

# Eléments de tectonique du Vercors

Professeur Olivier LACOMBE

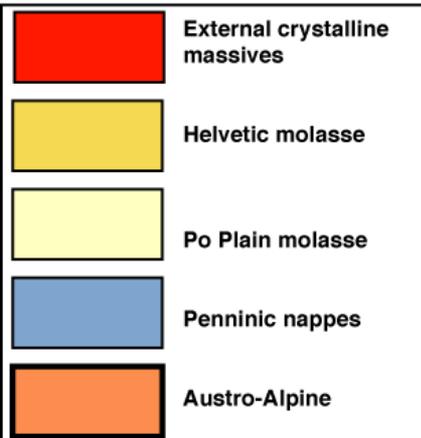
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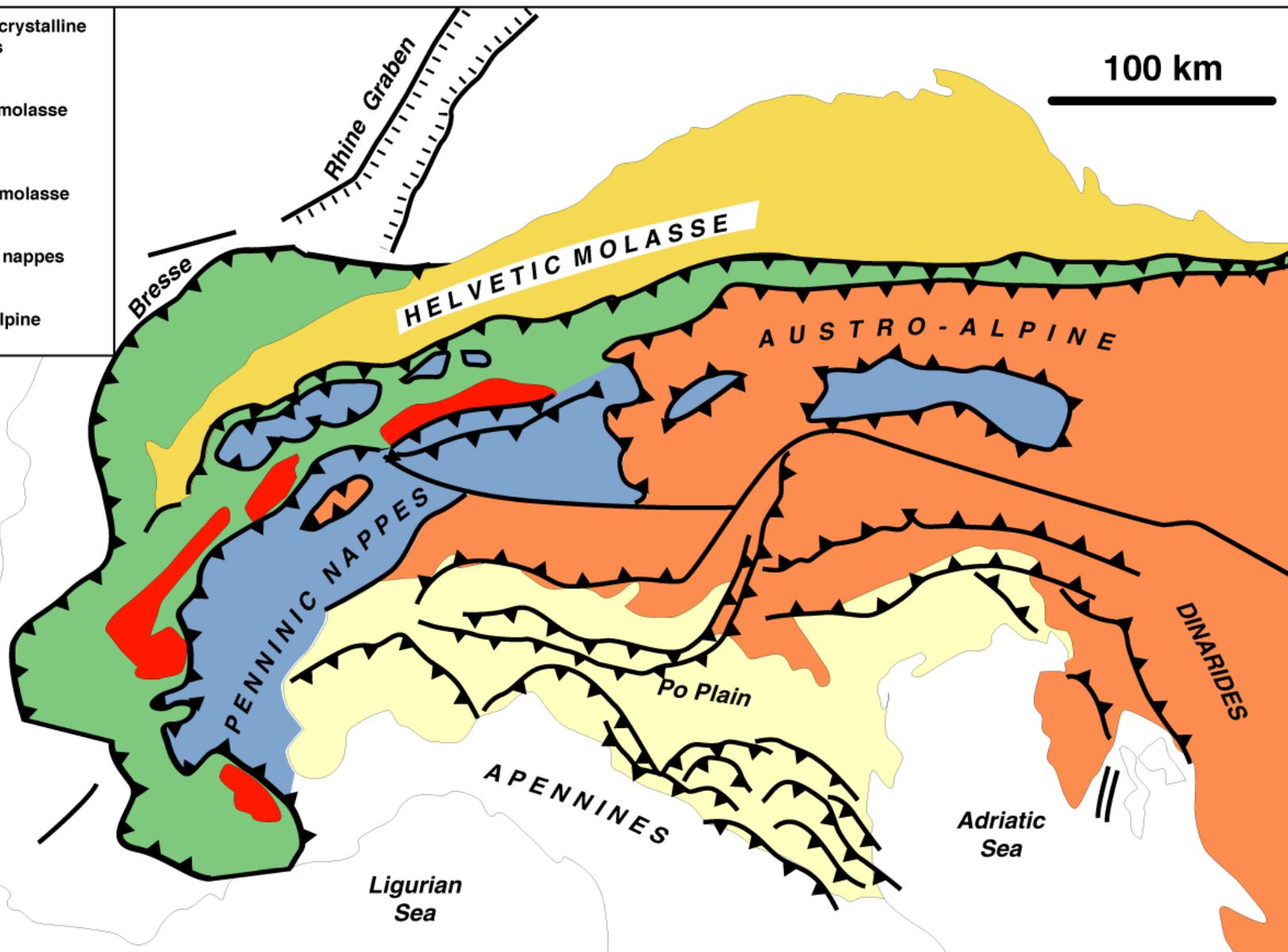
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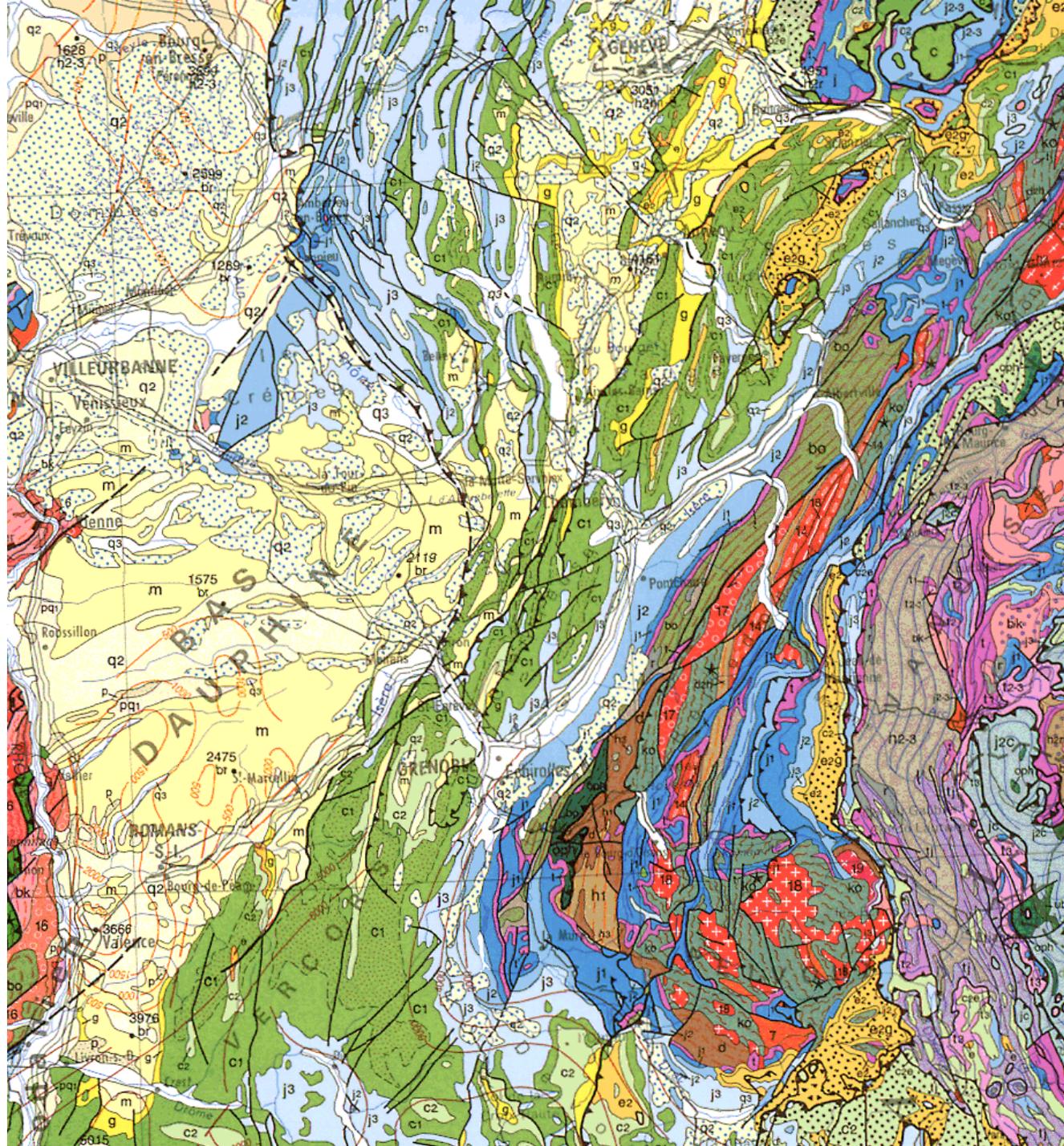
Institut des Sciences de la Terre  
de Paris

