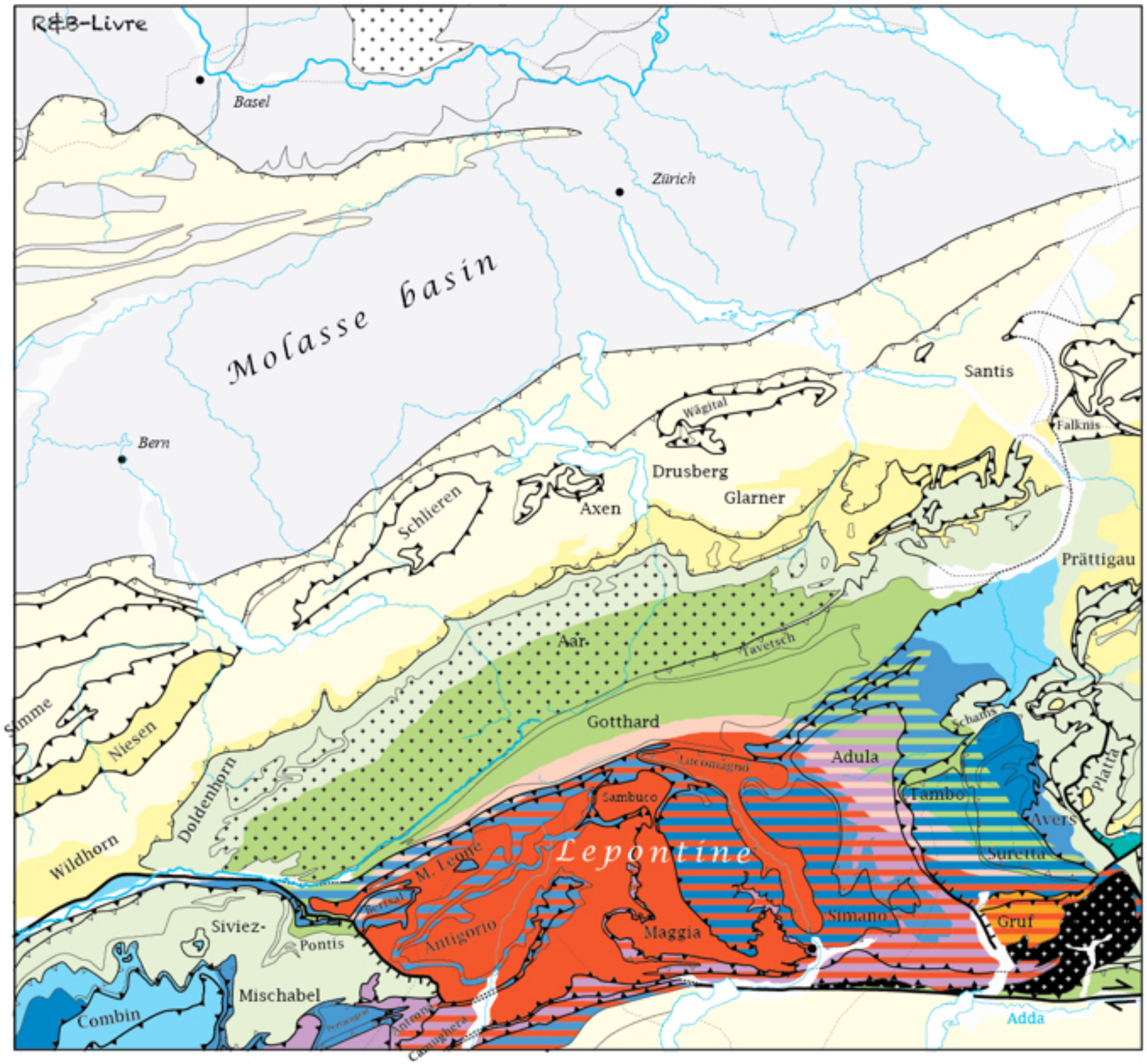


Eastern Alps : TRANSALP



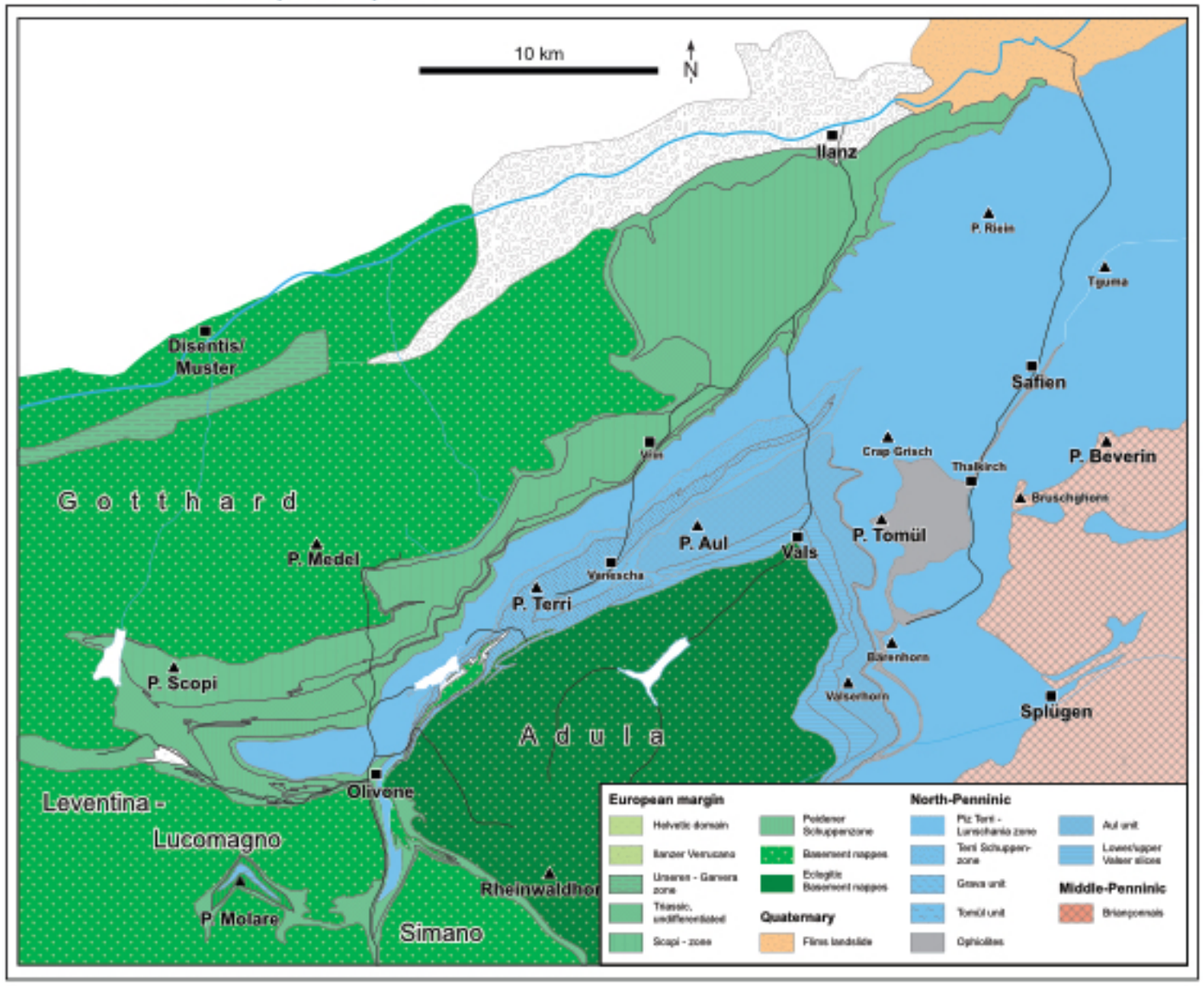
Bousquet et al., 2012

Le métamorphisme de collision



Subduction-continent transition

Wiederkehr et al., 2008; 2009



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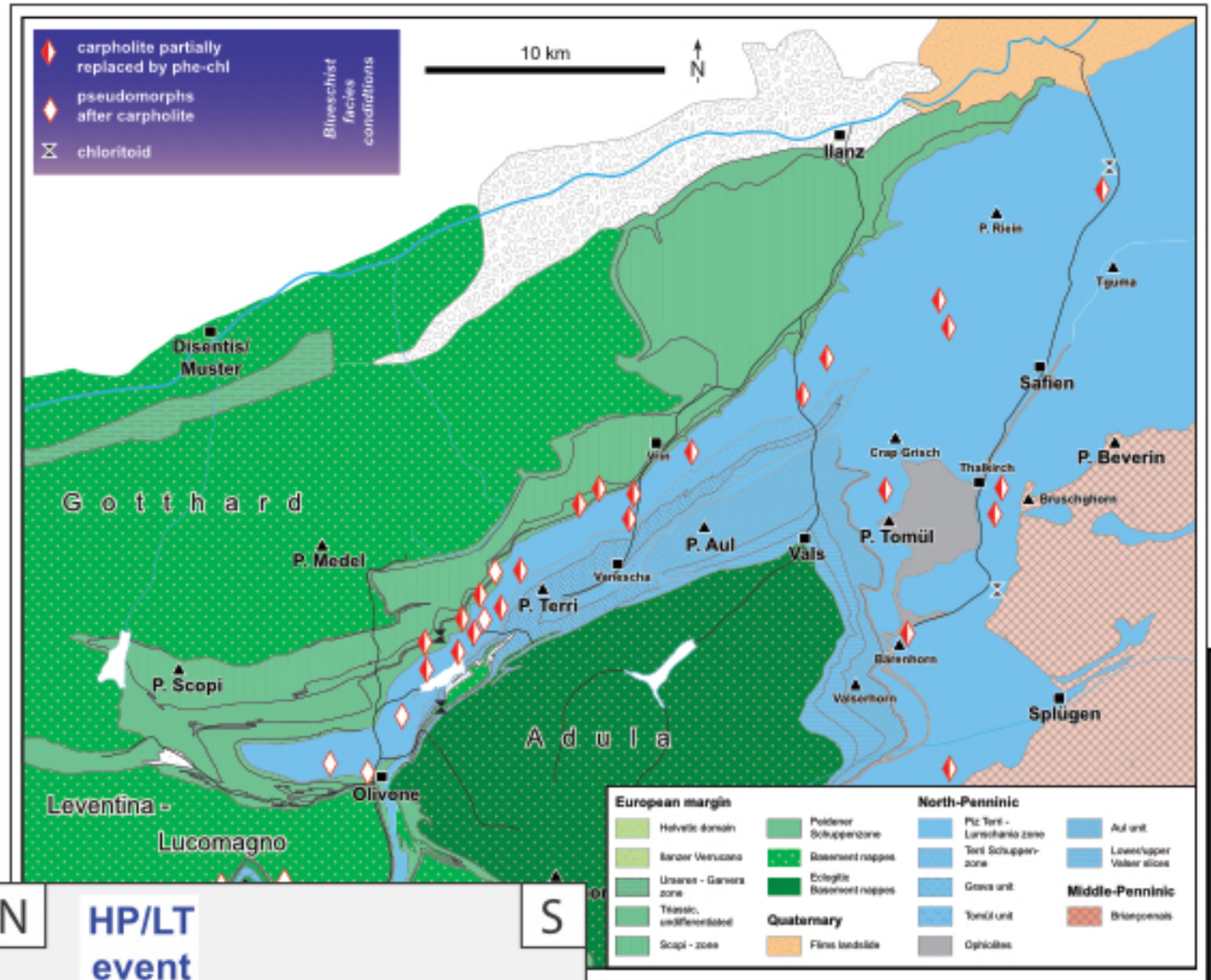

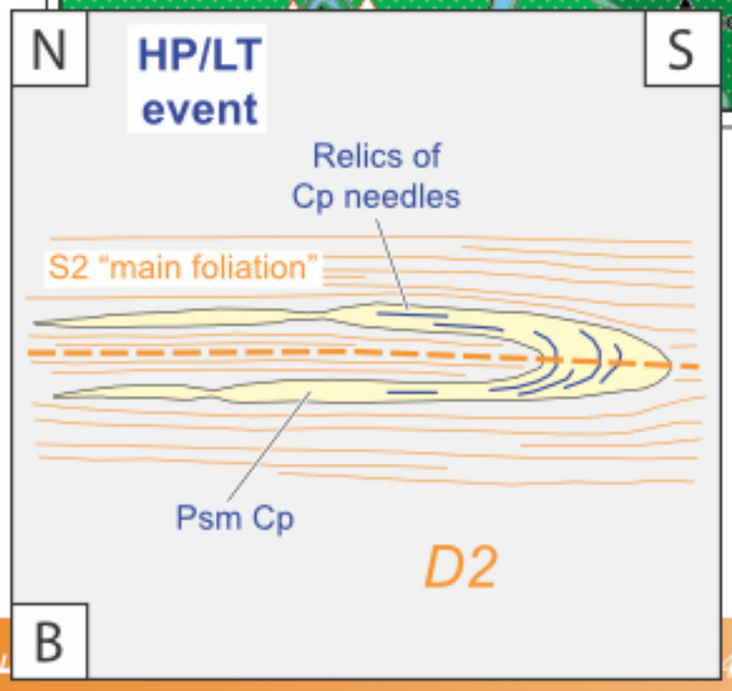

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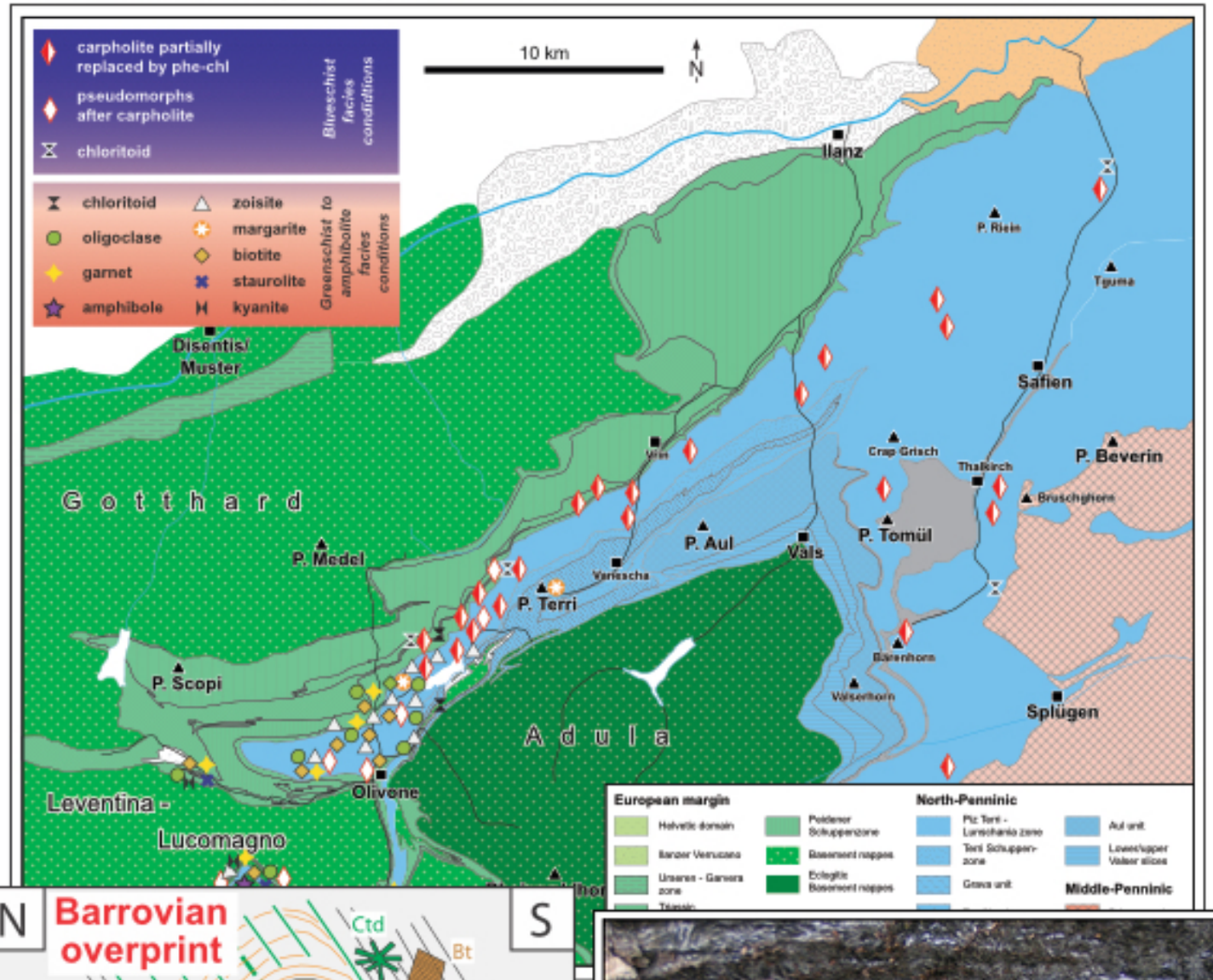

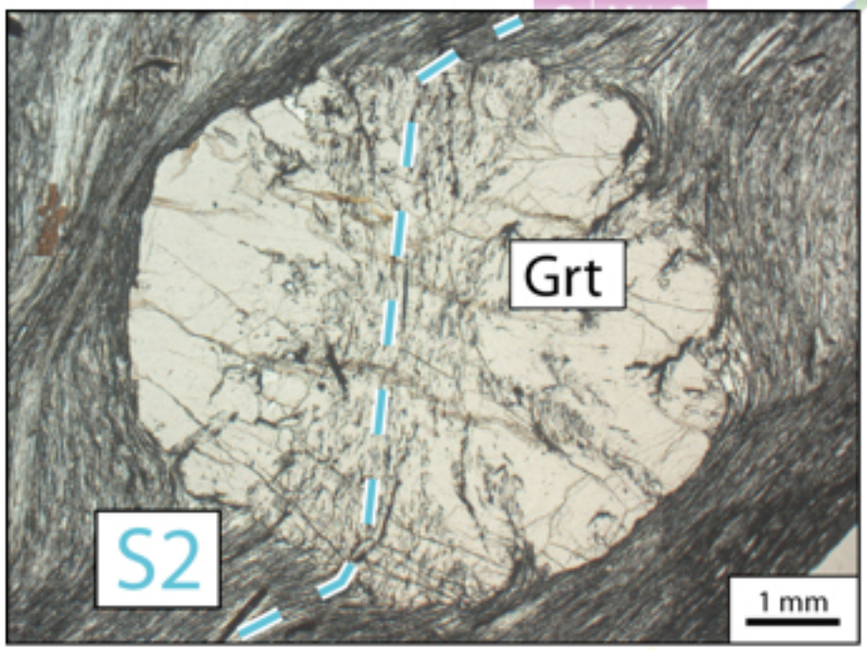

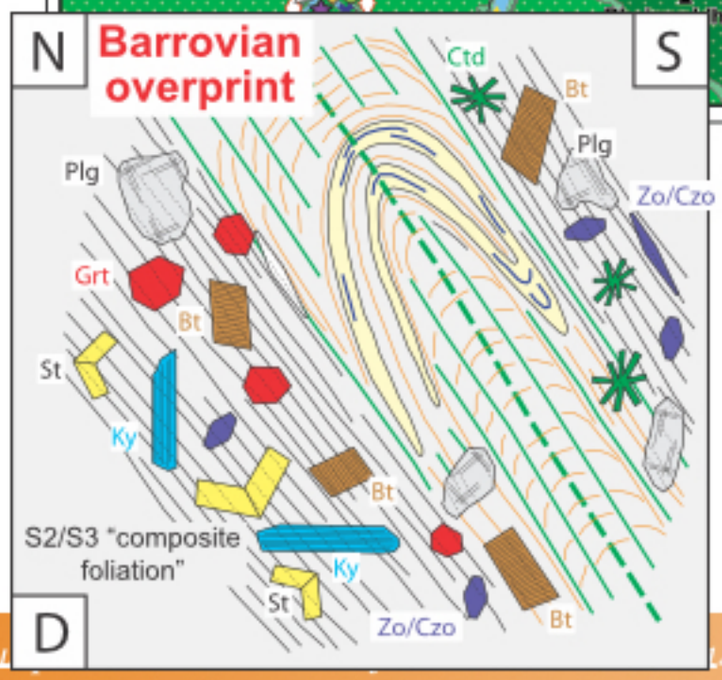

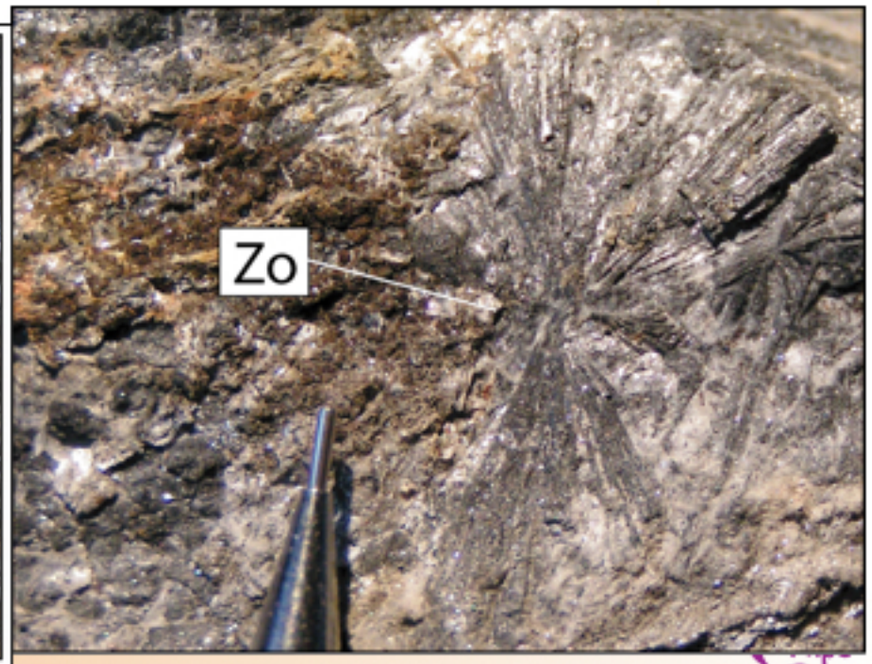

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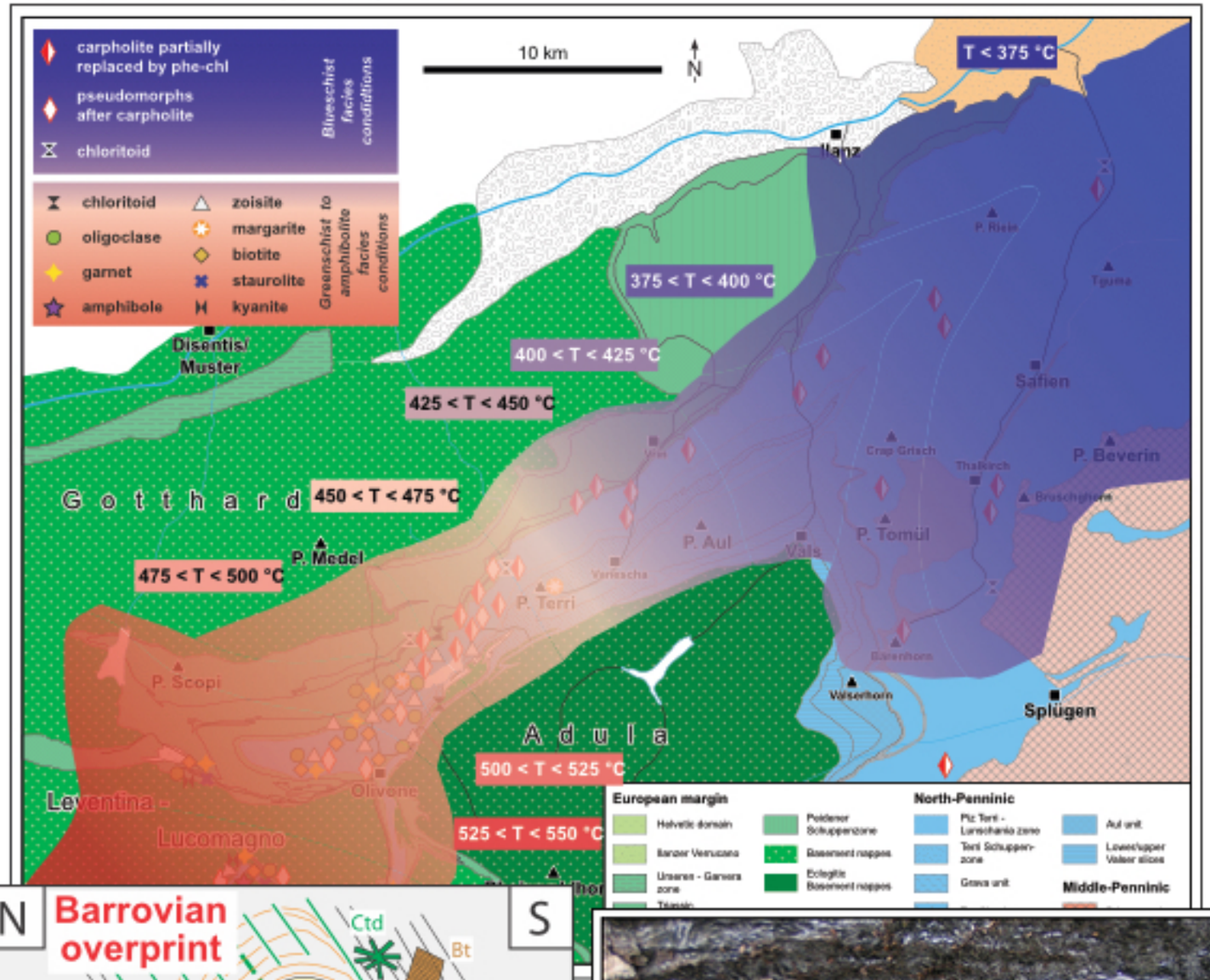

