Evolution du Relief des Alpes

Stéphane Guillot

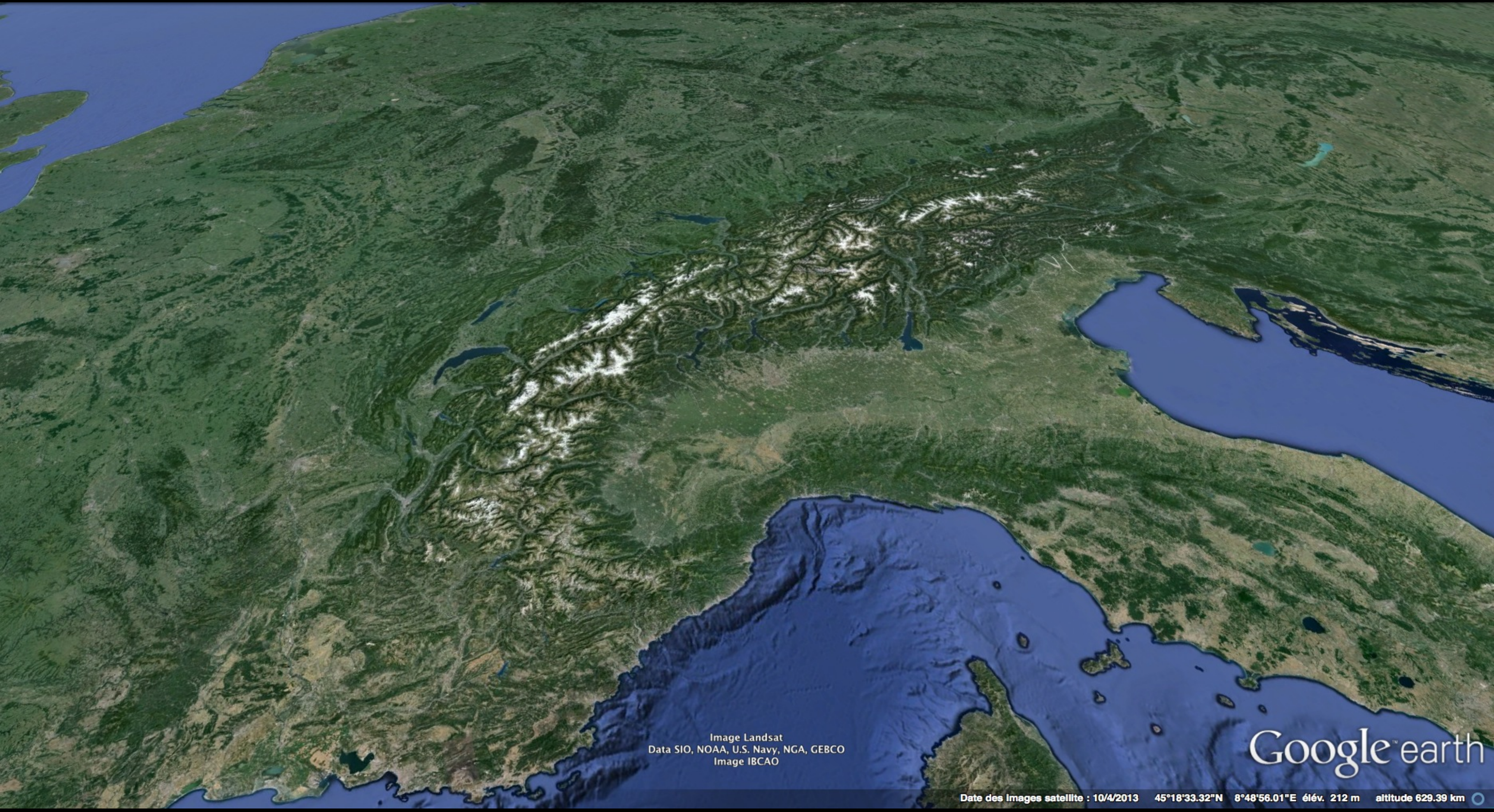
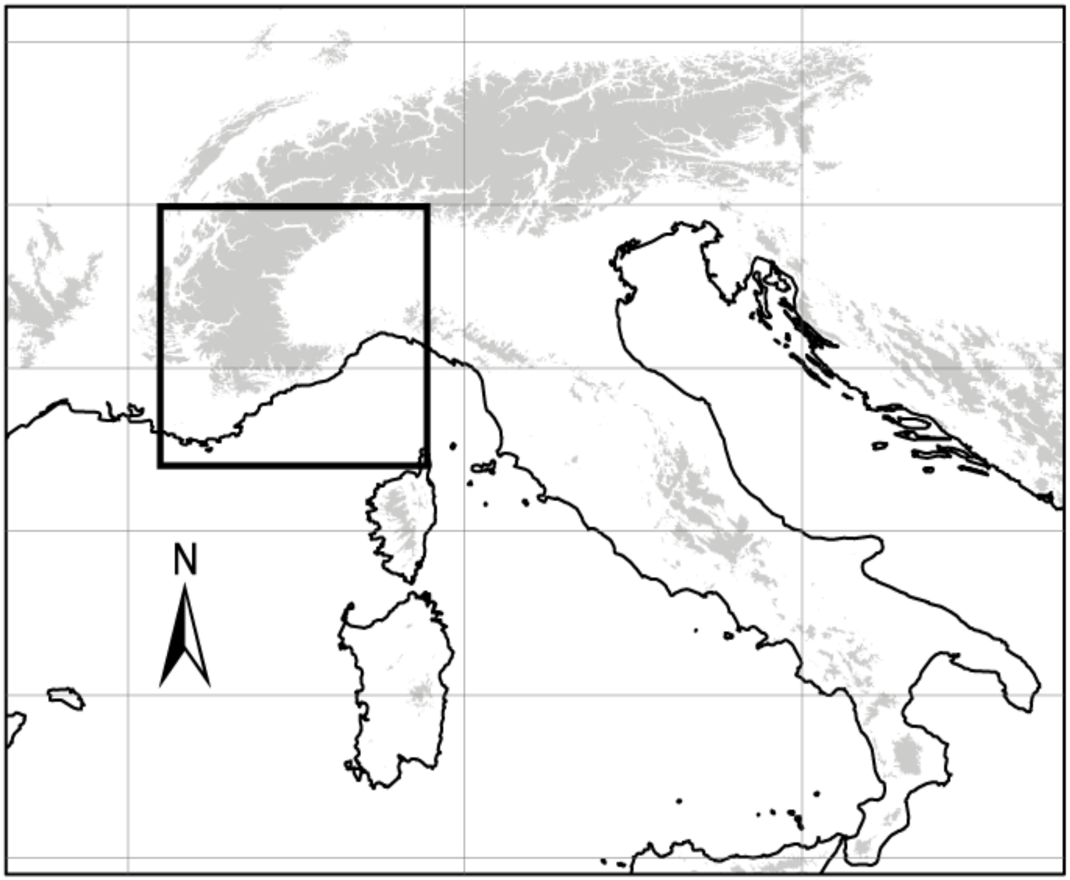


Image Landsat
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
Image IBCAO
Google earth
Date des images satellite : 10/4/2013 45°18'33.32"N 8°48'56.01"E élév. 212 m altitude 629.39 km

Study area



Pro- and retro-side foreland and external zone non or low-grade metamorphic rocks

- *Quaternary*
- *middle Miocene - Pliocene*
- *Lower Oligocene - lower Miocene*
- *Eocene to lower Oligocene*
- *Mesozoic cover*

Basement:

- *External Crystalline Massifs*
- *Andesitic volcanism*

Internal zone low-grade metamorphic rocks

- *Ophiolite*
- *Helminthoid flysch*

Internal zone high-pressure low temperature metamorphic rocks

- *Internal Crystalline Massifs*
- *Briançonnais zone*

Piedmont Schistes lustrés - Viso complex

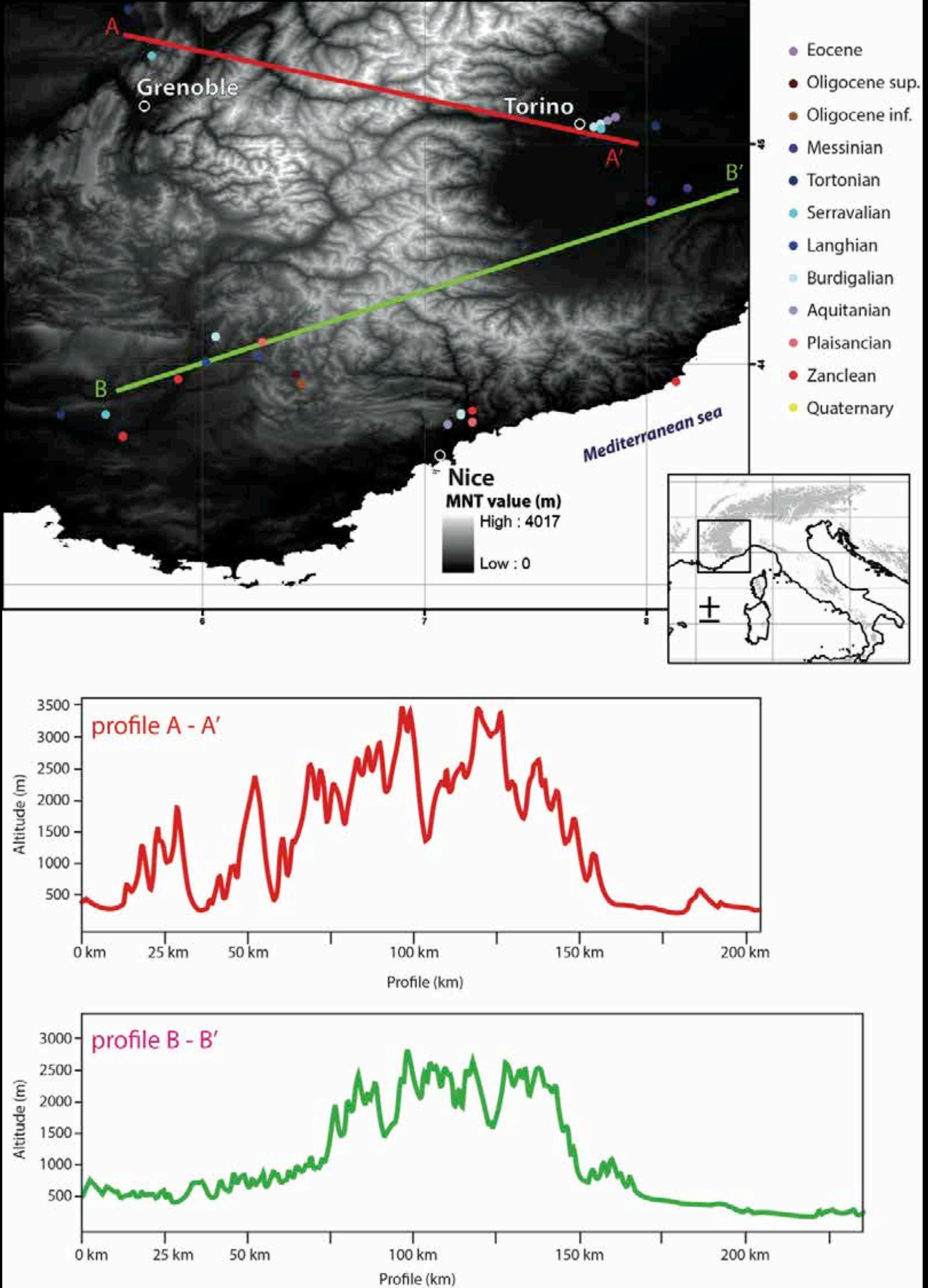
- *Internal Piedmont complex*
- *External Piedmont complex*

Apulian plate:

- *Austro-alpine zone*

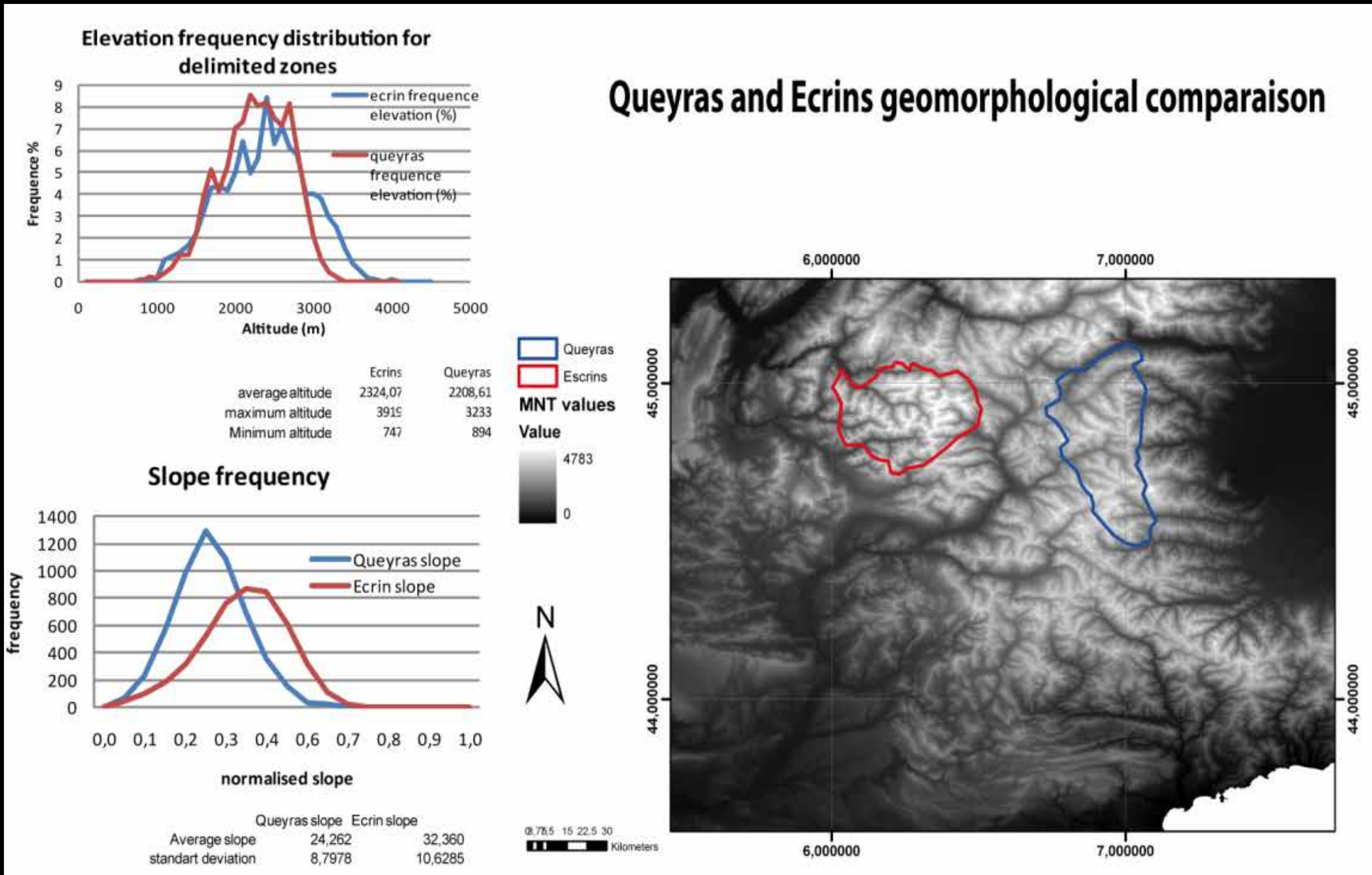
- Focus on the southern Western Alps

Jourdan, 2012



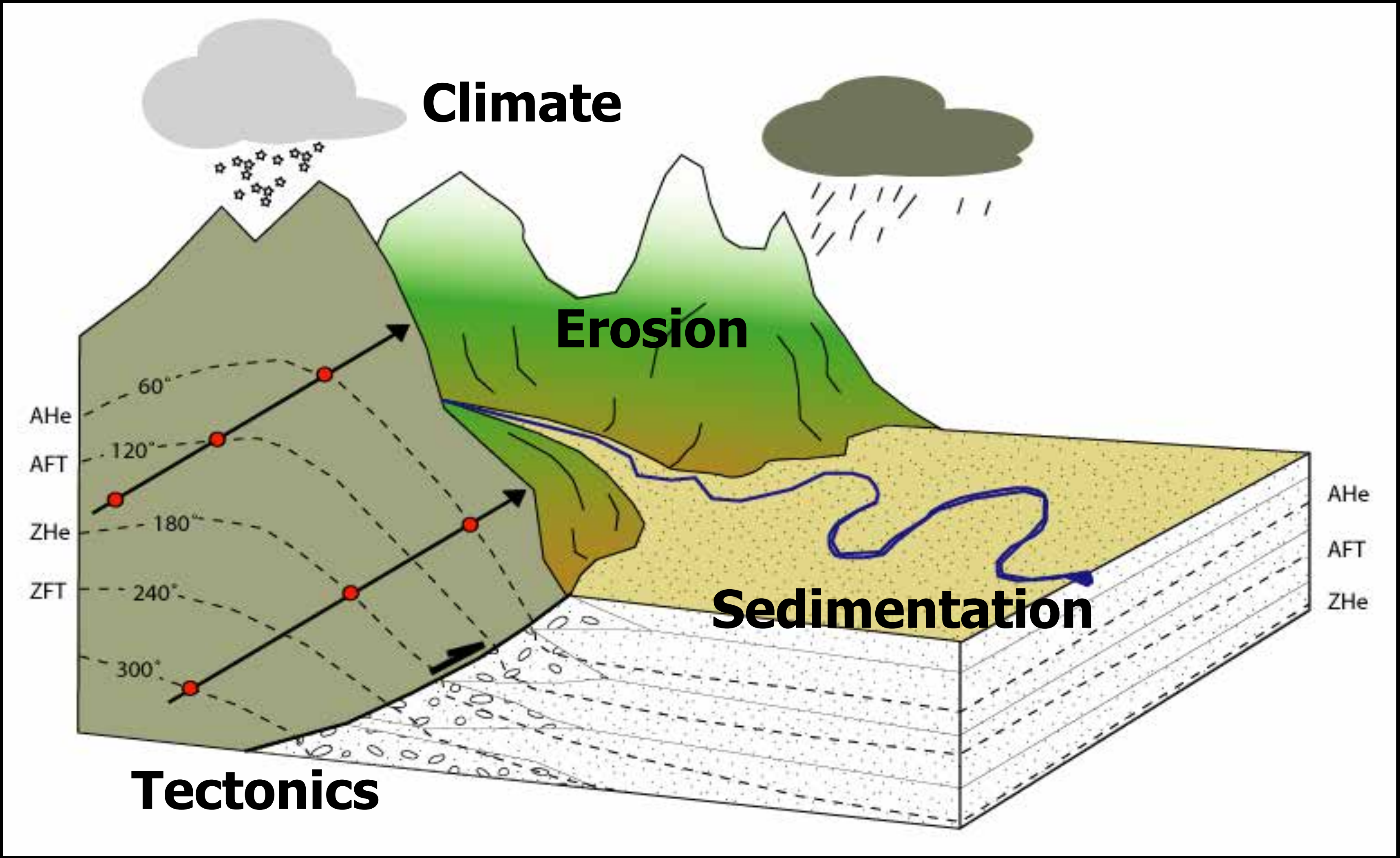
Jourdan, 2012

Les Ecrins incisés et pas le Queyras?