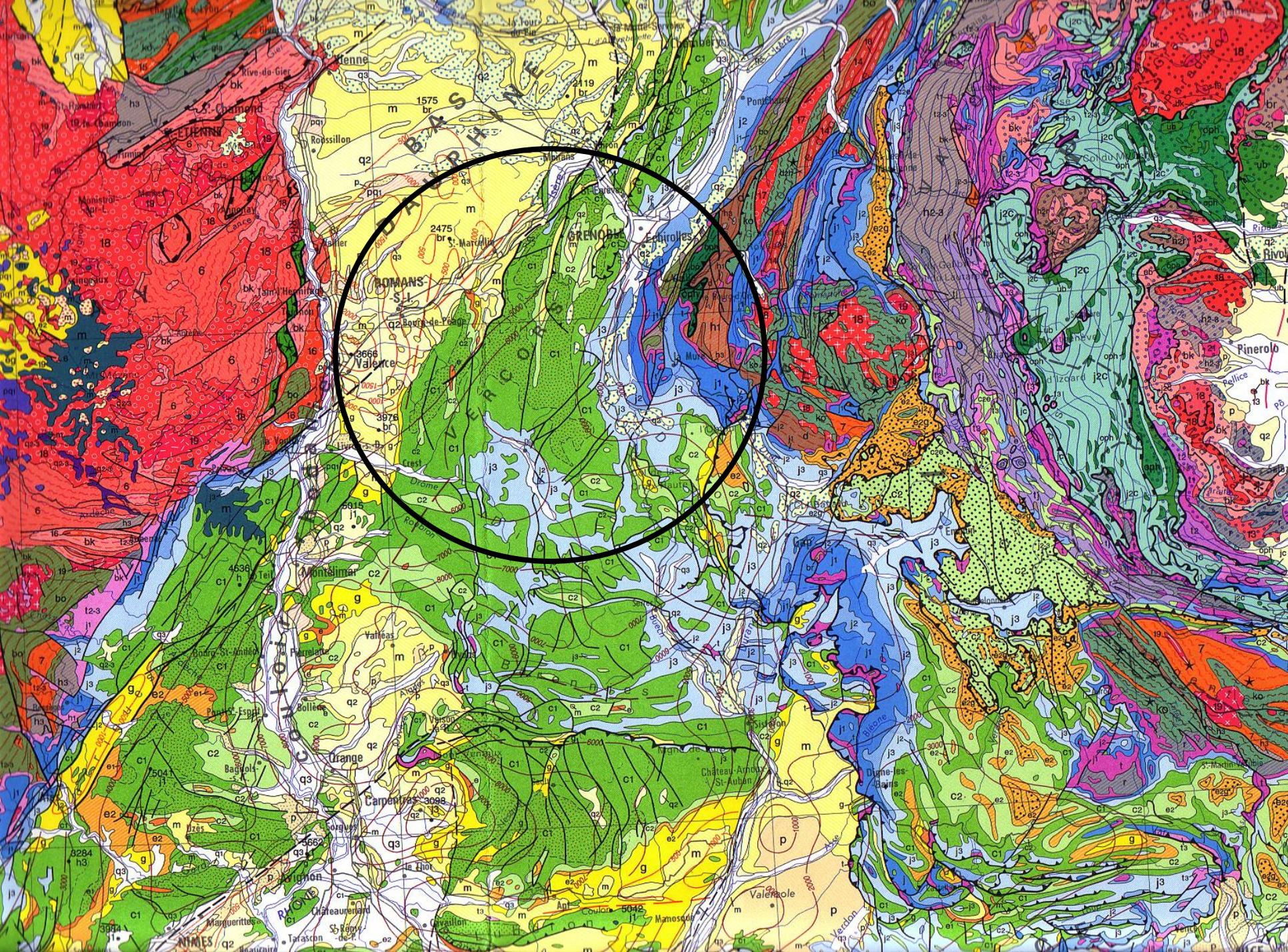


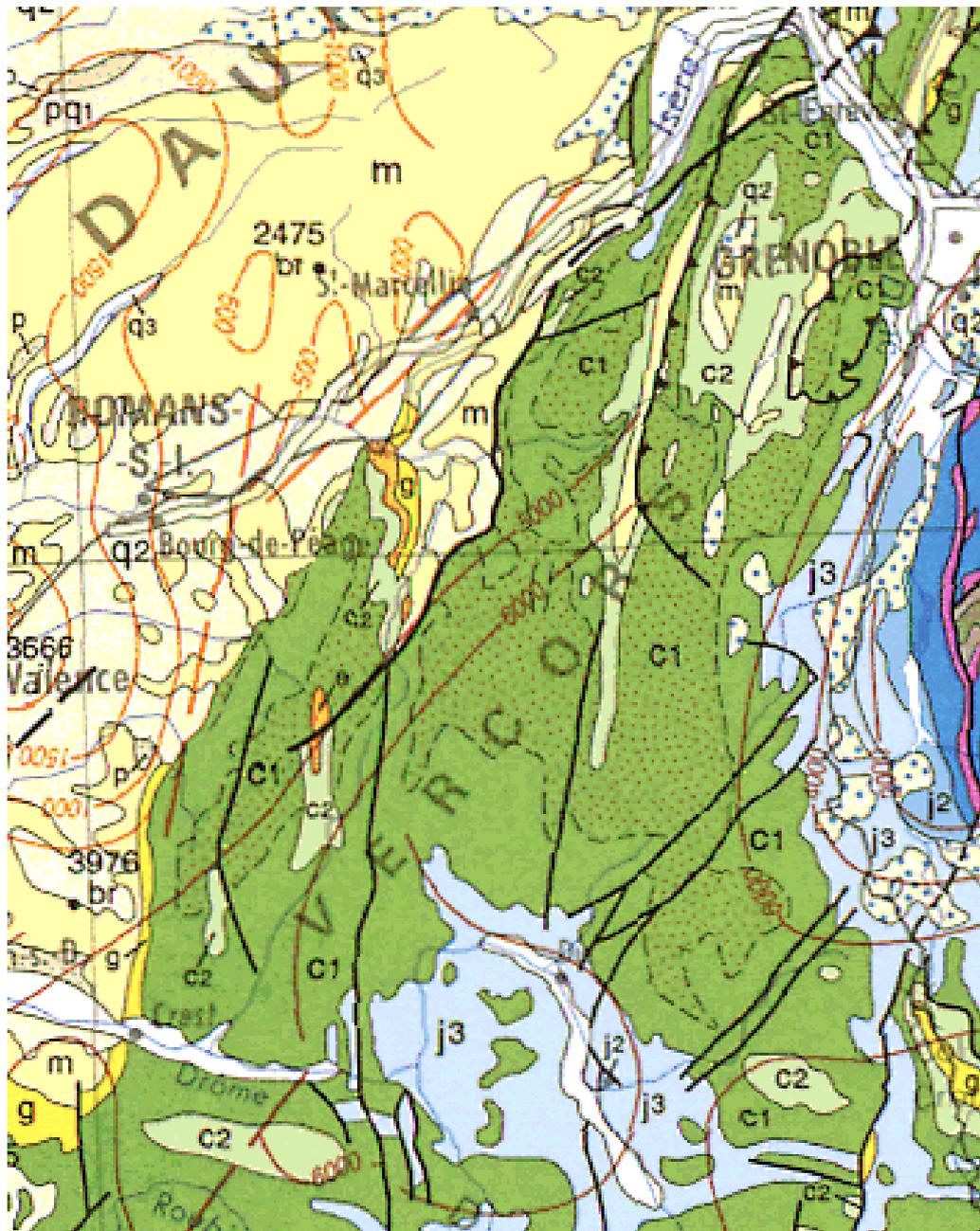
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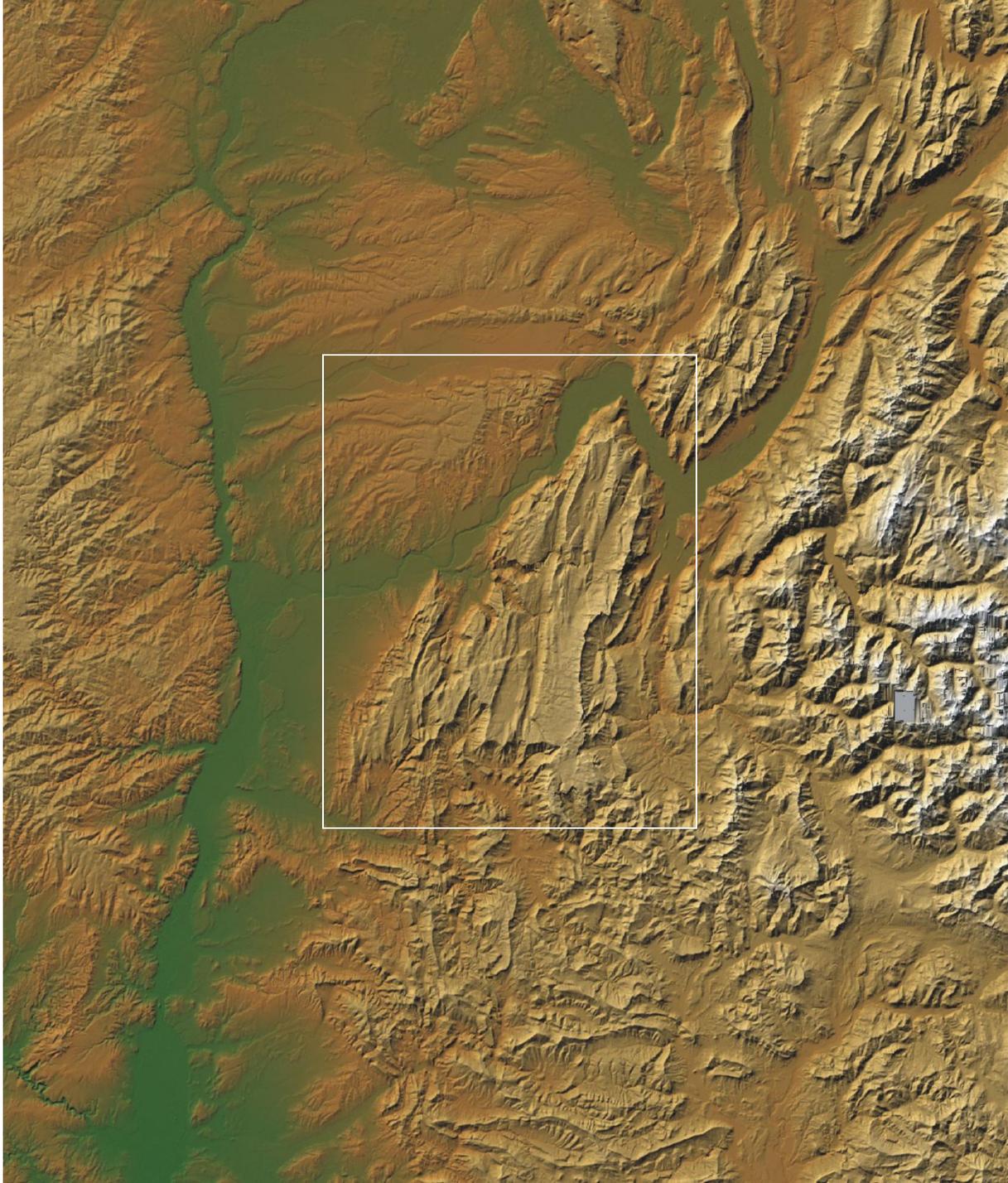