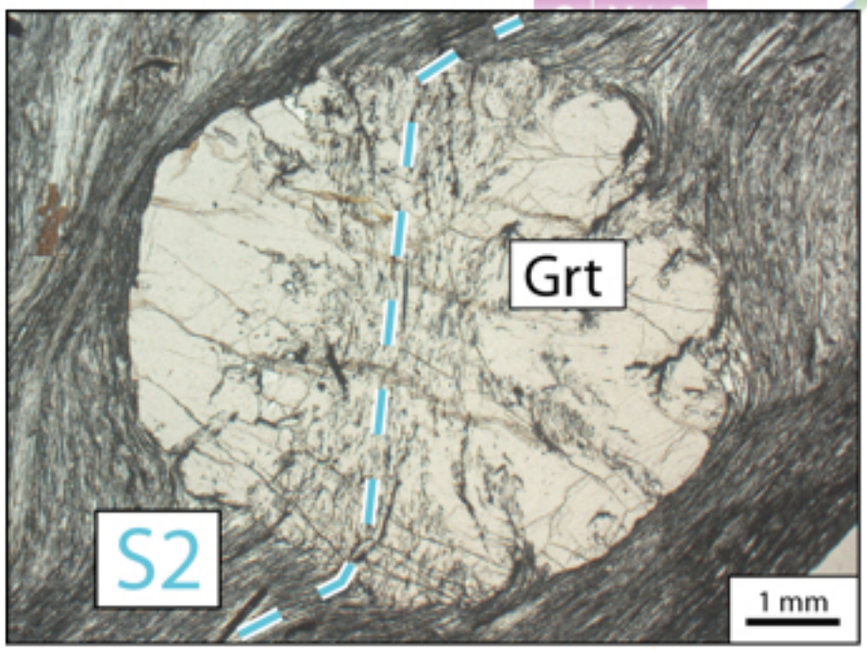

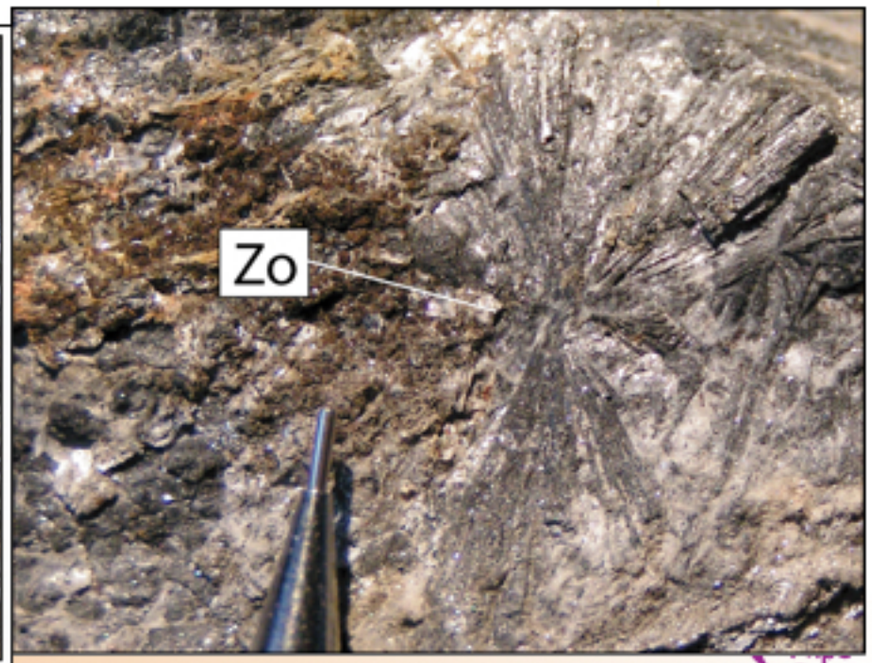

Subduction-continent transition

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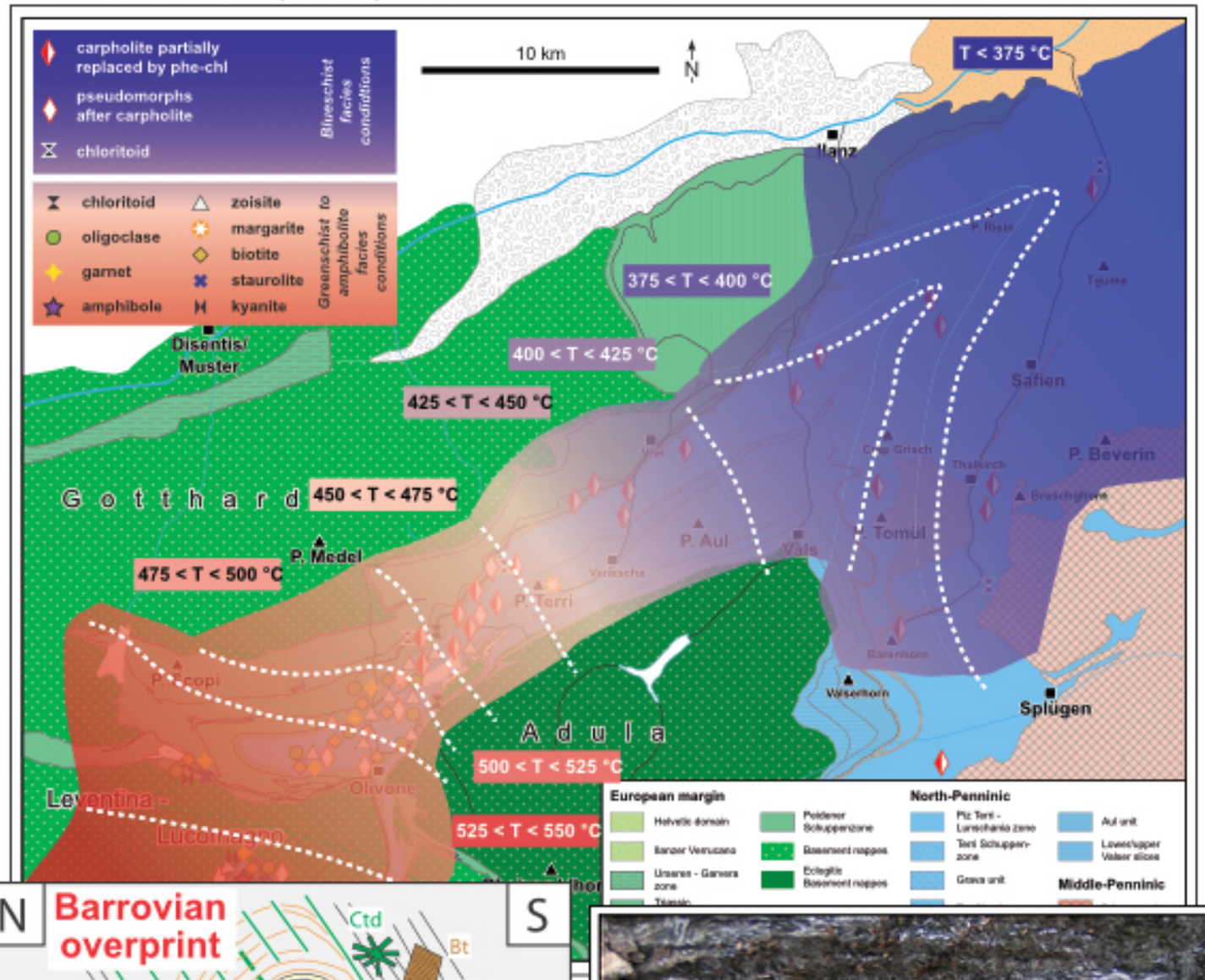
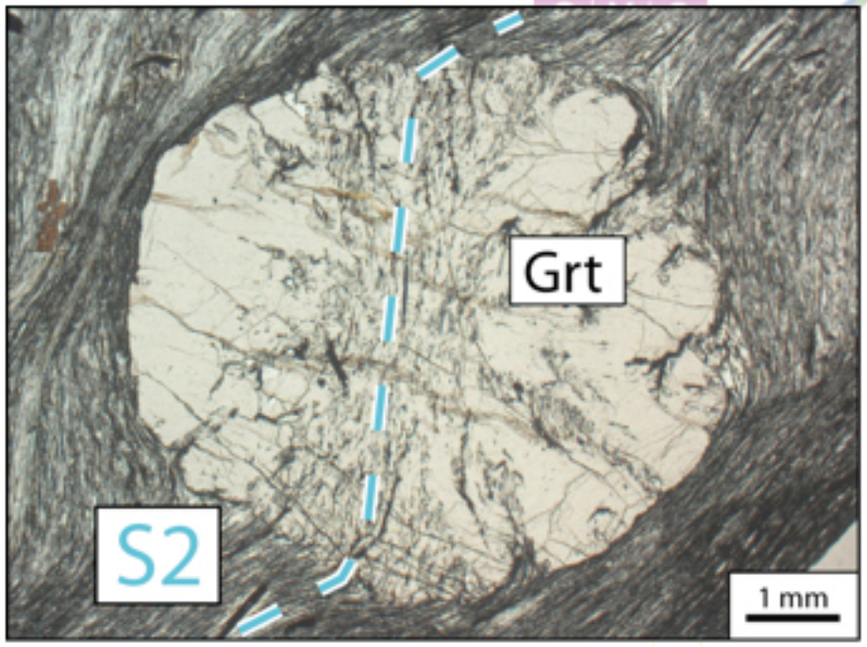
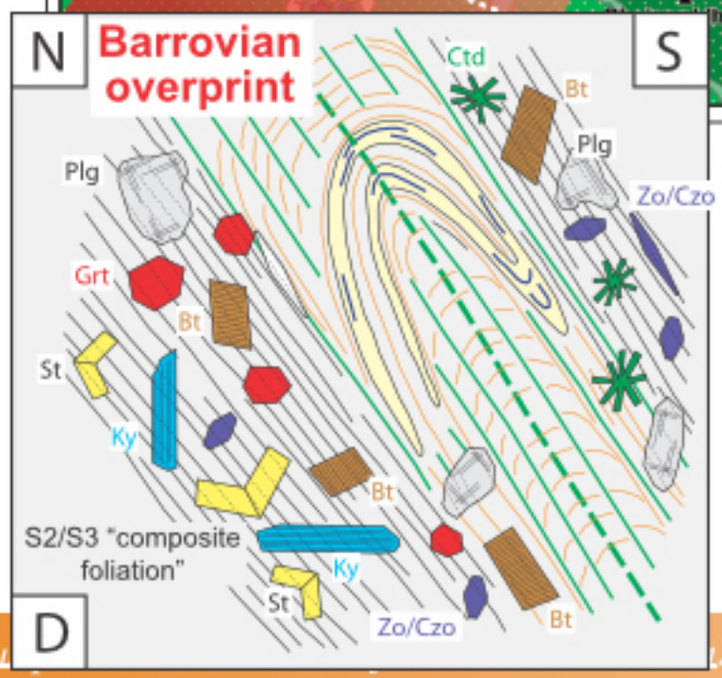
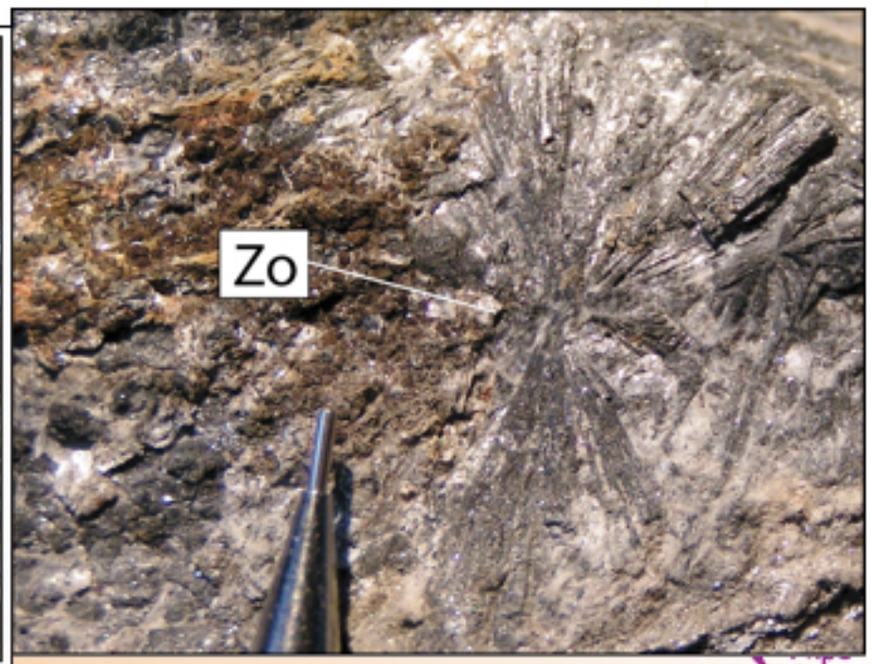