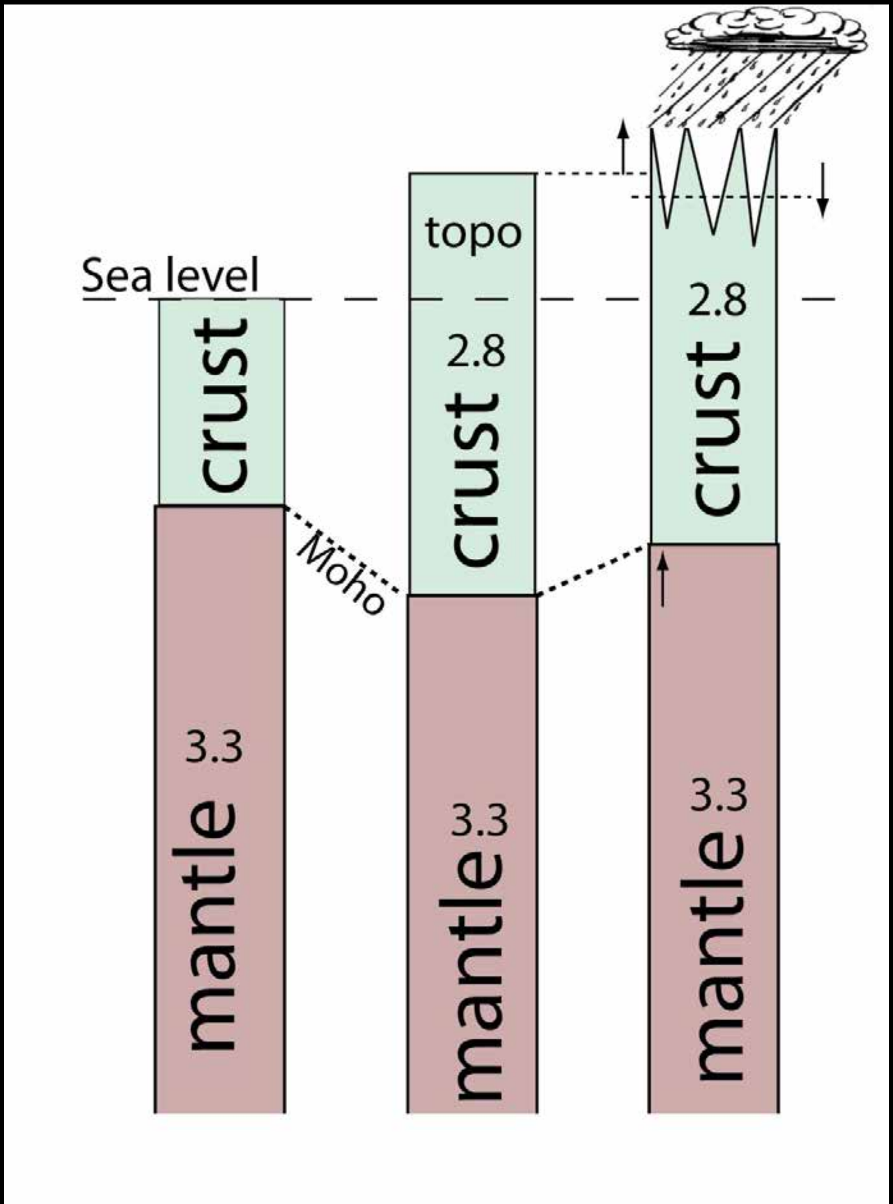
Jourdan, 2012

Thermochronological record of exhumation : lag time



Bernet, 2009

Importance des changements climatiques:



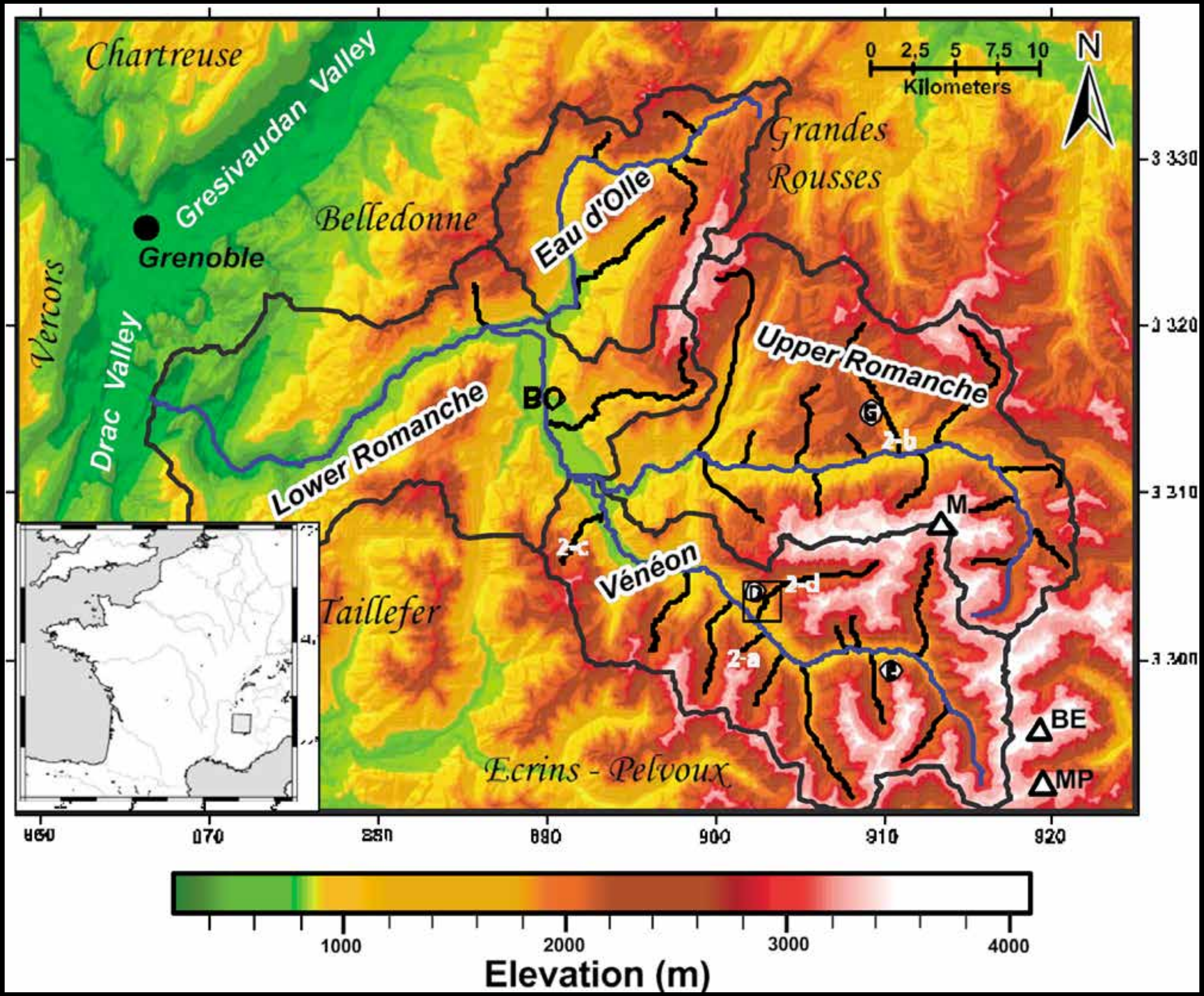
Principe d'équilibre isostatique:

Erosion d'une épaisseur moyenne "h":

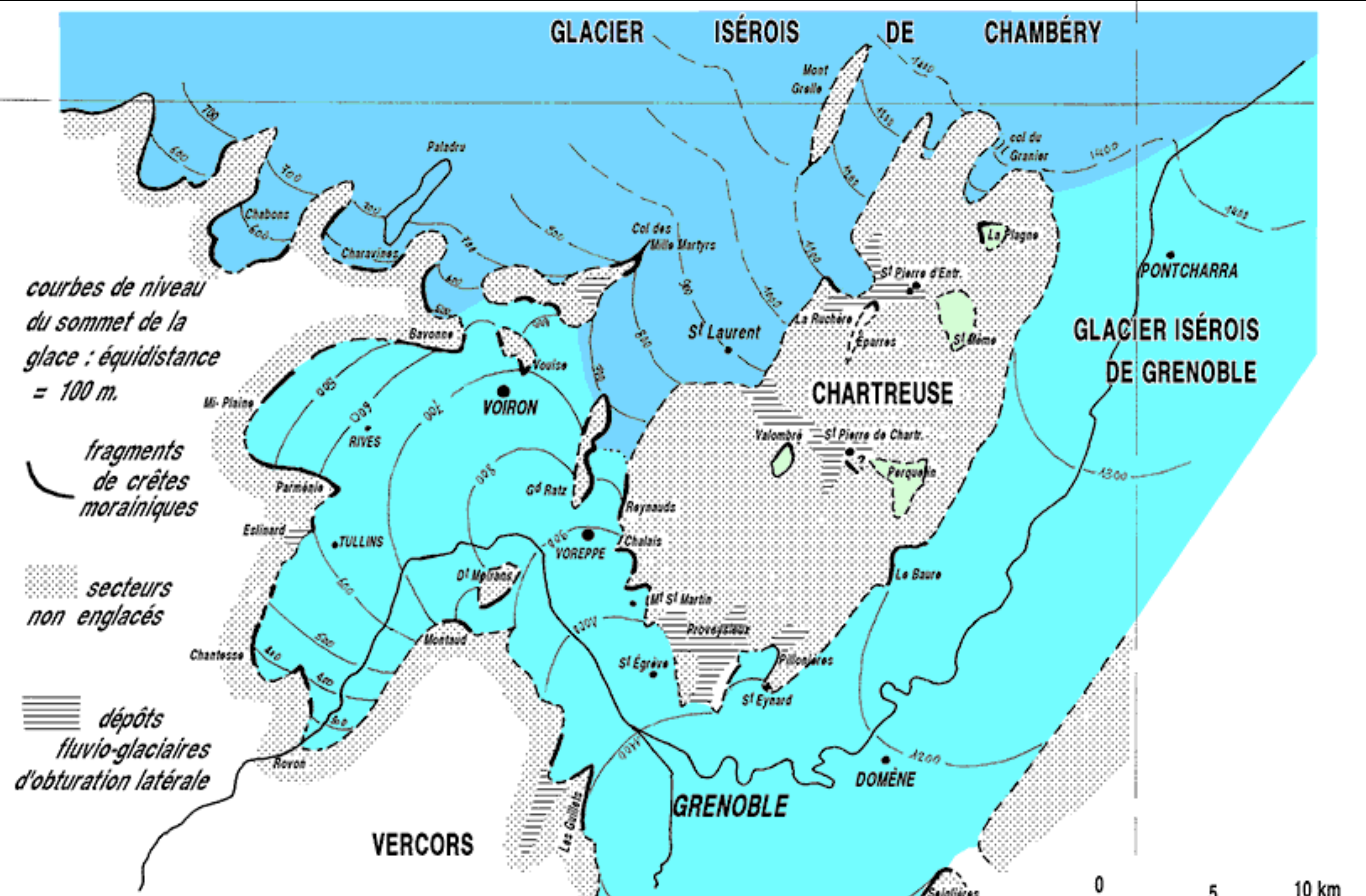
- diminution de l'altitude moyenne (h/6)
- augmentation potentielle de l'altitude des sommets (dépend de l'erosion des sommets, max=h)

Conséquences potentielles:

- Augmentation de la surface au dessus de l'ELA (creation de glaciers)
- renforcement de la barriere orographique (plus de precipitations en altitude)
- retroaction positive: augmentation de l'érosion

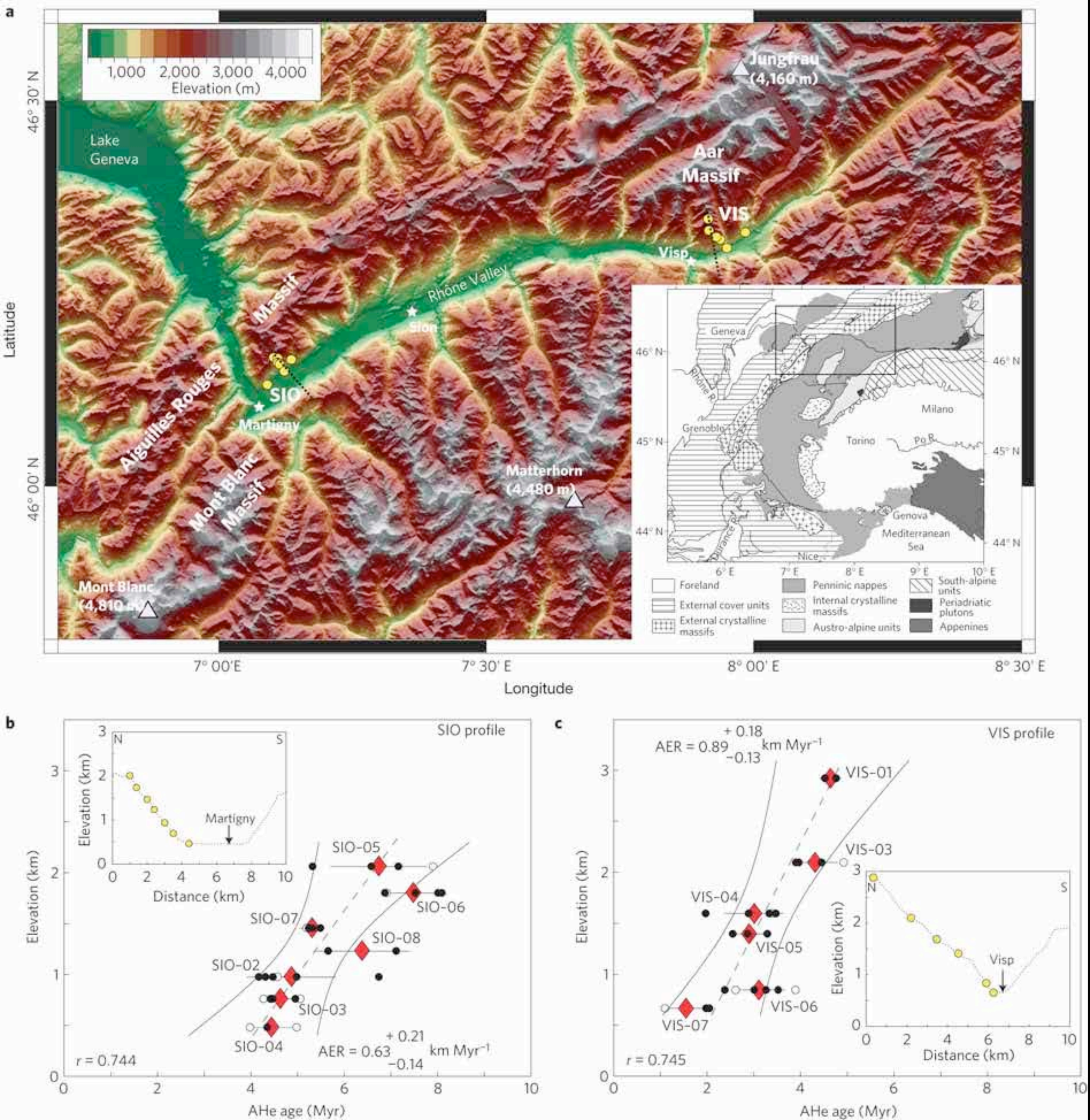


Van der Beek et al., 2010

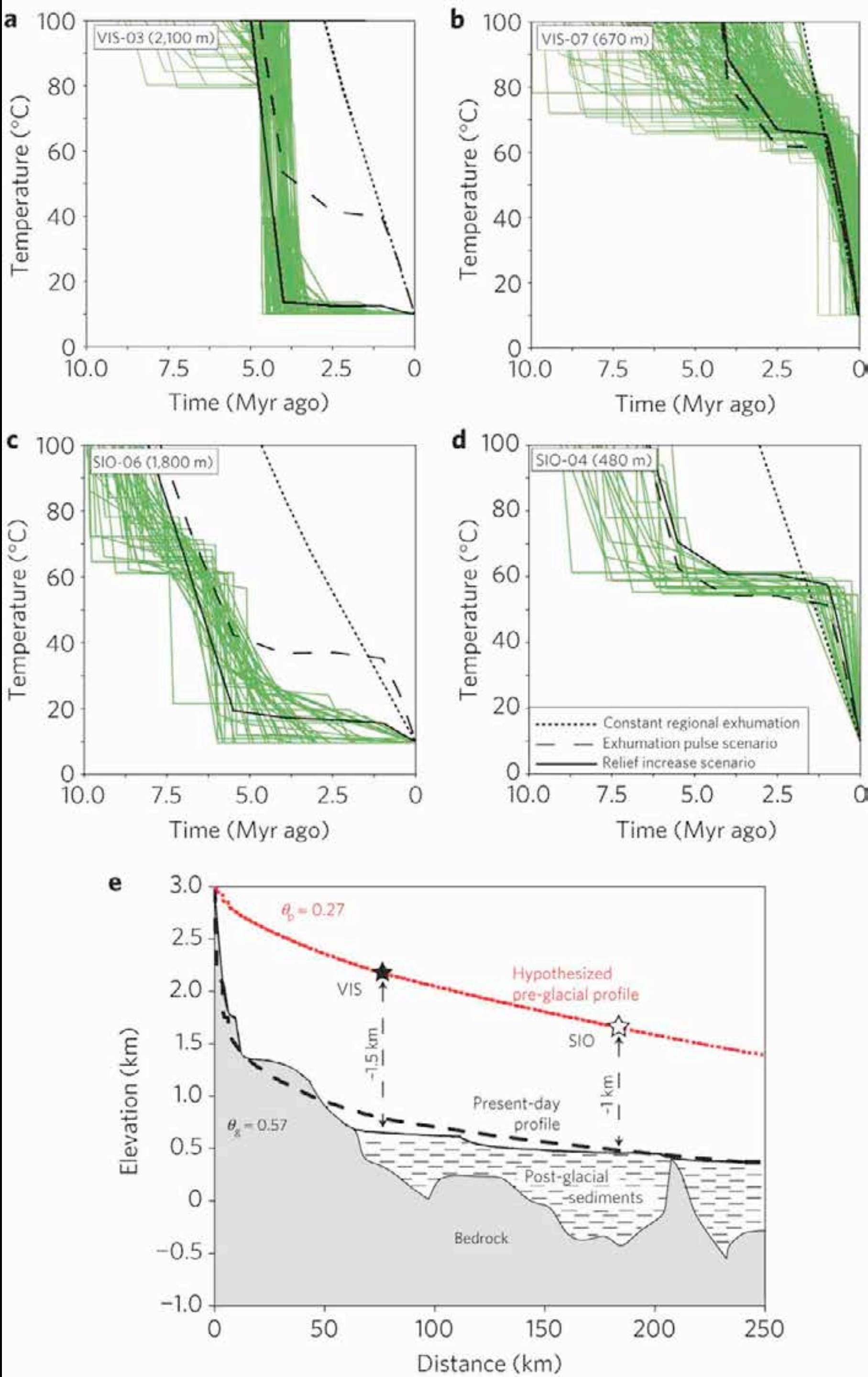


EXTENSION MAXIMALE DES GLACES LORS DE LA DERNIÈRE GRANDE CRUE ("WŪRM II")


CHARTREUSE
Gd Som
Dt de Crolles
Granier
BAUGES
Gd Colon
GRÉSIVAUDAN
BELLEDONNE
Casse Rousse
cliché M.GIDON