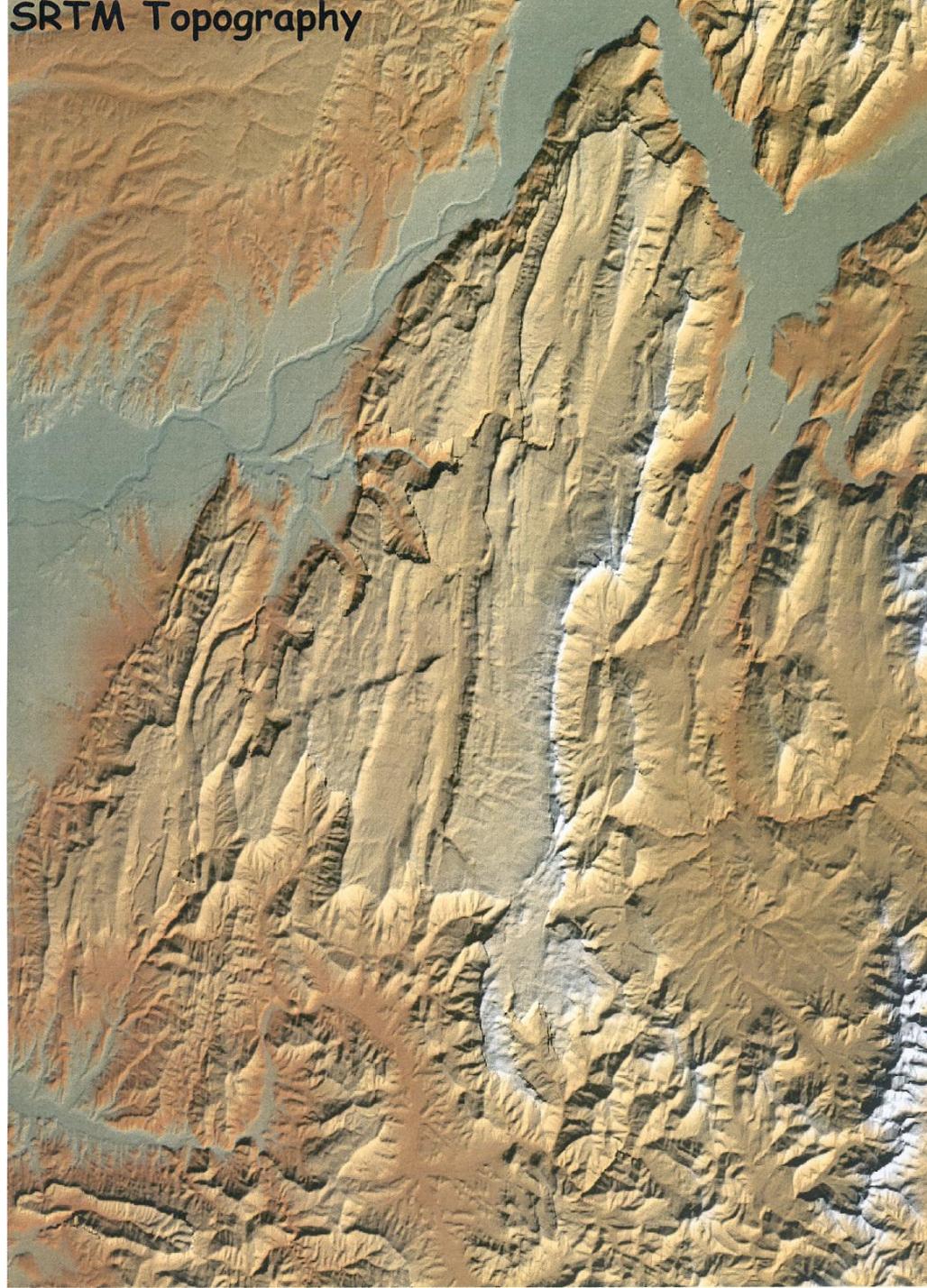




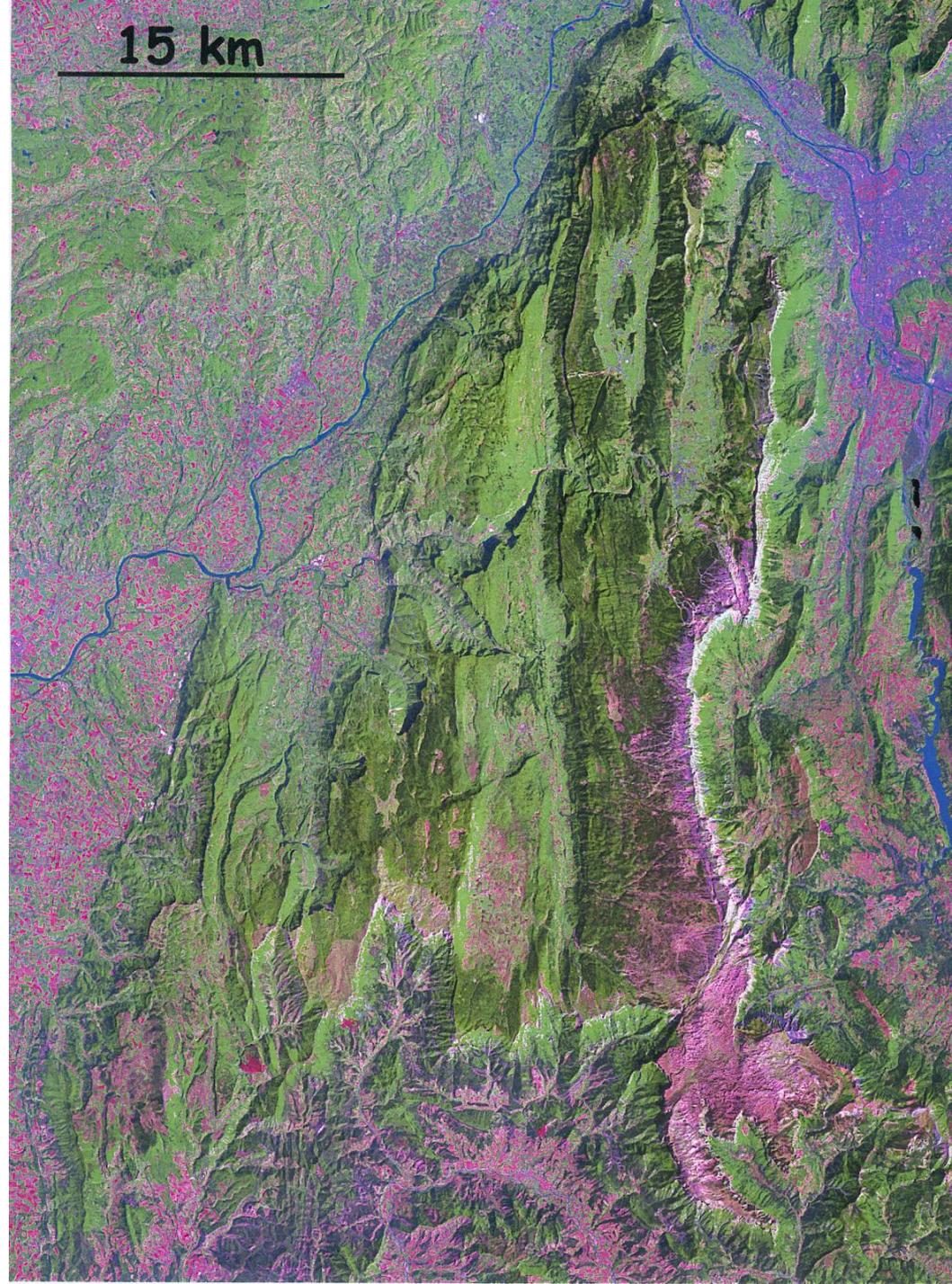


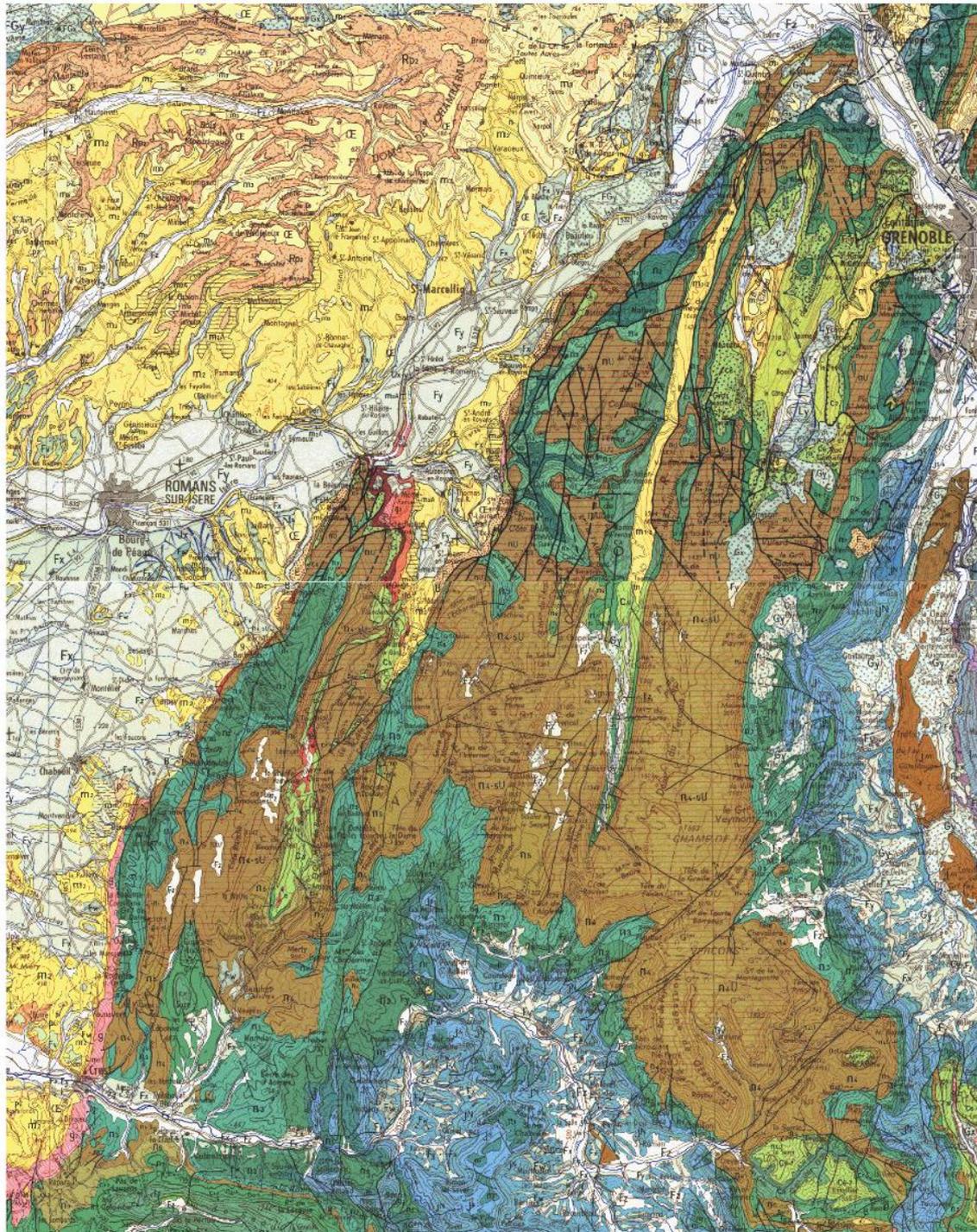


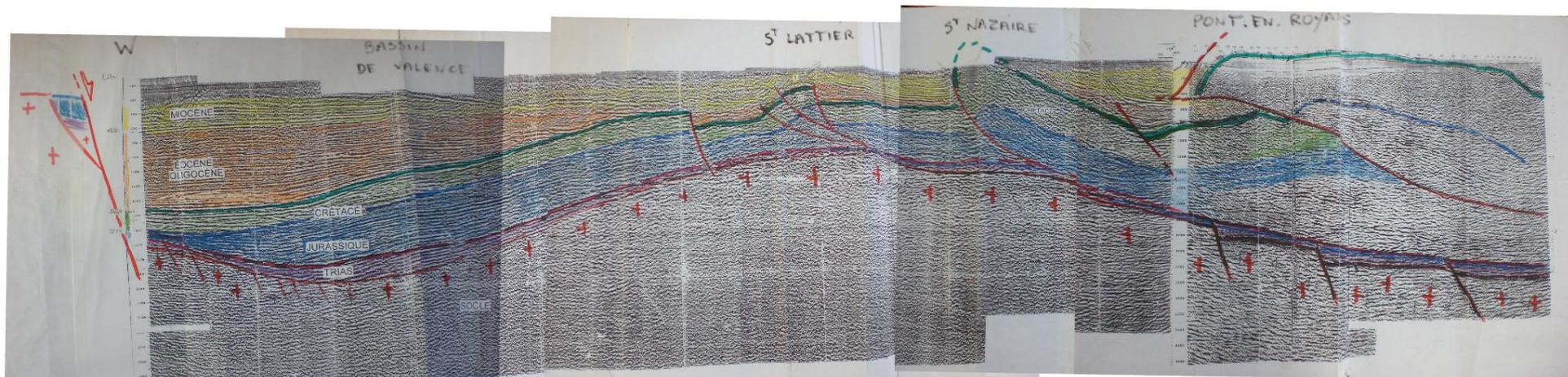
SRTM Topography



**Image Landsat**



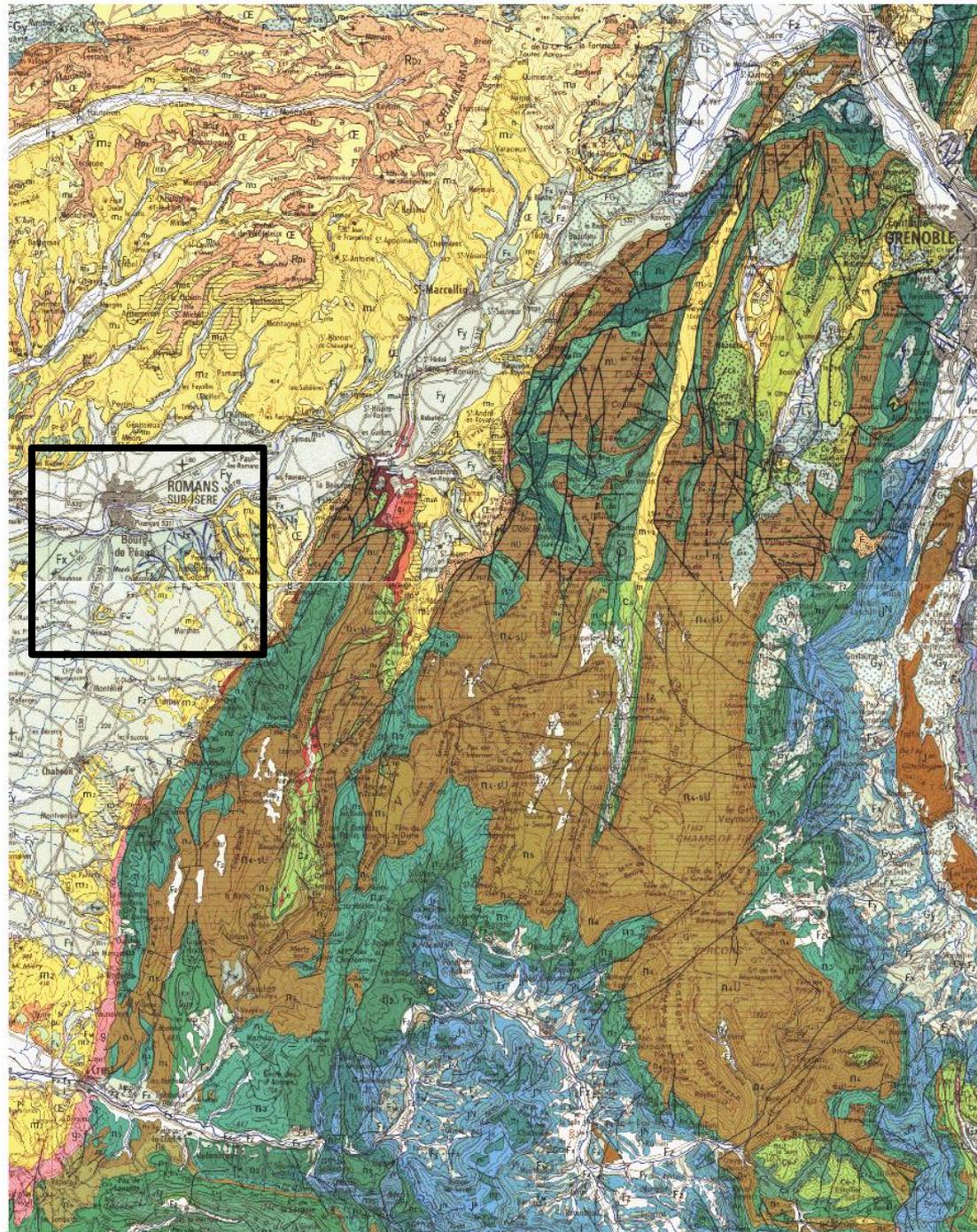




**La molasse du bassin d'avant-pays  
de Valence**

## Le rebord du Massif Central et le bassin de Valence.





*Molasses sableuses, Langhien, Bassin de Valence (Châteauneuf sur Isère)*