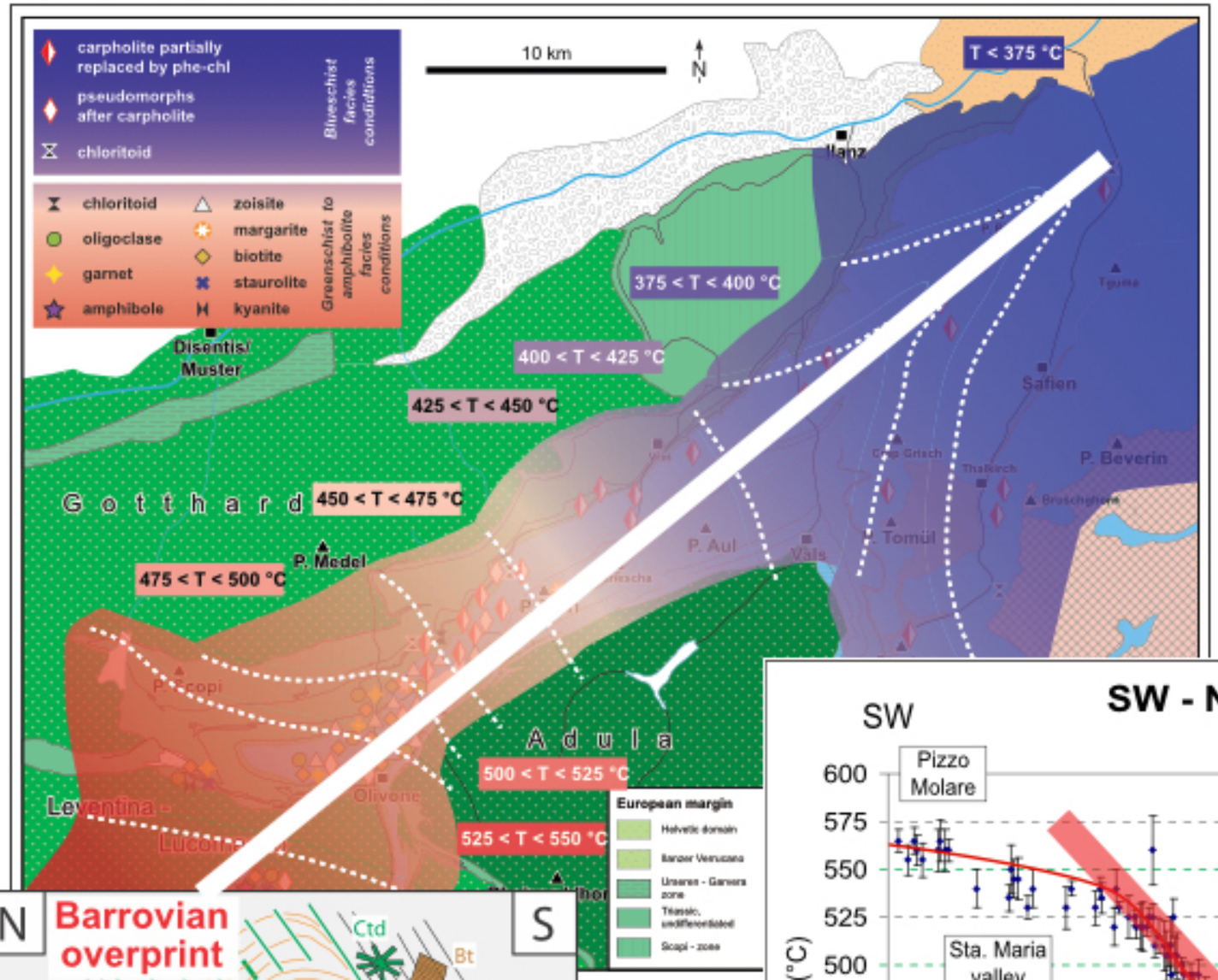


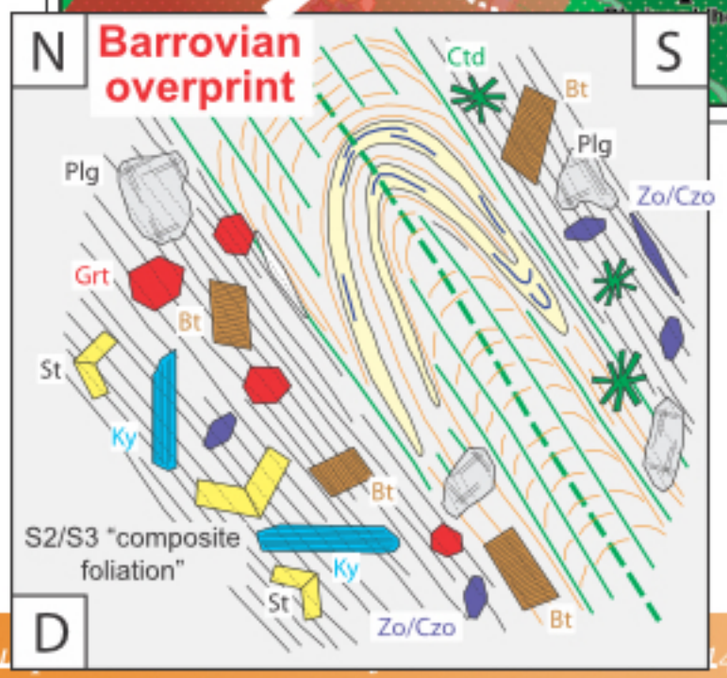


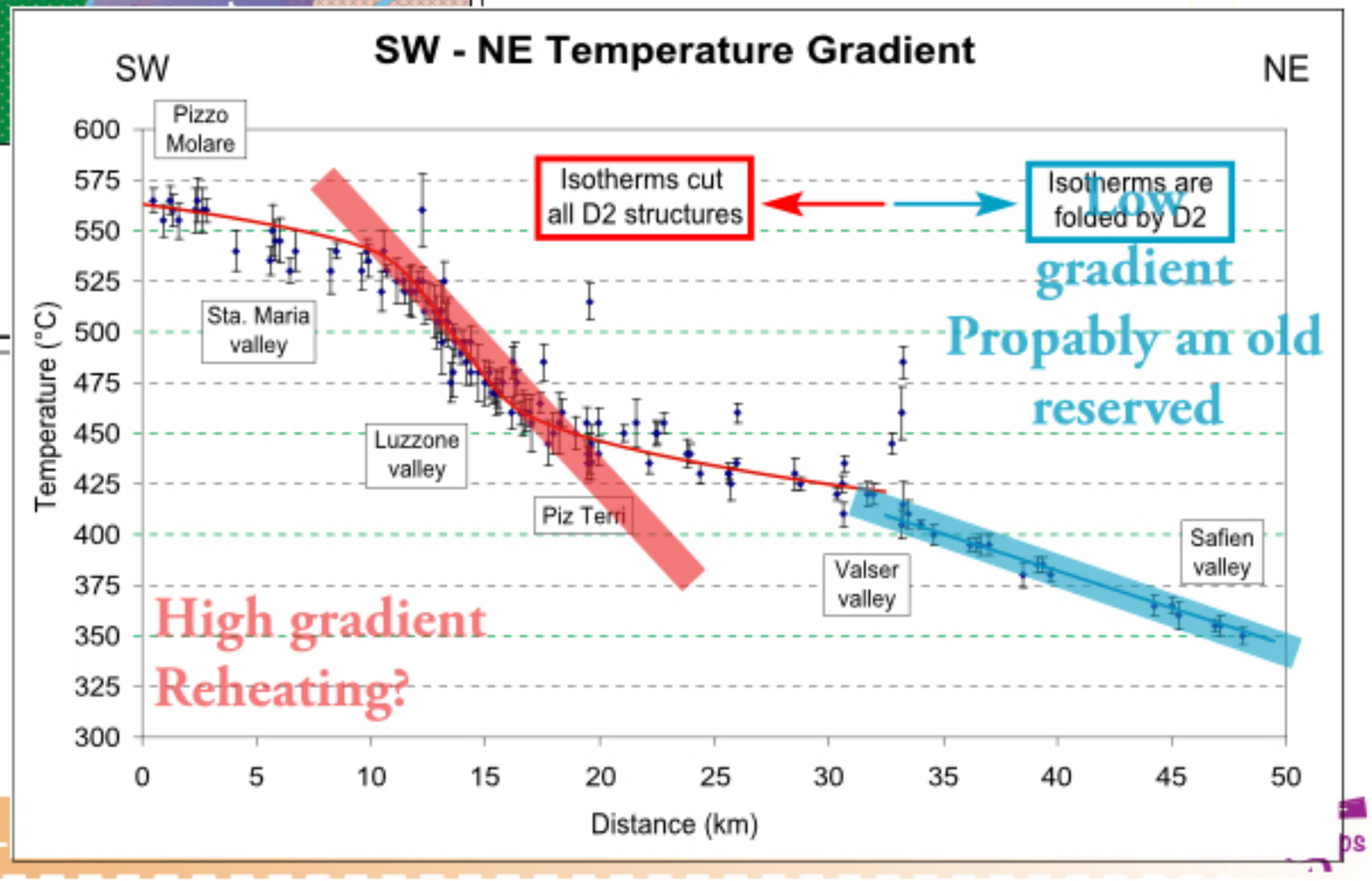


Subduction-continent transition

Wiederkehr et al., 2008; 2009

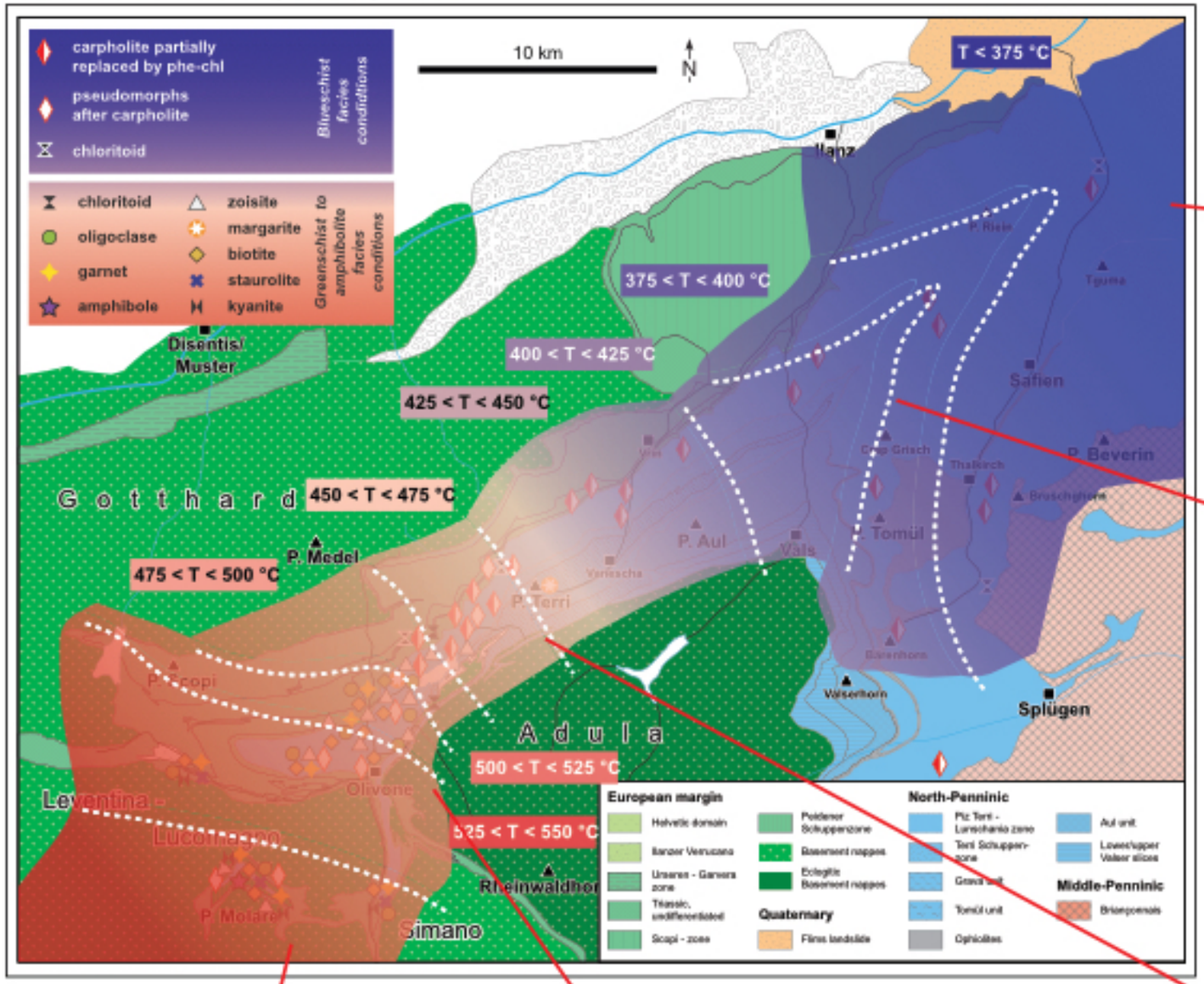


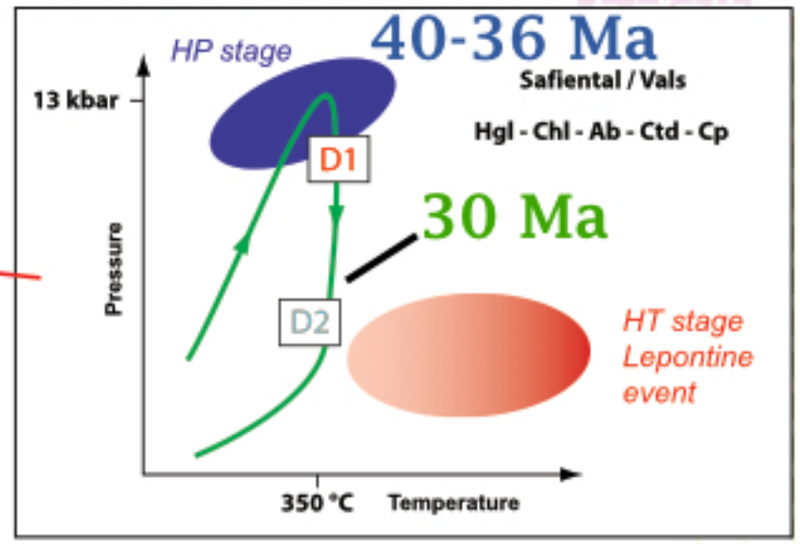


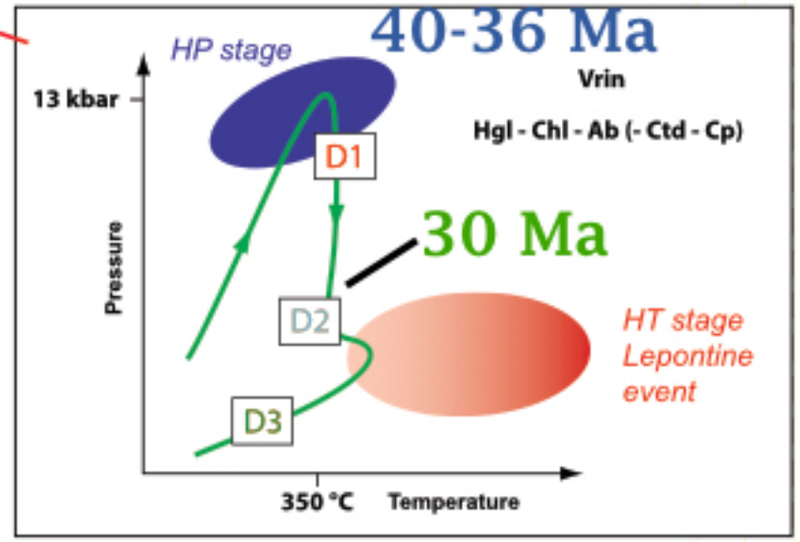


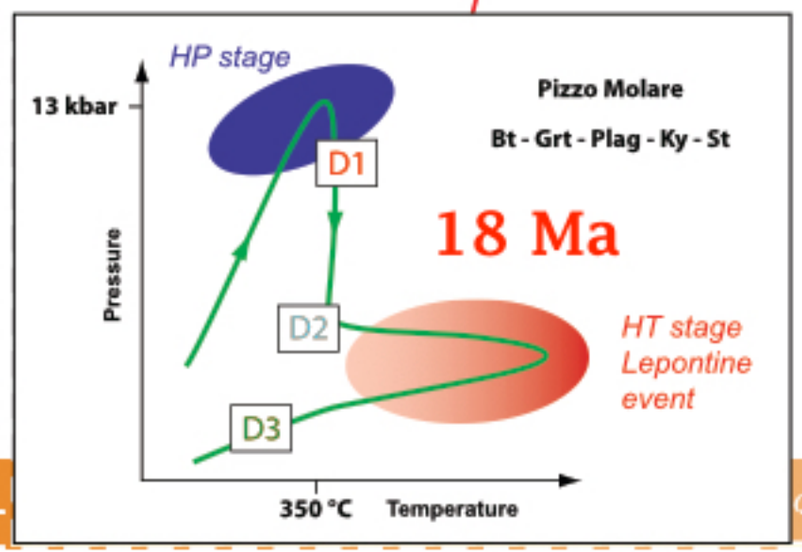
Subduction-continent transition

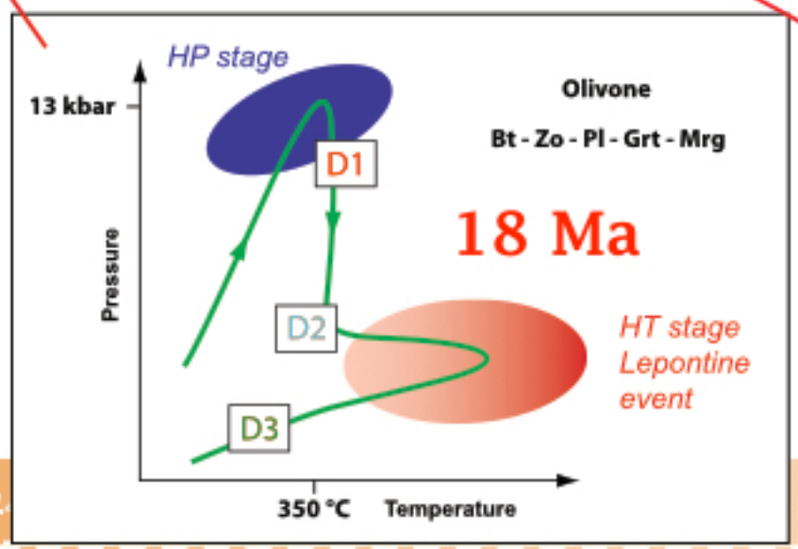
Wiederkehr et al., 2008; 2009

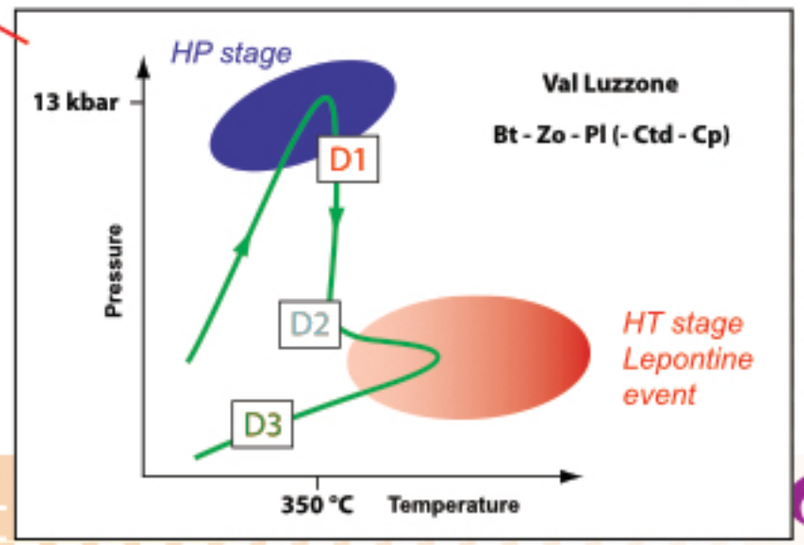




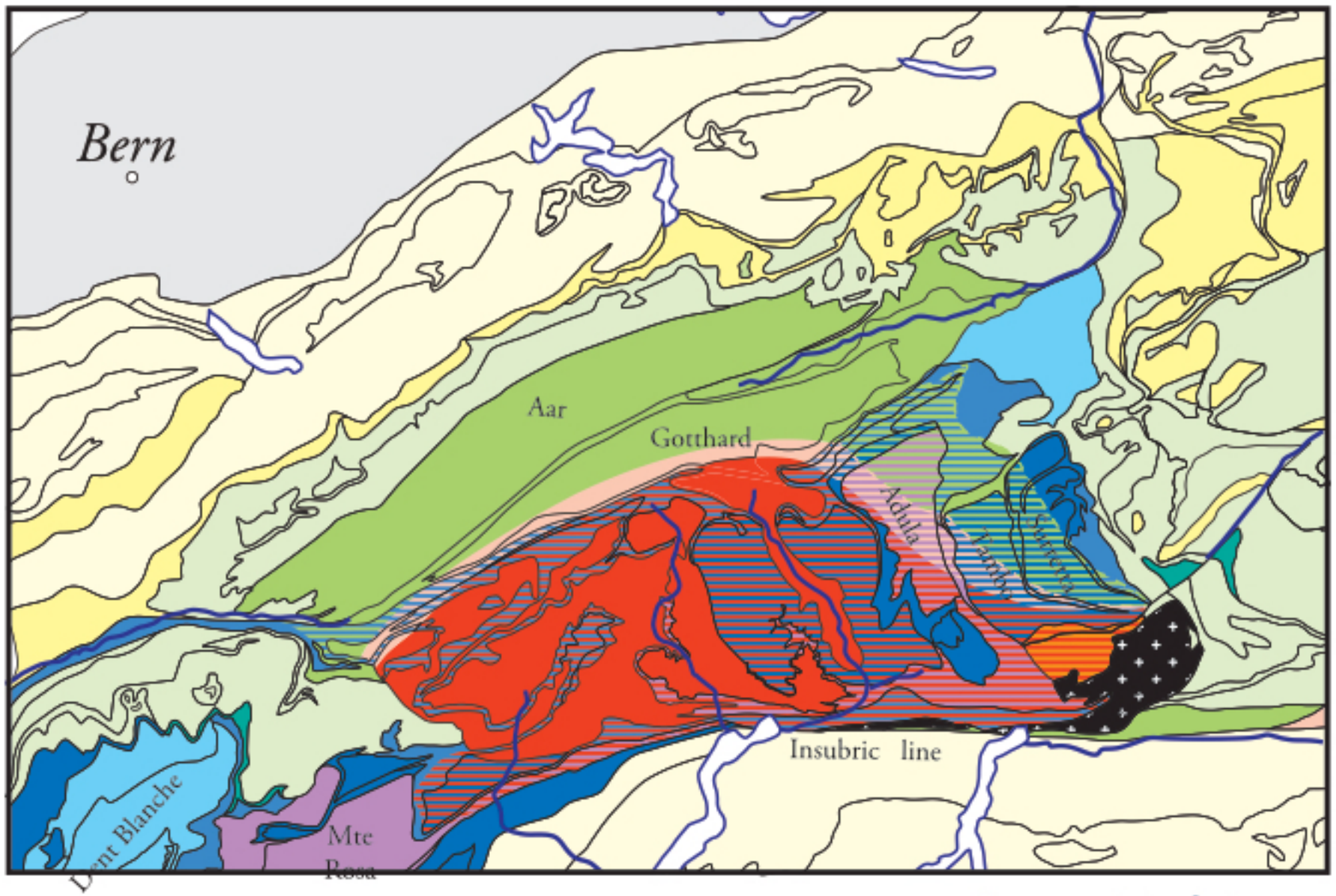








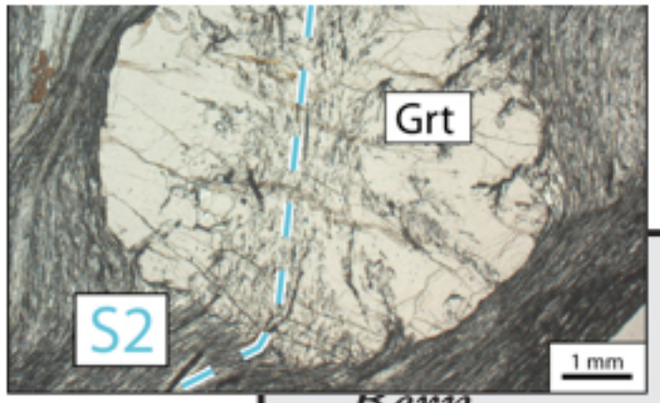
Dôme lépontin dome : synthèse

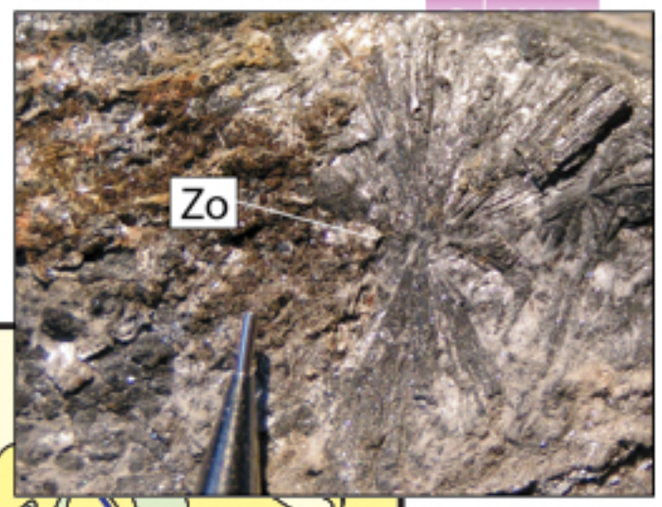


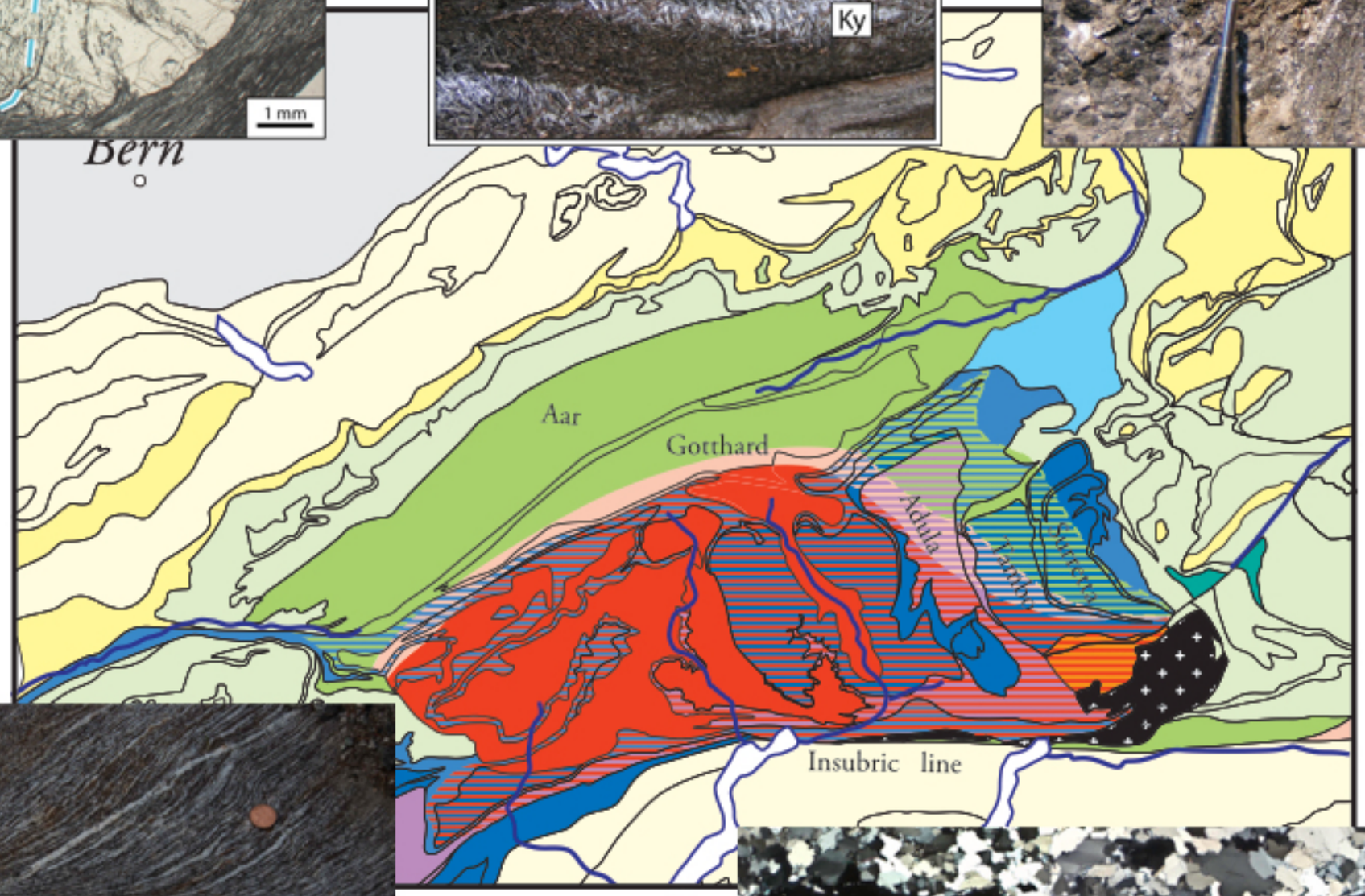
Bousquet et al., in prep

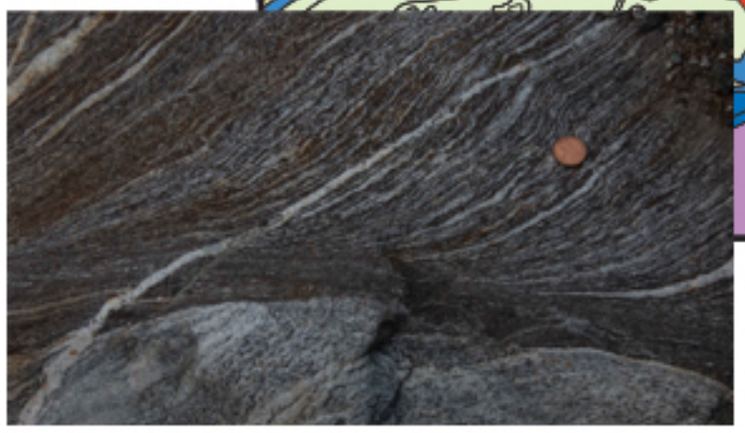
Dôme lépontin dome : synthèse

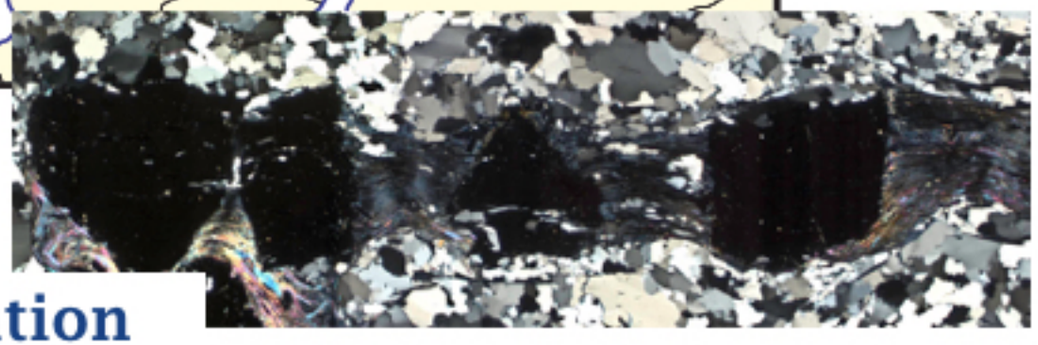
Nord : Métamorphisme HT post-deformation





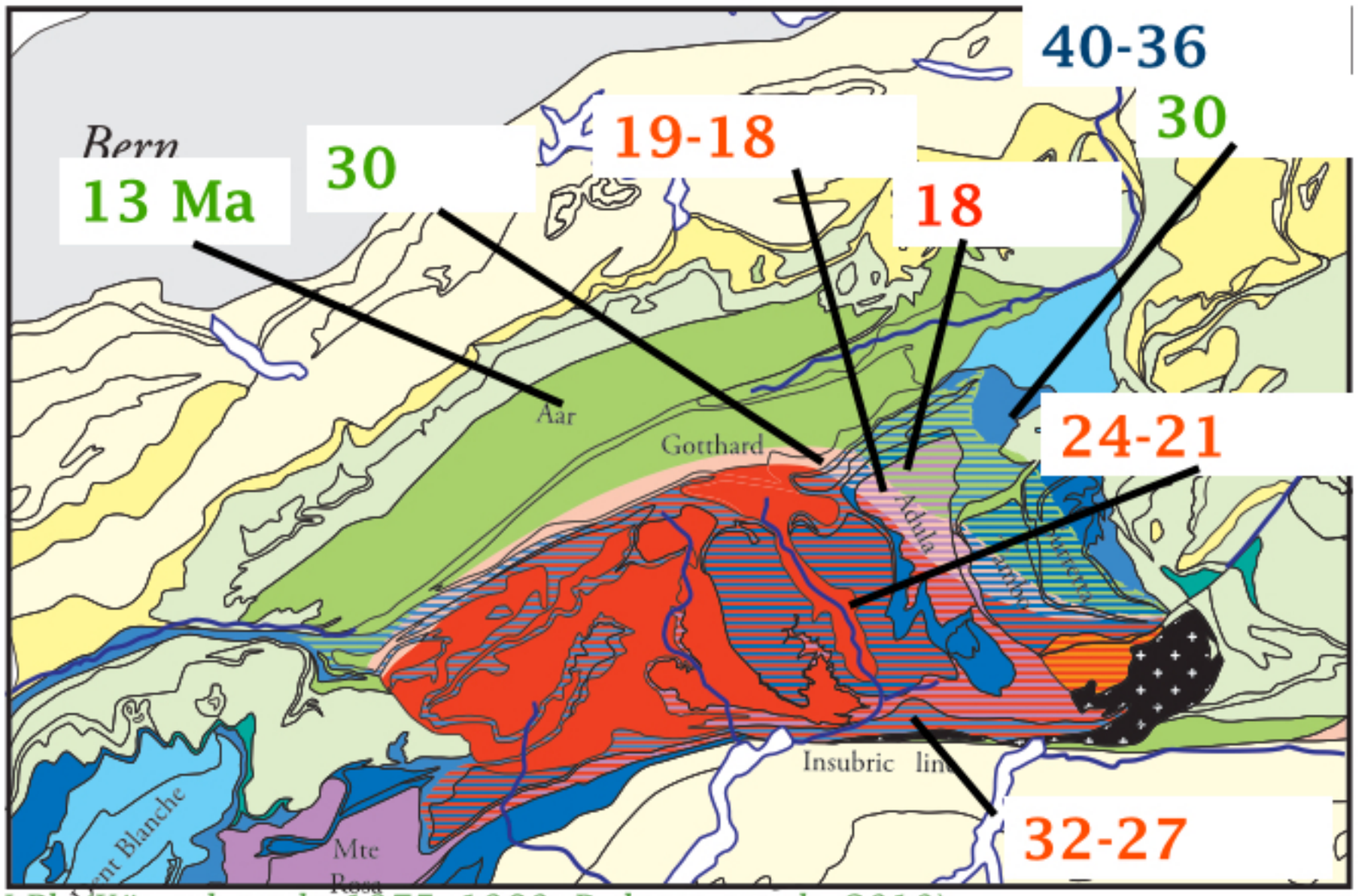






Sud : Métamorphisme HT syn-deformation

Dôme lépontin dome : synthèse

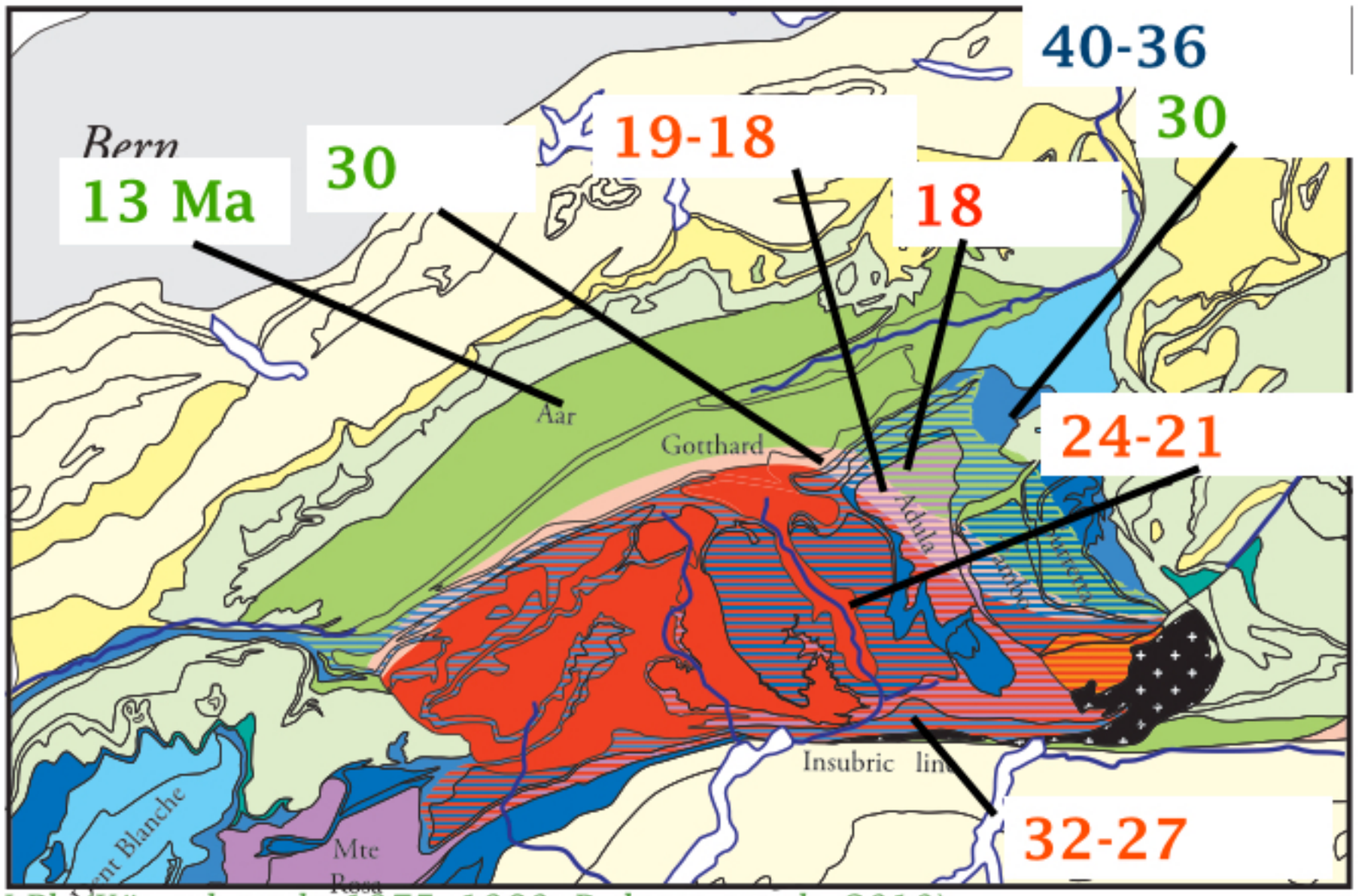


* U-Pb (Köppel et al., 1975, 1980; Rubatto et al., 2010)
 Allanite (Janots et al., 2008)
\+ Ar-Ar (JRolland et al., 2009)
\# Ar-Ar Wiederkehr et al., 2010

Bousquet et al., in prep

Dôme lépontin dome : synthèse

Lepontin metamorphic thermal event
not an homogeneous event



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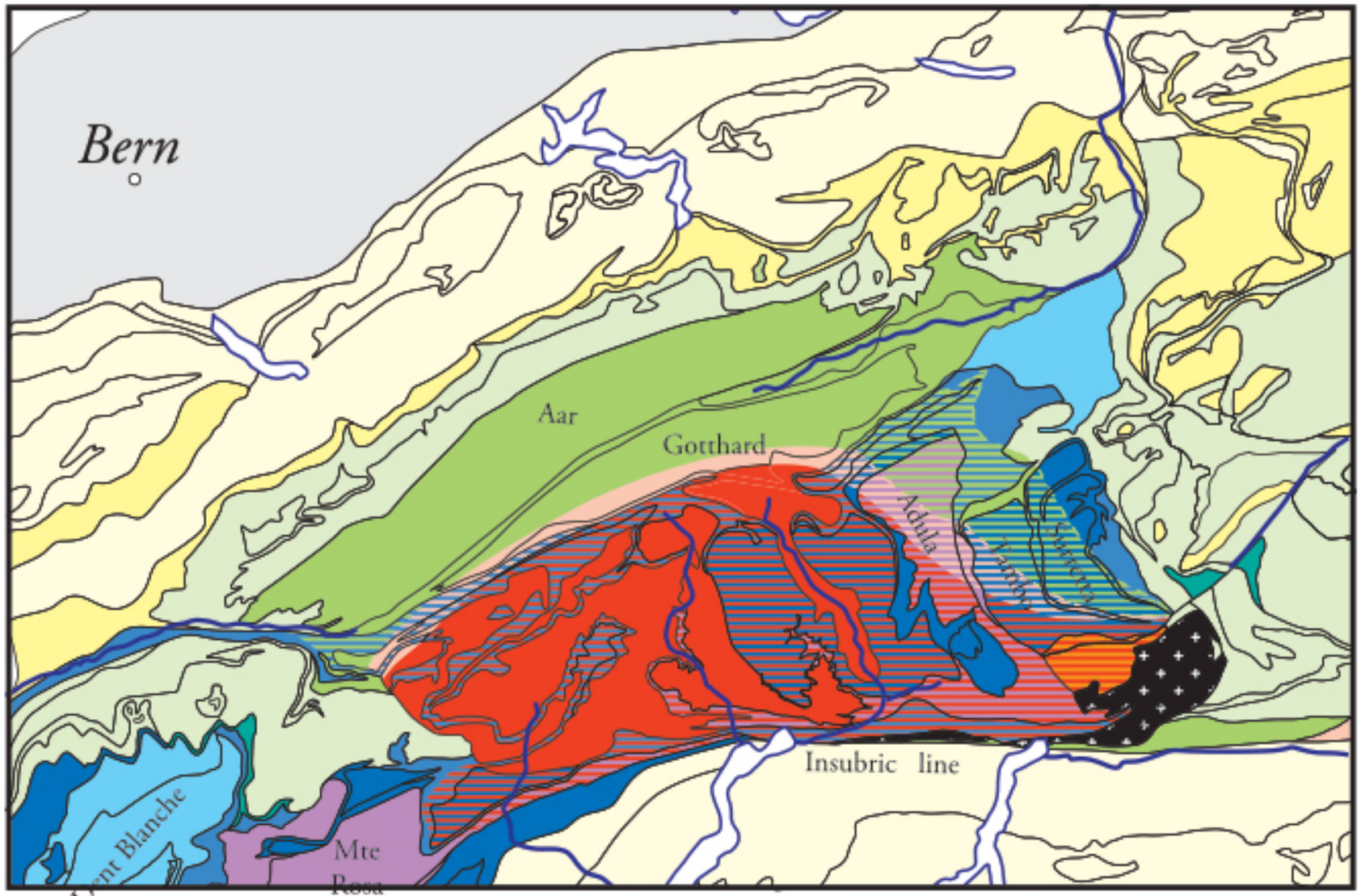
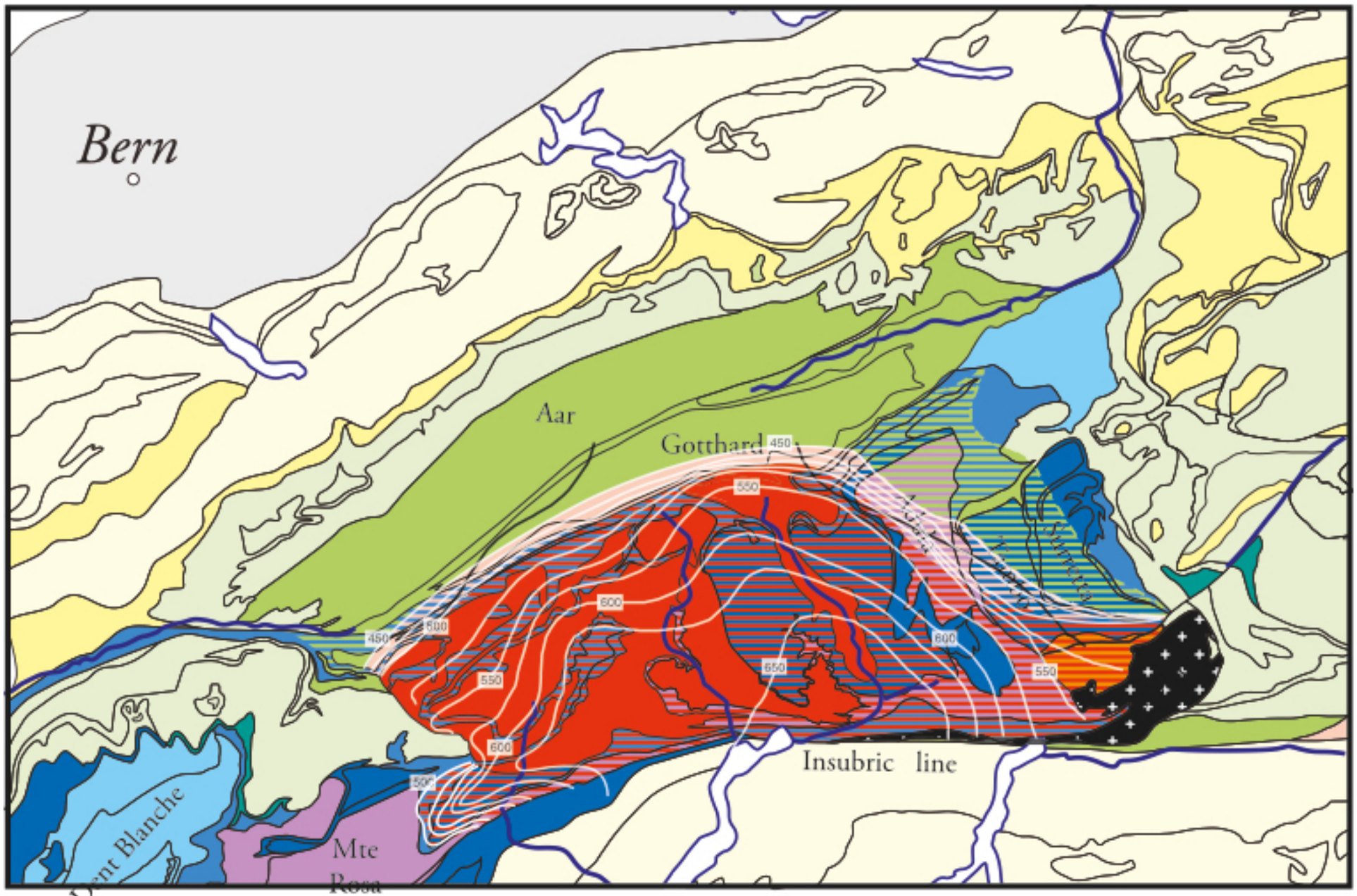
Bousquet et al., in prep