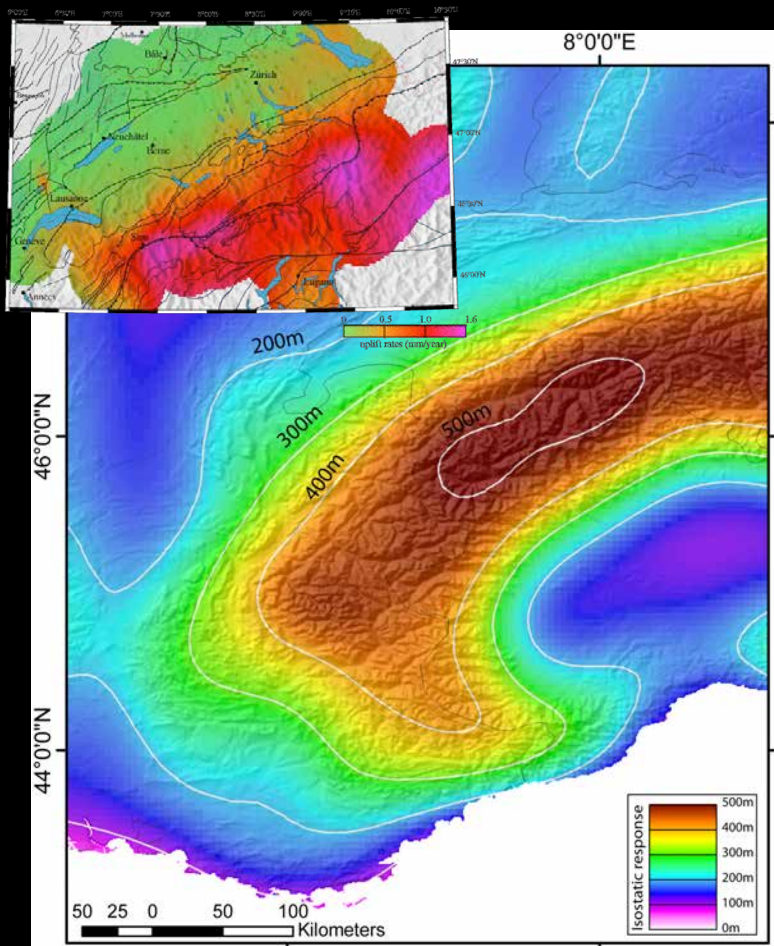


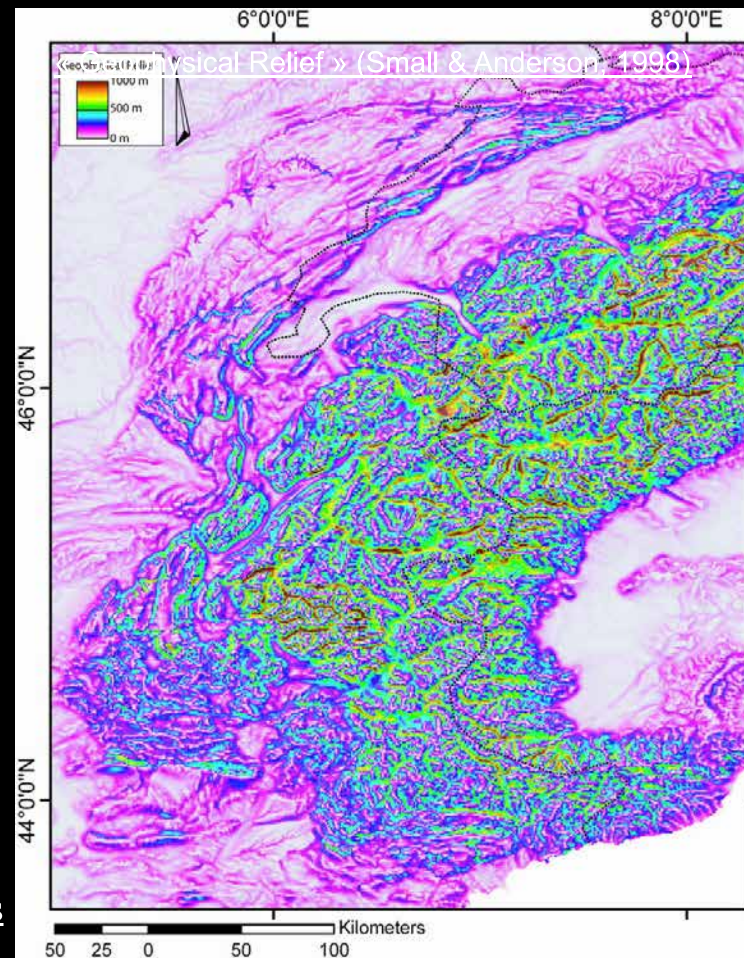
Valla et al., 2011



Valla et al., 2011

Climat, érosion et tectonique alpine



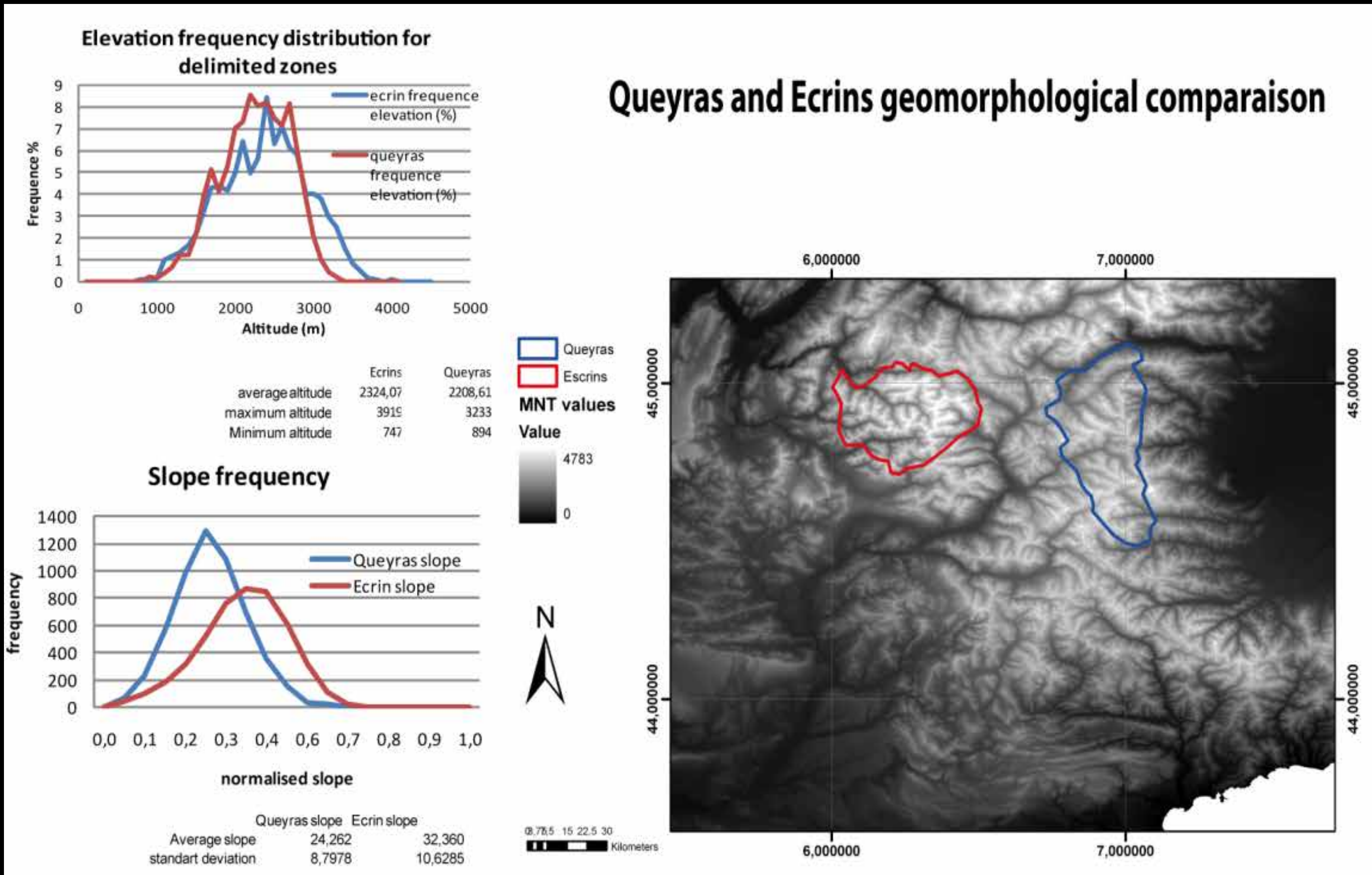


Effets de l'érosion

- augmentation du flux sédimentaire, redistribution des masses
- changement de l'état de contraintes
- ***Surrection induite par la compensation isostatique***

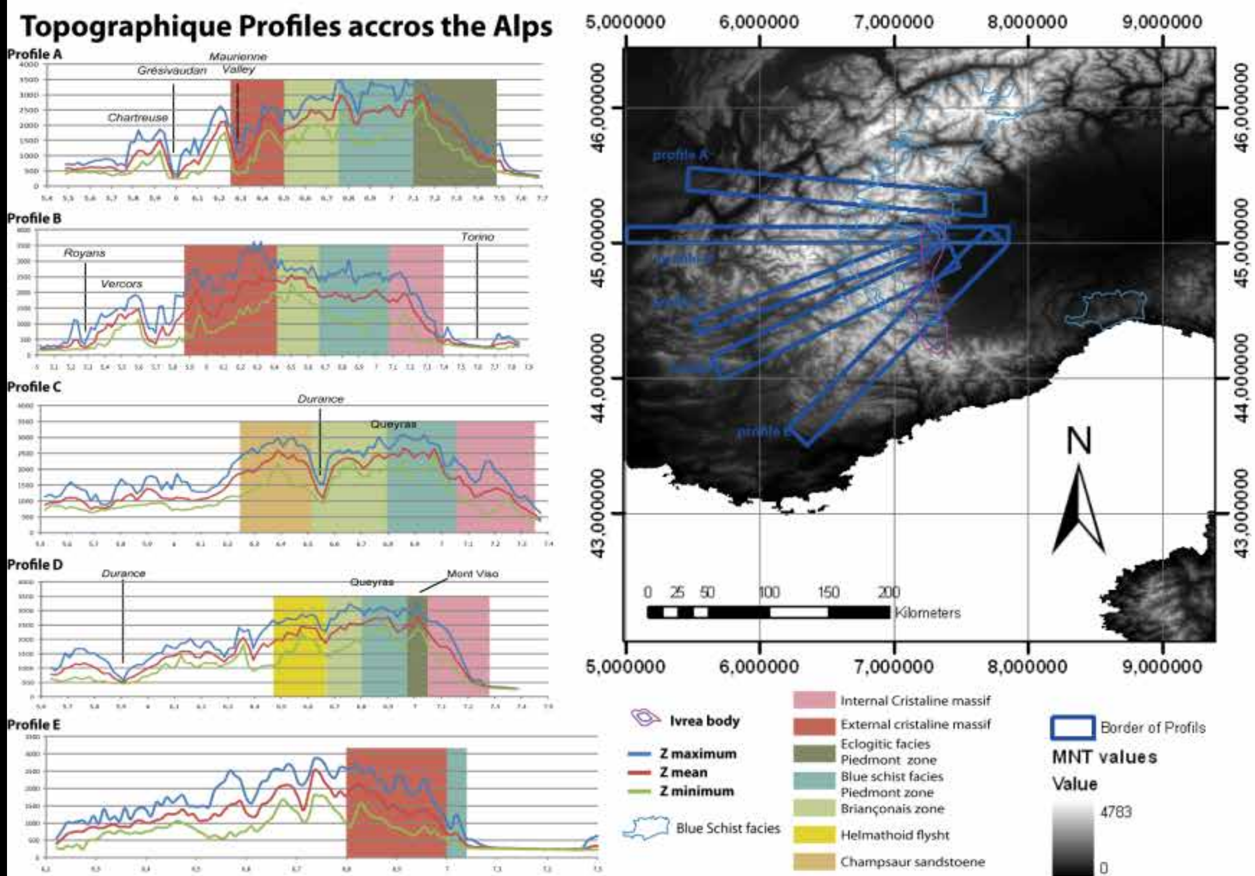
Champagnac et al, 2007; Vernan et al.,2013

Pourquoi les écrins incisés et pas le Queyras?



Jourdan, 2012

Observation géomorphologique sur le Queyras



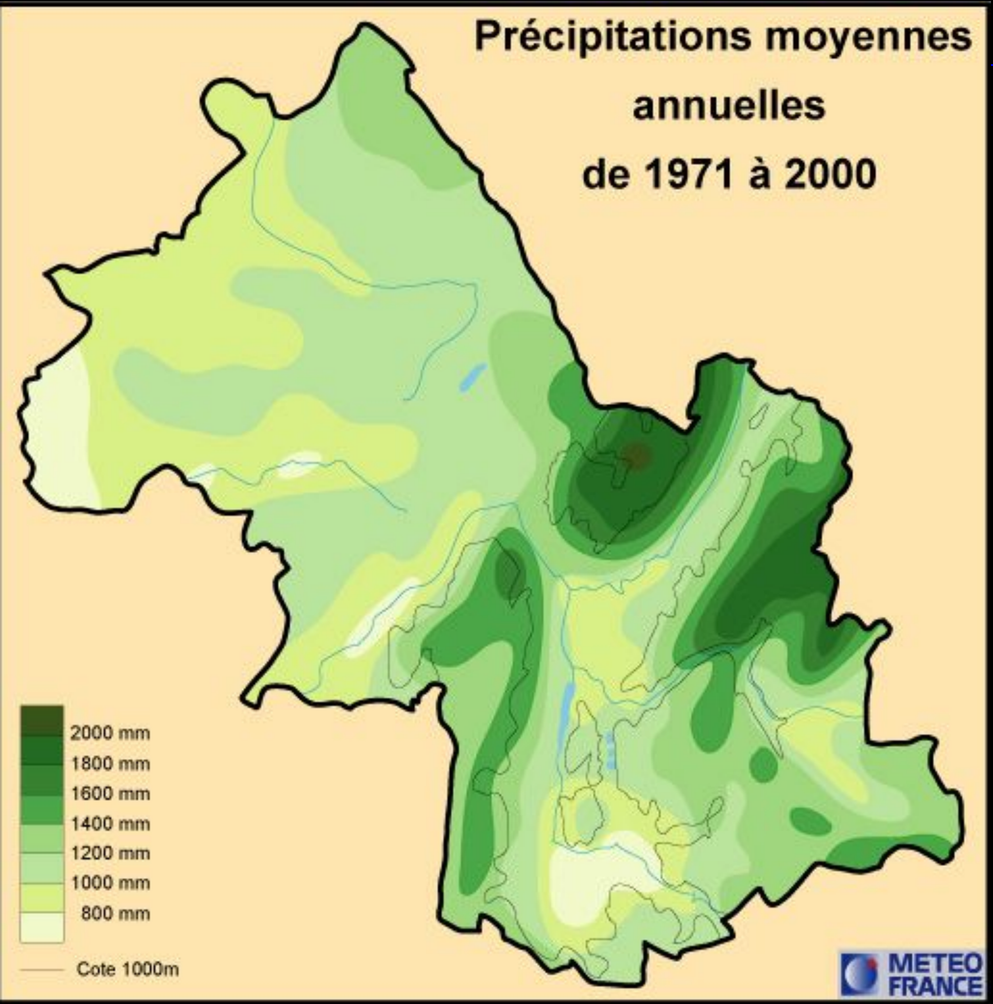
Jourdan, 2012

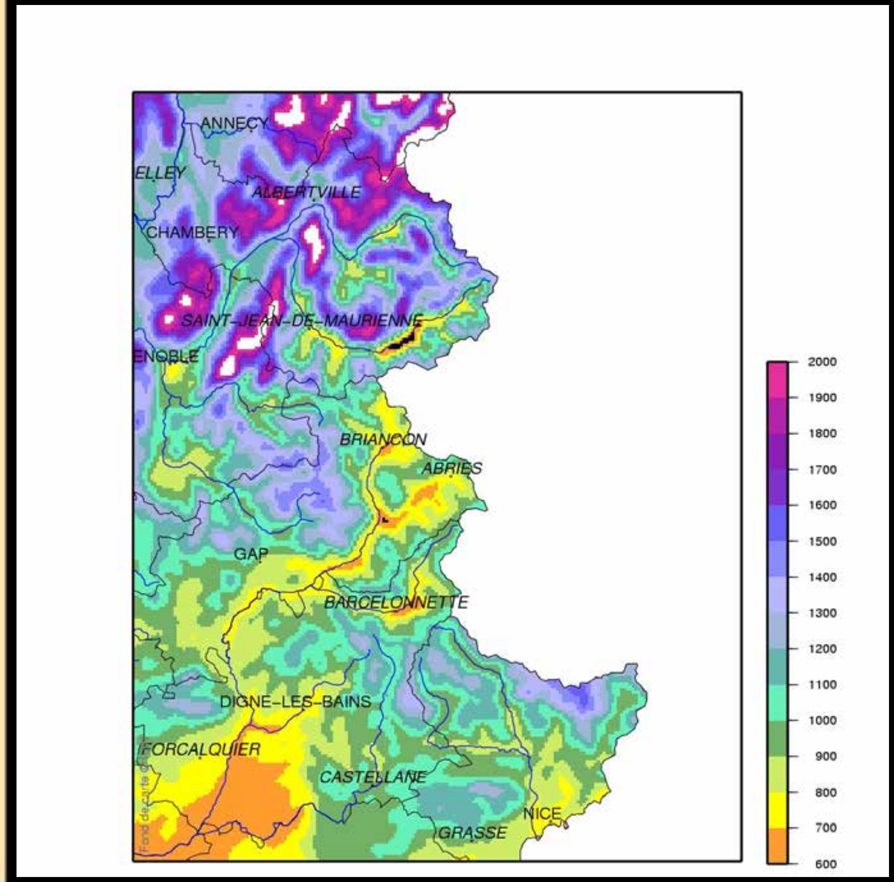
METEO FRANCE
Toujours un temps d'avance

CARTOGRAPHIE DE NORMALES AURELHY

Précipitations (en mm)