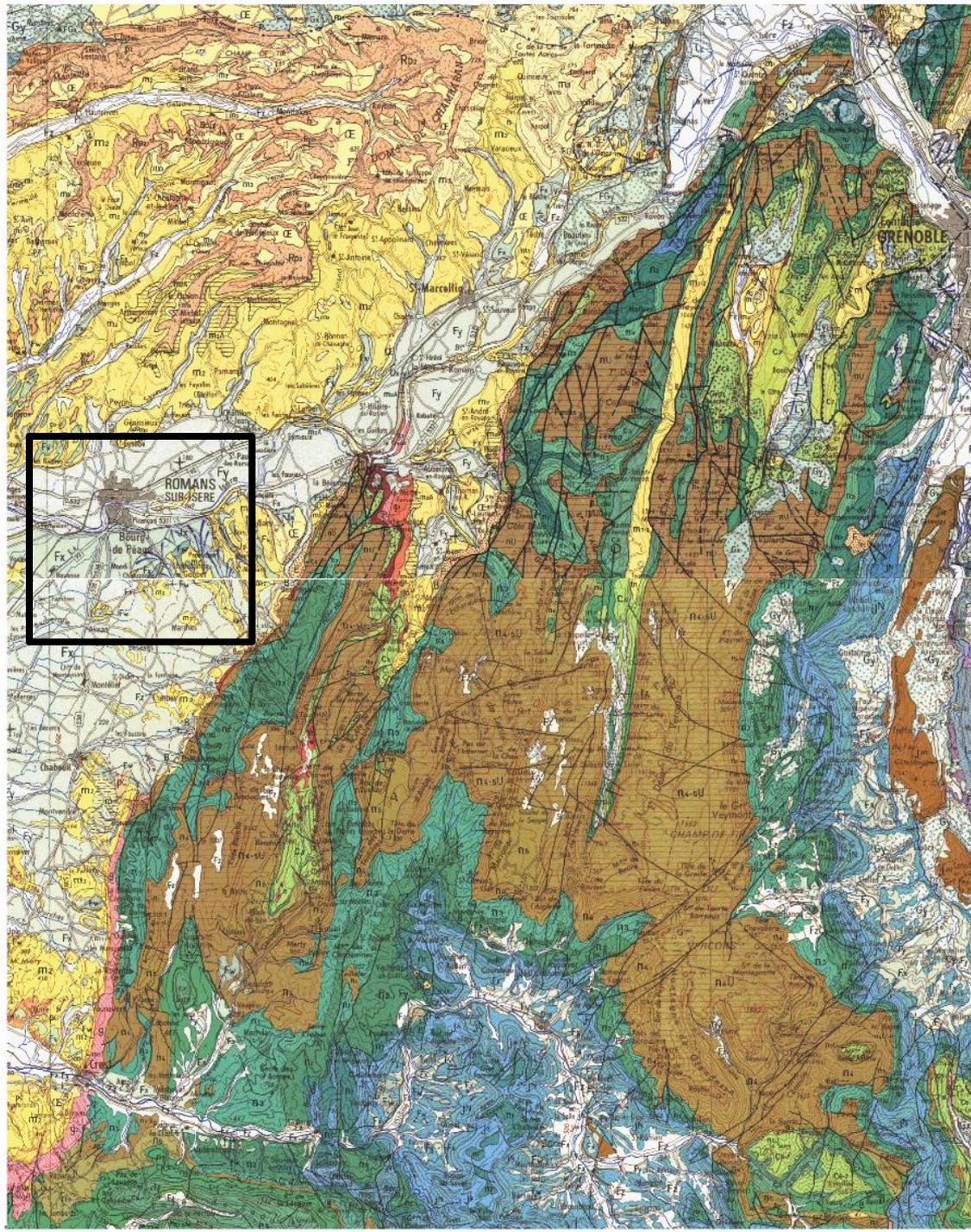




*Faïlle inverse, Langhien, Anticlinal de St Lattier*



**Le Vercors :**  
**Plis et chevauchements**





5<sup>T</sup> LATTIER



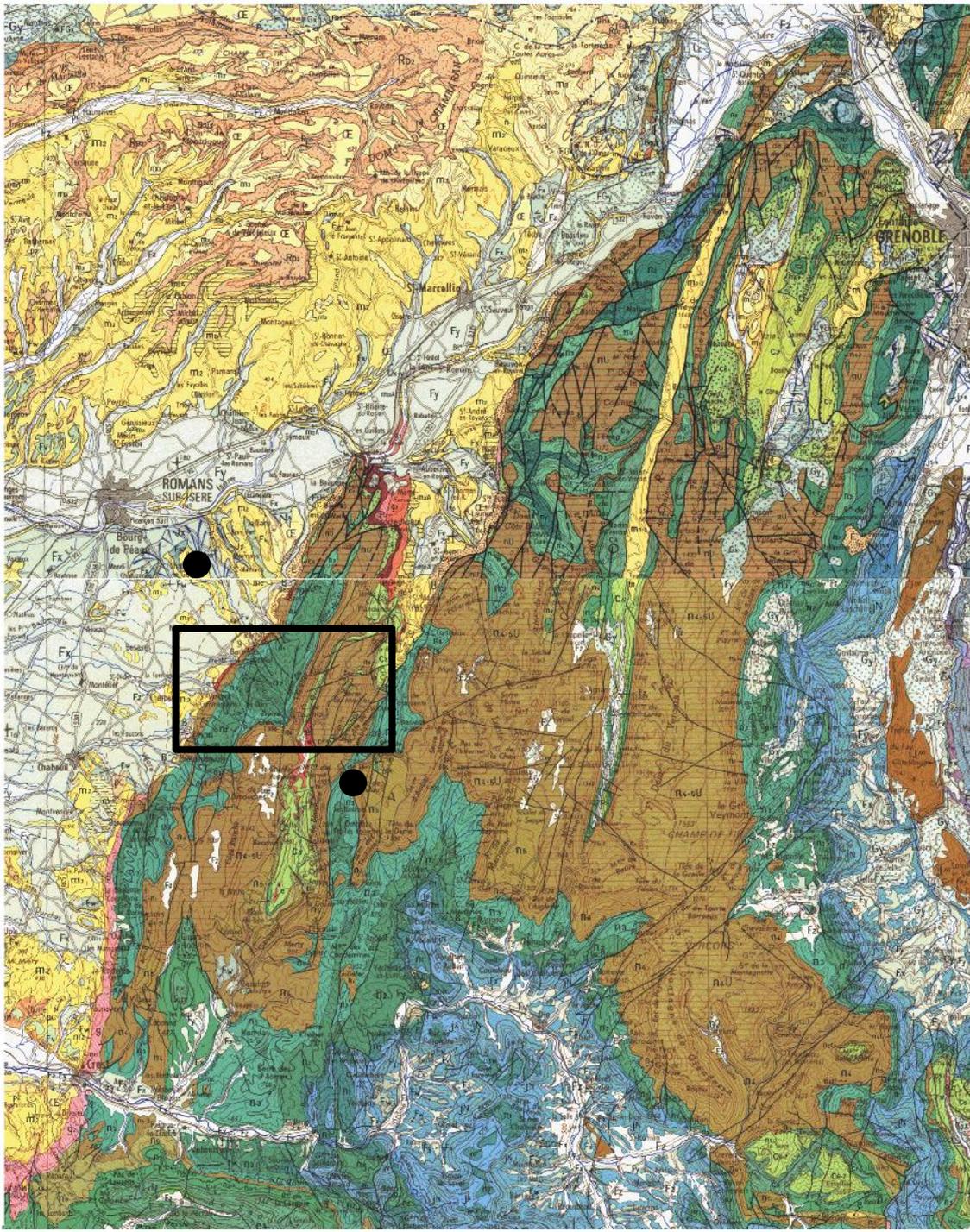


Image Landsat

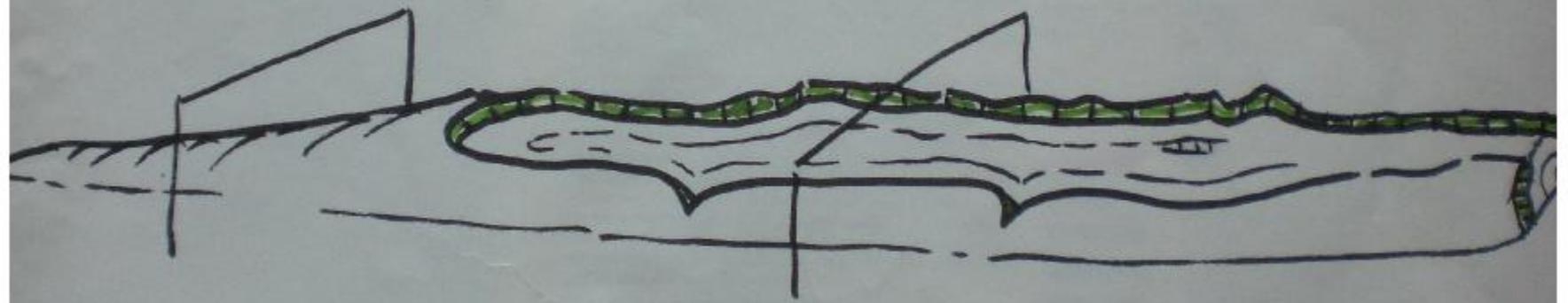


*Vue depuis l'Ouest de l'anticlinal de Saint Nazaire en Royans*



N

S



N

S

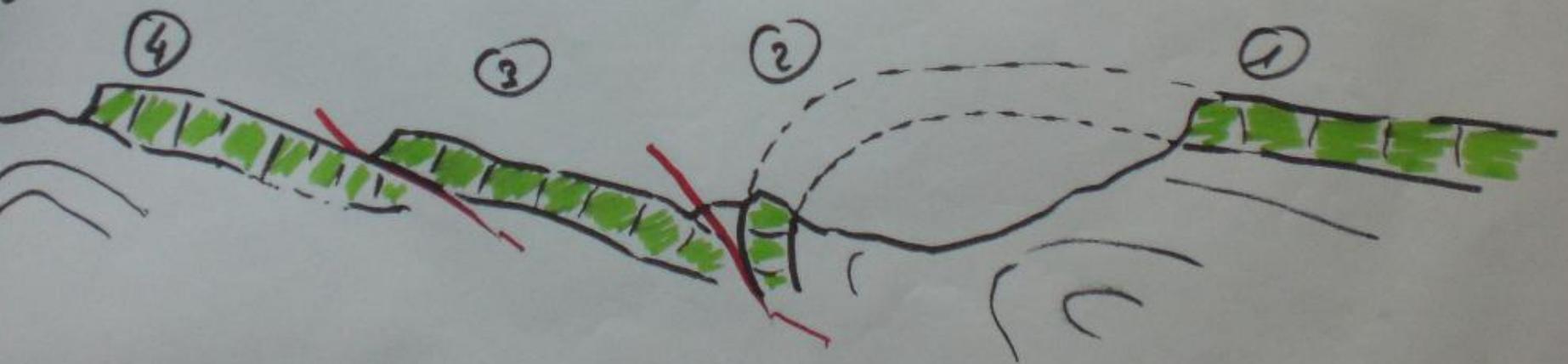
*Vue depuis le Sud-Est du flanc est de l'anticlinal de Saint Nazaire en Royans*