Collision dans les Alpes Centrales



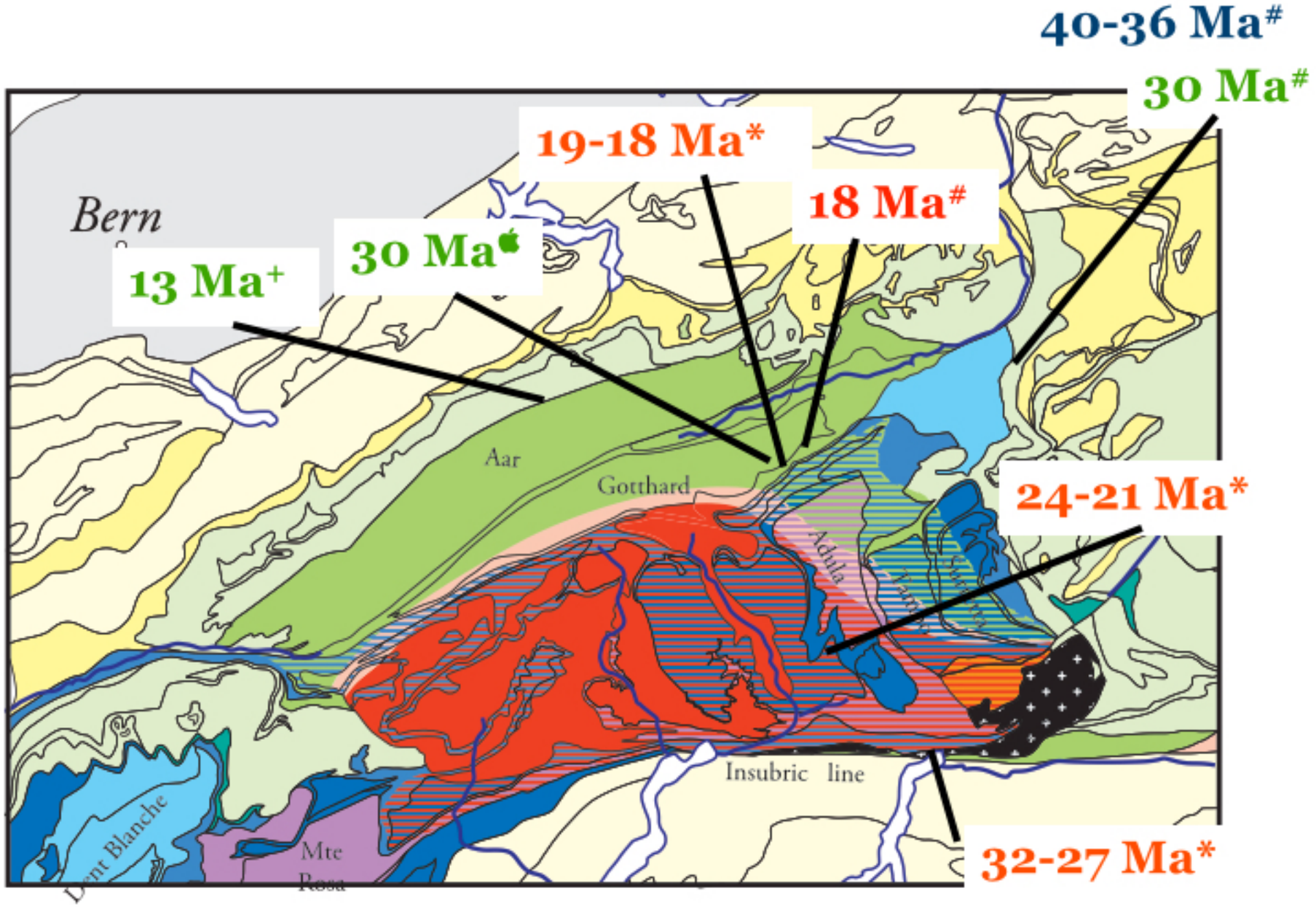
Bousquet et al., in prep

Collision dans les Alpes Centrales



Bousquet et al., in prep

Le metamorphisme thermique
n'est pas un évènement simple



* U-Pb (Köppel et al., 1975, 1980; Rubatto et al., 2010)
 Allanite (Janots et al., 2008)
+ Ar-Ar (Rolland et al., 2009) # Ar-Ar Wiederkehr et al., 2010, Tectonics

Bousquet et al., in prep

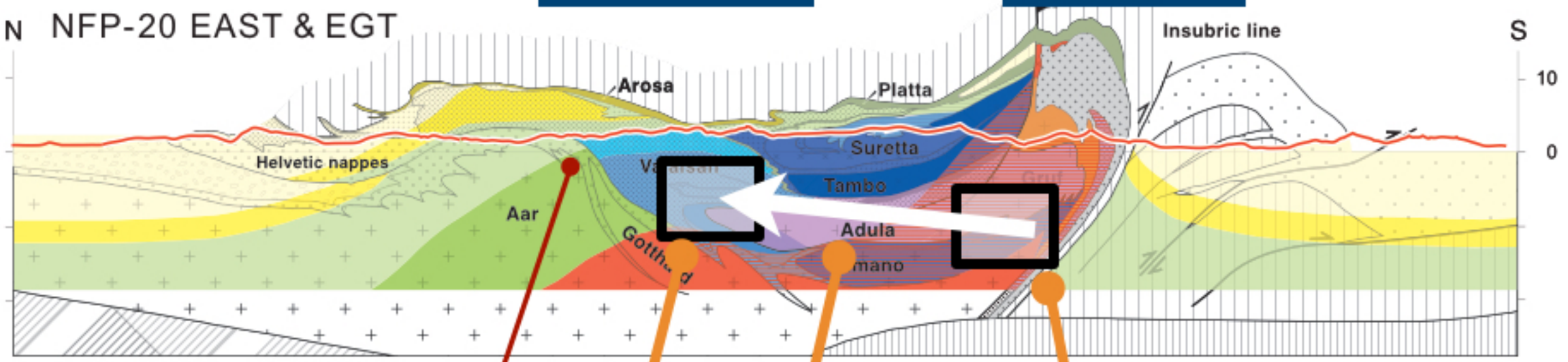
Collision processes

Migration of the HT from South to North with change of heat transfer mechanism

Exhumation controlled by

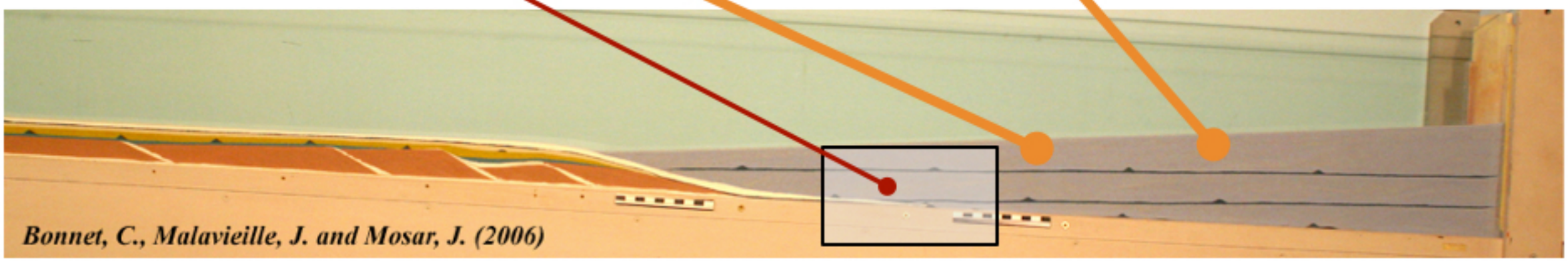
the erosion → **Conduction**

the tectonics → **Advection**



Bousquet et al., 2008

30 Ma ***19-15 Ma*** ***24-21 Ma*** ***32-30 Ma***



Bonnet et al., 2007

Collision processes

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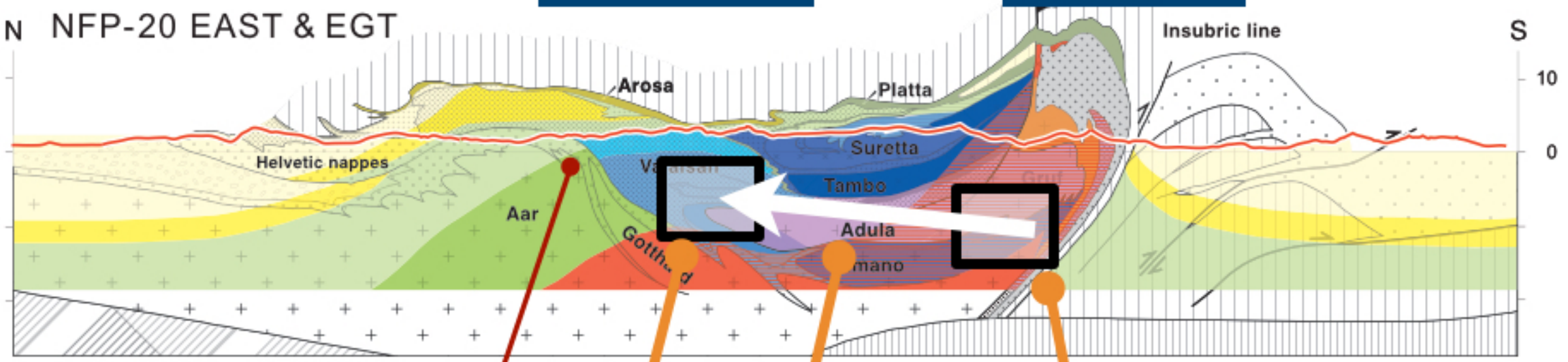
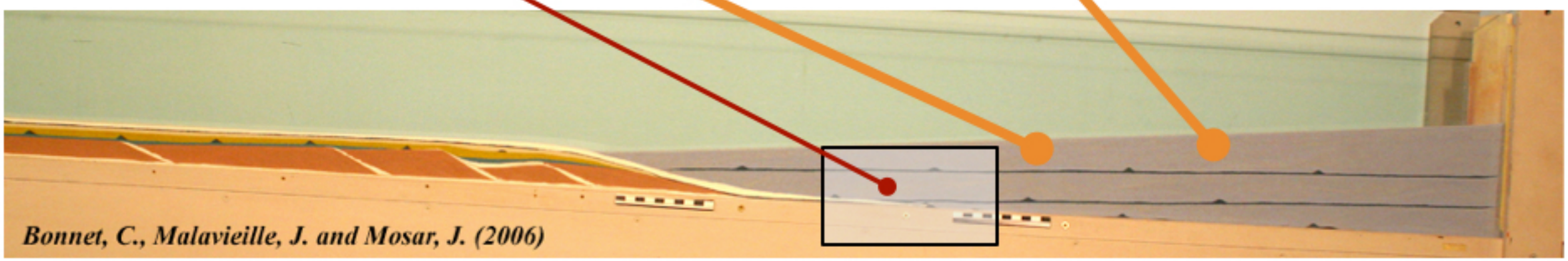