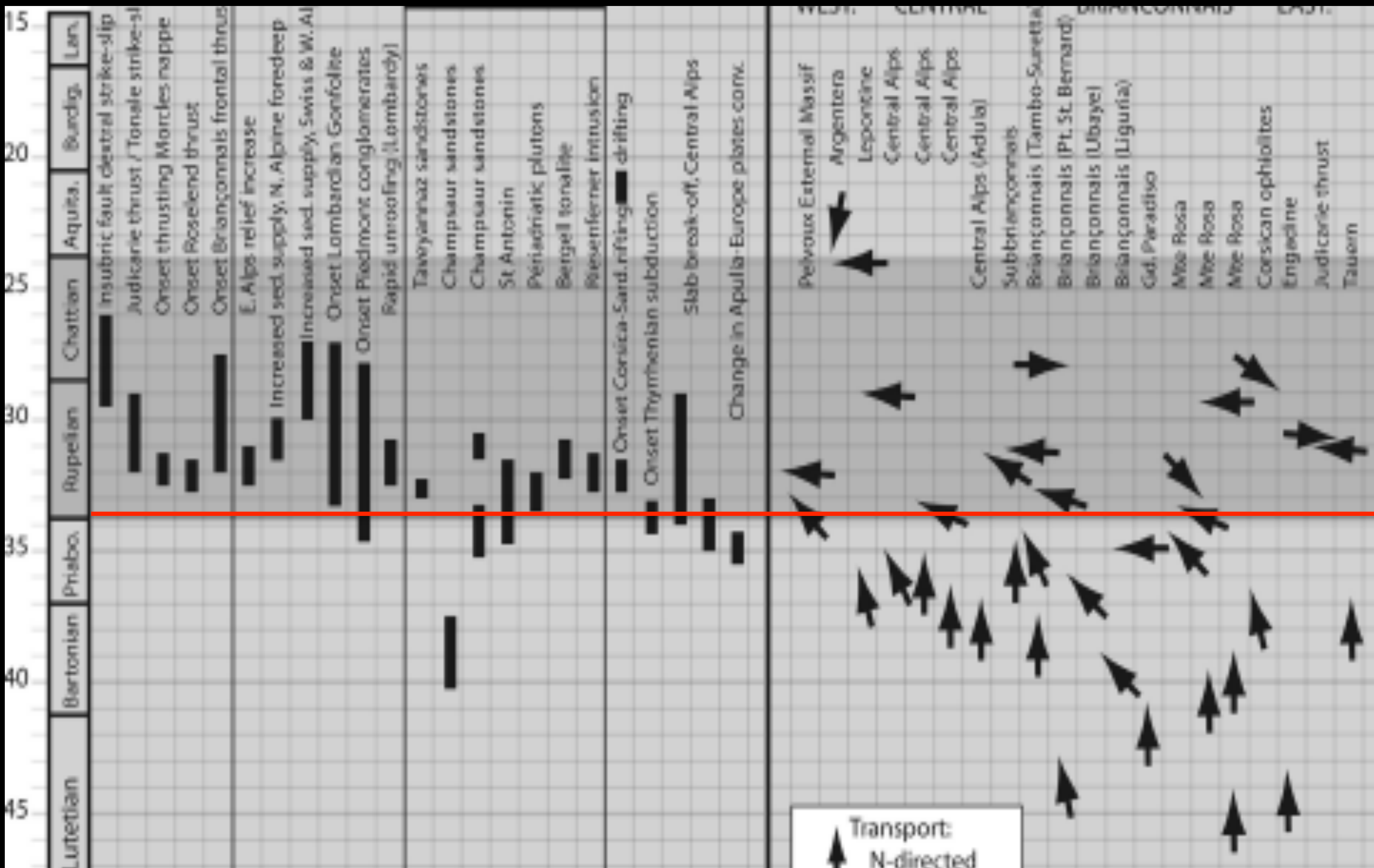
Normales annuelles





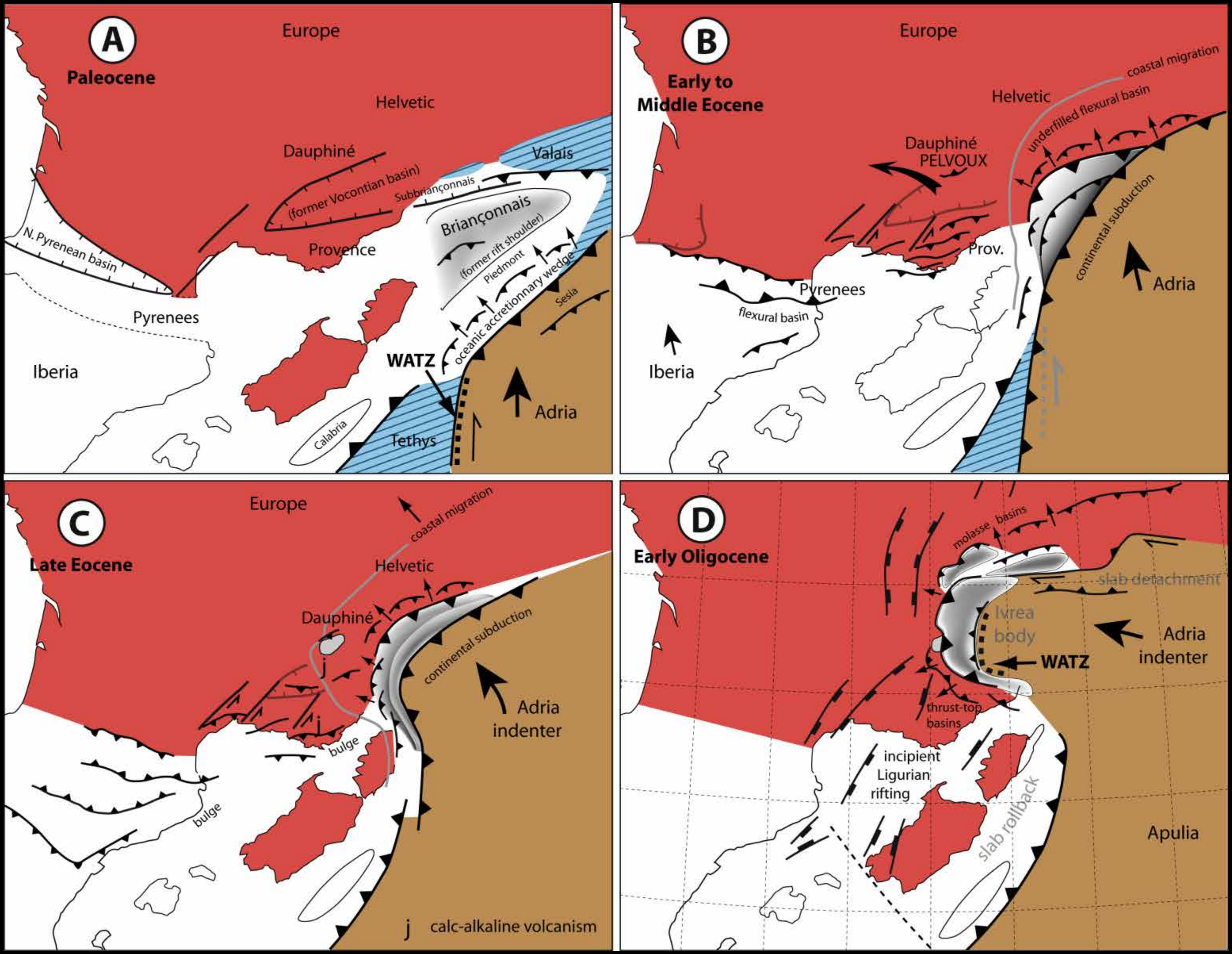
Depuis quand il y a des reliefs dans les Alpes ?

Compilation of tectonic, sedimentologic, paleomagnetic, petrologic data



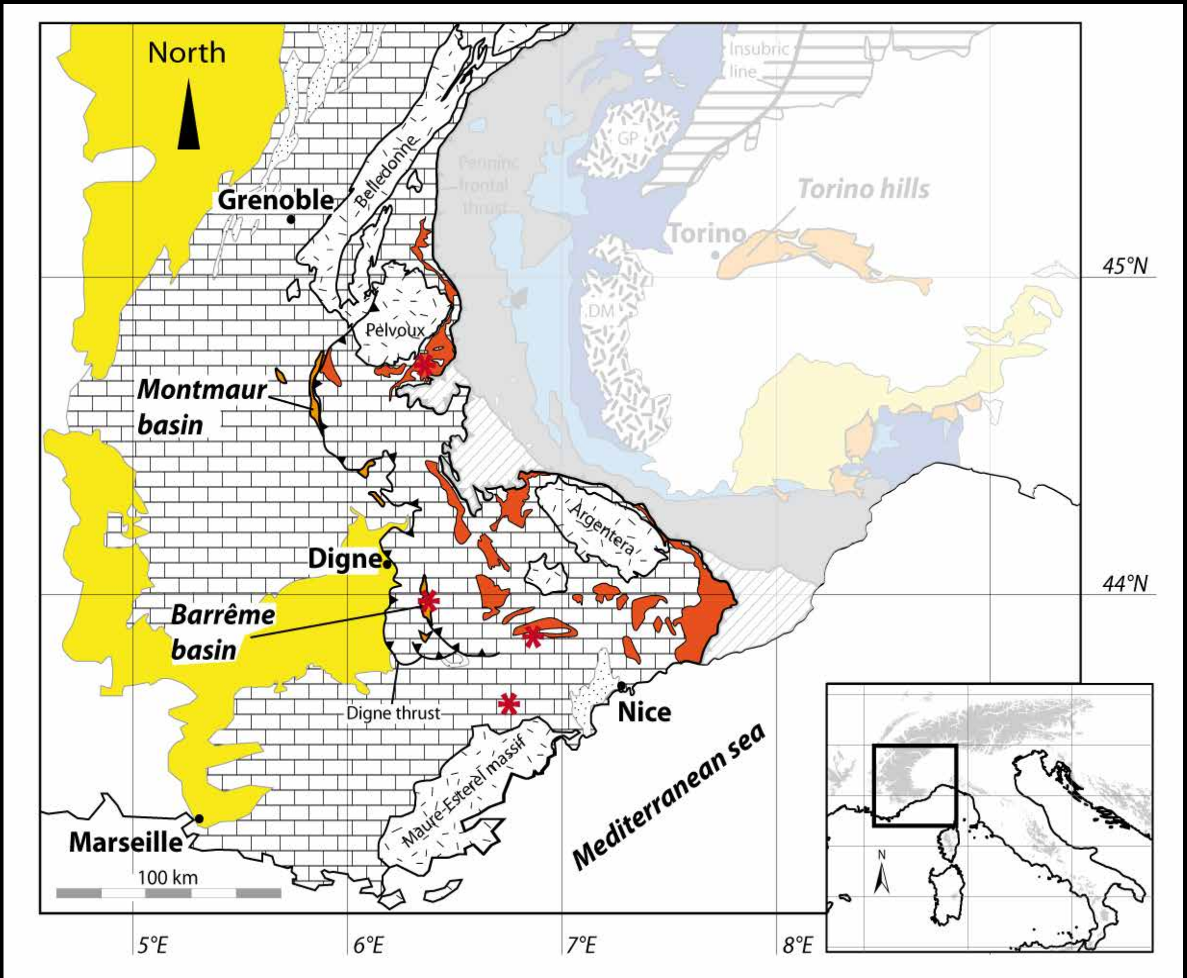
Dumont et al. 2011, 2012

Alpine geodynamic framework



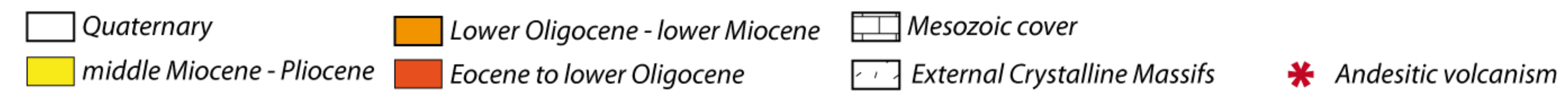
Dumont et al. 2011, 2012

Main geological units of the Western Alps: External units



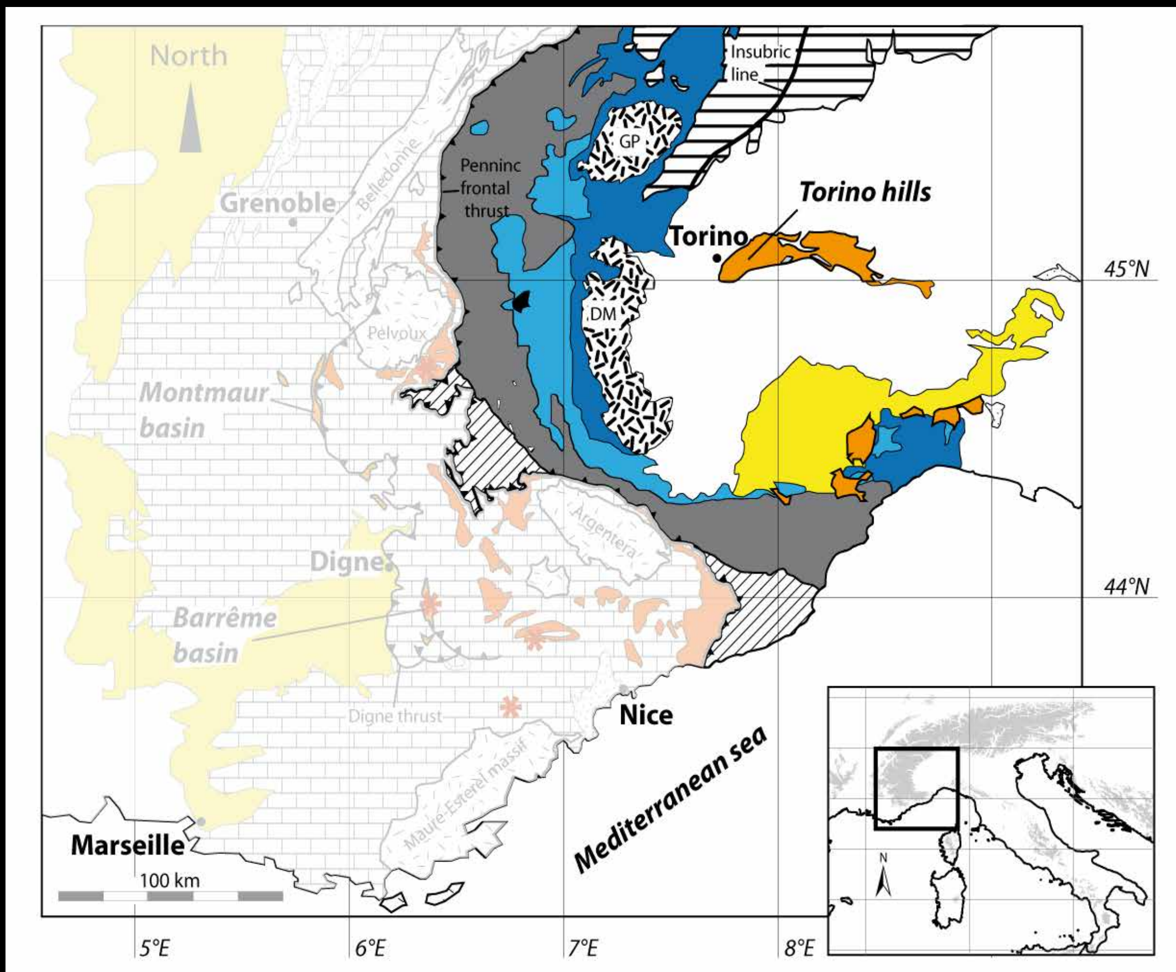
External Western Alps units :

- External Crystalline Massifs
- Subalpine chains
- Foreland basin remnants
- Andesitic volcanism (35 – 30 Ma)



Saint-Joseph de Rivière conglomérats delta miocène

Main geological units of the Western Alps: Internal units

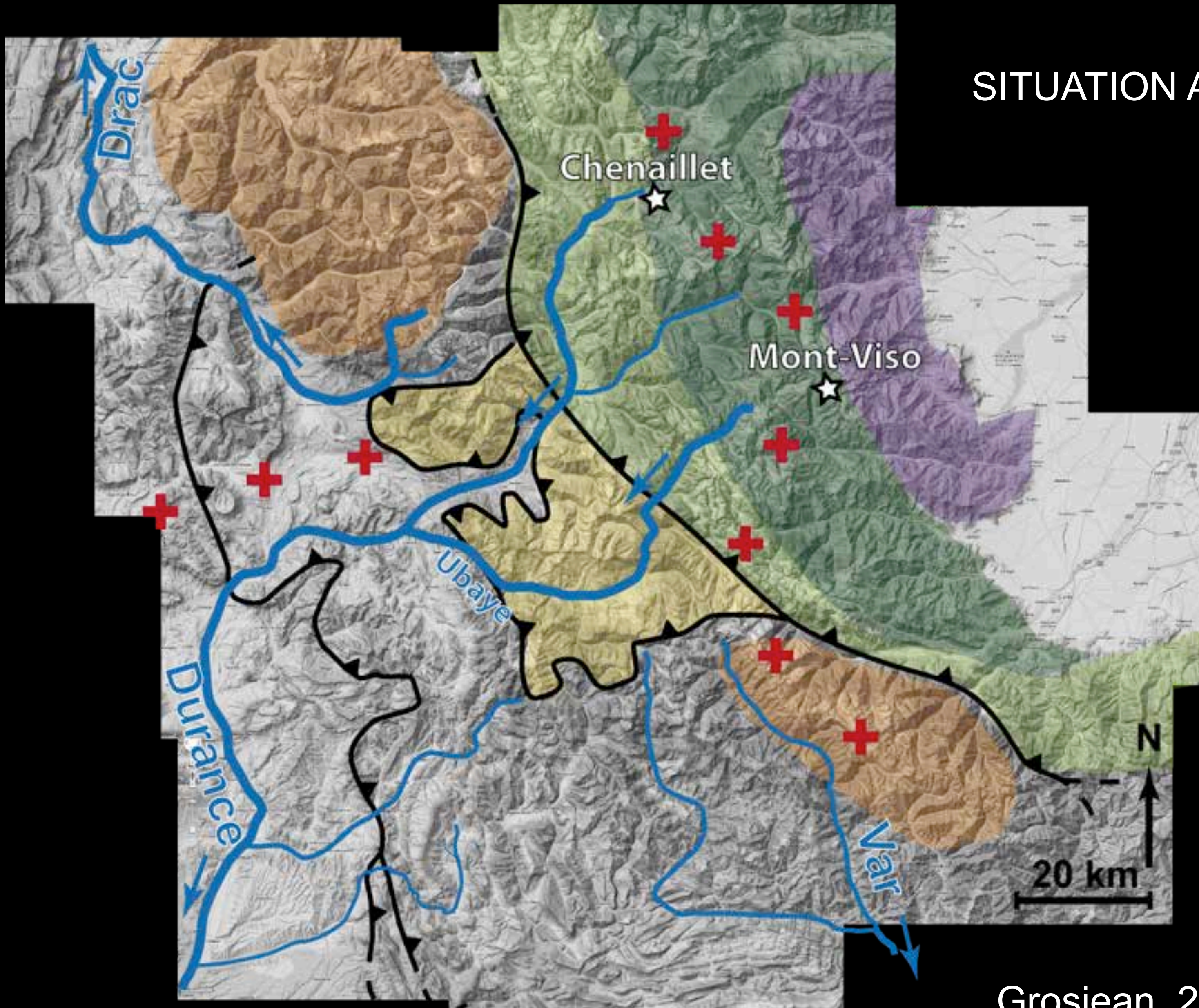


Internal Western Alps units:

<u>Non-metamorphic:</u>
- Helminthoid flysch
- Obducted Ophiolite

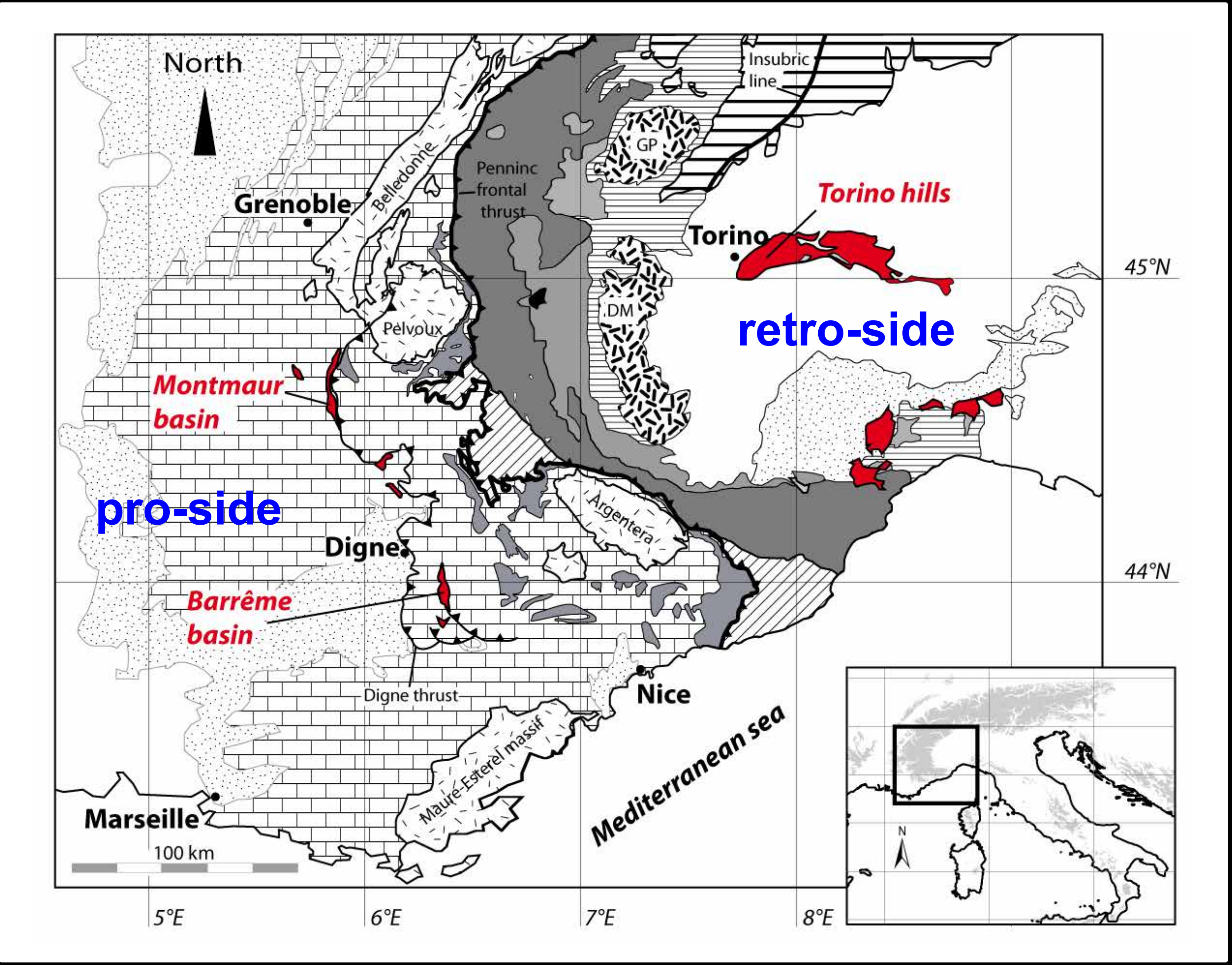
<u>Metamorphic:</u>
- Briançonnais zone
- Piedmont zone
- Internal Crystalline Massifs