Anticlinel de  
ST Nazaire

Anticlinel de  
Pont en Royant





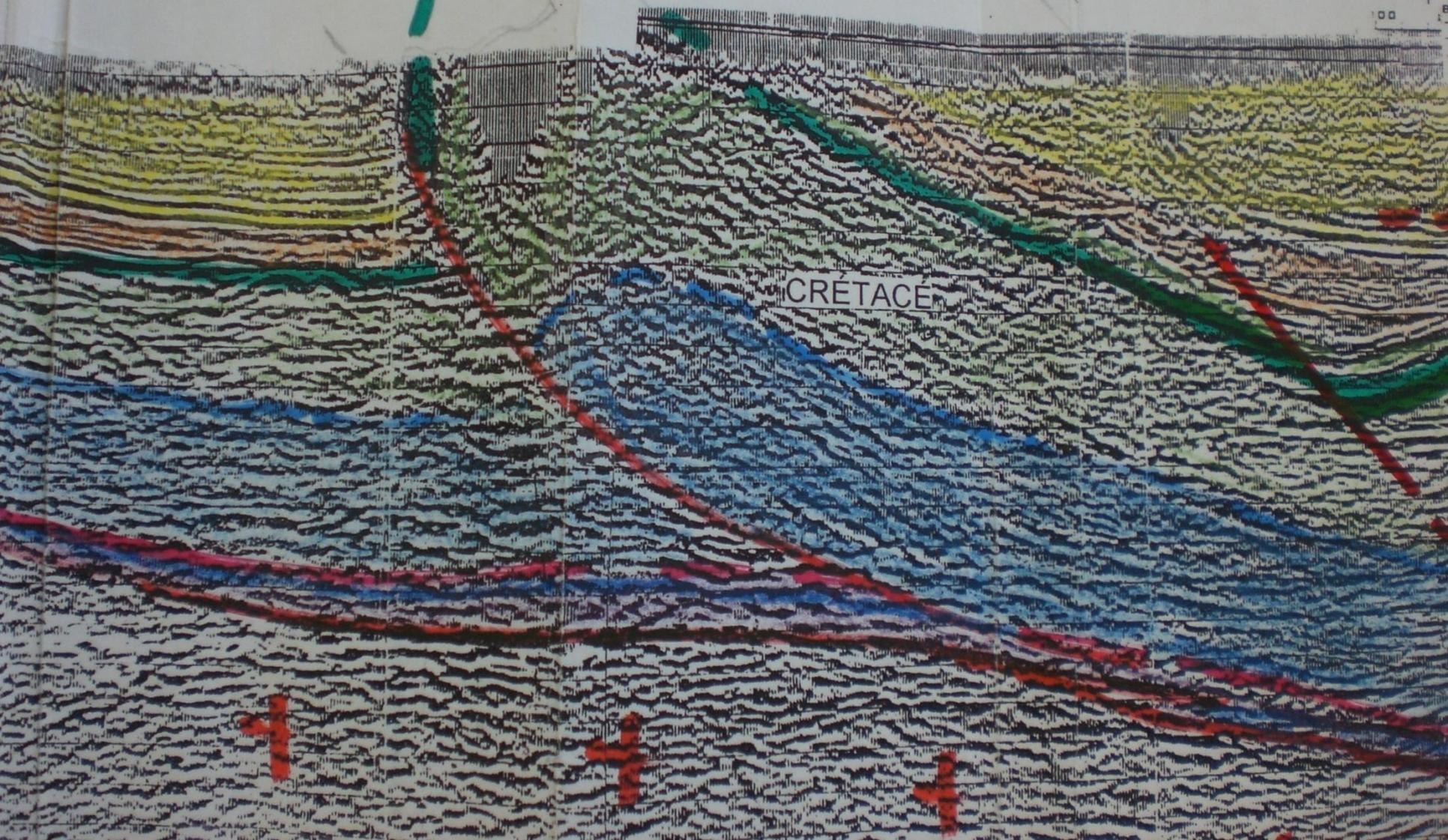




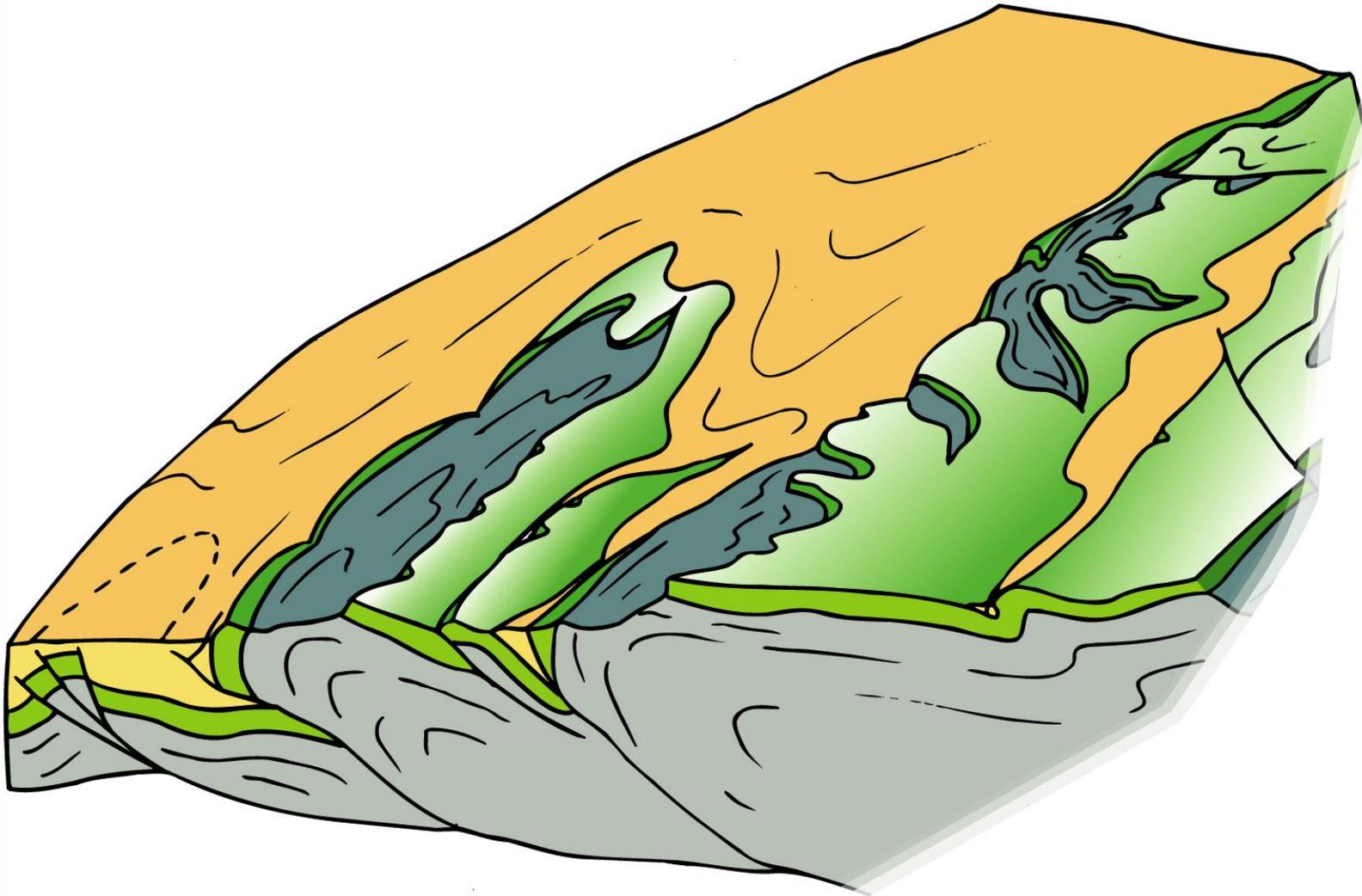
ST NAZAIRE

2  
A

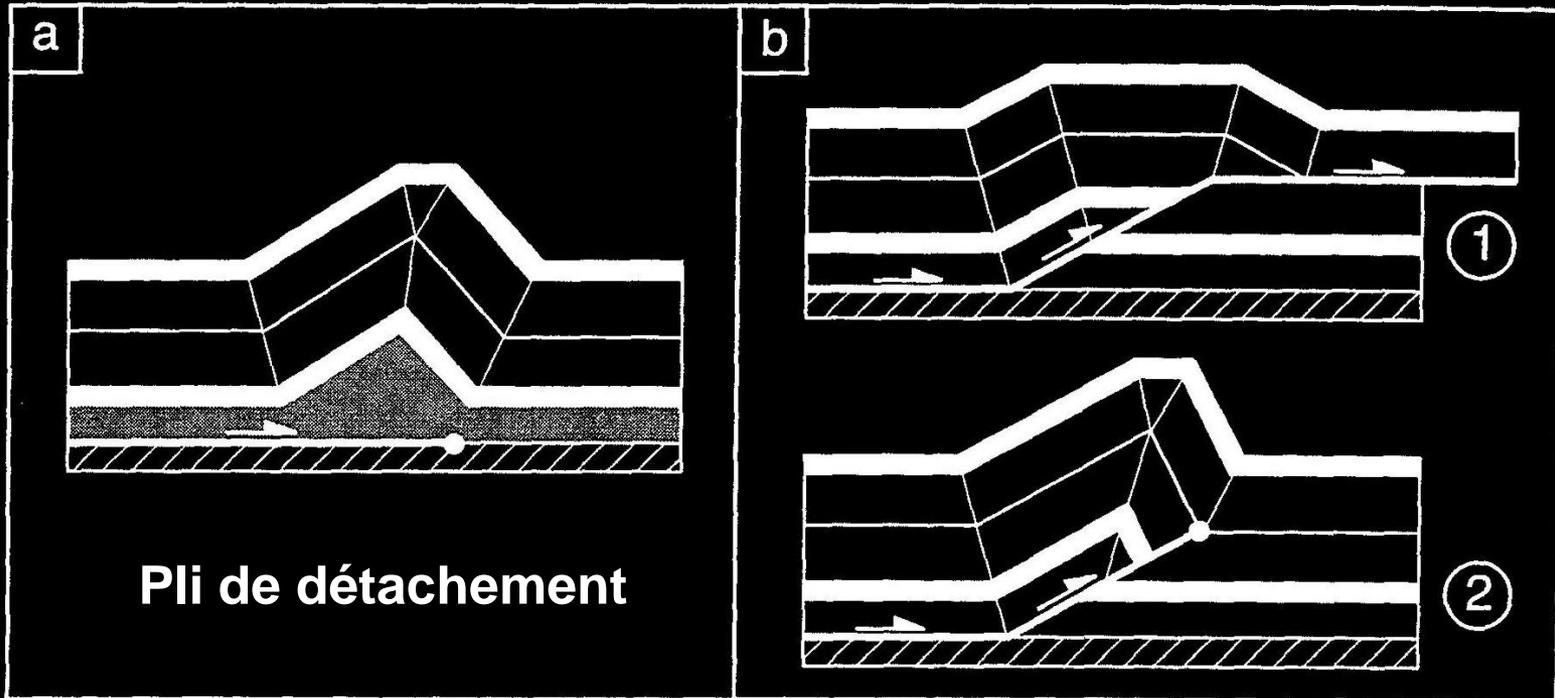
105  
1  
00



# Le style tectonique du Vercors



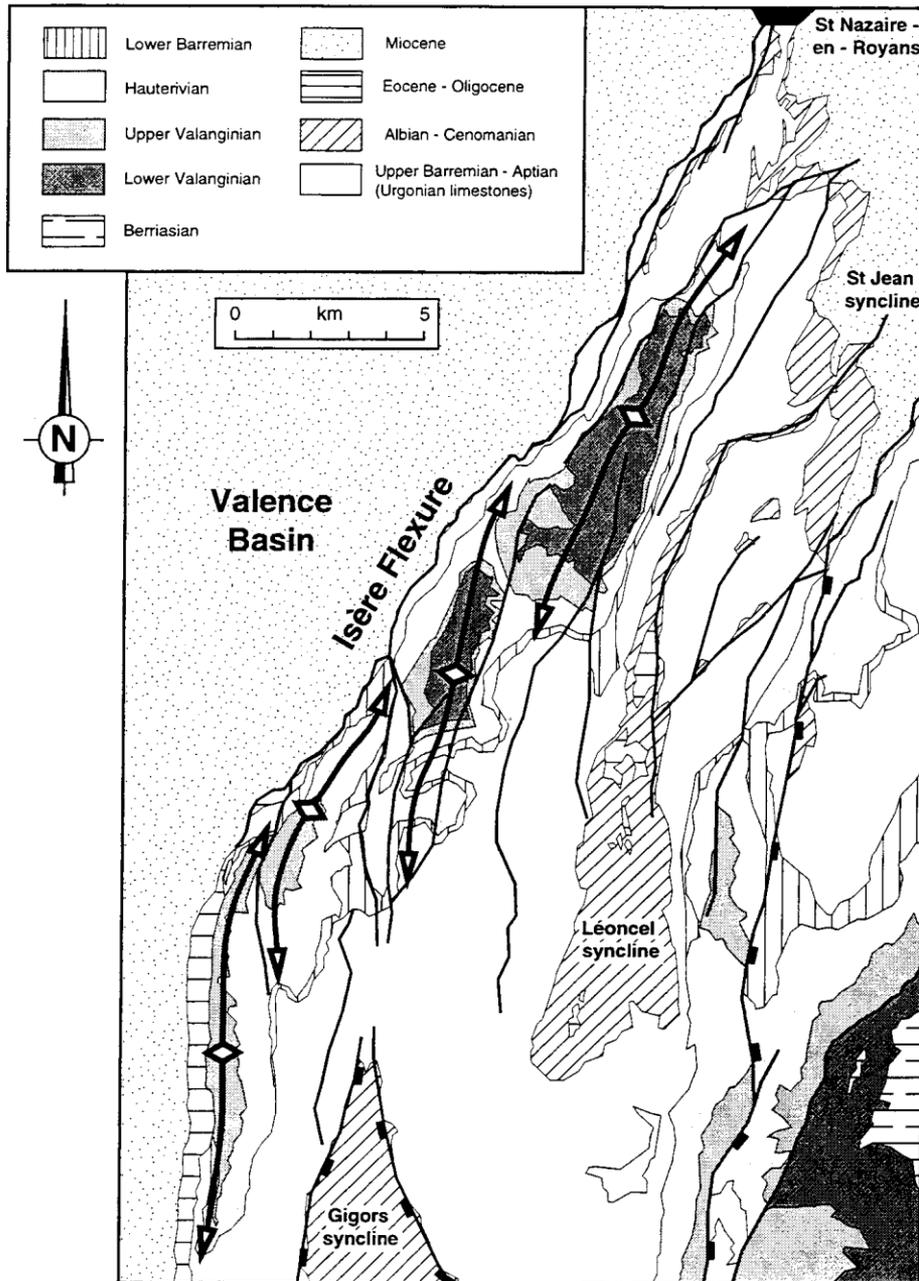
## Pli passif sur rampe



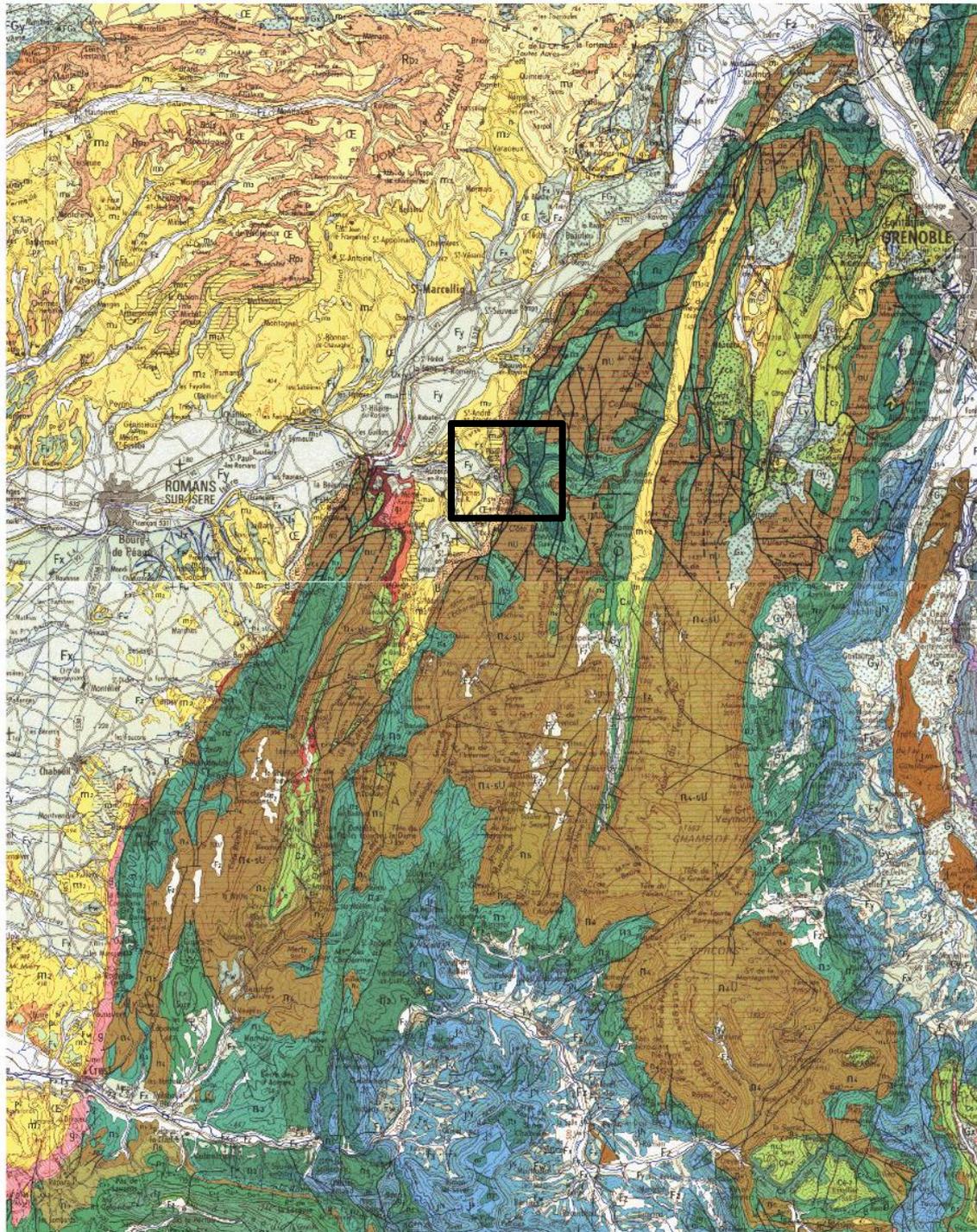
**Pli de détachement**

**Pli de propagation**

- Un pli de couverture développé au dessus d'un décollement épais est appelé : pli de décollement (« *detachment fold* »)
- Si deux niveaux de décollement sont reliés par une faille inverse (rampe) traversant en oblique la couche résistante, alors on peut créer un pli de cintrage sur rampe ou pli passif sur rampe (« *fault-bend fold* »)
  - Si le pli se développe en même temps que la rampe, alors on parle de pli de propagation de rampe (« *fault-propagation fold* »).



(Philippe, 1995)



*Anticlinal de Pont-en-Royans*



*Anticlinal de Pont-en-Royans*





*Molasses marines burdigaliennes , Pont en Royans*



ST Naz.



Pt Roy.

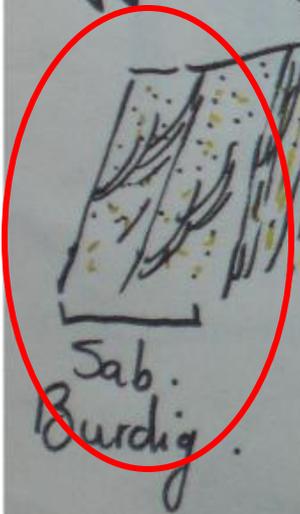
Aer.  
p. lito. grés  
Burdig.

Aquitano.  
Burdig.

Sables  
quartz.  
Eocene

Campano.  
Maest.

E



Sab.  
Burdig.

p. congl.  
à huîtres  
matrice grés  
carb.

Cong.  
laustre  
Olig.



*Alternances pélito-gréseuses marines burdigaliennes , Pont en Royans*



ST Naz.