Bousquet et al., 2008

30 Ma *19-15 Ma* *24-21 Ma* *32-30 Ma*

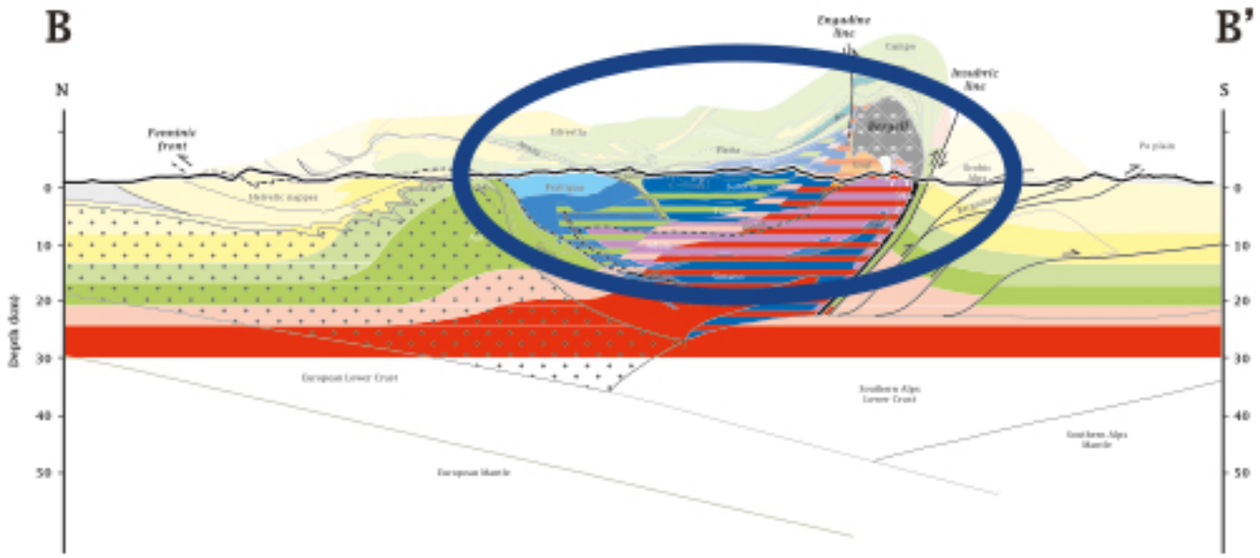


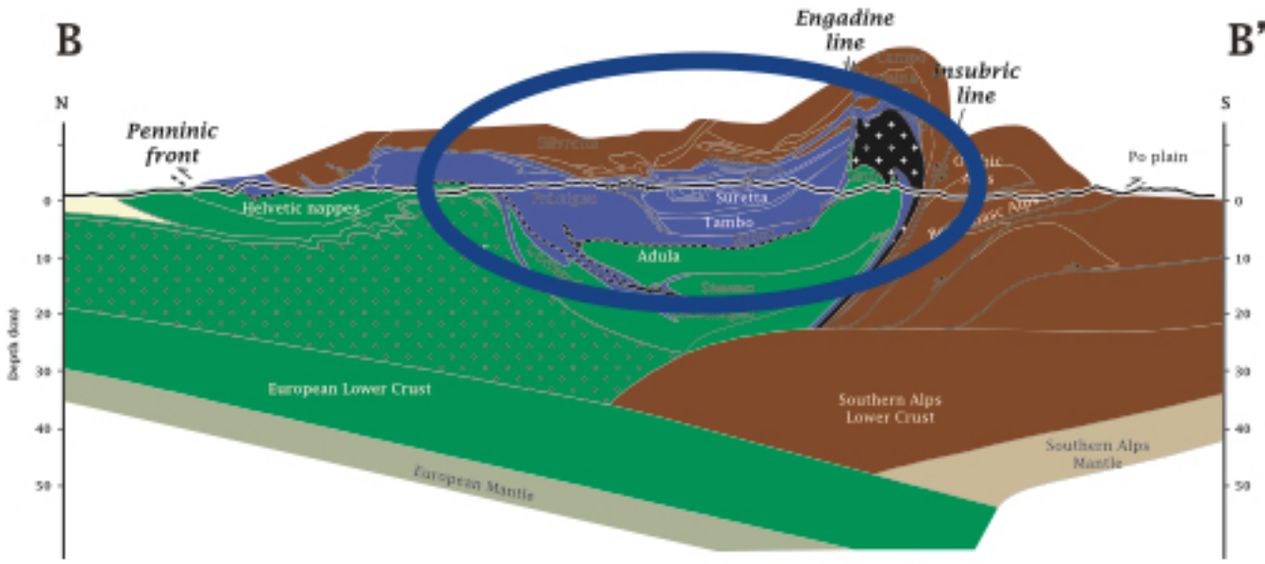
Bonnet et al., 2007

Le métamorphisme de collision

Conséquence de l'accrétion continentale

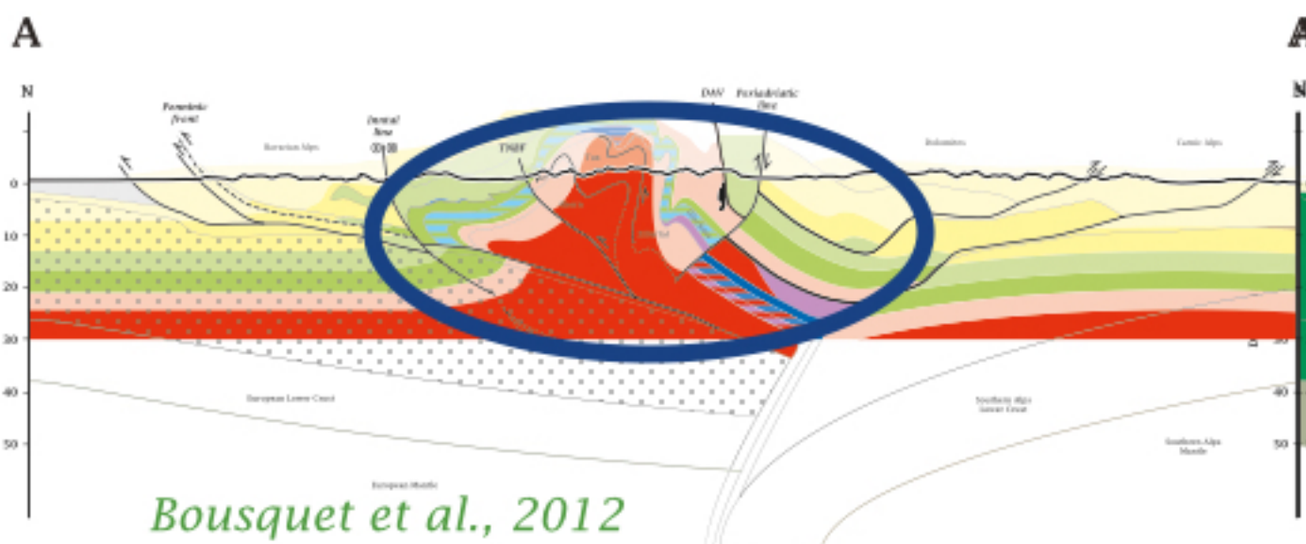
Central Alps



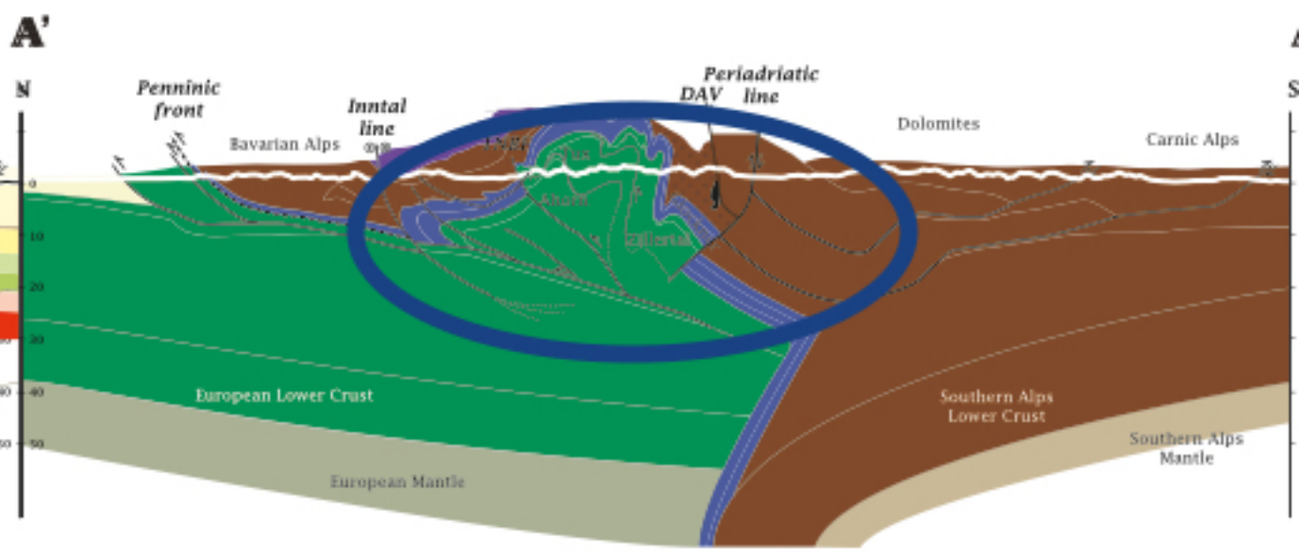


Eastern Alps

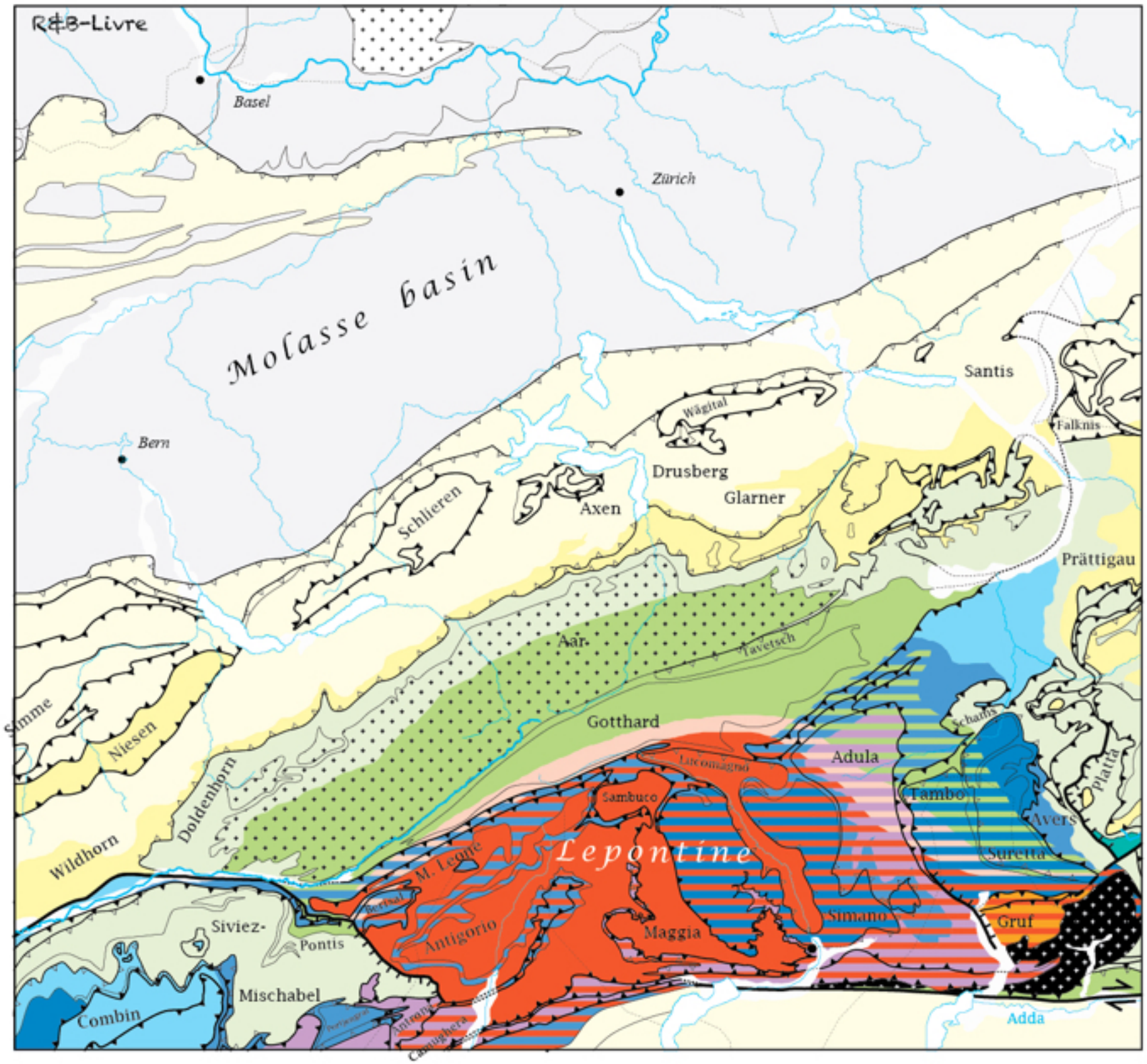
Croûte continentale européenne



Bousquet et al., 2012

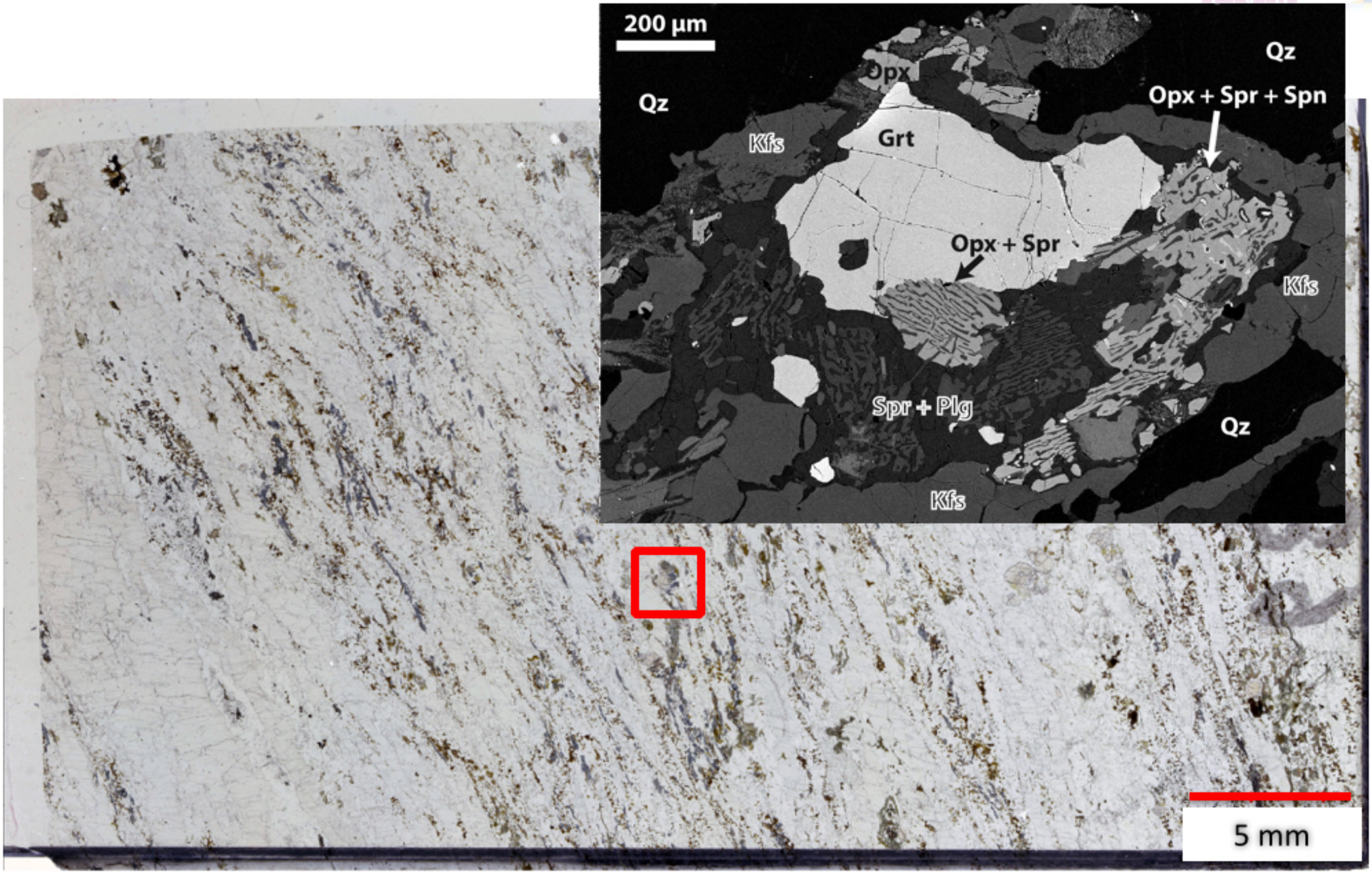


Le métamorphisme de collision



Les granulites alpines

Les granulites alpines

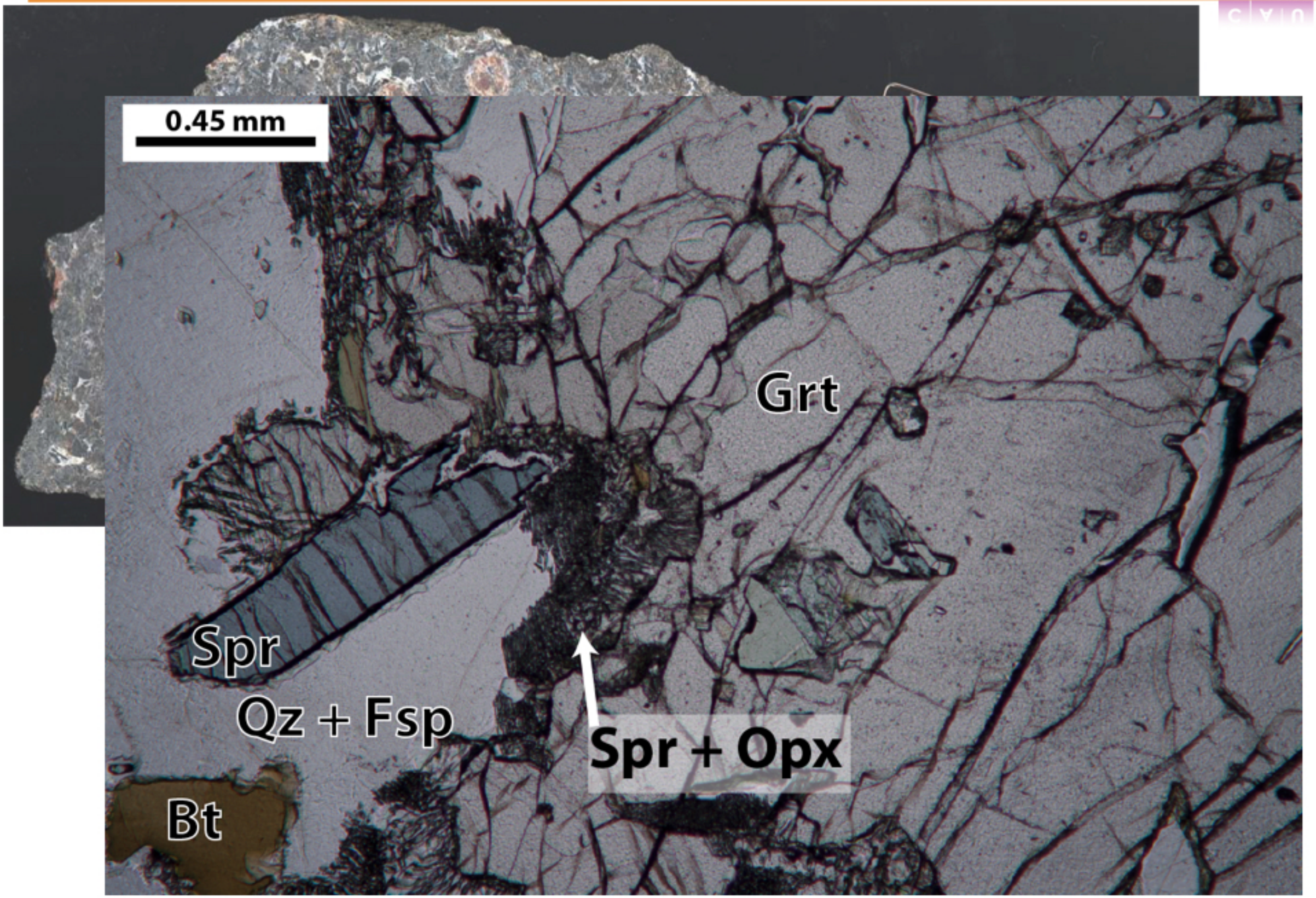


Oalmann et al., in prep.

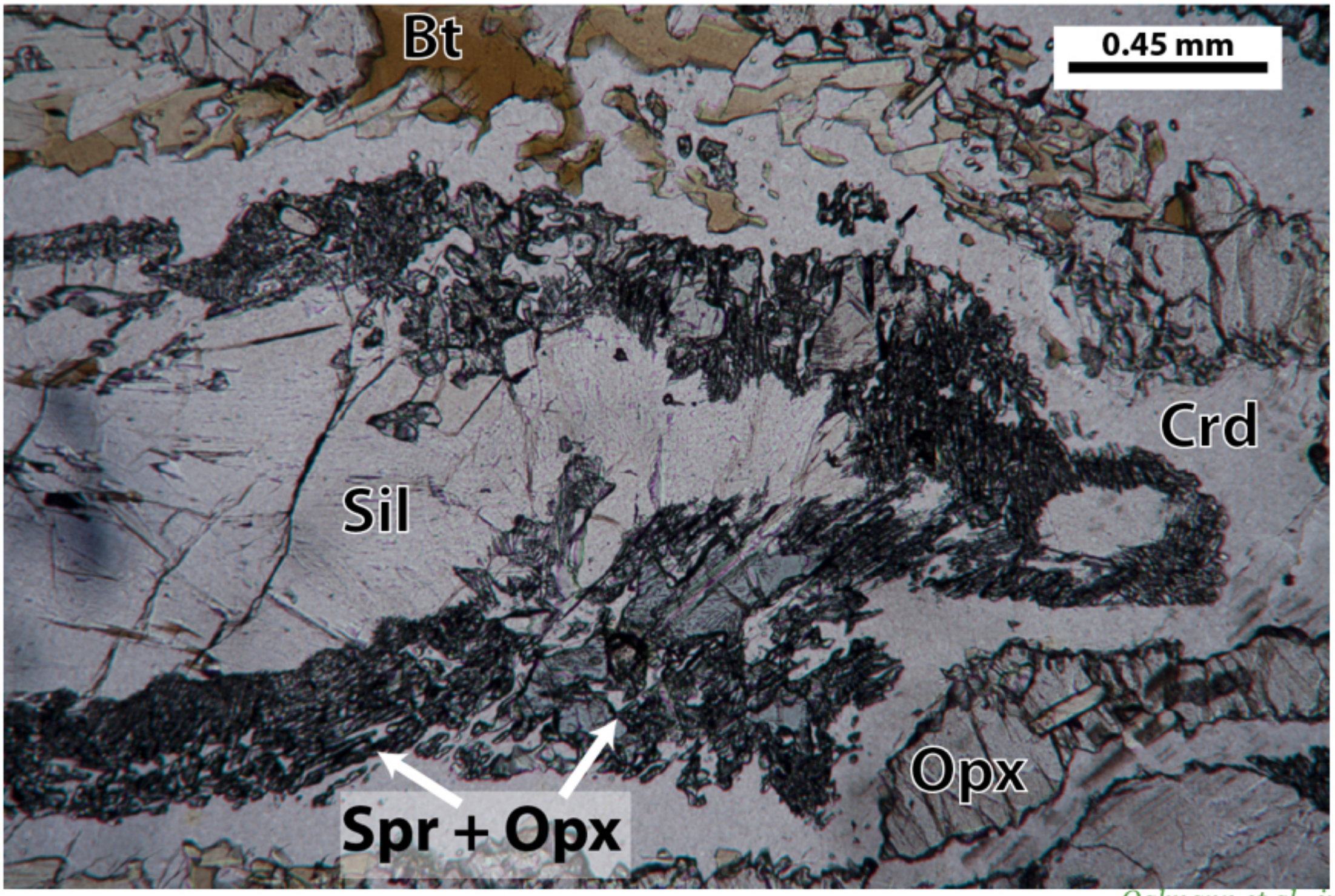
Les granulites alpines

Oalmann et al., in prep.

Les granulites alpines



Oalmann et al., in prep.



Oalmann et al., in prep.

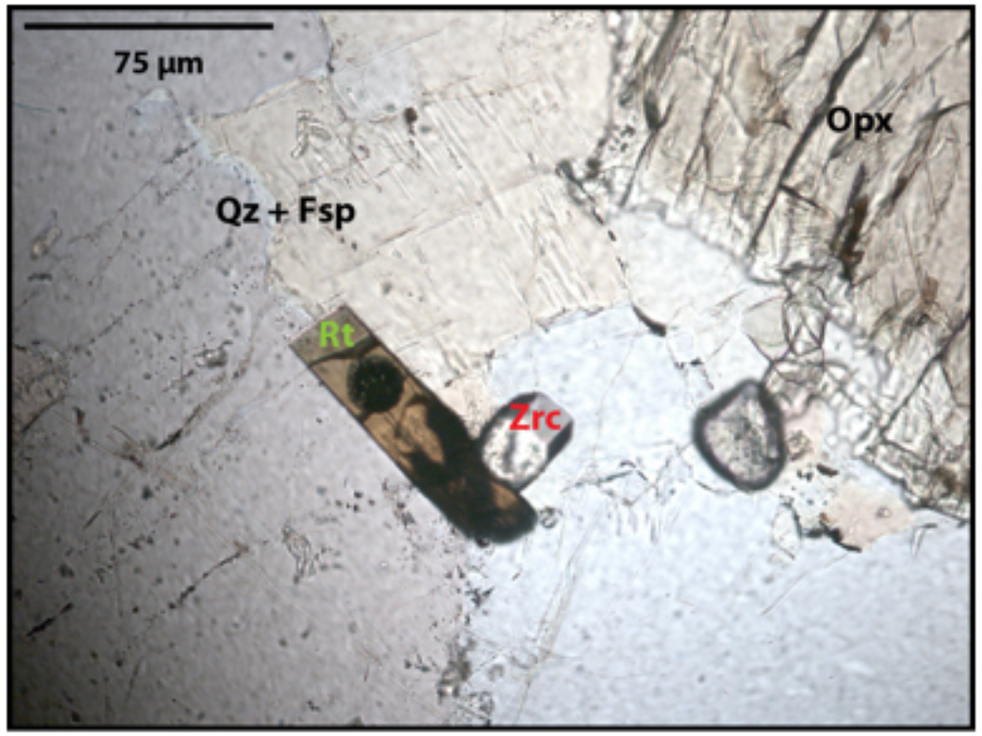
Les granulites alpines

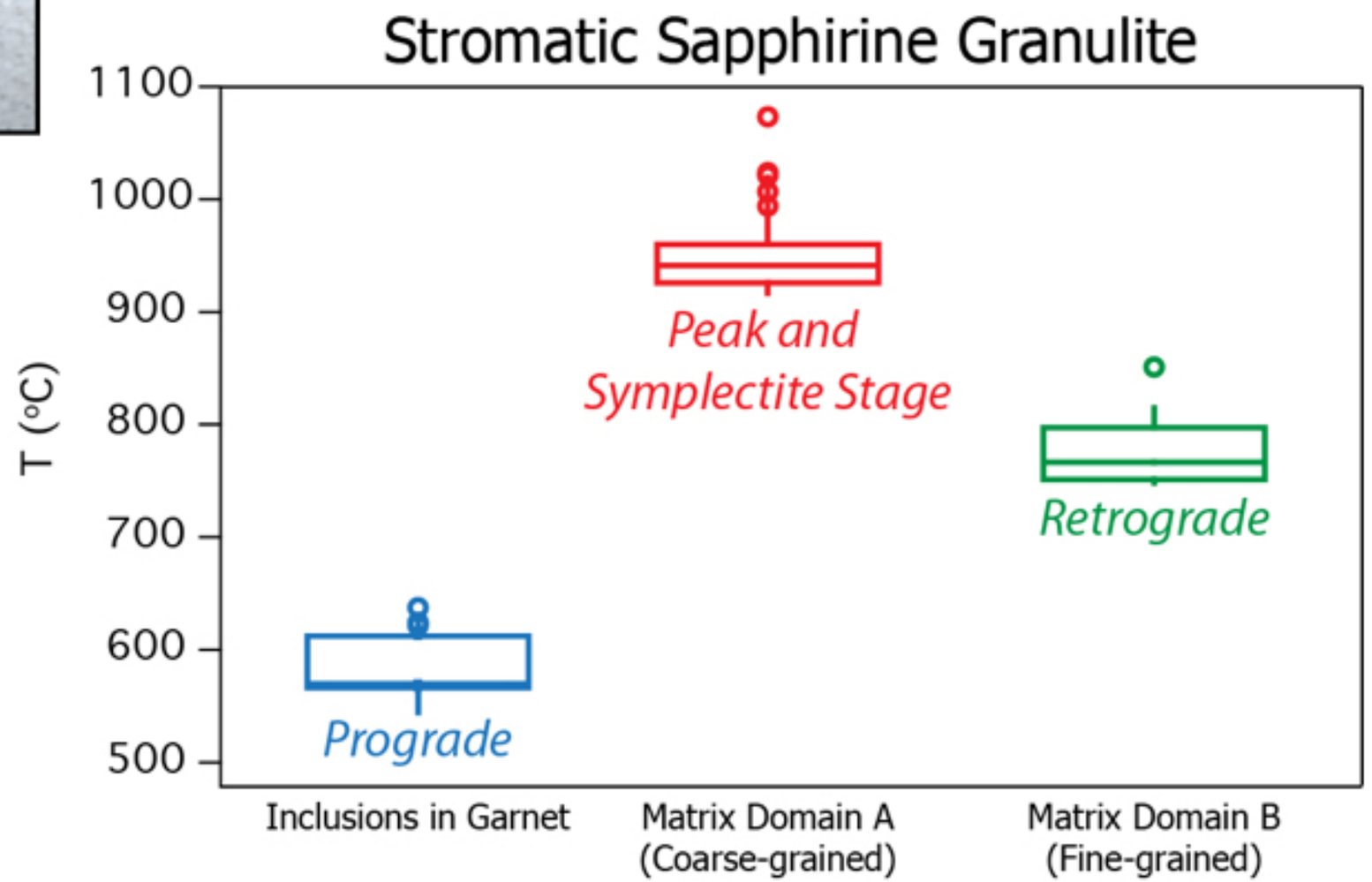
Migmatites du manteau sub-continental, Gruf

Migmatites crustales, Gruf

Migmatites crustales, Gruf

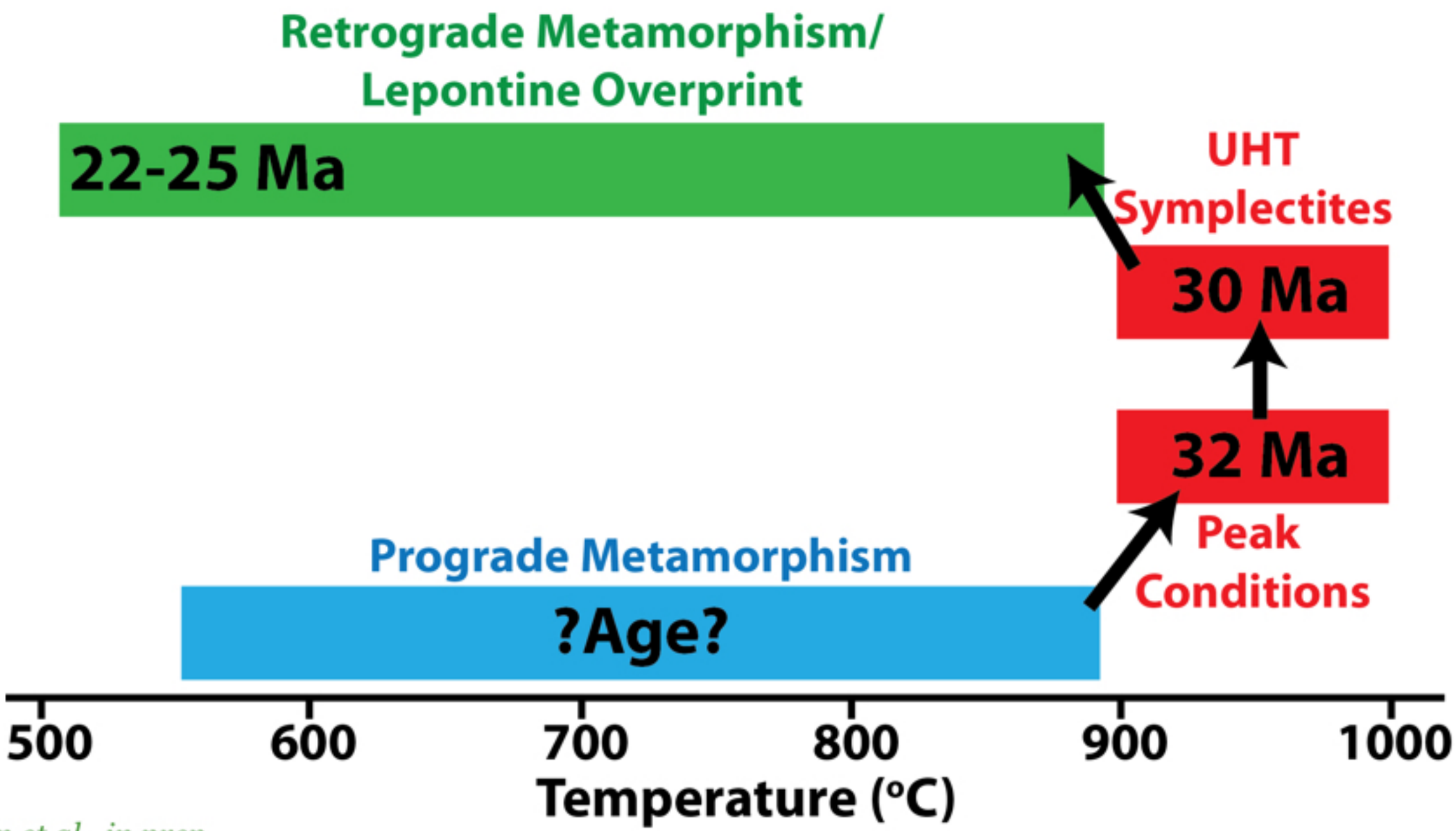
Granulites alpines





Oalmann et al., in prep.

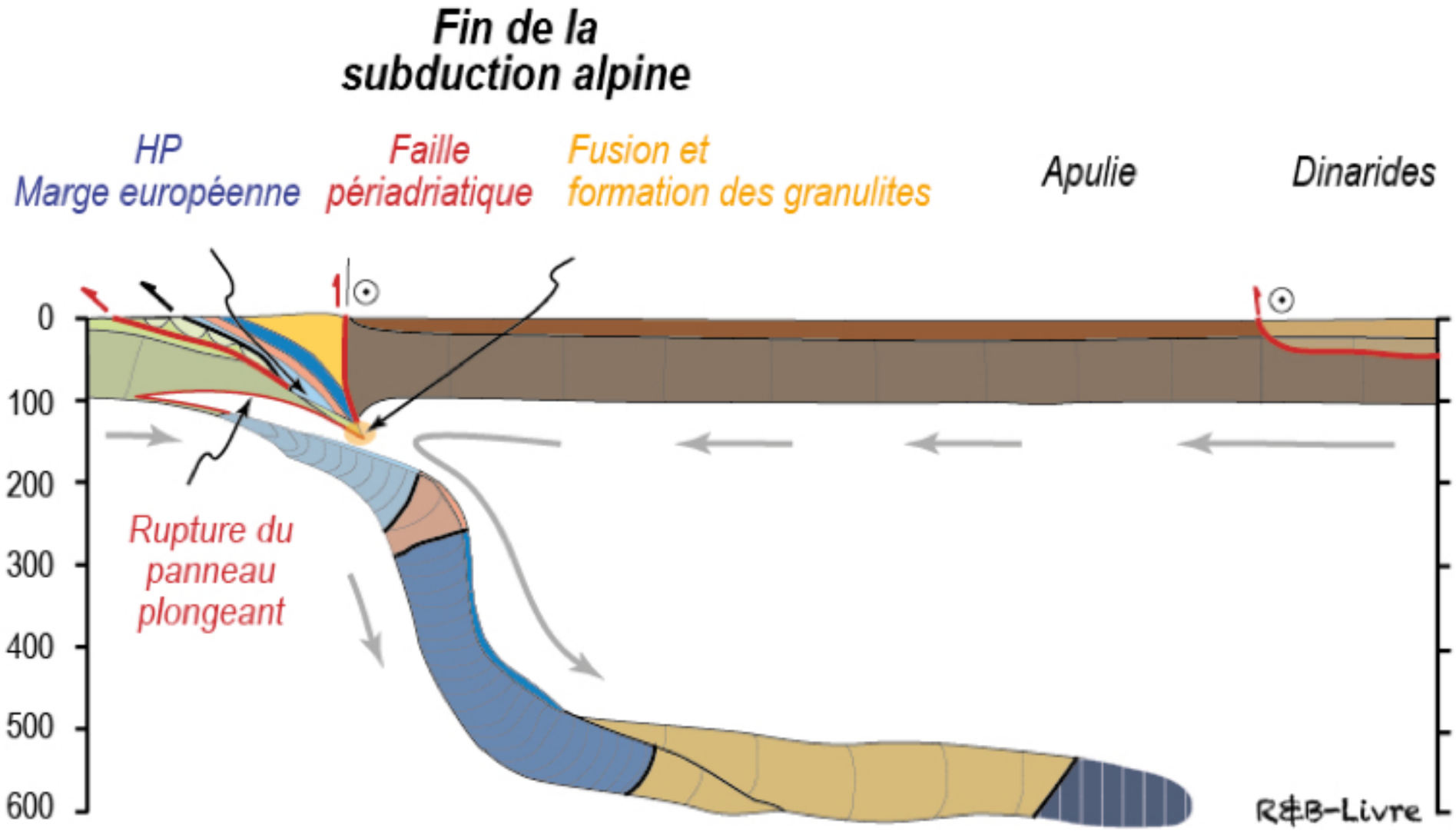
Évolution thermique des granulites du Gruf



Oalmann et al., in prep.

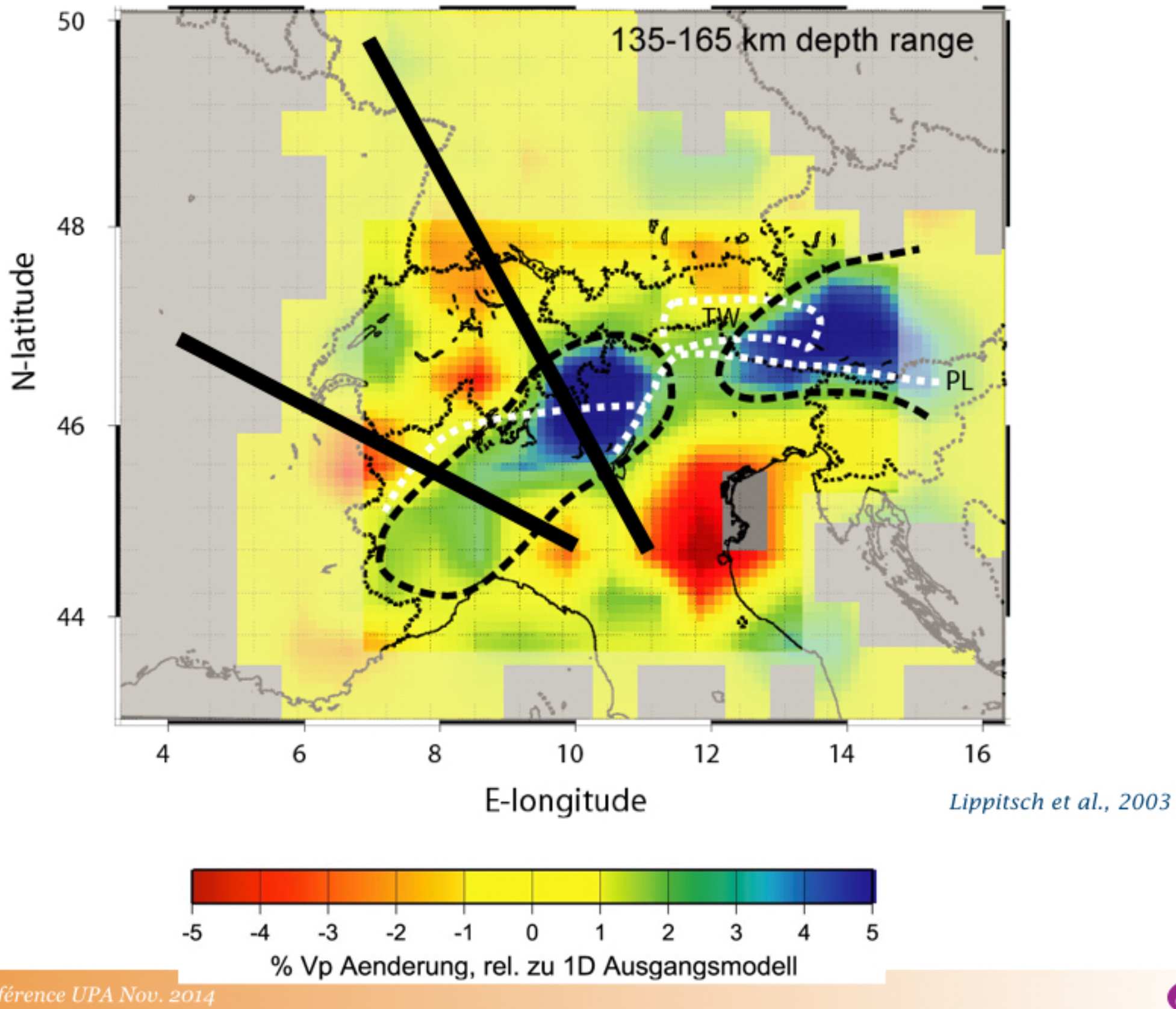
Interprétation du métamorphisme de UHT

Rupture du panneau plongeant (slab)



Fusion de la croûte et du manteau
=> **1)** métamorphisme de UHT (Granulites)