SITUATION ACTUELLE



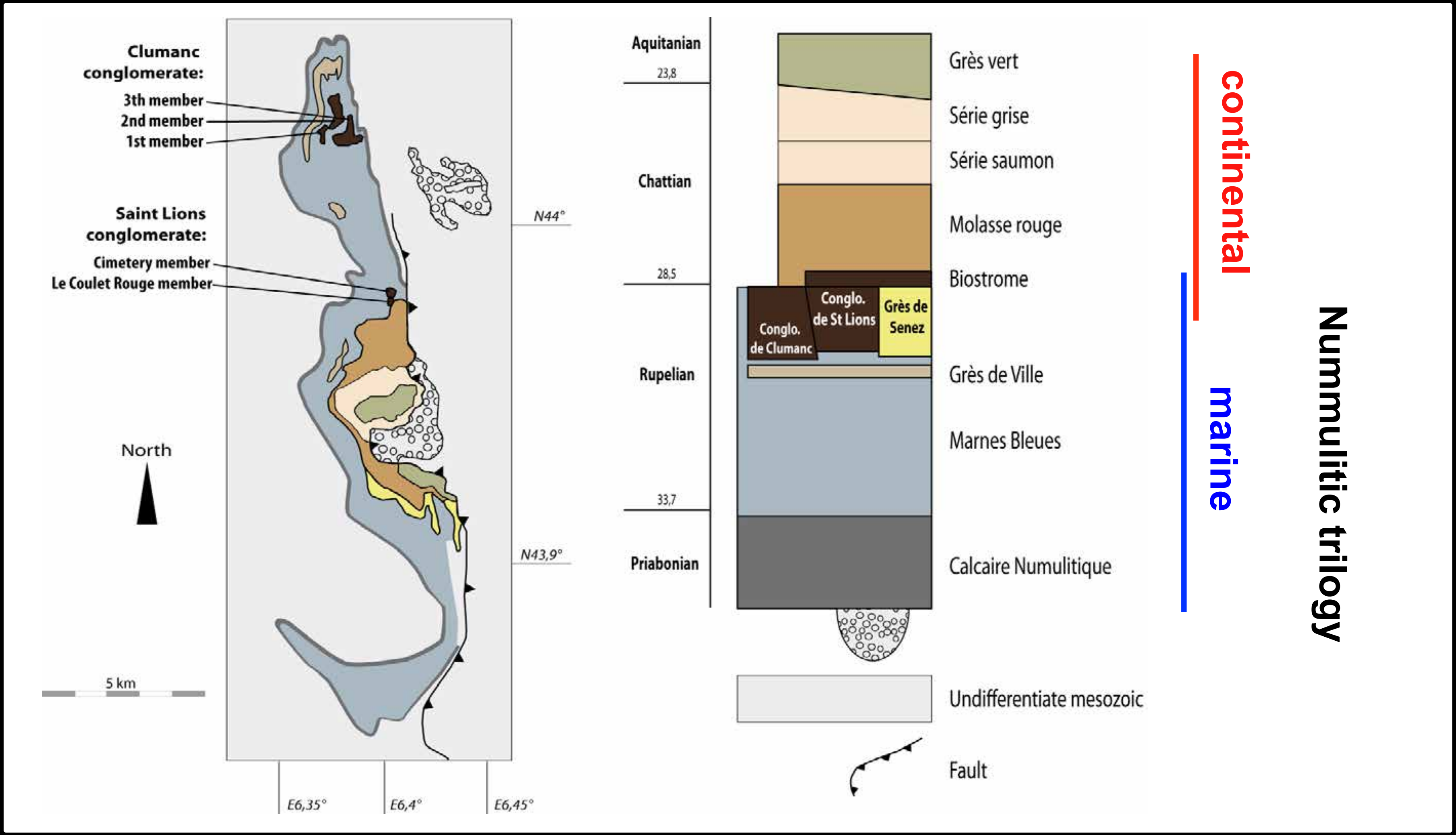
Grosjean, 2012

Oligo-Miocene foreland basins 35-15 Ma

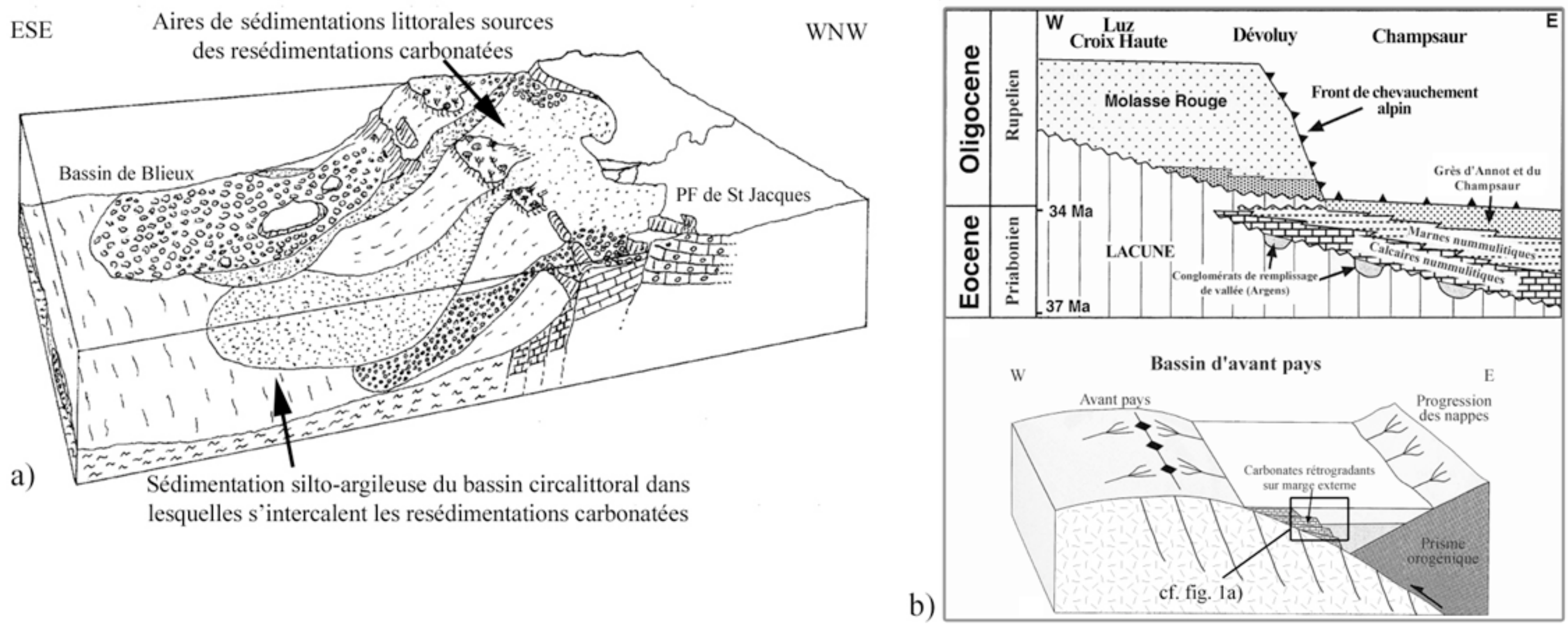


Jourdan, 2012

Barrême basin



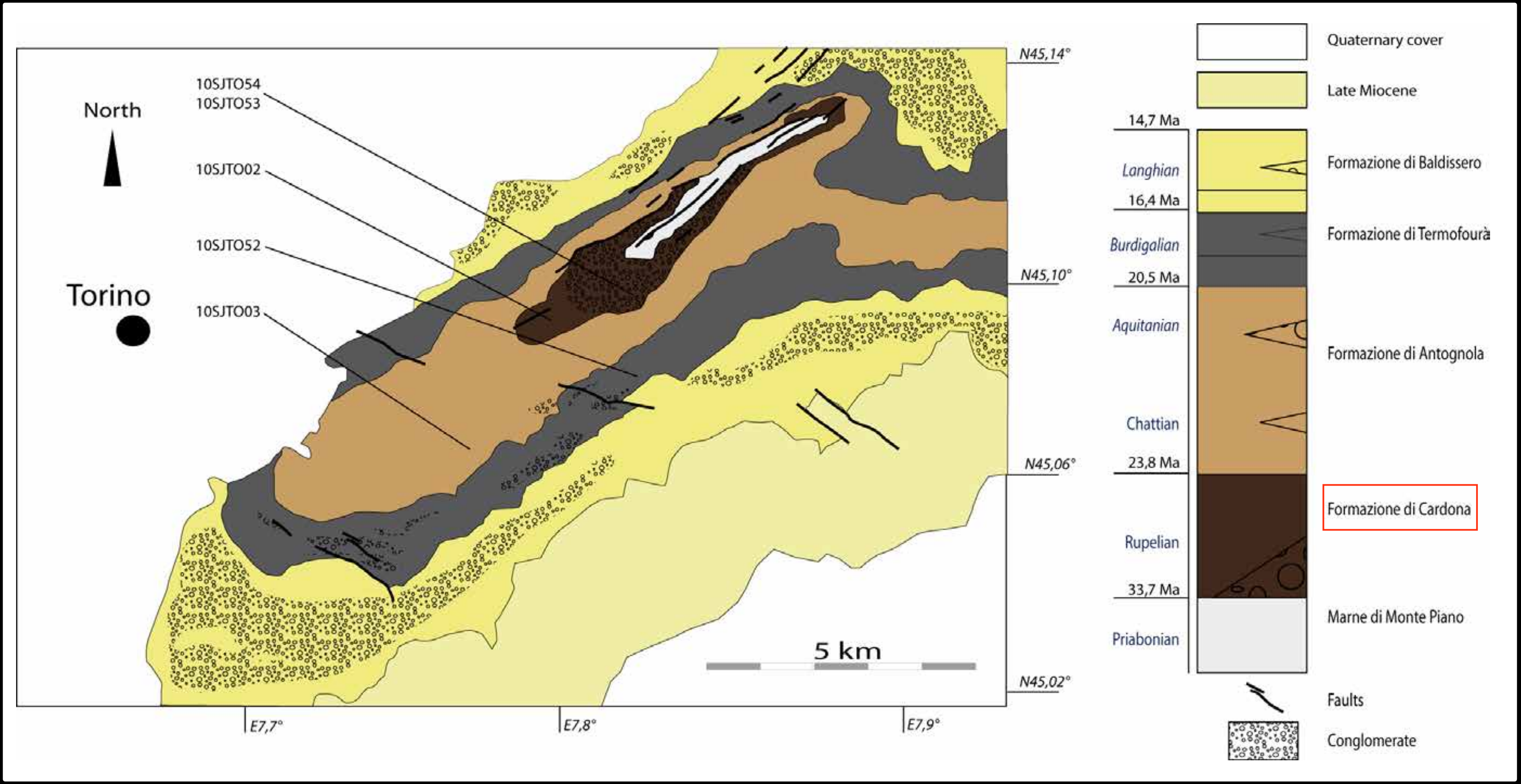
Jourdan et al., 2012



a) Esquisse paleogéographique représentant les resédimentations carbonatées («Calcaires Nummulitiques») se mettant en place en bas de pente dans la partie sud-occidentale littorale du bassin sub-alpin Priabonien et correspondant à la région de Blieux (d'après Floquet & Léonide, 2005) ;
b) Diagramme litho-chronostratigraphique du bassin d'avant-pays alpin à l'Eocène-Oligocène (adapté, à partir de Gupta, 1997).

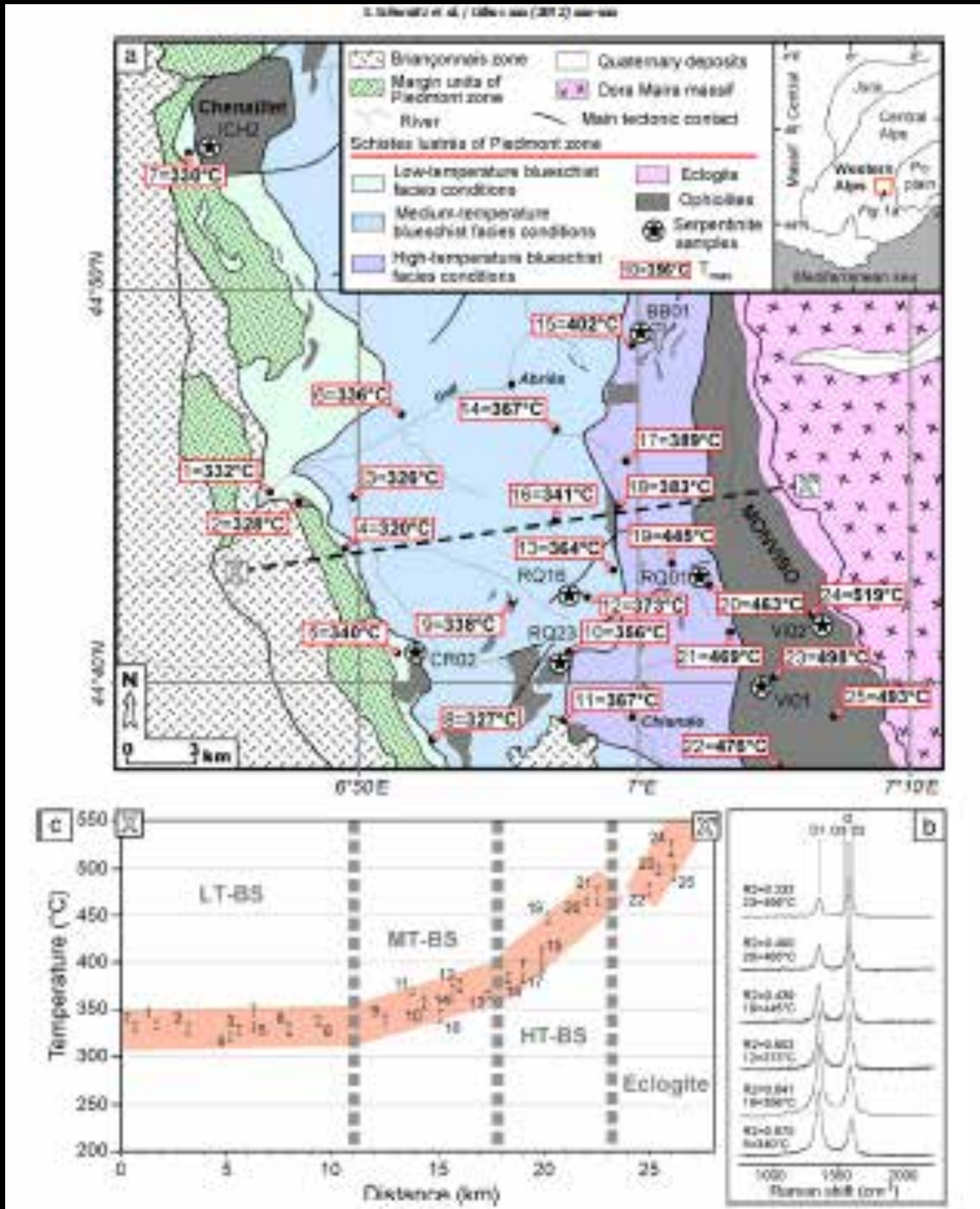
Sinclair, 1994

Torino hills



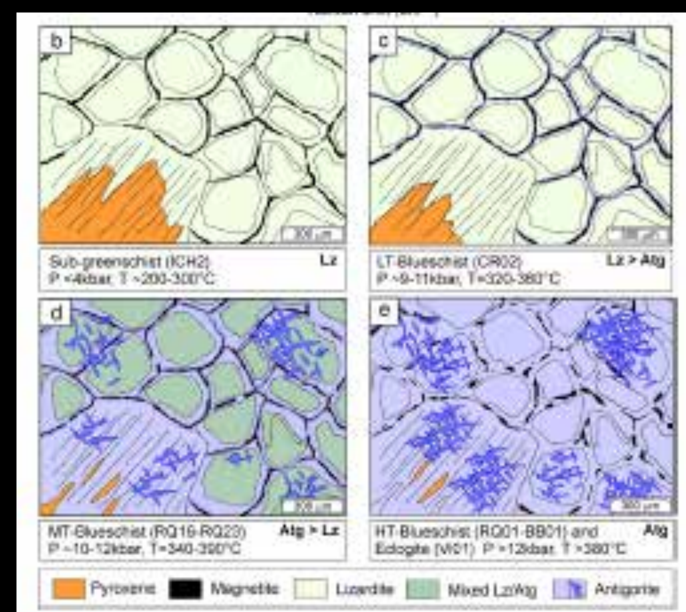
- Torino hills sedimentary record from the Eocene to the Quaternary
- The Cardona Formation (Rupelian) begins to record erosion of the Western Alps

Jourdan et al., 2012



Discriminating the nature of the serpentinites in the Internal Alps

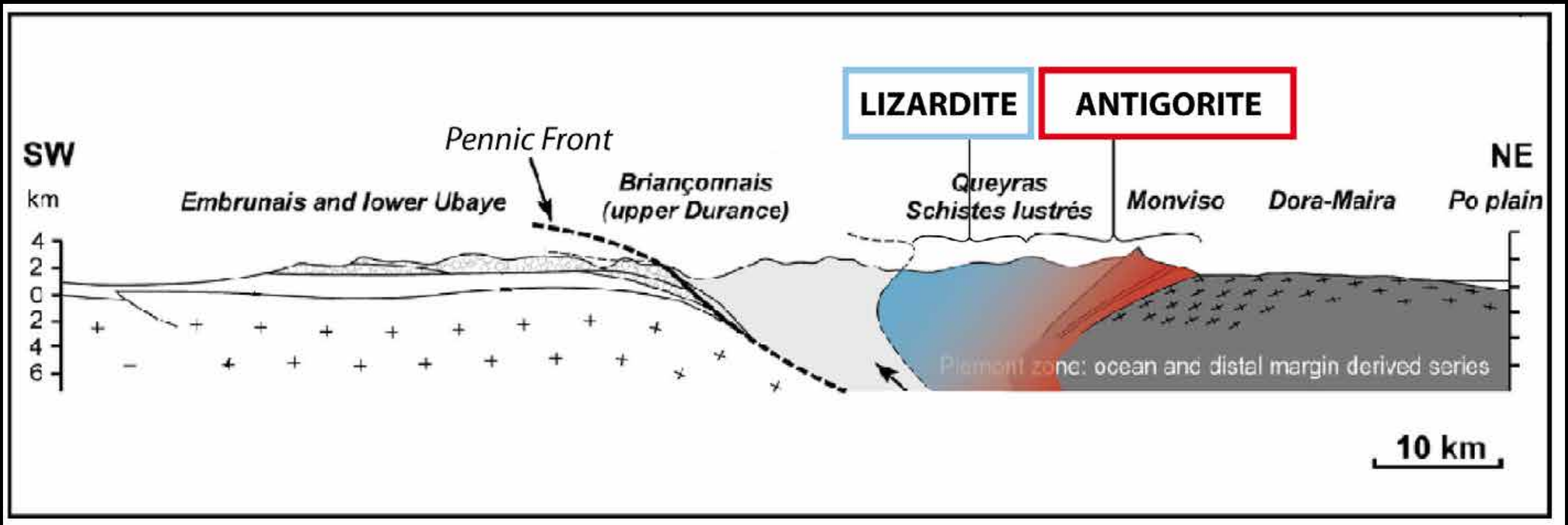
Schwartz et al., 2013



Pebble origin in the Oligocene-Miocene sediments : Serpentinites, Radiolarites, Basalts

Cordey et al. 2012

Serpentinite types in the Internal Western Alps



Schwartz et al. 2012, 2013

- Antigorite occurs in the eastern part and antigorite + lizardite in the western part of the Internal Western Alps

Serpentinite evolution through stratigraphic record

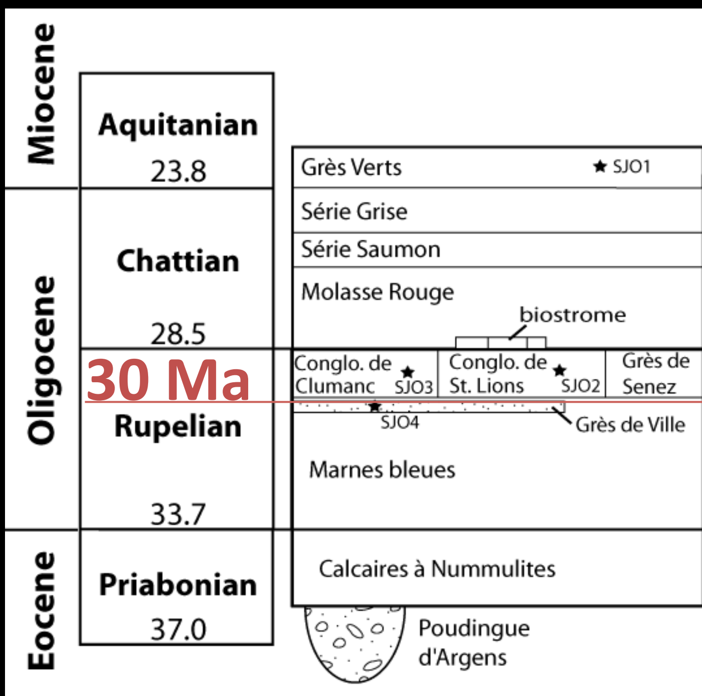
- Antigorite = high-grade metamorphic serpentinite
- Lizarditite = low-grade metamorphic serpentinite