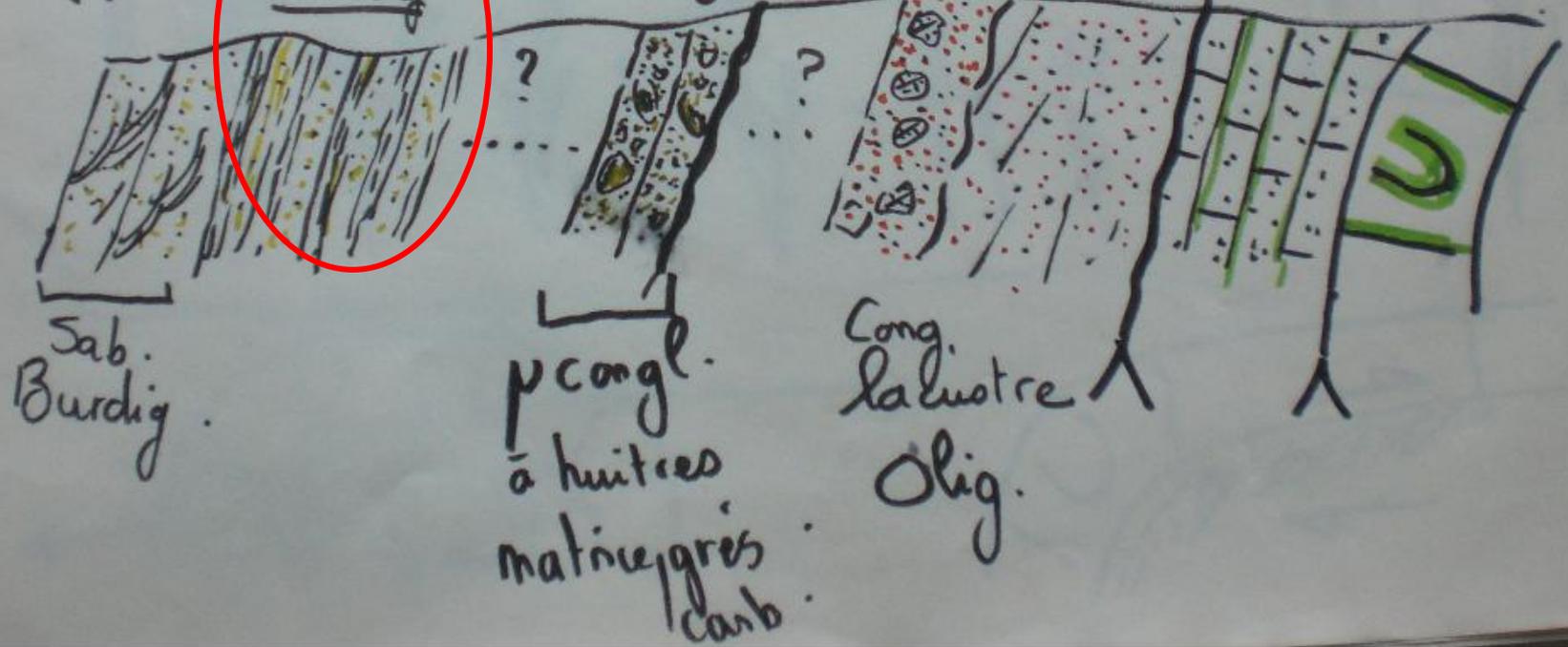


W  
 AOT  
 paléo. grés  
 Burdig

Aquitano.  
 Burdig

Sables  
 quartz.  
 Eocene

Campano.  
 Maest. E



Sab.  
 Burdig.

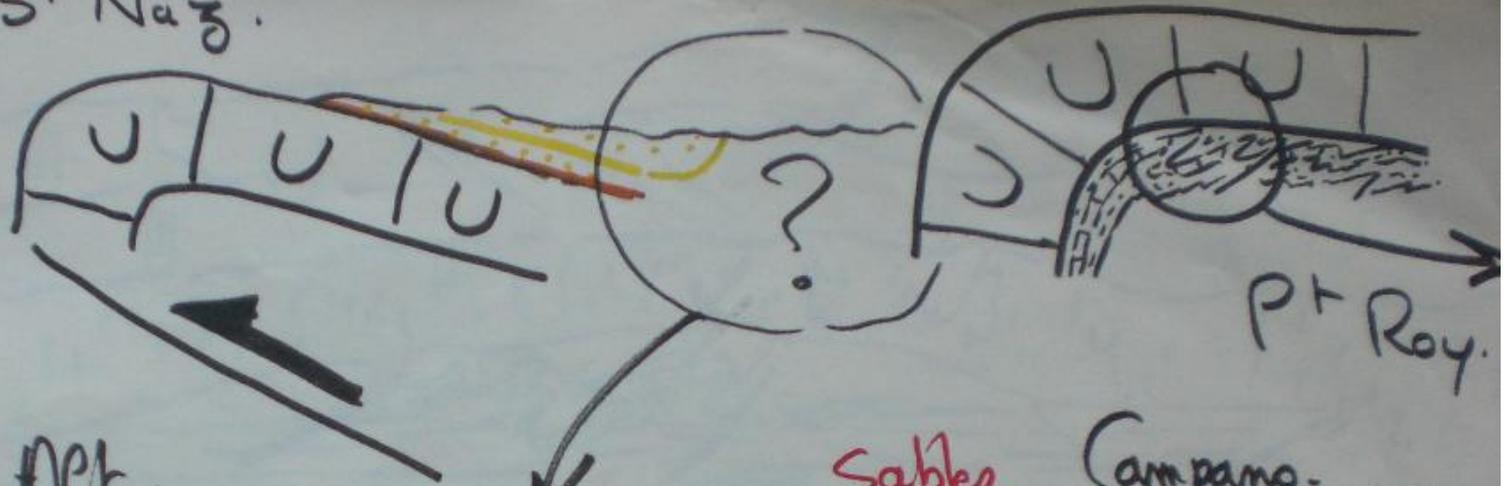
p congl.  
 à huîtres  
 matrice grés  
 carb.

Cong.  
 laustre  
 Olig.

*Microconglomérat à huitres aquitano-burdigalien , Pont en Royans*



ST Naz.



Pt Roy.

Aet.  
p. lito. grès  
Burdig

W

Aquitano.  
Burdig

Sables  
quartz.  
Eocene

Campano.  
Maest.

E



Sab.  
Burdig.

p. cong.  
à huîtres  
matrice grès  
carb.

Cong.  
laustre  
Olig.

*Conglomérat lacustre oligocène, Pont en Royans*





ST Naz.



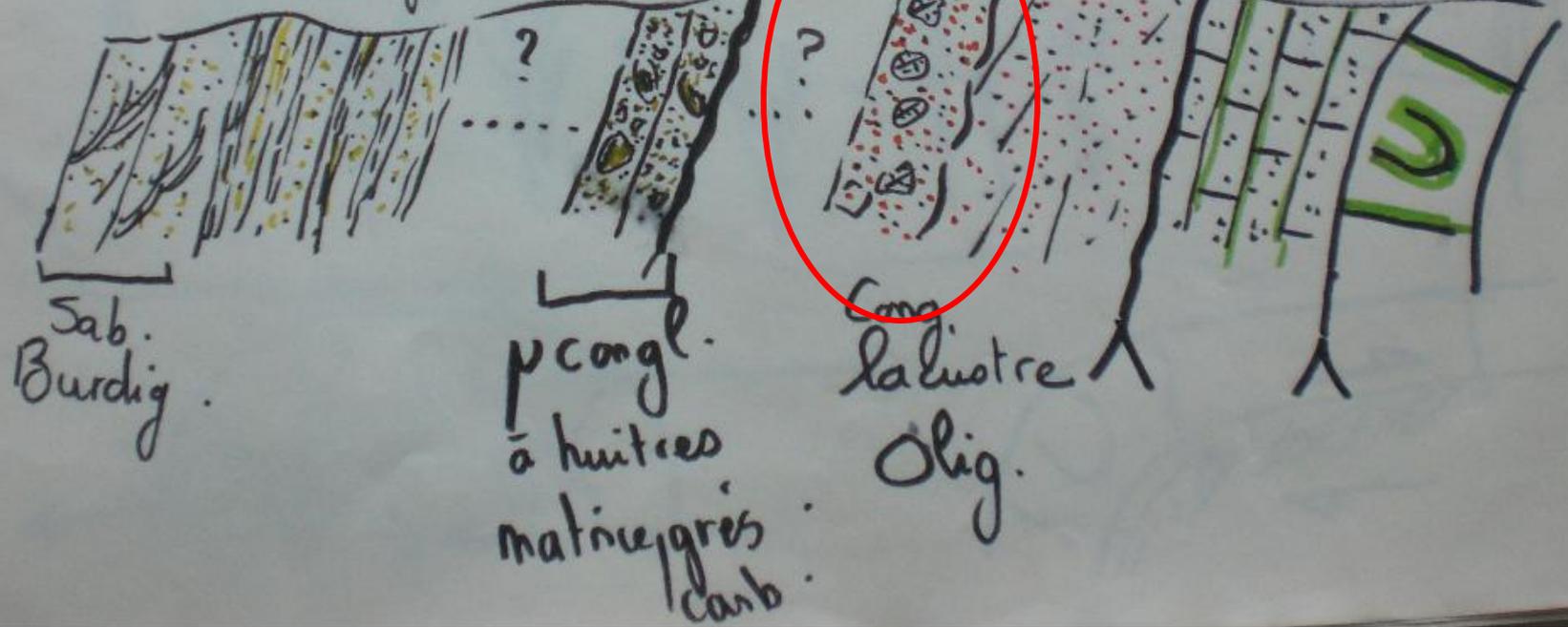
Net.  
p. lito. grès  
Burdig.

Aquitano.  
Burdig.

Sables  
quartz.  
Eocene

Campano.  
Maest.

E



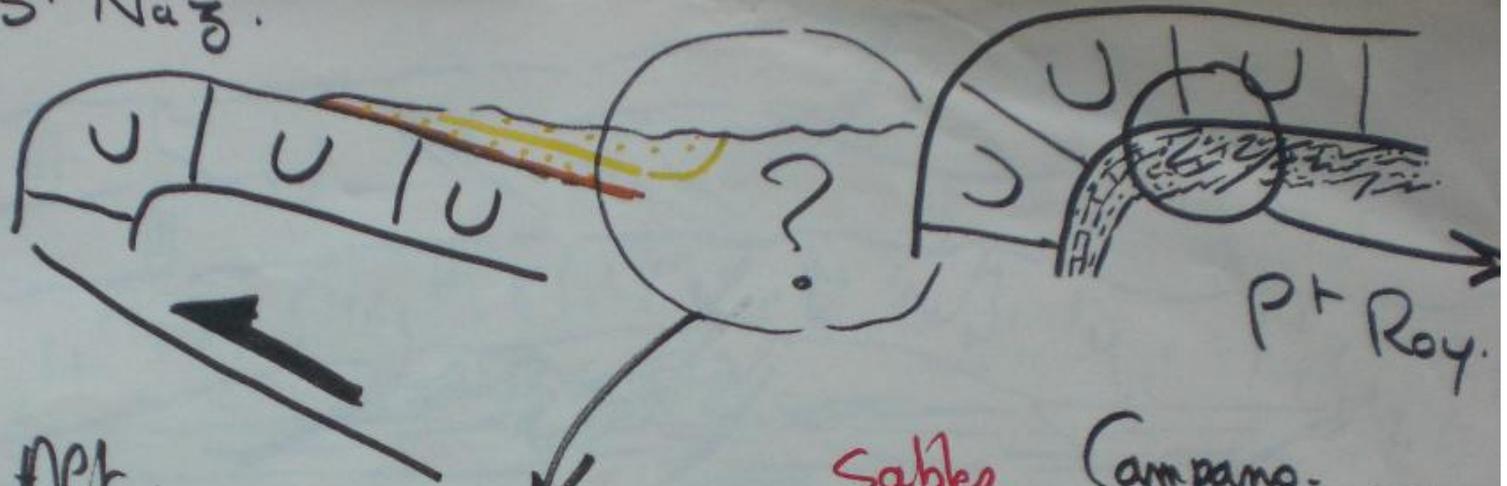
*Base du conglomérat oligocène  
érodant les sables blancs  
de l'Eocène sup., Pont en Royans*



*Base du conglomérat oligocène érodant les sables blancs de l'Eocène sup., Pont en Royans*



ST Naz.