Tomography of the slab

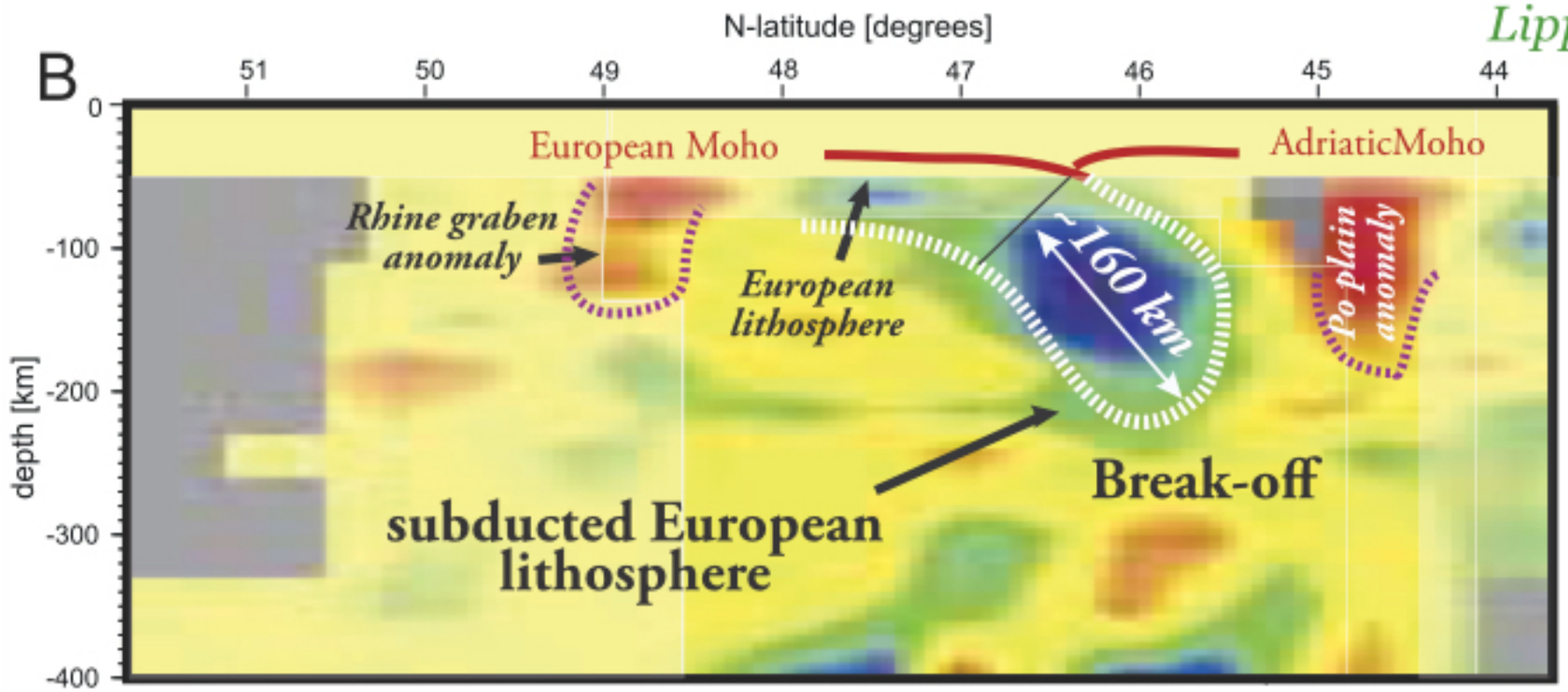


Lippitsch et al., 2003

Tomography of the slab

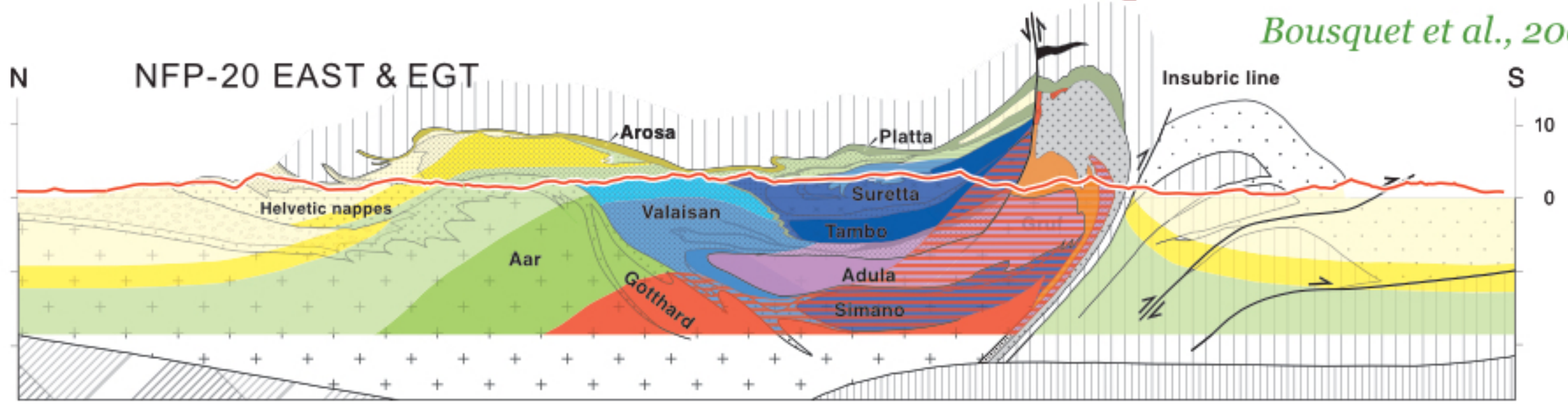
Central Alps

Lippitsch et al., 2003



160 km of subducted Europe

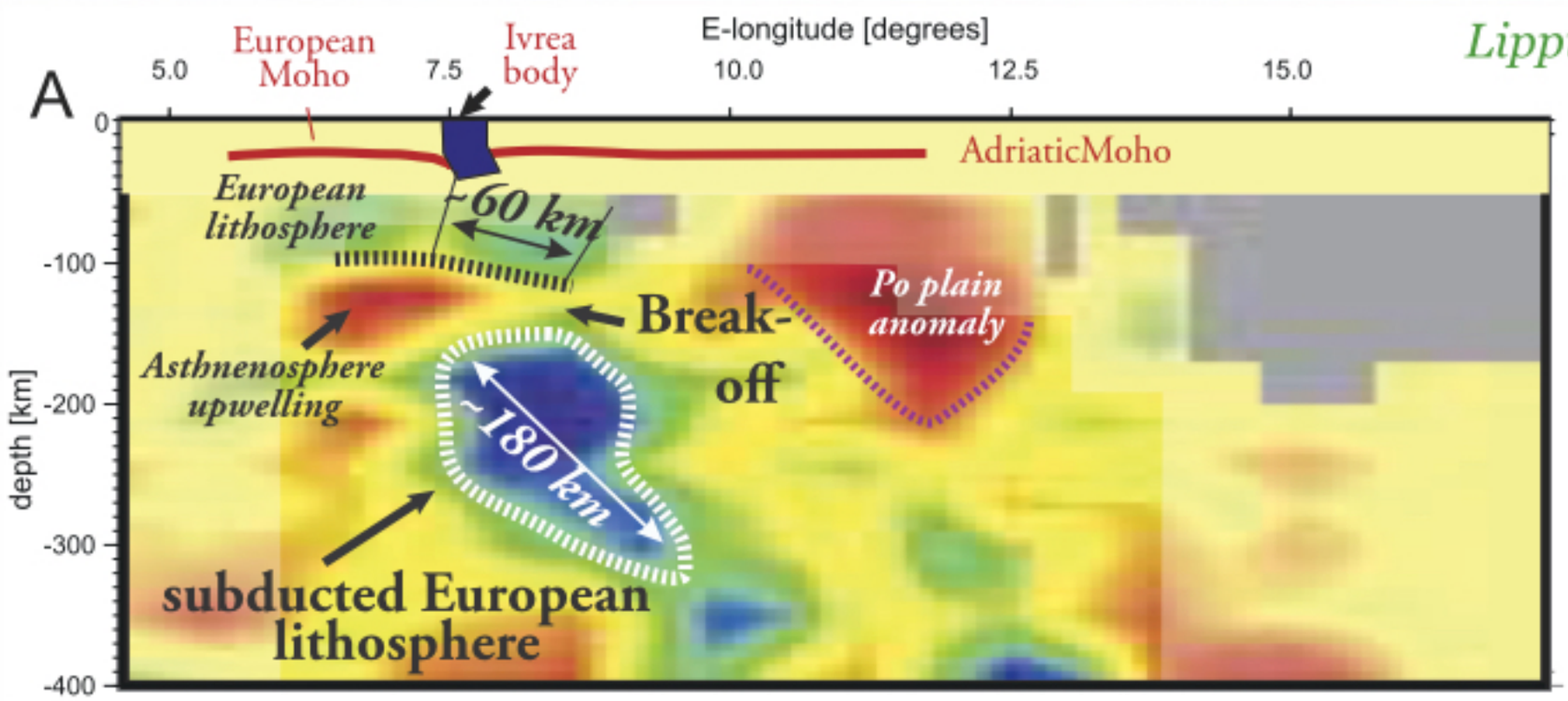
Bousquet et al., 2008



✓accretion of european continental crust (*Adula, Simano, Leventina, Gotthard*)
✓HT metamorphism

Tomography of the slab

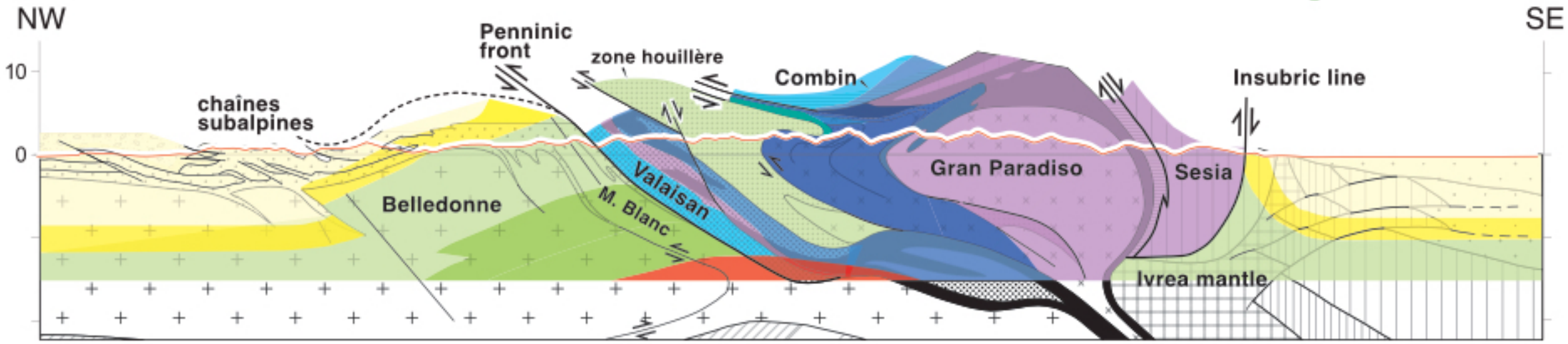
Western Alps



Lippitsch et al., 2003

240 km of subducted Europe

ECORS-CROP

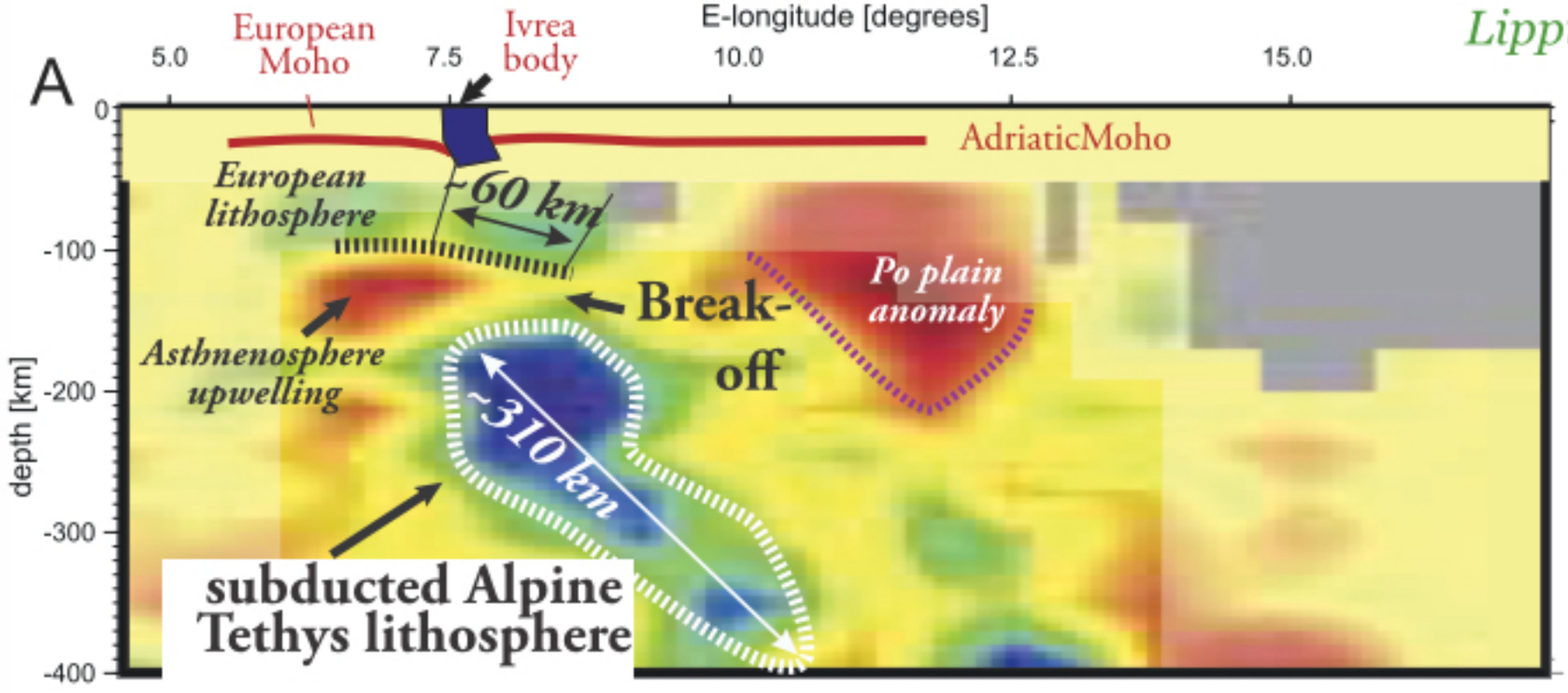


Bousquet et al., 2008

✓No accretion of european continental upper crust
✓HP-LT metamorphism preserved - No HT metamorphism

Tomography of the slab

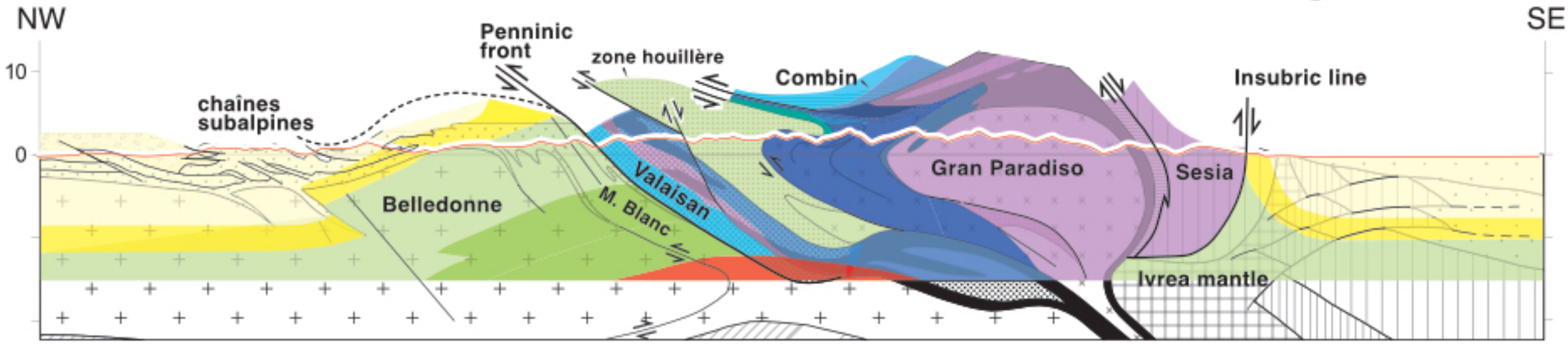
Western Alps



Lippitsch et al., 2003

60 km of subducted Europe

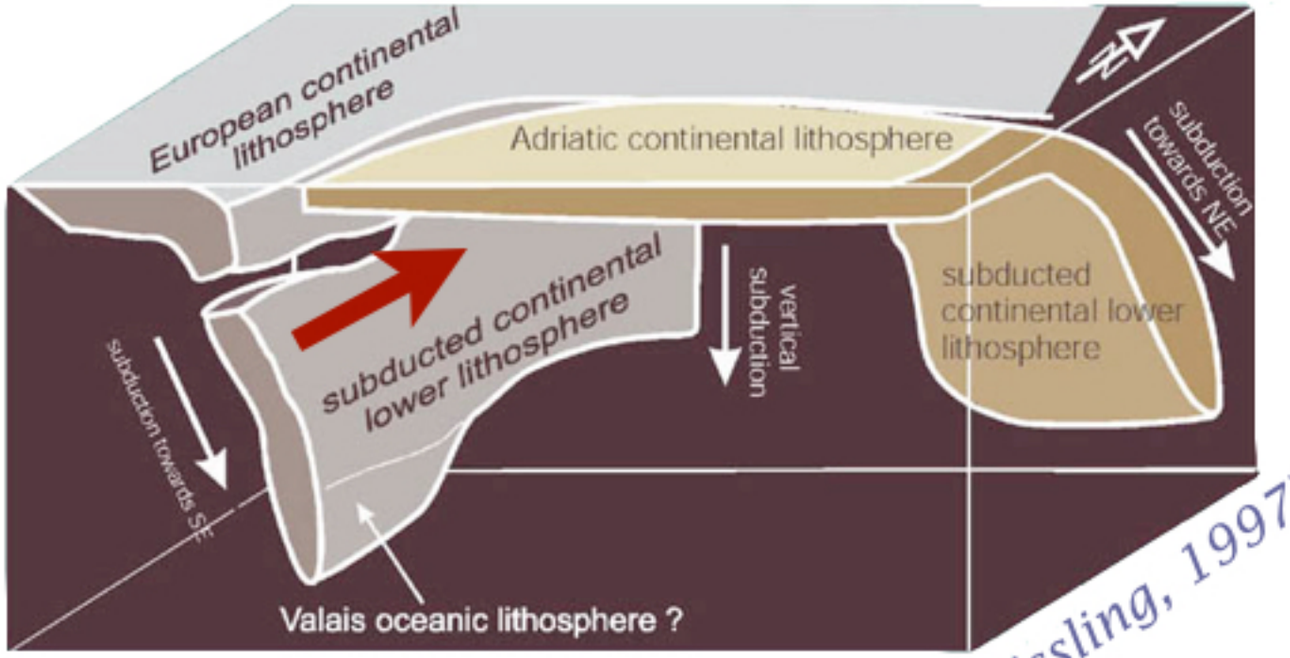
ECORS-CROP



Bousquet et al., 2008

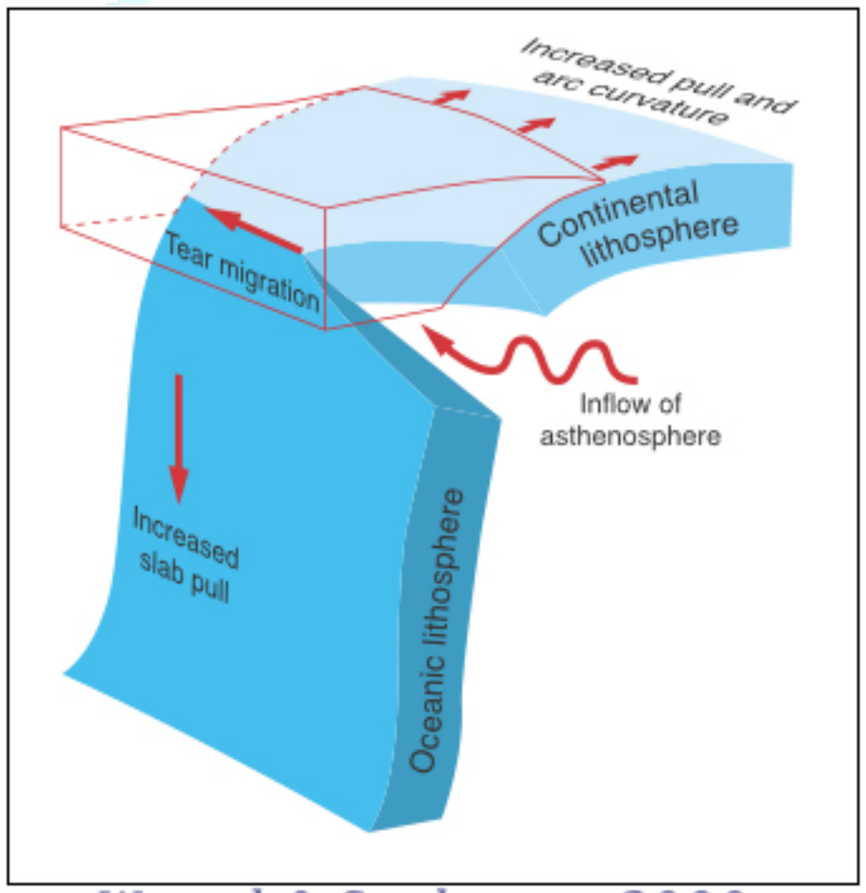
✓No accretion of european continental upper crust
✓HP-LT metamorphism preserved - No HT metamorphism

Propagation of the tear



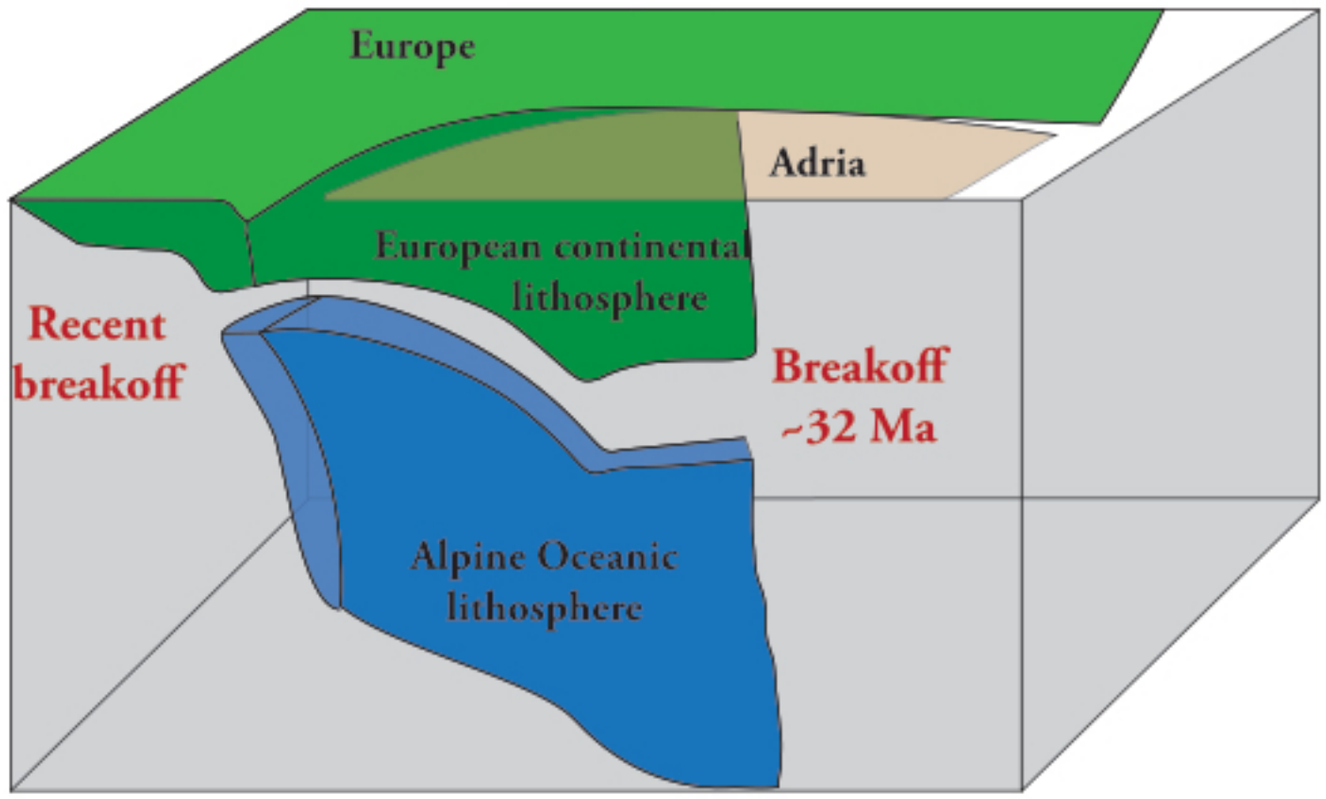
(Kissling, 1997)