Schwartz et al. 2012 (Barrême) Jourdan et al. 2012 (Torino hills)

Oligocene pro-side foreland basin

« Matériel exotique » = ophiolites/blueschists
Termier 1895 in Chauveau and Lemoine 1961

Barrême basin



Paleocurrent: NE –SW

Paleocurrent: S – N

Joseph and Lomas 2004

Source areas

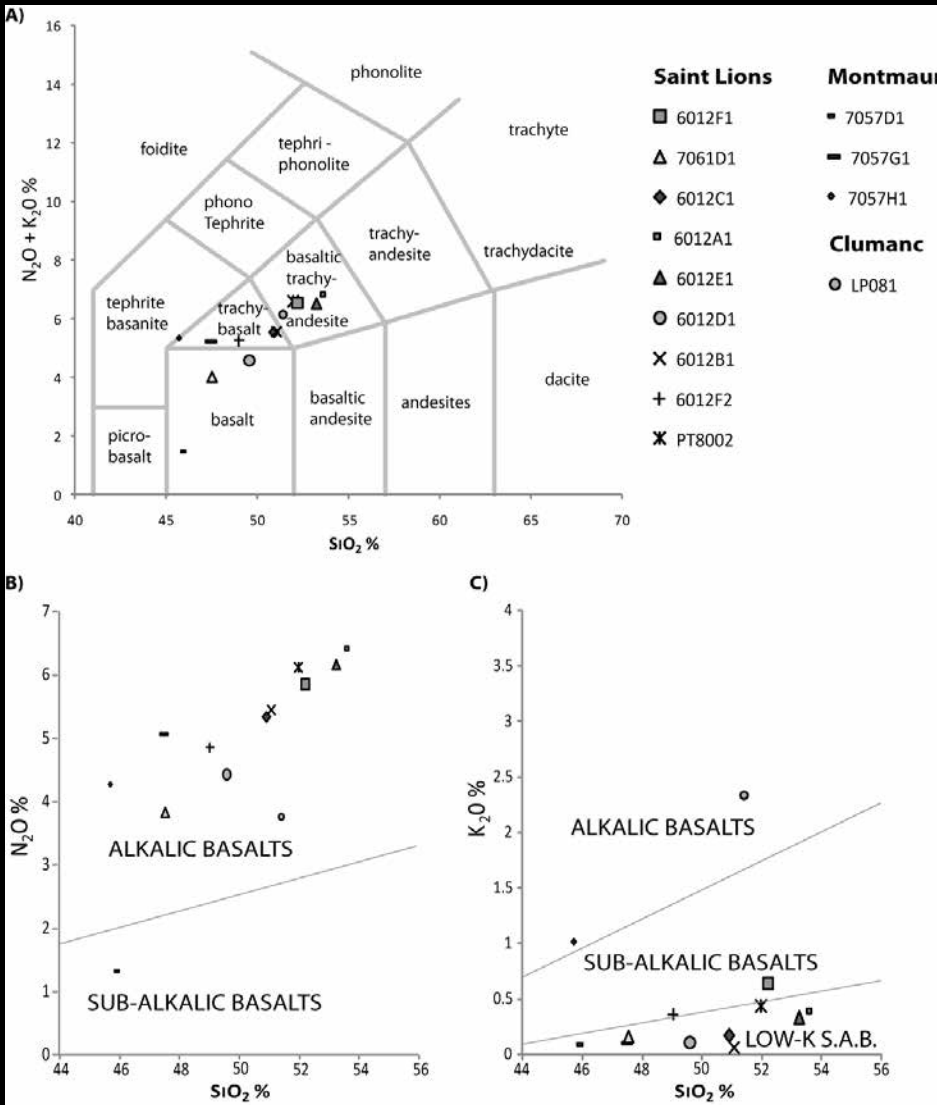
Internal Western Alps

Corsica, Maures-Estérel massif

- At 30 Ma deposition of pebbles from the Internal Alps
- Significant change in paleocurrent directions

Jourdan et al., 2012

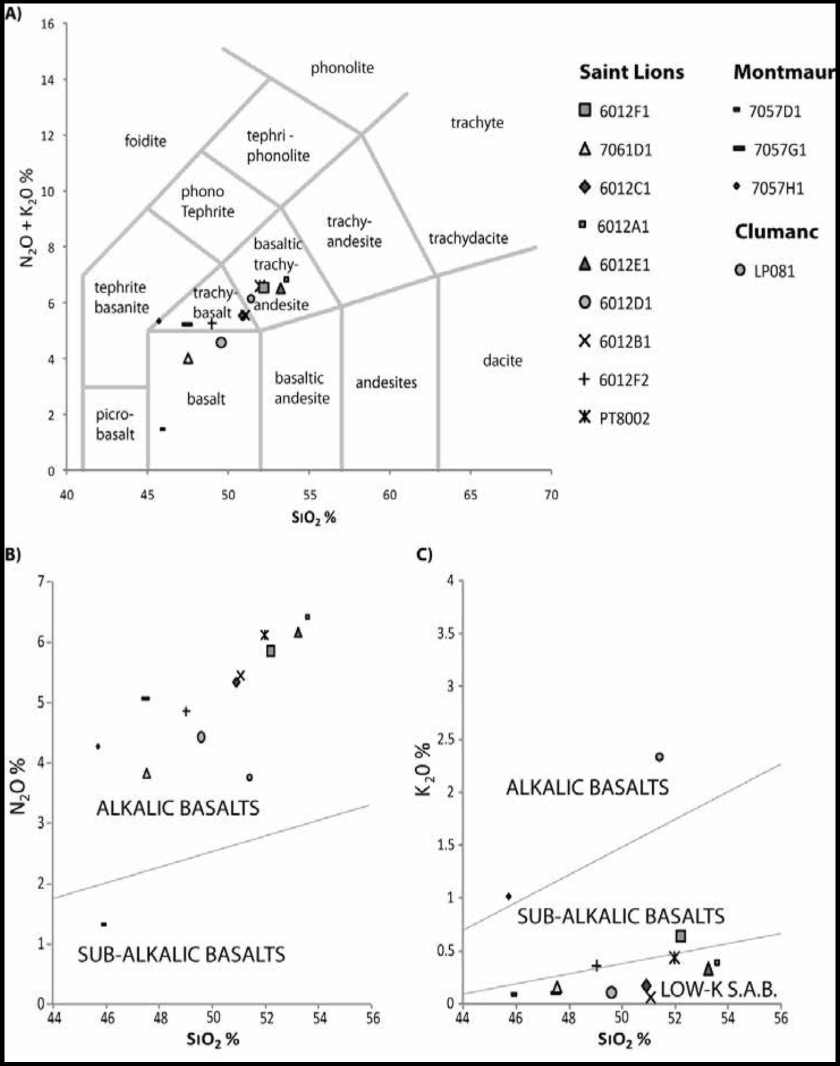
Geochemical analyses



- Major and trace element analyses for basalt pebble characterization for provenance analysis

Jourdan et al., 2012

Geochemistry of basalt pebbles in the foreland basin



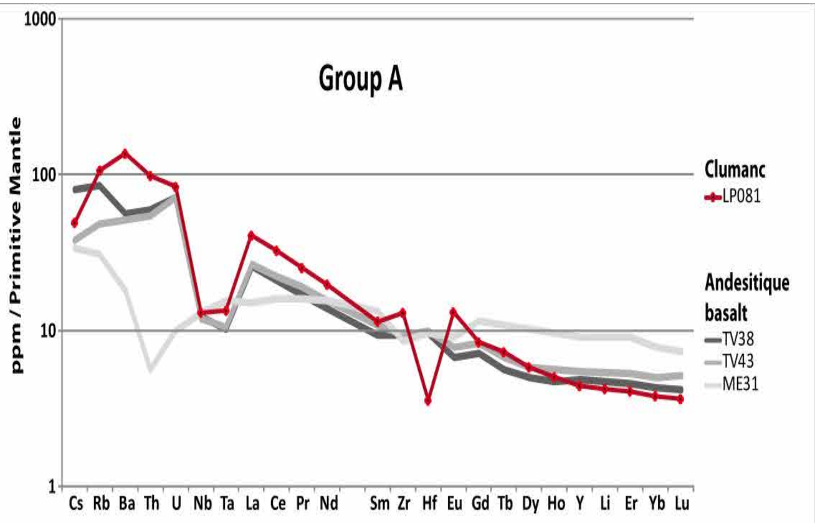
- Before such pebbles were described only as andesites

- Major element analyses show that non-metamorphic basalts from the 30 Ma Barrême basin and Montmaur conglomerates are:
  - Basaltic trachy-andesitic
  - Trachy basalt
  - Basalt

and fall mainly into the alkalic basalt or low-K sub-alkalic basalt fields

Jourdan et al. Journal of Geology, Chicago, 2012

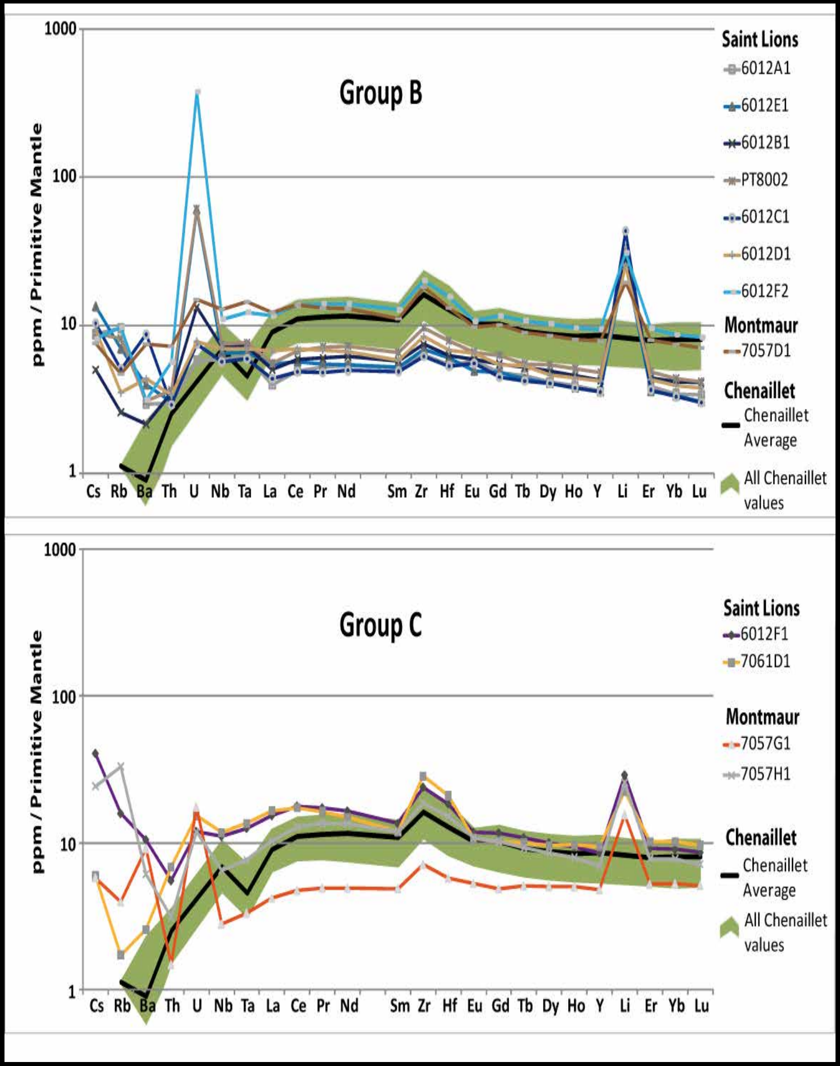
Geochemistry of basalt pebbles in the foreland basin



- The basalt pebble A from the Clumanc conglomerate is similar to andesitic basalt from the Taveyannaz and Champsaur units (*Boyet et al. 2001*)

Jourdan et al. Journal of Geology, 2012

Geochemistry of basalt pebbles in the foreland basin



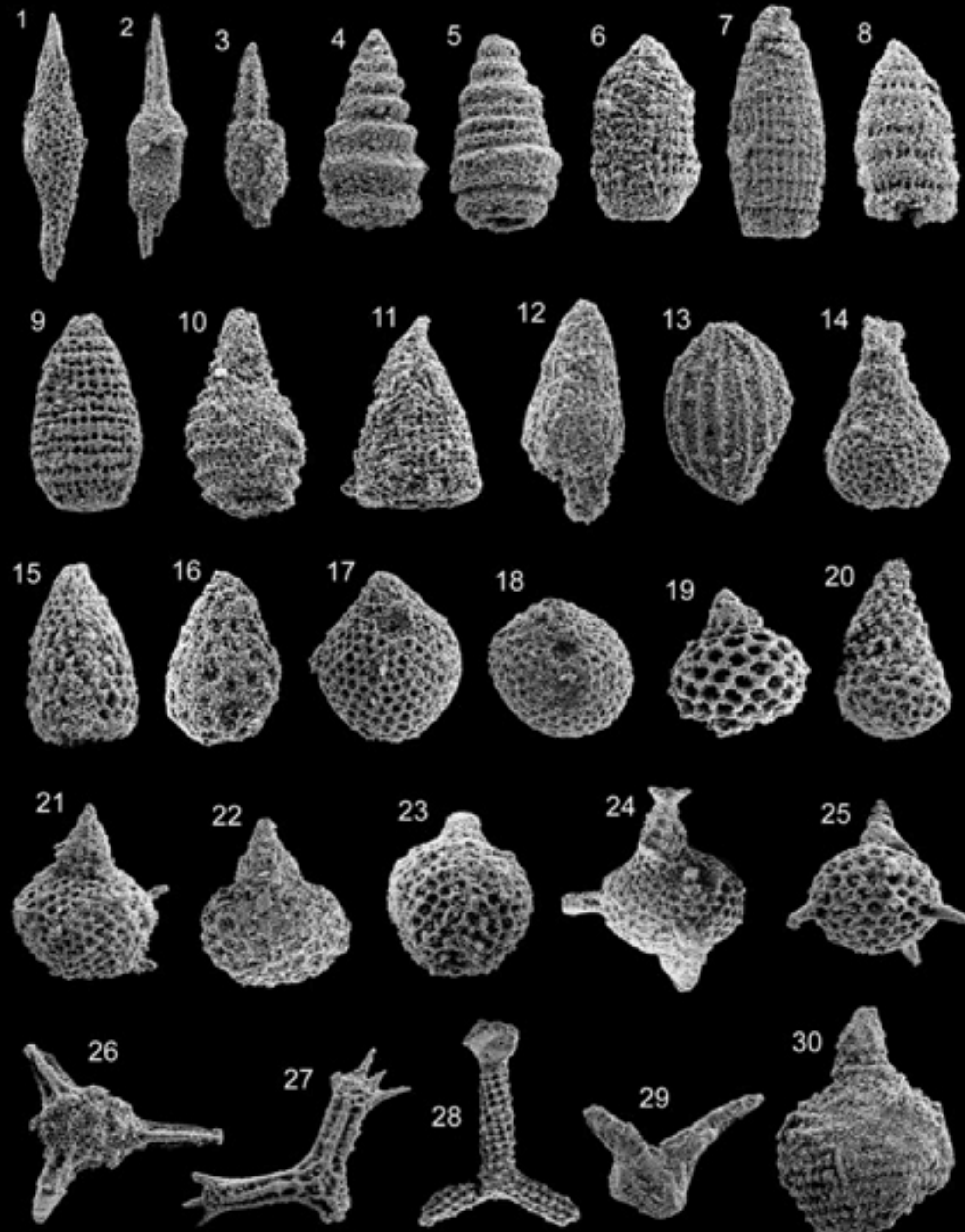
- Group B and C have patterns somewhat similar to basalt from the obducted Chenaillet ophiolite unit

- Positive anomalies are caused by hyrdothermal alteration in the source and/or weathering in the sedimentary system

Jourdan et al. Journal of Geology, Chicago, 2012

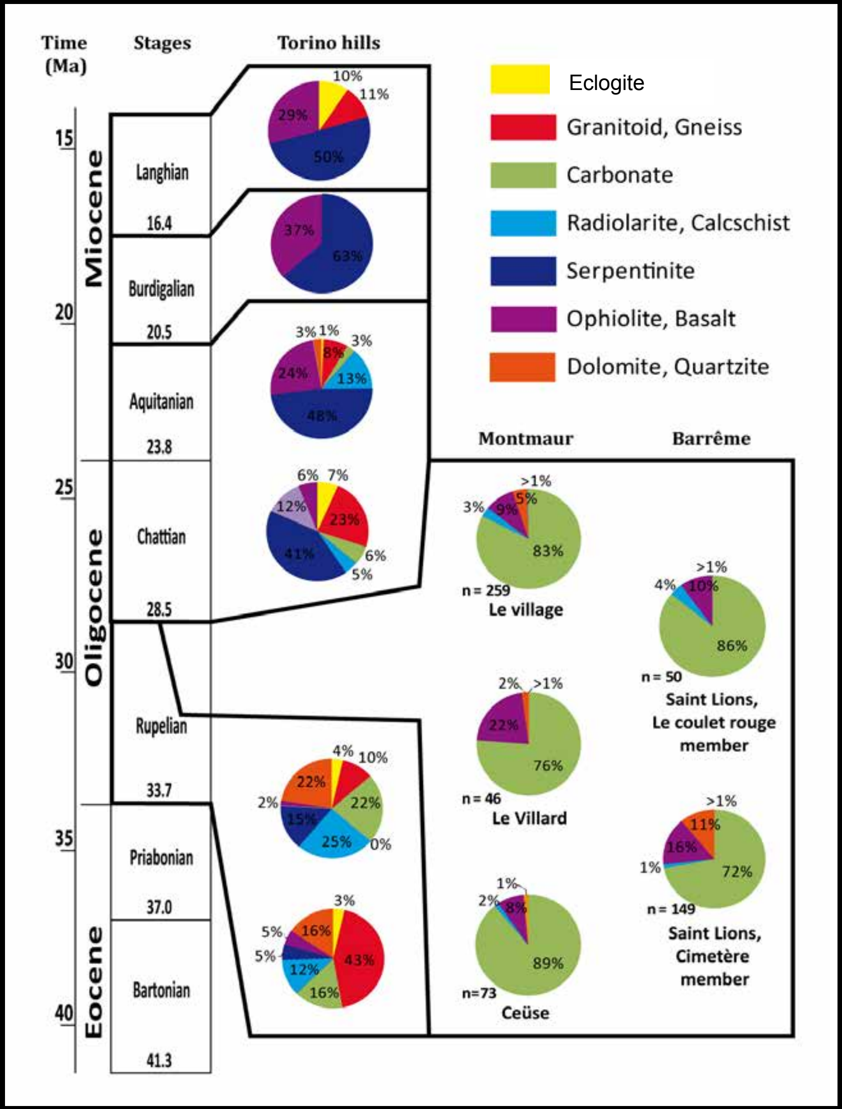
Pebble origin in the Oligocene-Miocene sediments : Serpentinites, Radiolarites, Basalts

Cordey et al. 2012



Cordey et al.
Swiss Geol J, 2012

Pebble population evolution

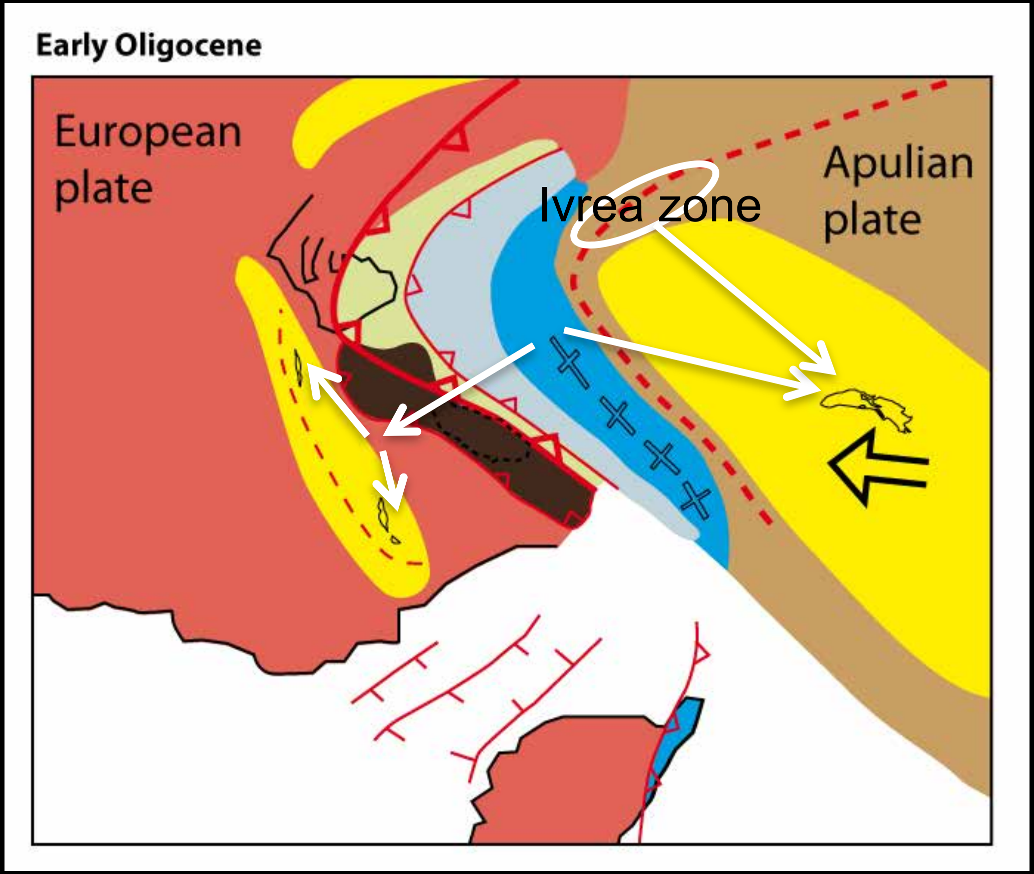


- Proportion of serpentinite pebbles strongly increases from the Late Oligocene in the Torino hills

- The presence of basalt pebbles in all Oligocene foreland basin remnants hints at a wide distribution of obducted ophiolites in the Western Alps at that time

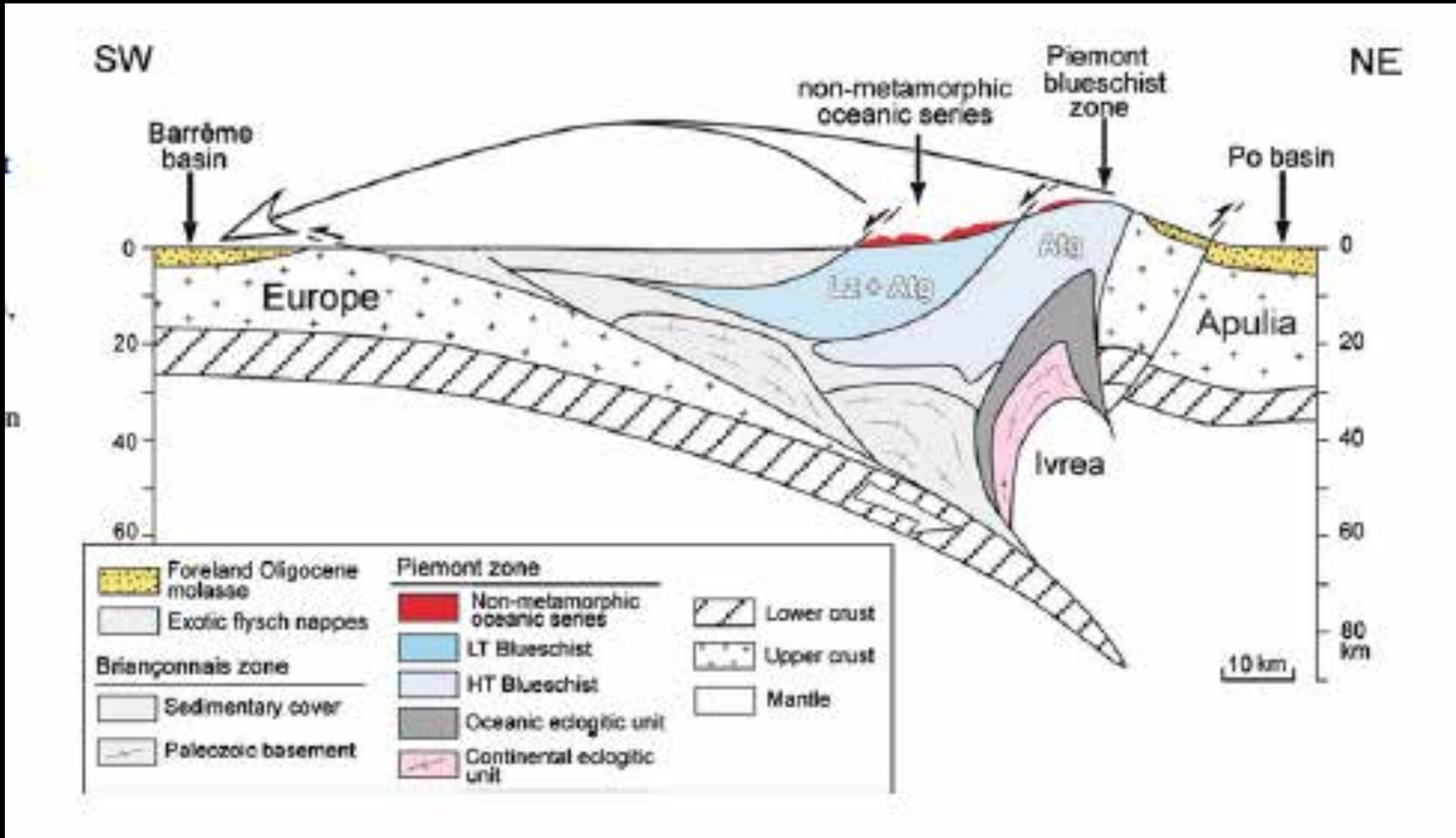
Polino et al. 1991 (Torino hills) and Jourdan et al. Journal of Geology 2012

Sediment provenance



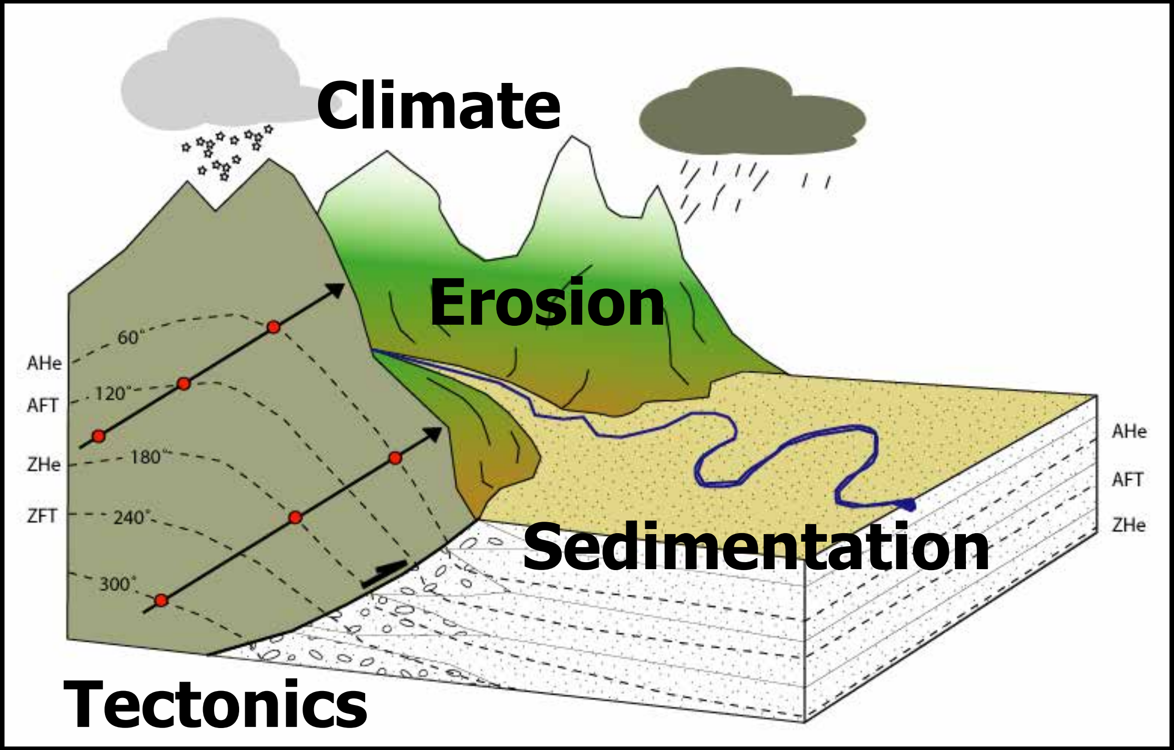
Jourdan et al., 2012

Torino hills: Granodiorite pebbles derived from the Ivrea zone and serpentinite pebbles from the Piedmont zone
Barrême basin: Basalt pebbles from Chenaillet or similar ophiolites. Zircons from the Internal Alps



Cordey et al. Swiss Geol J, 2012

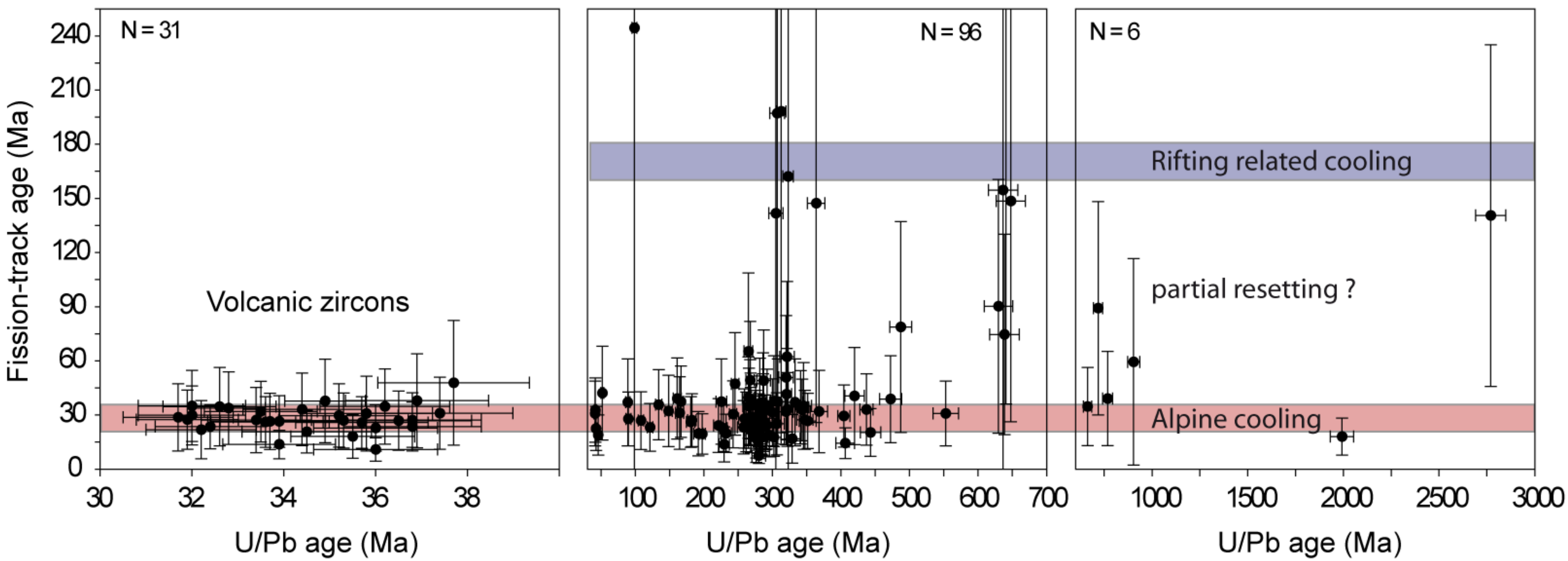
Thermochronological record of exhumation : lag time



Bernet 2009

- With depth temperature increase depending thermal gradient
- Exhumational cooling of rocks
- The time of cooling below the closure temperature is recorded in apatites and zircons

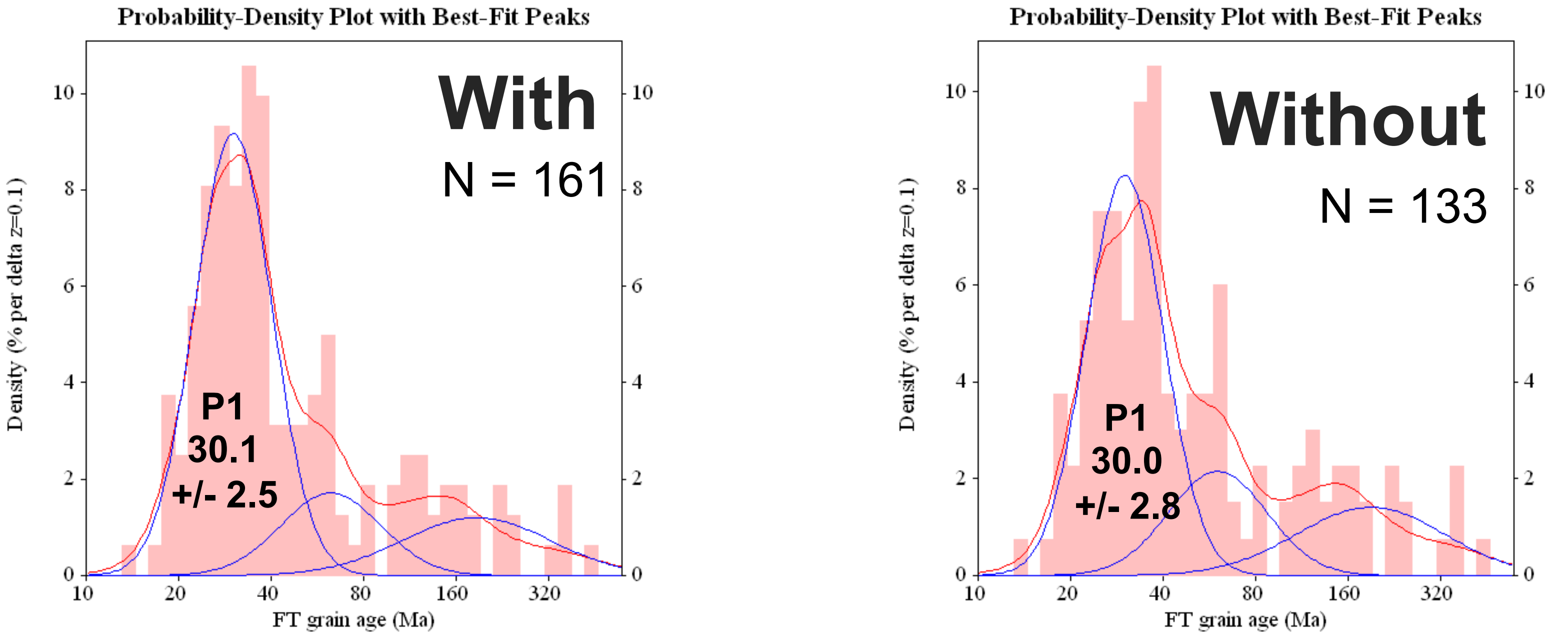
ZFT and U-Pb double dating results in the pro-side foreland basin



- A strong Alpine cooling signal in spite of the presence of Oligocene volcanic zircons

Jourdan et al. Lithosphere,2013

ZFT and U-Pb double dating results in the pro-side foreland basin

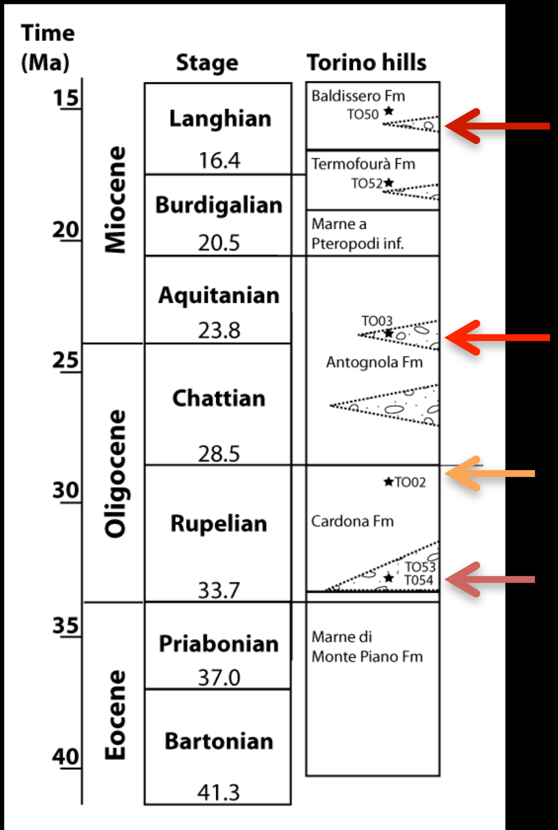


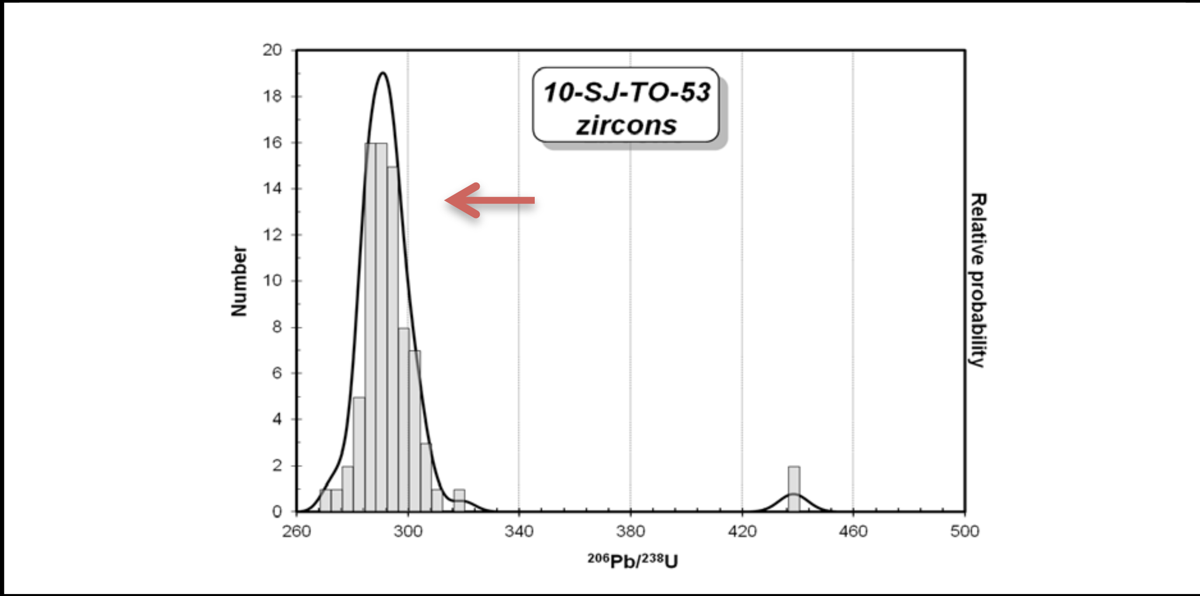
St. Lions Conglomerate, Barrême basin

- Removal of volcanic zircons from the dataset to obtain a pure exhumation signal