Towards the NE
Active phenomenon

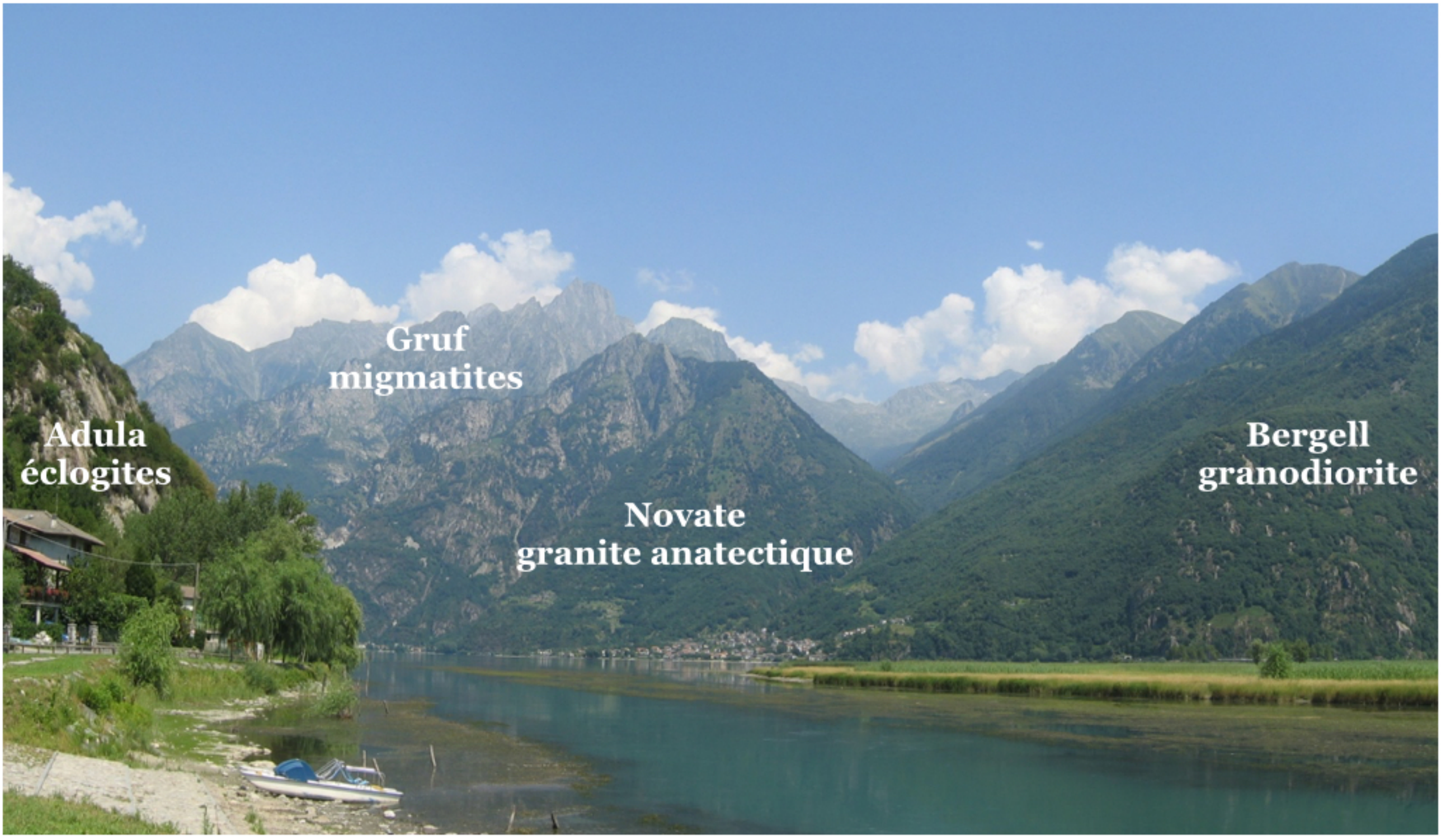


Wortel & Spakman, 2000

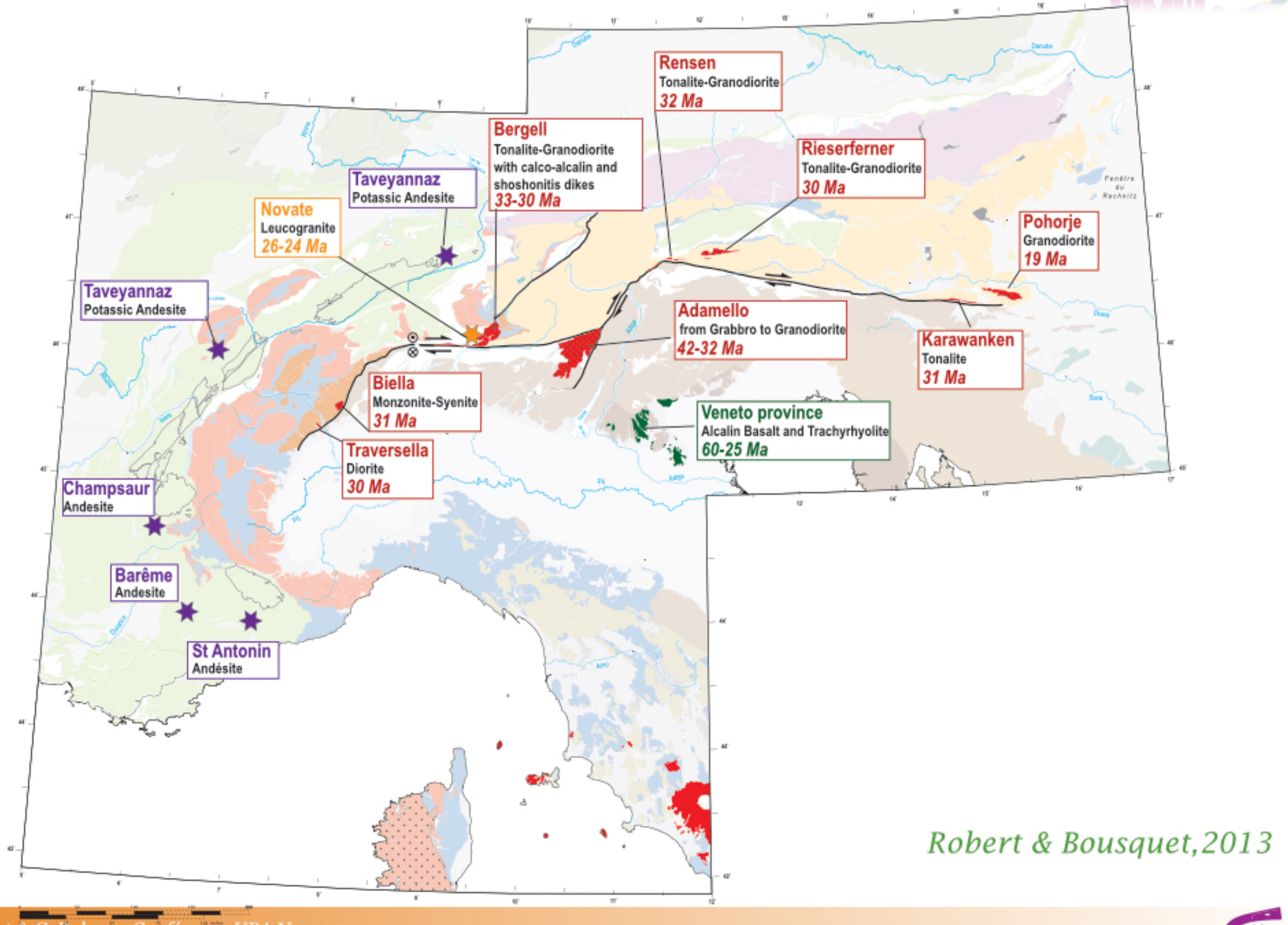
Towards the SW
Already done



Le magmatisme alpin



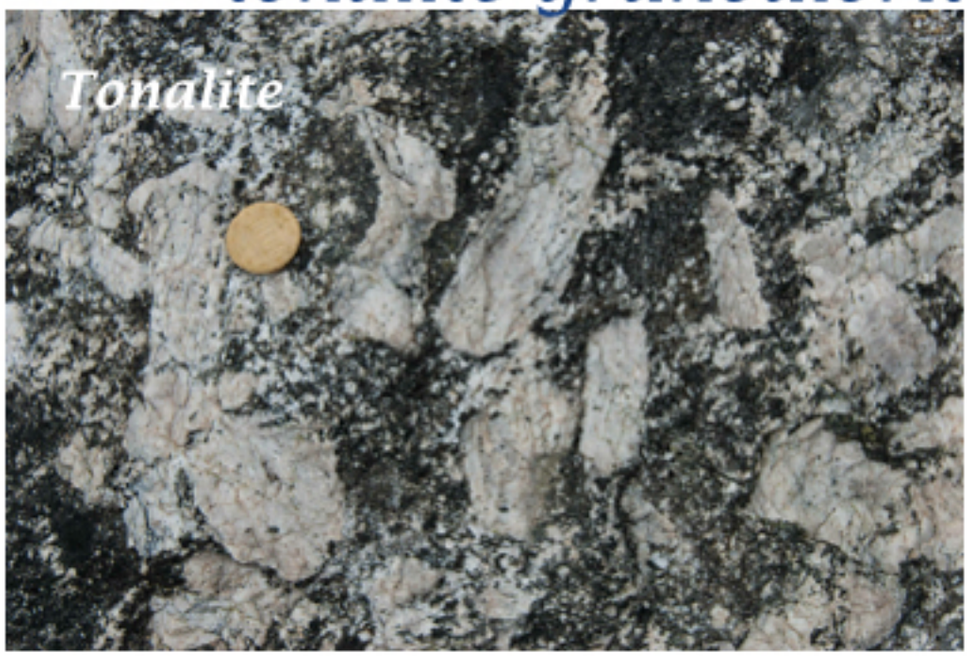
Le magmatisme alpin



Robert & Bousquet,2013

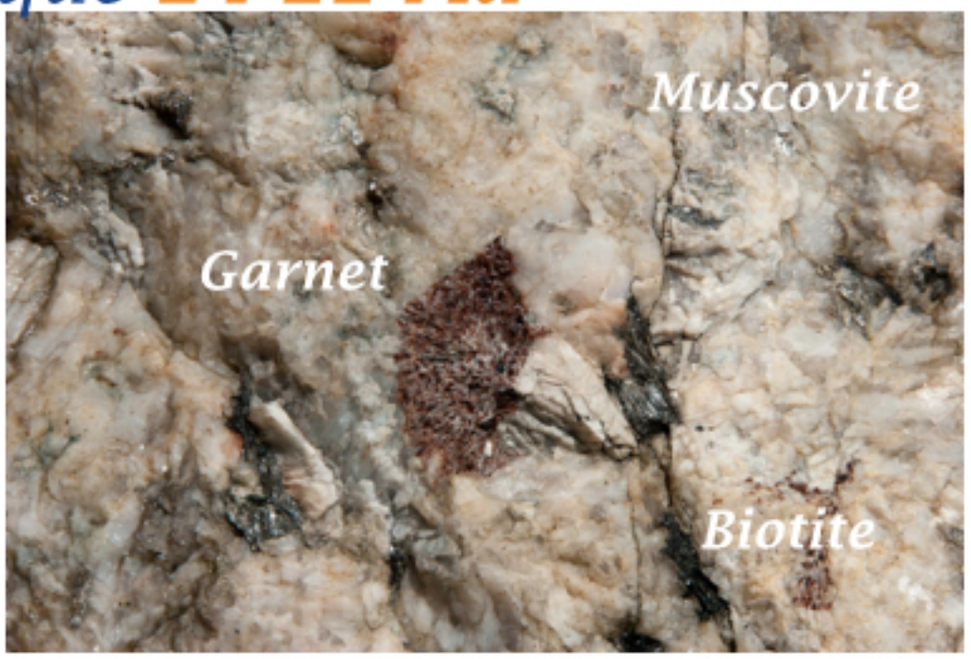
Bergell

tonalite-granodiorite à amphiboles **35-30 Ma**



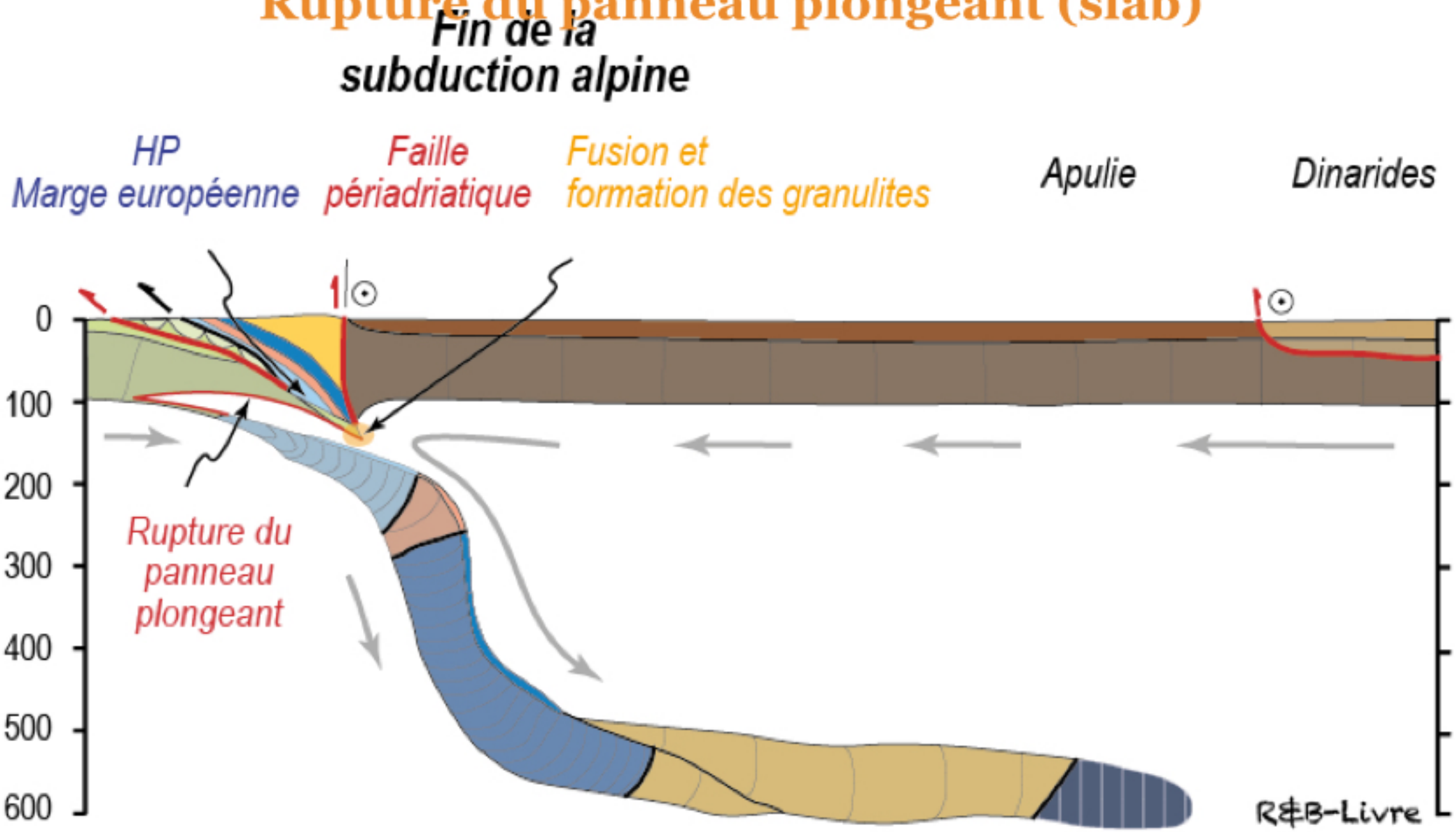
Novate

granite anatectique **24-22 Ma**



Rupture du panneau plongeant (slab)

Rupture du panneau plongeant (slab)

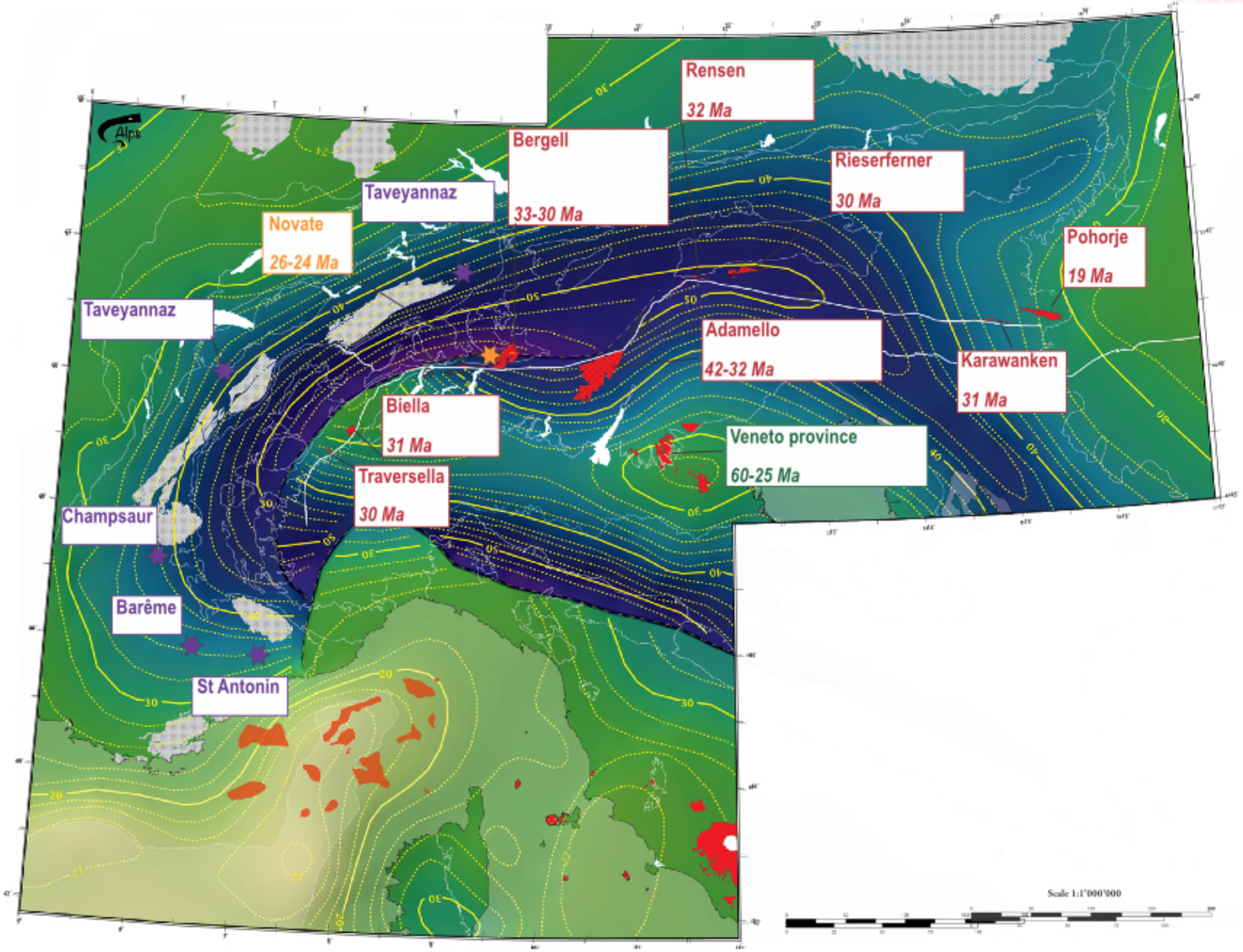


Fusion de la croûte et du manteau

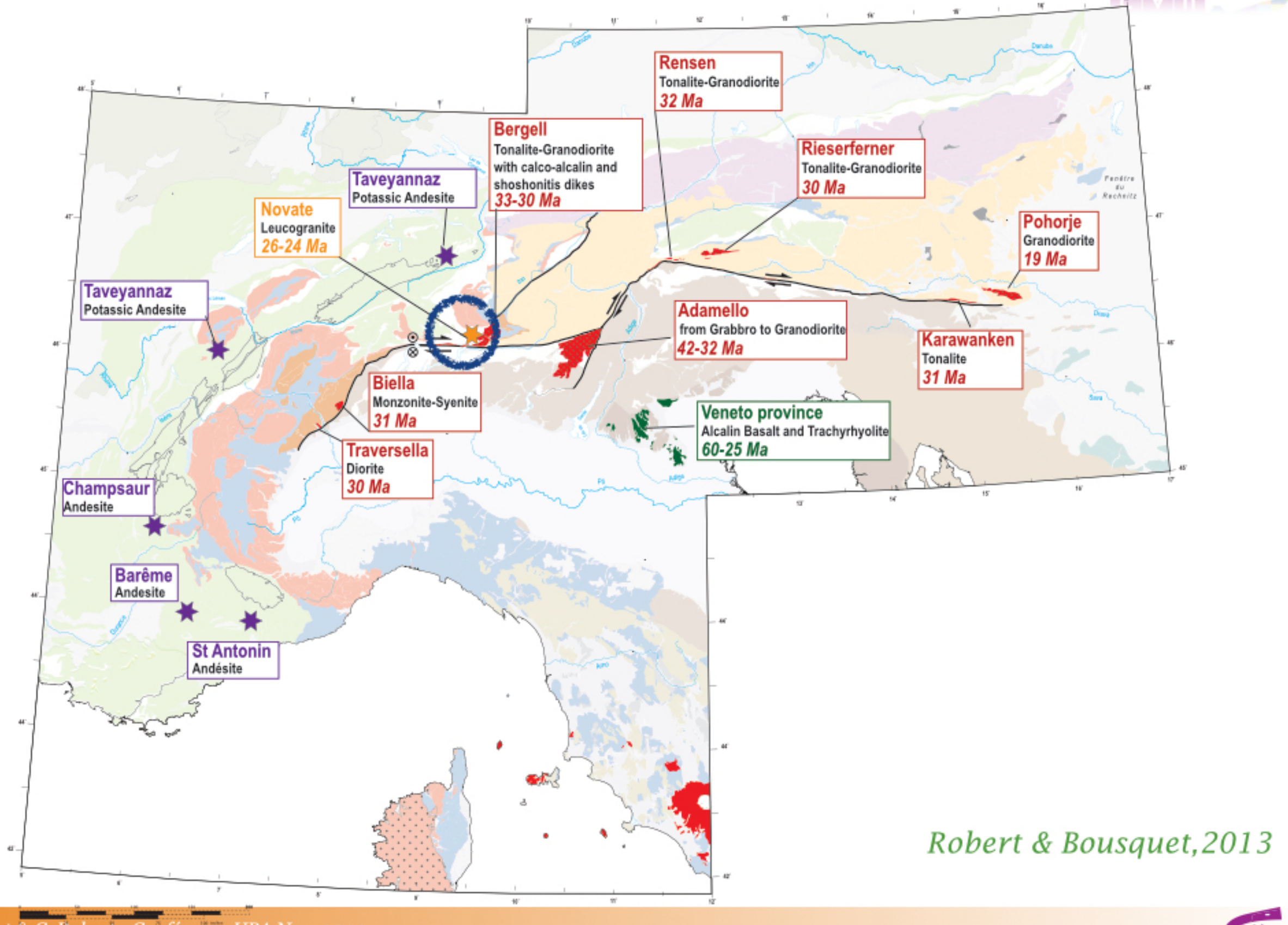
=> **1)** métamorphisme de UHT (Granulites)

=> **2)** mélange des magmas

Le magmatisme alpin



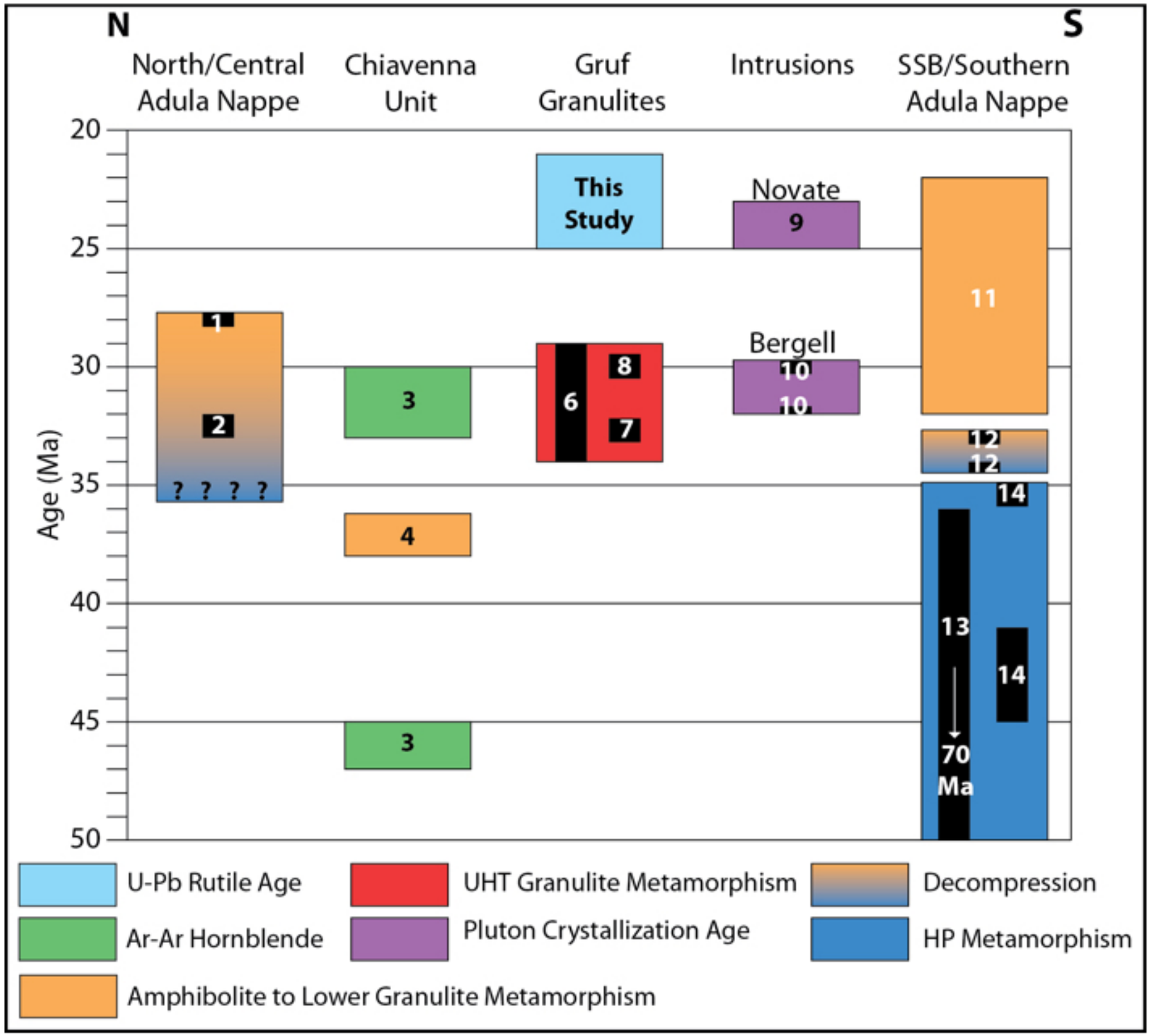
Le magmatisme alpin



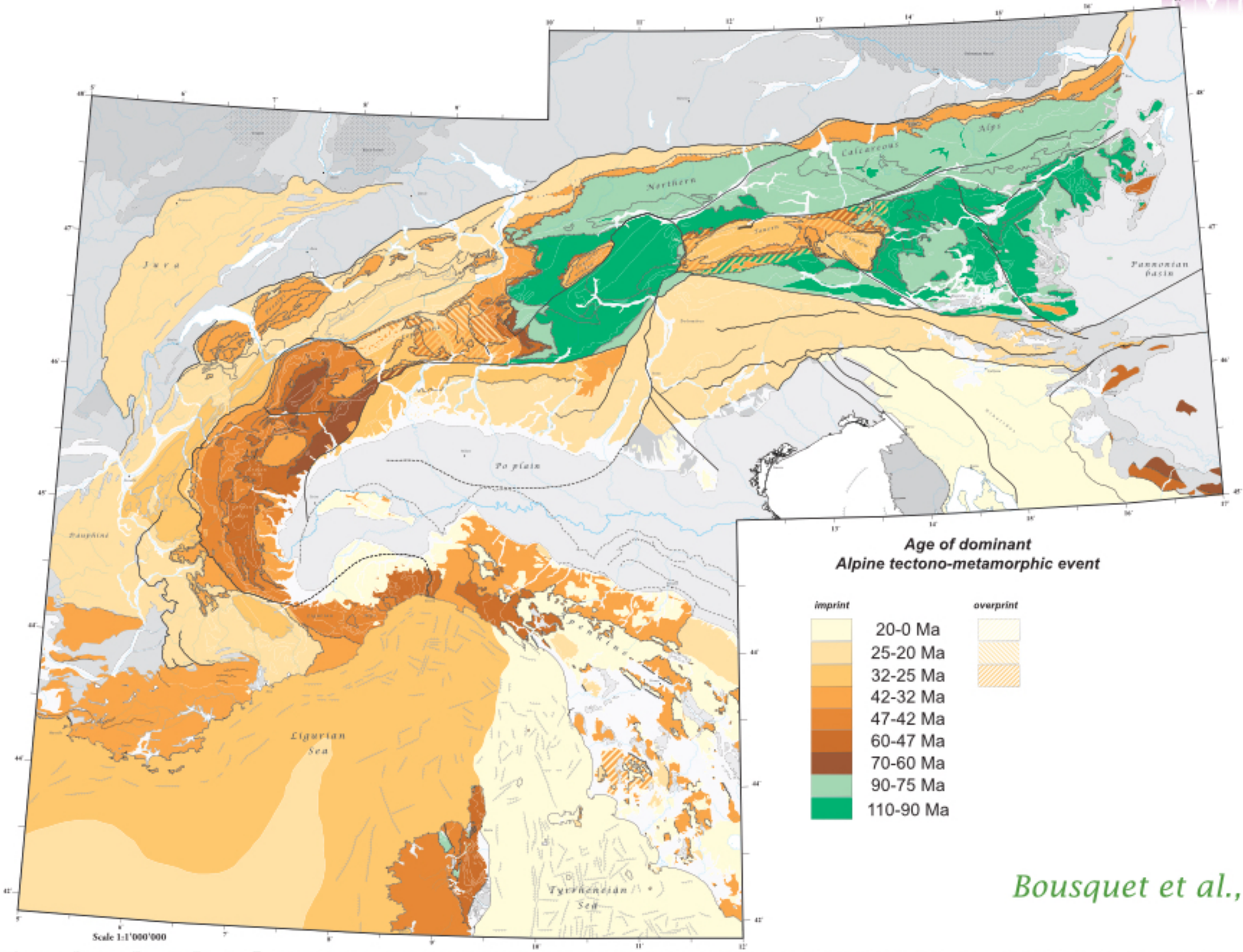
Robert & Bousquet,2013

Veines magmatiques précoces déformées

Dykes tardifs non déformés à Beryl-Muscovite-Grenat


N
S
North/Central Adula Nappe
Chiavenna Unit
Gruf Granulites
Intrusions
SSB/Southern Adula Nappe
20
25
30
35
40
45
50
Age (Ma)
This Study
Novate
9
Bergell
10
10
11
1
2
? ? ? ?
3
4
6
8
7
12
12
14
13
14
3
70 Ma
U-Pb Rutile Age
UHT Granulite Metamorphism
Decompression
Ar-Ar Hornblende
Pluton Crystallization Age
HP Metamorphism
Amphibolite to Lower Granulite Metamorphism