Jourdan et al. Lithosphere,2013

ZFT-U/Pb double dating results Torino hills

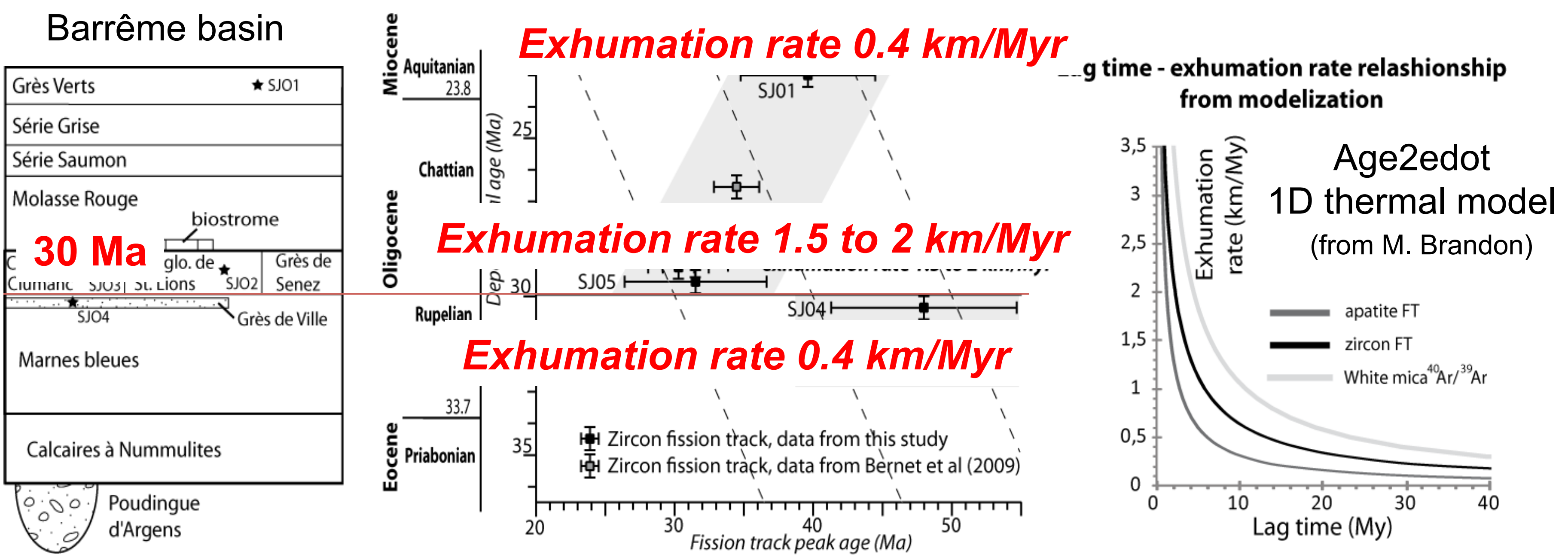




- Granodiorite signal : U/Pb age of about 290 Ma
- Alpine ZFT signal is less developed than in the pro-side foreland basin deposits
- No Oligocene volcanic zircons

Jourdan et al. Lithosphere, 2013

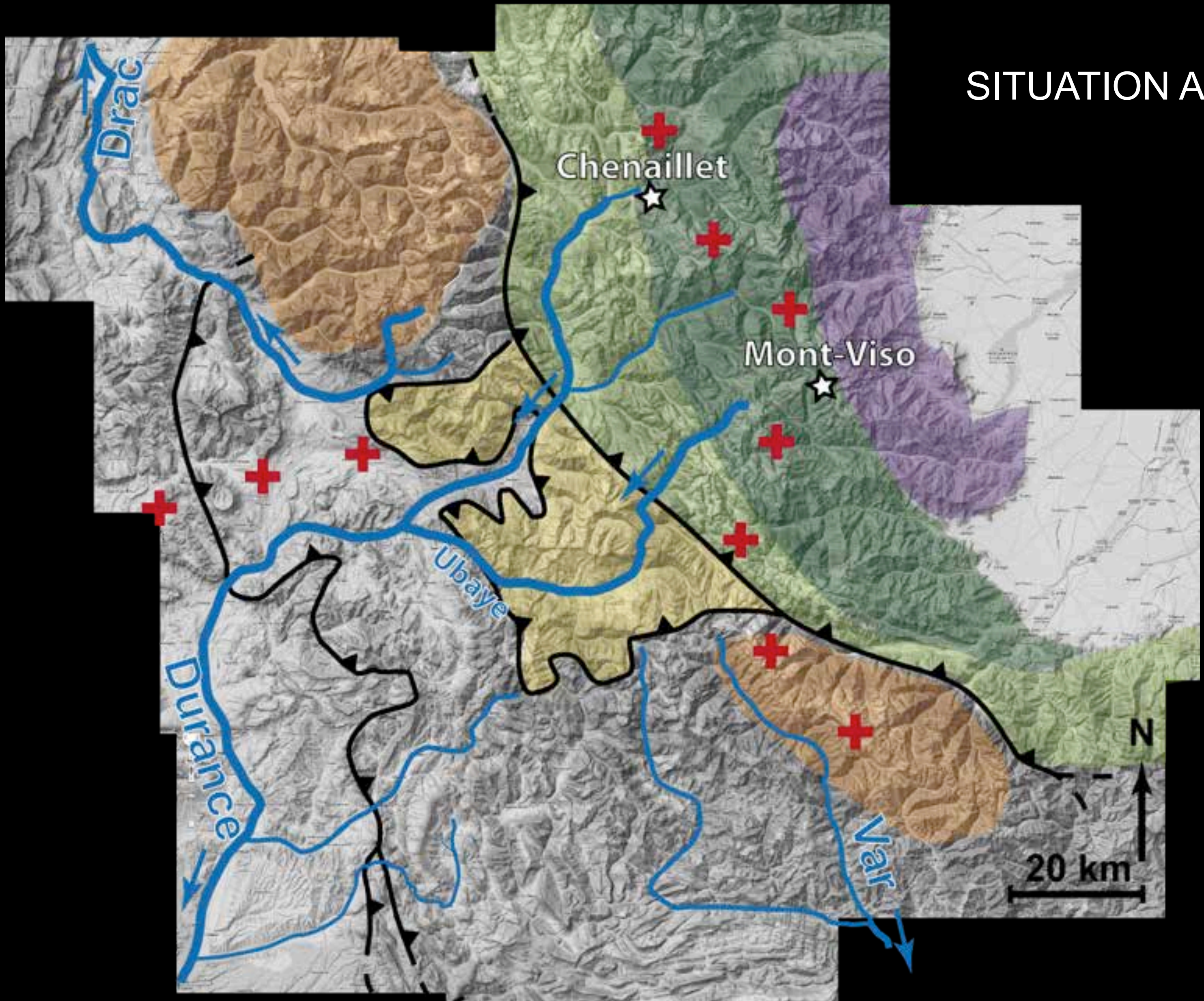
Pro-side foreland P1 zircon fission-track signal



- Brief period of fast exhumation at ~1.5 to 2 km/Myr
- Arrival of pebbles from Internal Alps is contemporaneous with this brief pulse of rapid erosional exhumation

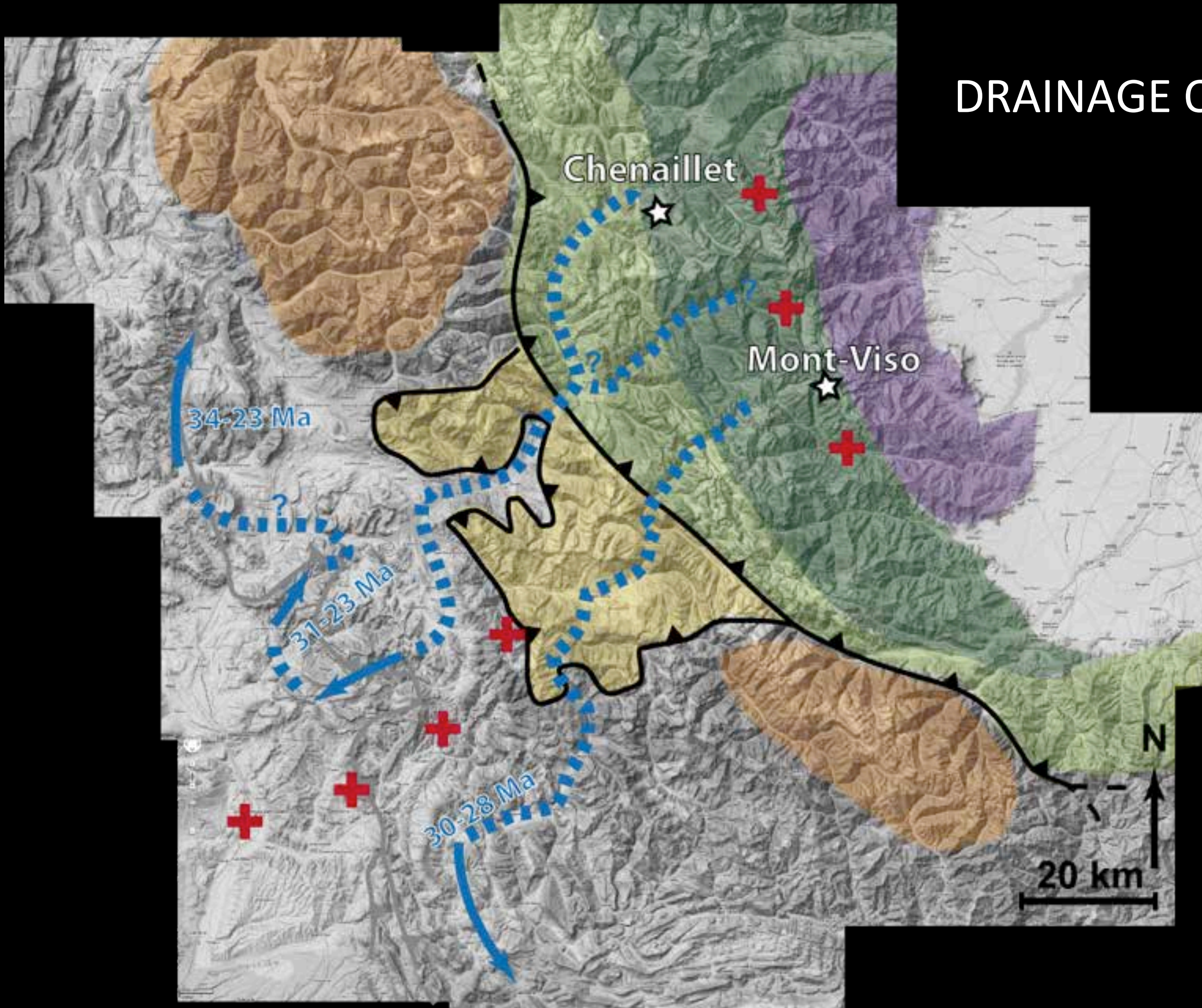
Jourdan et al. Lithosphere 2013

SITUATION ACTUELLE



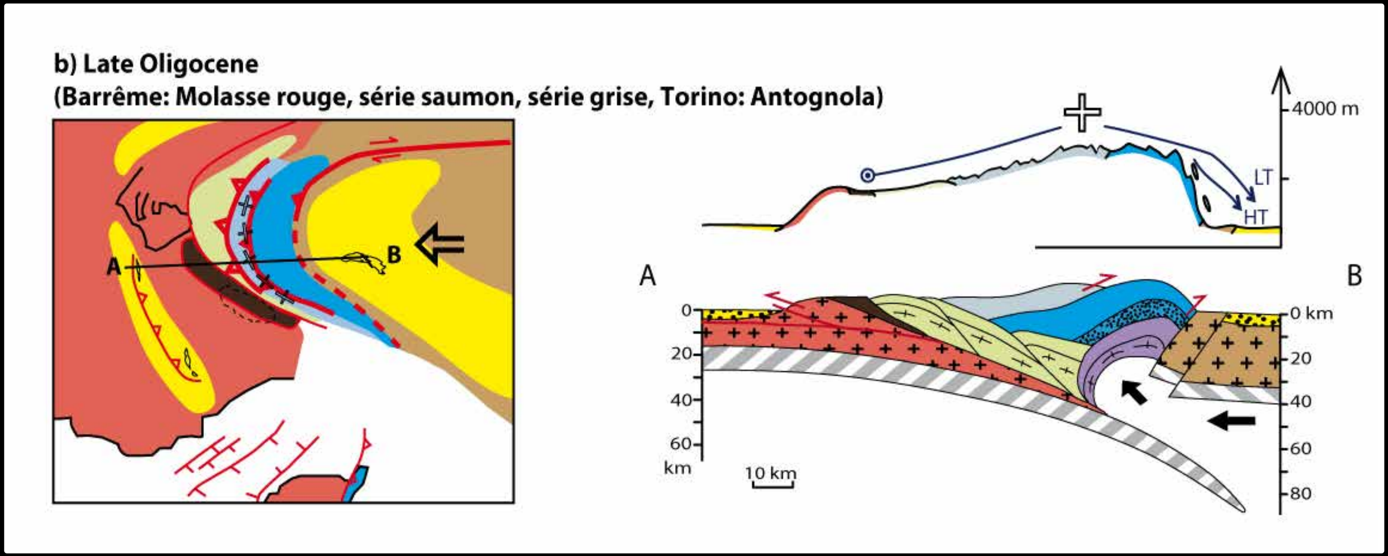
Grosjean, 2012

DRAINAGE OLIGOCENE



Grosjean, 2012

Drainage divide evolution

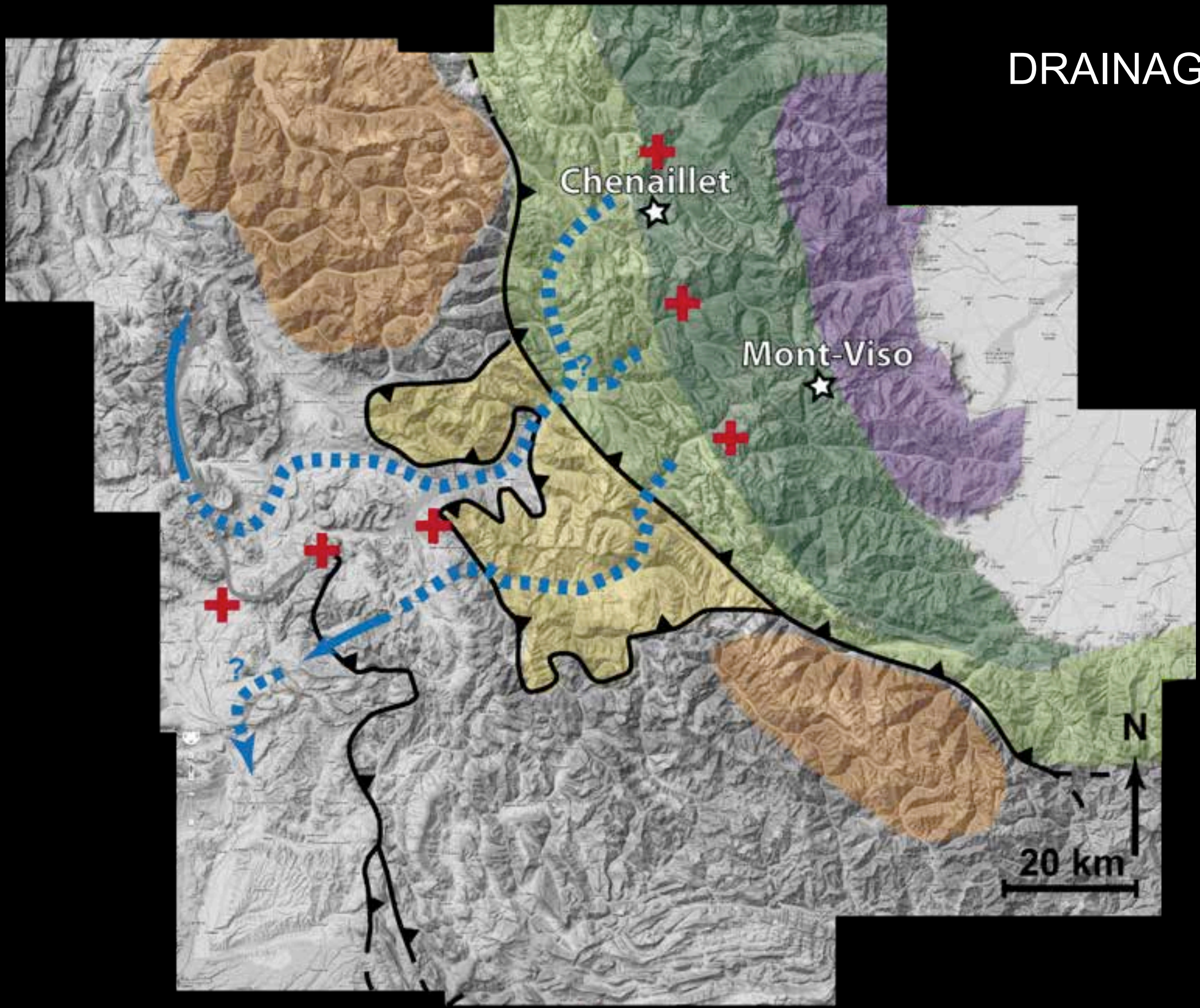


Exhumation rate 1.5 to 2 km/Myr

Jourdan et al Journal of Geology , 2012

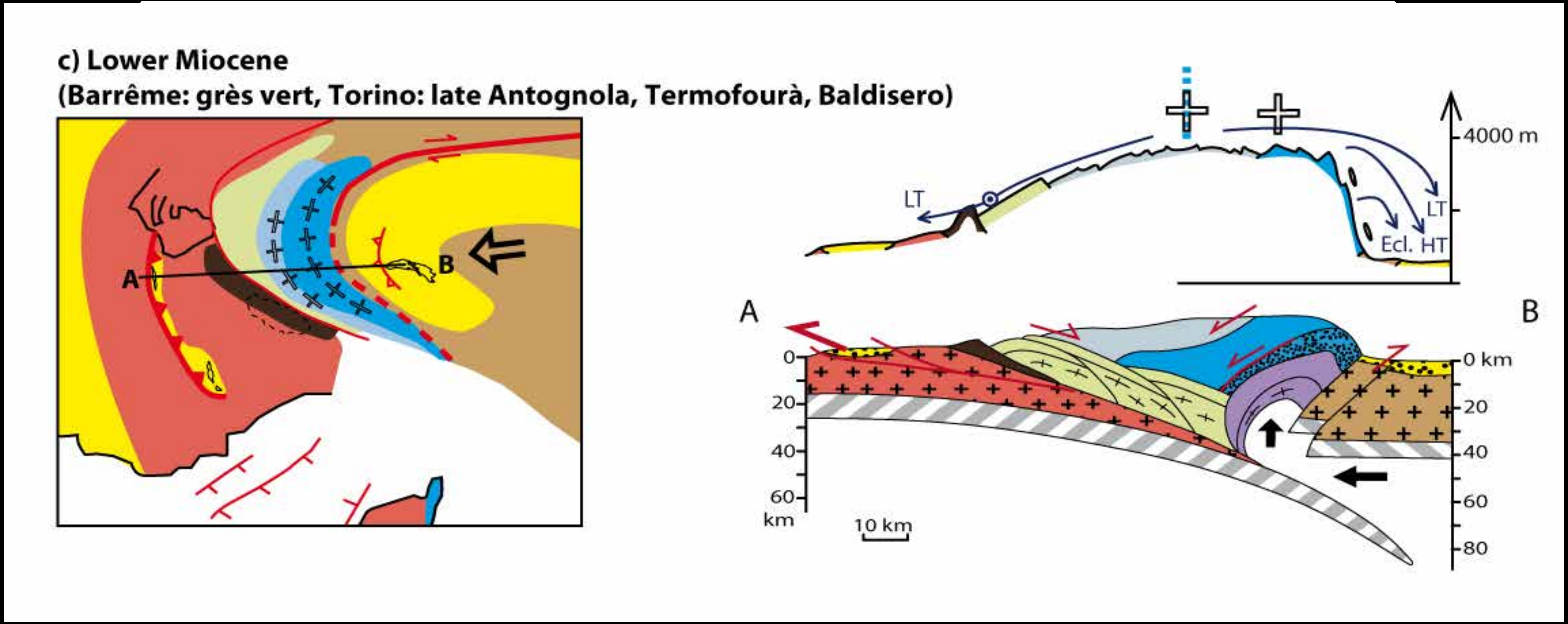
- Pebble lithologies in foreland basins on both sides of the Alps allow tracing the drainage divide evolution
- Large pebbles in the Torino hills show the proximity of steep relief

DRAINAGE MIOCENE



Grosjean, 2012

Drainage divide evolution



Exhumation rate 0.4 km/Myr

Jourdan et al Journal of Geology , 2012

- Pebble lithologies in foreland basins on both sides of the Alps allow tracing the drainage divide evolution
- Large pebbles in the Torino hills show the proximity of steep relief

Conclusion : Reliefs des Alpes

Les reliefs récents à actuels (< 5 Ma) sont formés par incision glaciaire

Les reliefs dans les Alpes existent depuis environ 30 Ma (probablement plus mous qu'actuellement)

Les altitudes > 3000 mètres existent depuis 30 Ma

Les altitudes > 4000 mètres plus récentes (< 5 Ma)

La ligne de partage des eaux à peu changée