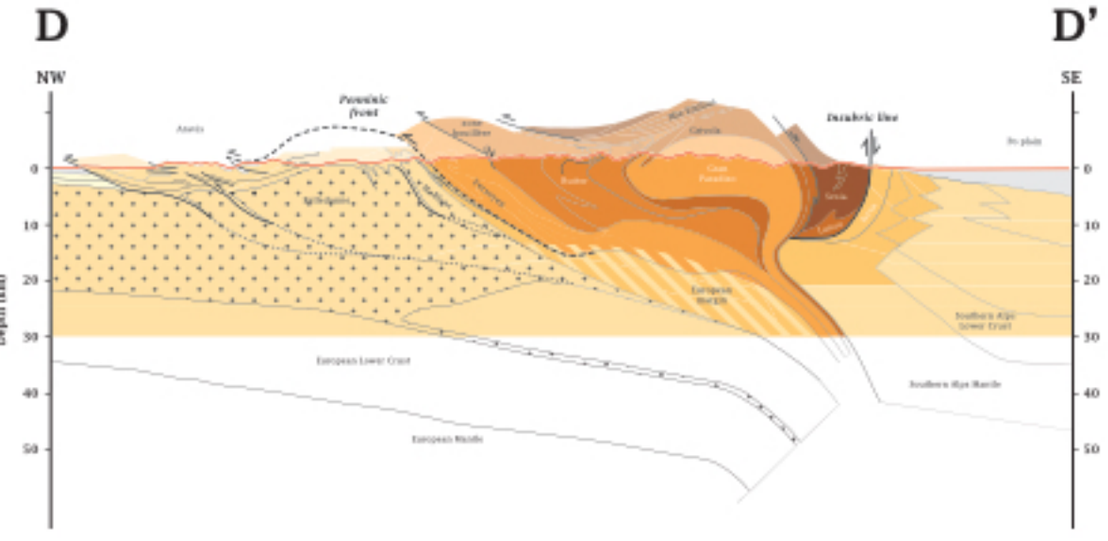
Les âges de la construction de la chaîne



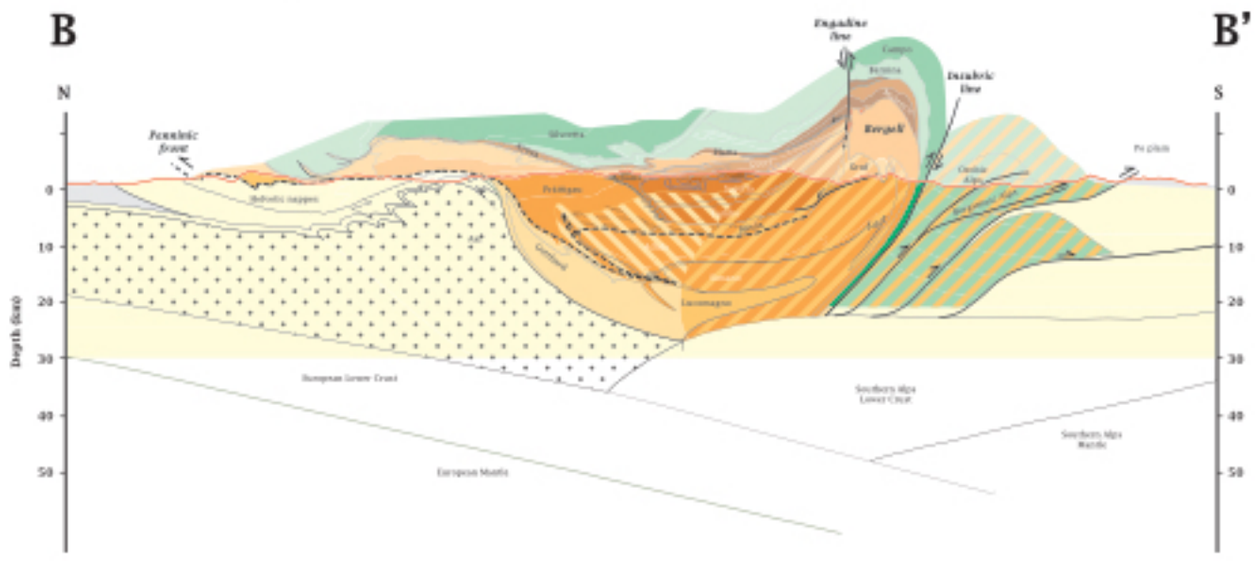
Bousquet et al., 2012

Les âges de la construction de la chaîne

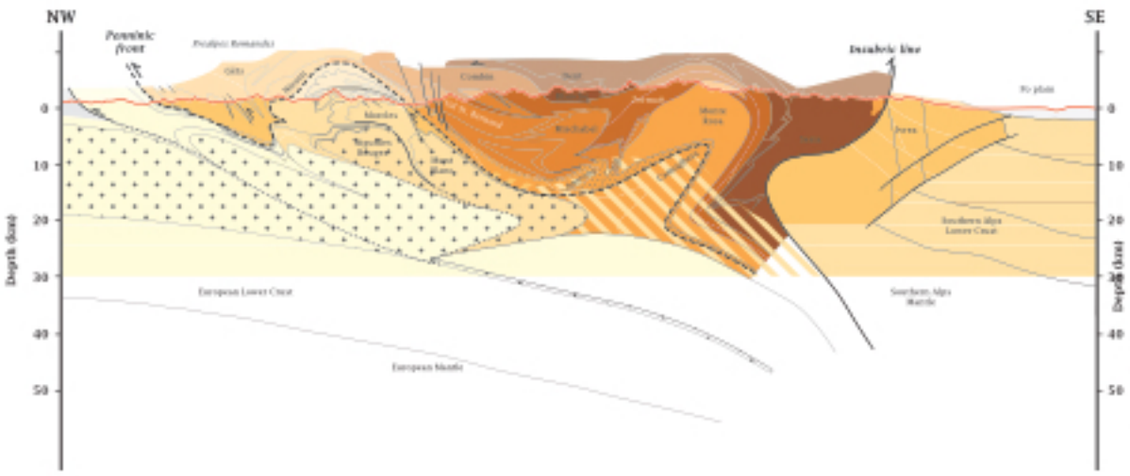
Western Alps : ECORS-CROP



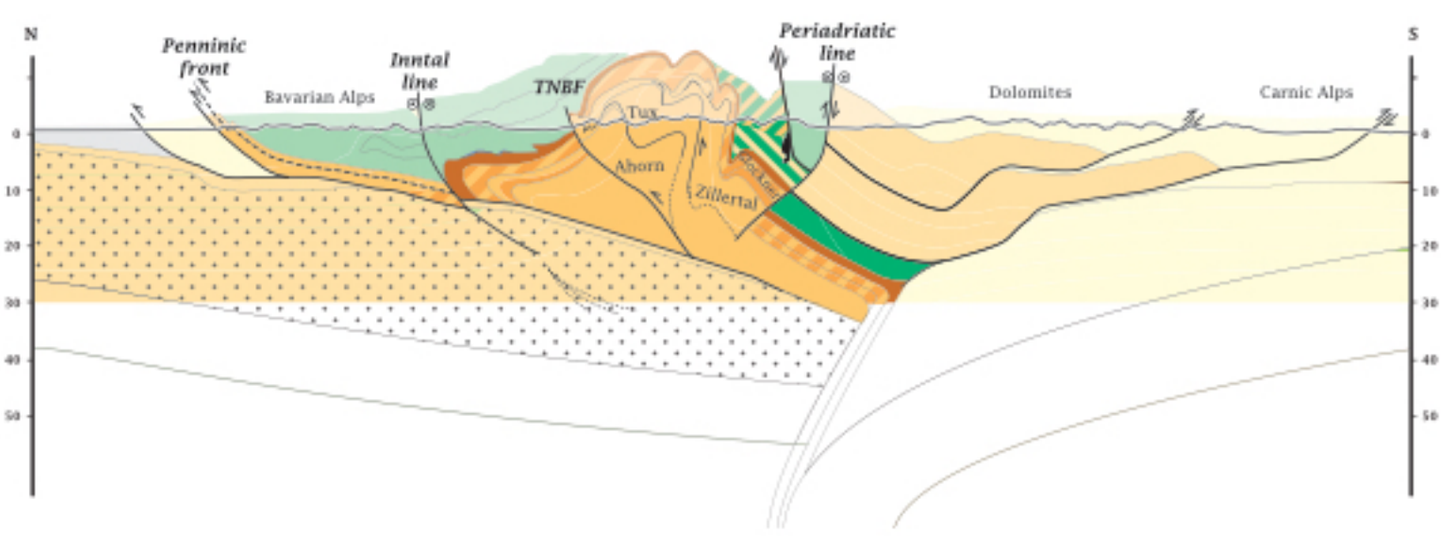
Central Alps : NFP-20 East



Northwestern Alps : NFP-20 West



Eastern Alps : TRANSALP



Bousquet et al., 2012

Les évènements thermiques de la chaîne

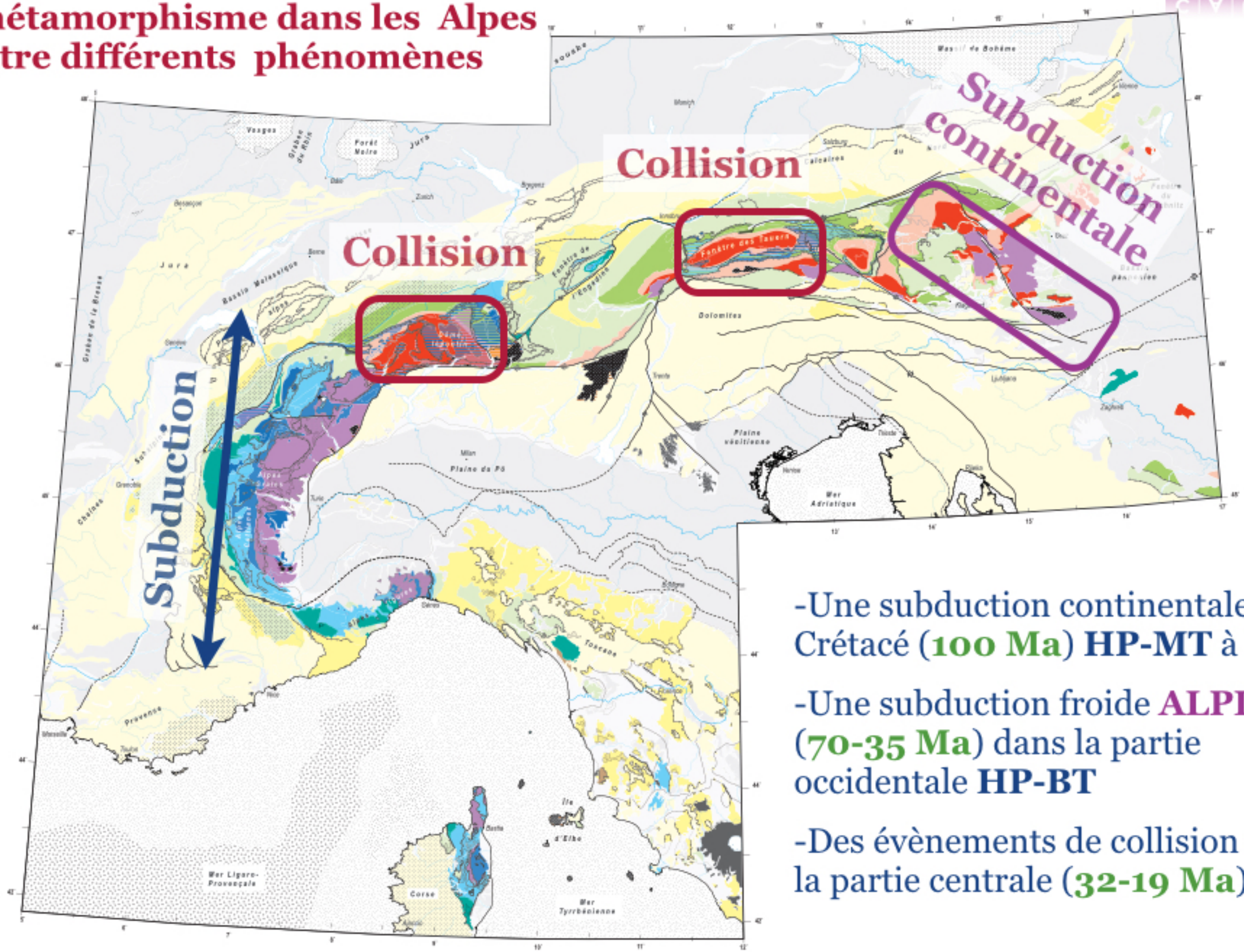
Dernier évènement métamorphique ~15 Ma

Dernier évènement métamorphique 25-20 Ma

Dernier évènement métamorphique 35-32 Ma

Dernier évènement métamorphique 5-0 Ma

Le métamorphisme dans les Alpes montre différents phénomènes

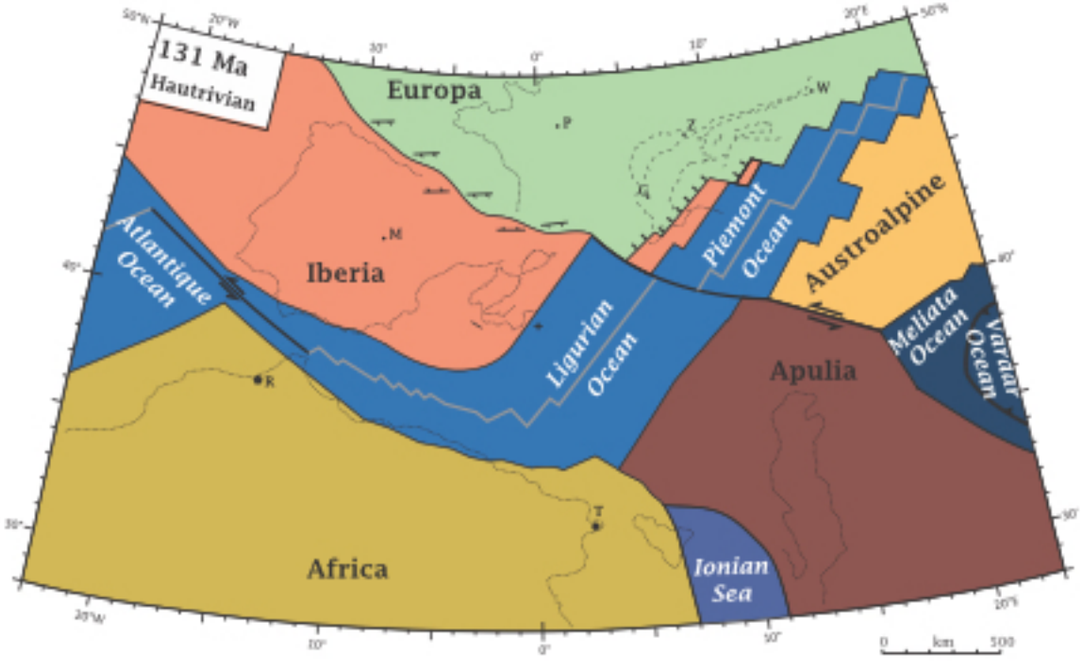


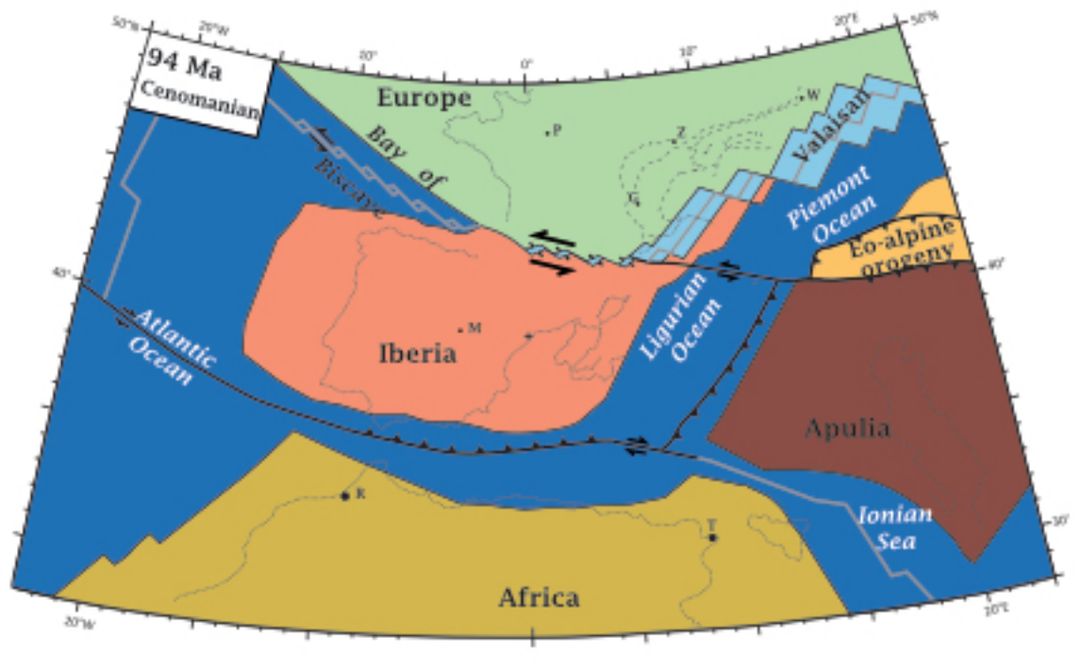
-Une subduction continentale au Crétacé (**100 Ma**) **HP-MT** à l'est

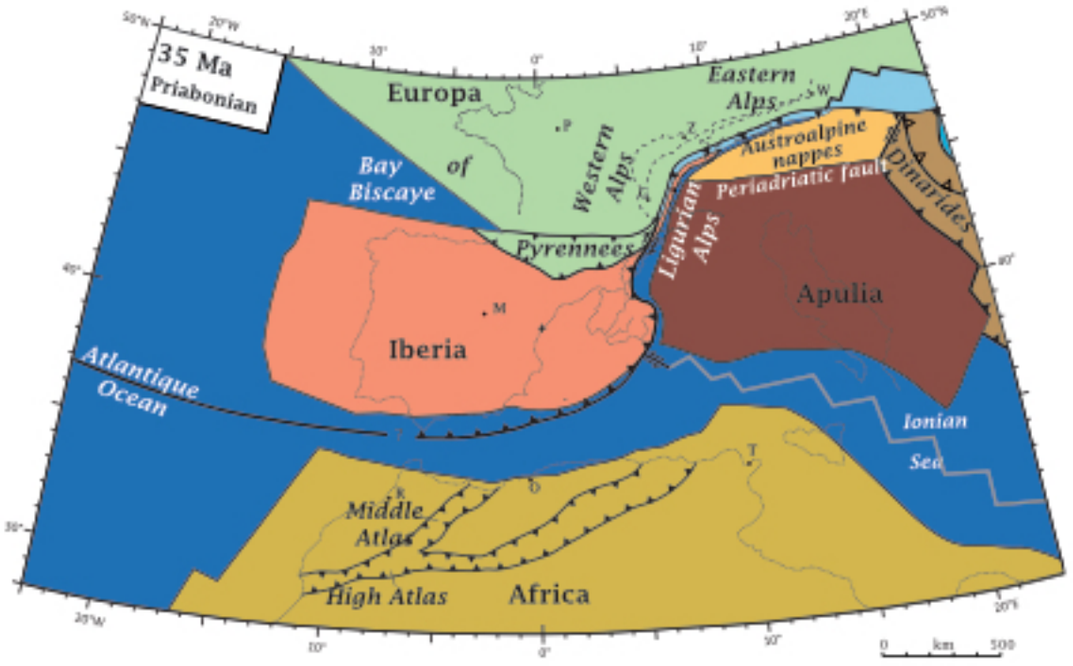
-Une subduction froide **ALPINE** (**70-35 Ma**) dans la partie occidentale **HP-BT**

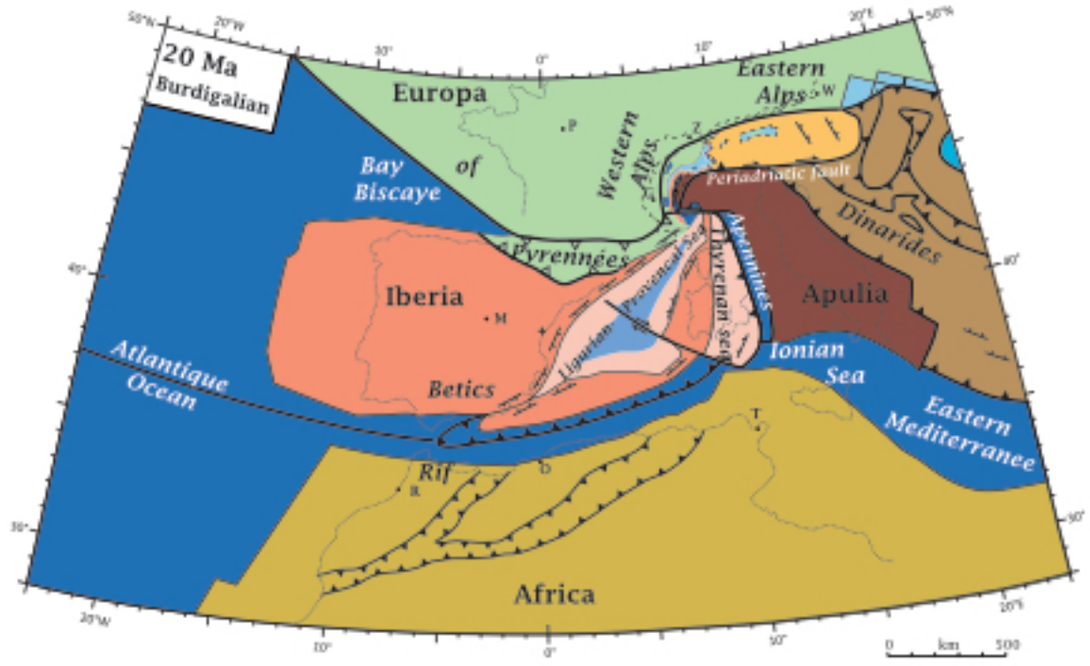
-Des évènements de collision dans la partie centrale (**32-19 Ma**)

Paleogeography

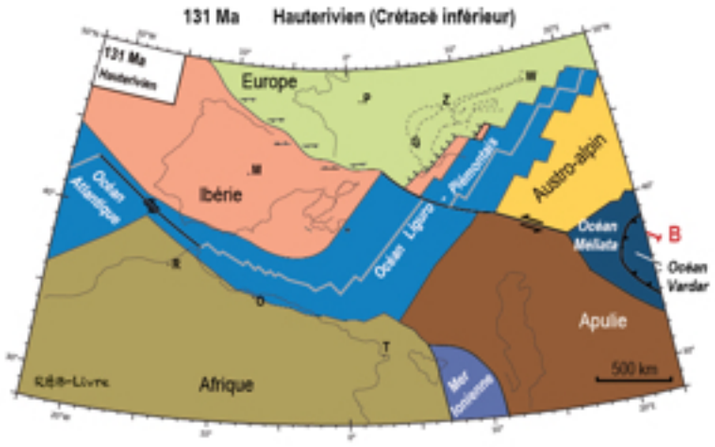


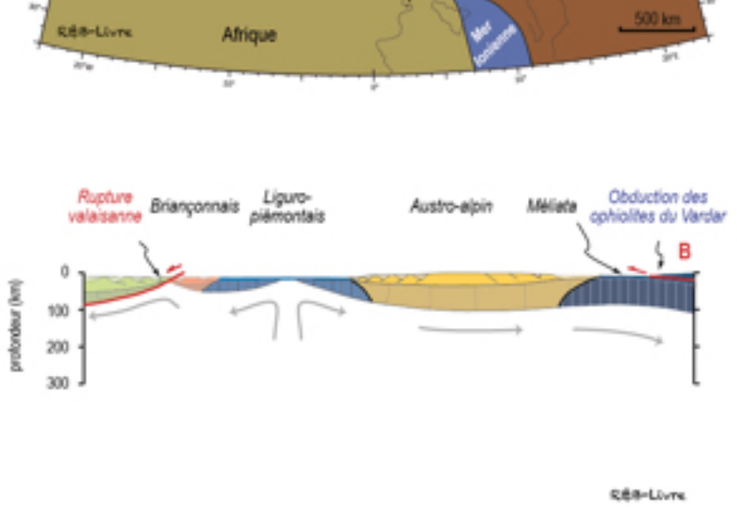


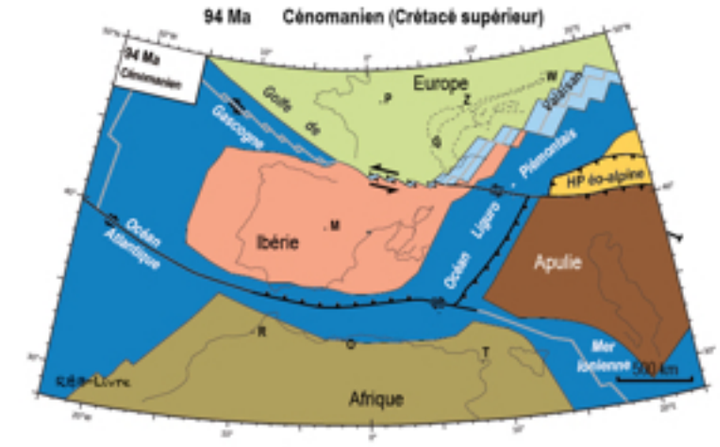


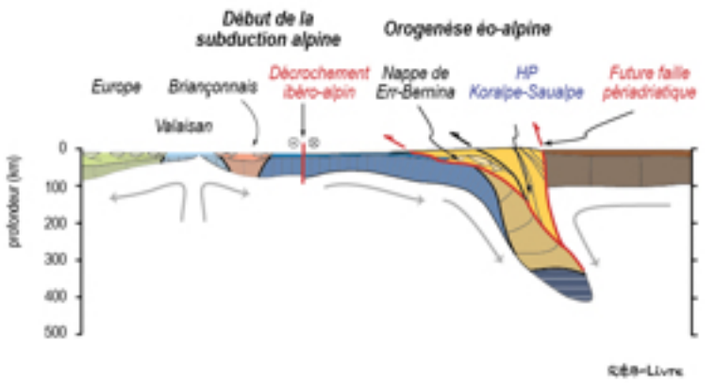


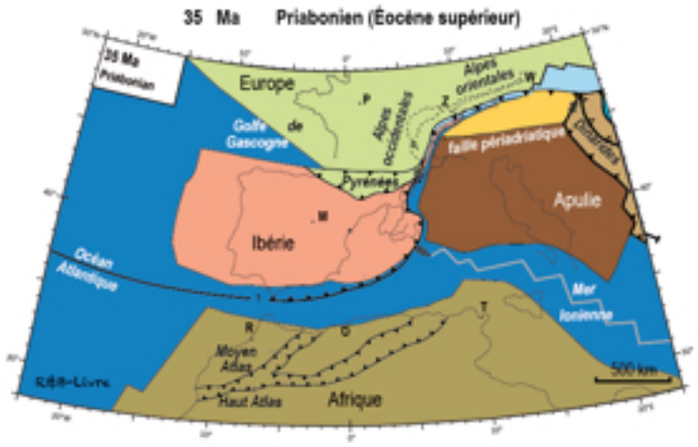
Paléogéographie: Synthèse

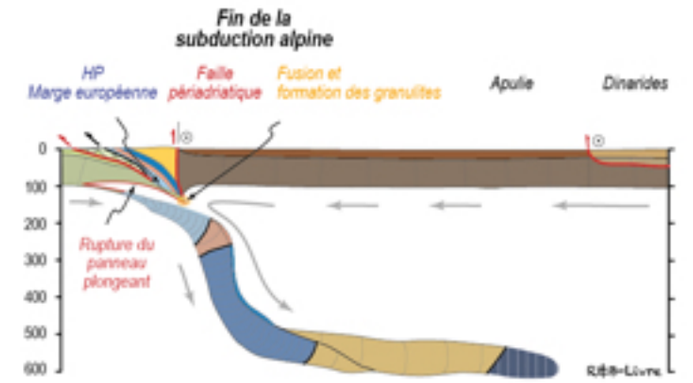












Bousquet et al., 2012
Robert & Bousquet, 2013

Nouvelles polémiques :-)

Combien d'océans ?

3 zones de subduction sont observées dans les Alpes

✓ *une à l'est (métamorphisme HP à 100 Ma)*

✓ *2 dans les Alpes Centrales et occidentales, séparées par un domaine non métamorphique*

La rupture du slab ?

Vraisembablement la rupture se produit à la TOC

✓ *Peu de lithosphère continentale européenne subduite dans les Alpes occidentales*

✓ *Propagation de la rupture d'est en ouest*

Gradient thermique de la subduction ?

Diminution des taux de convergence synchrone du refroidissement de la subduction

✓ *Accrétion de nombreux sédiments*

✓ *Fort découplage entre les plaques sup. et inf.*

Volcanisme, magmatisme

Question ouverte

Merci de votre attention