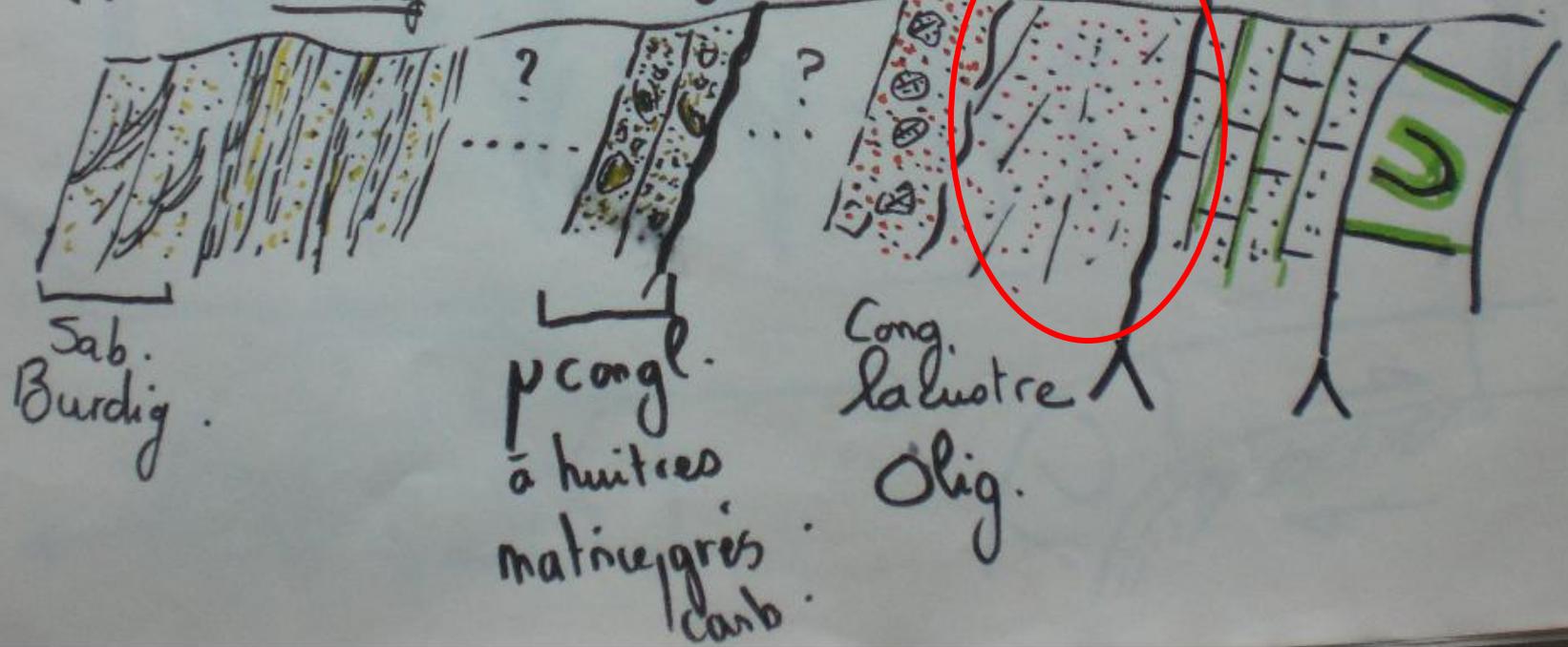
Pt Roy.

W  
 Net.  
 pétro. grés  
 Burdig

Aquitano.  
Burdig

Sables  
 quartz.  
 Focene

Campano.  
 Maest.  
 E



Sab.  
Burdig.

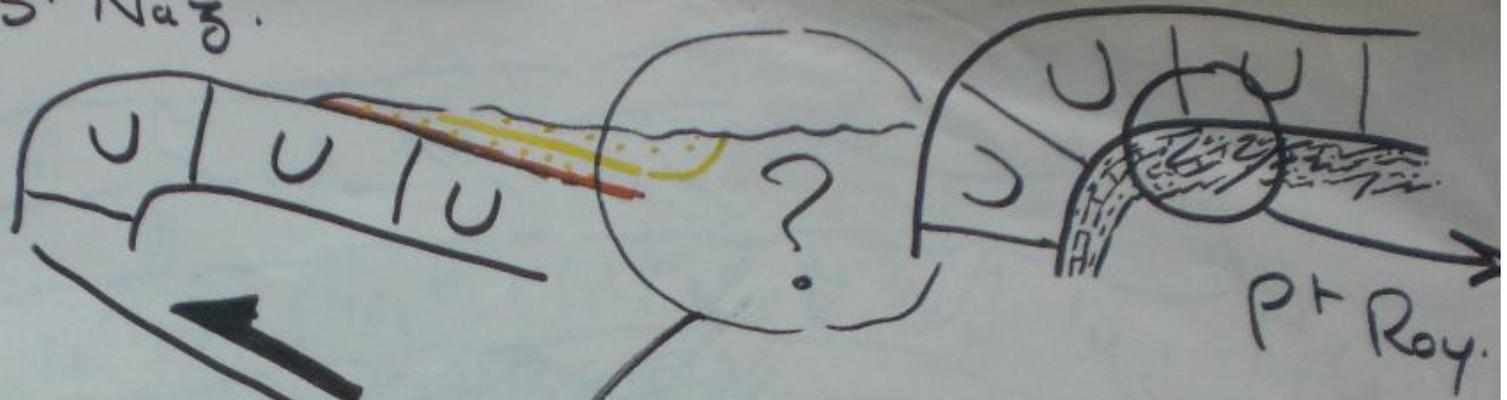
p congl.  
 à huîtres  
 matrice grés  
 carb.

Cong.  
 laustre  
 Olig.

*Calcaires gréseux du Campano-Maestrichtien, Pont en Royans*



ST Naz.



Pt Roy.

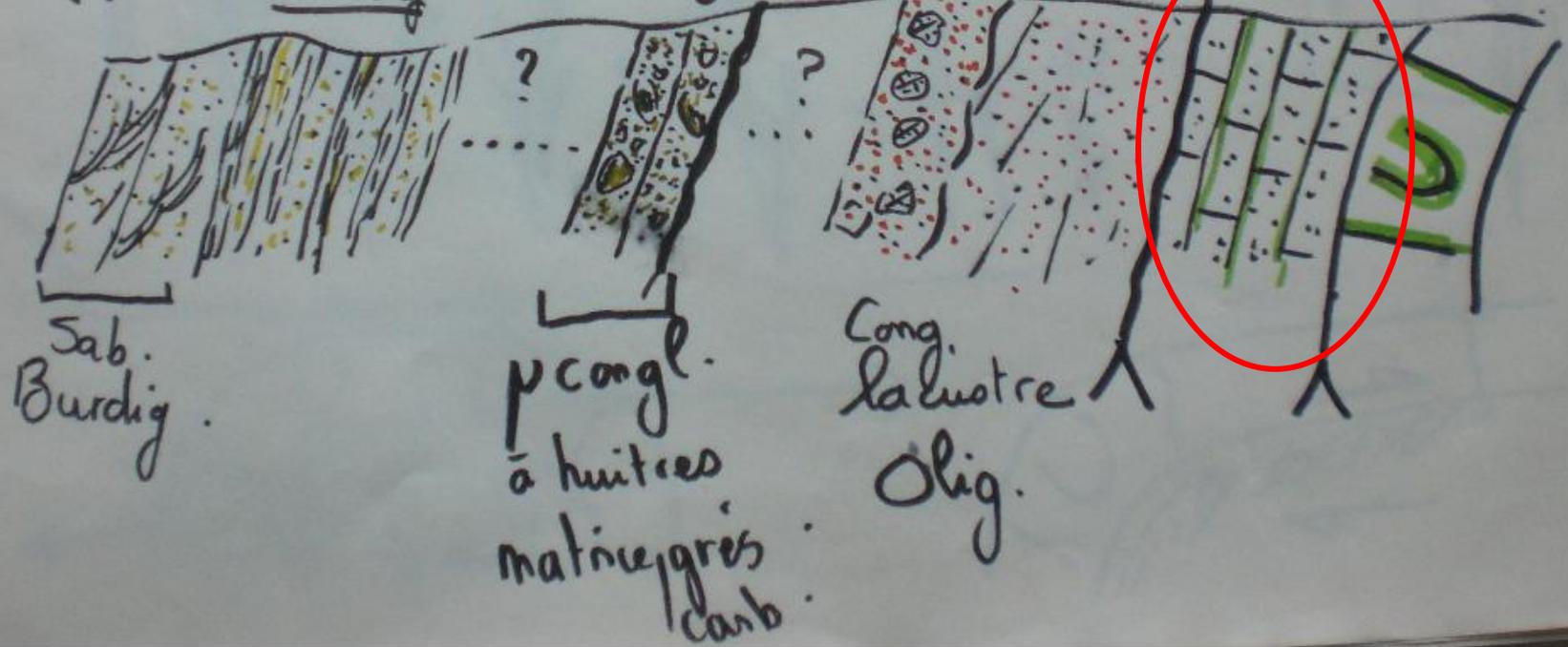
Net.  
p. lito. grés  
Burdig

Aquitano.  
Burdig

Sables  
quartz.  
Fouca

Campano.  
Maest.

E



Sab.  
Burdig.

p. congl.  
à huîtres  
matrice grés  
carb.

Cong.  
laustre  
Olig.

*Calcaires urgoniens barrémo-aptiens,  
Pont en Royans*



*Pont en Royans*



ST Naz.



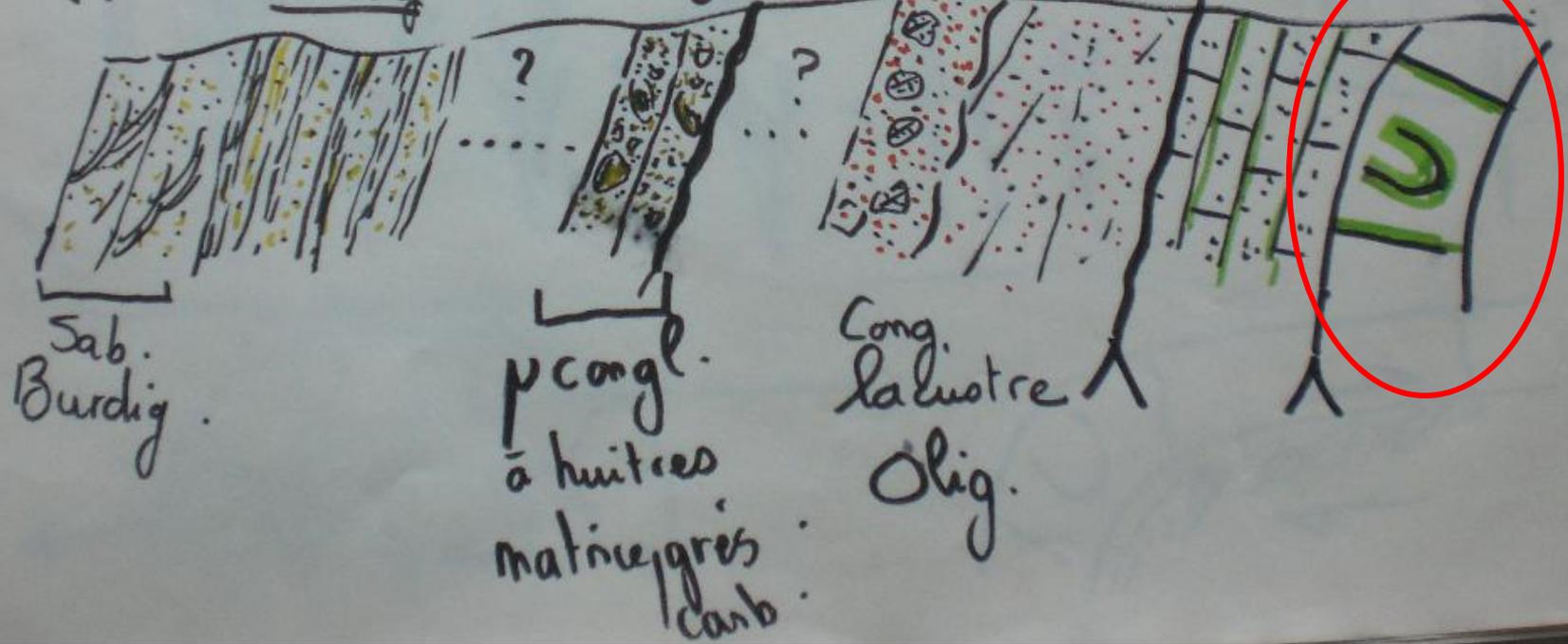
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Burdig

Aquitano.  
Burdig

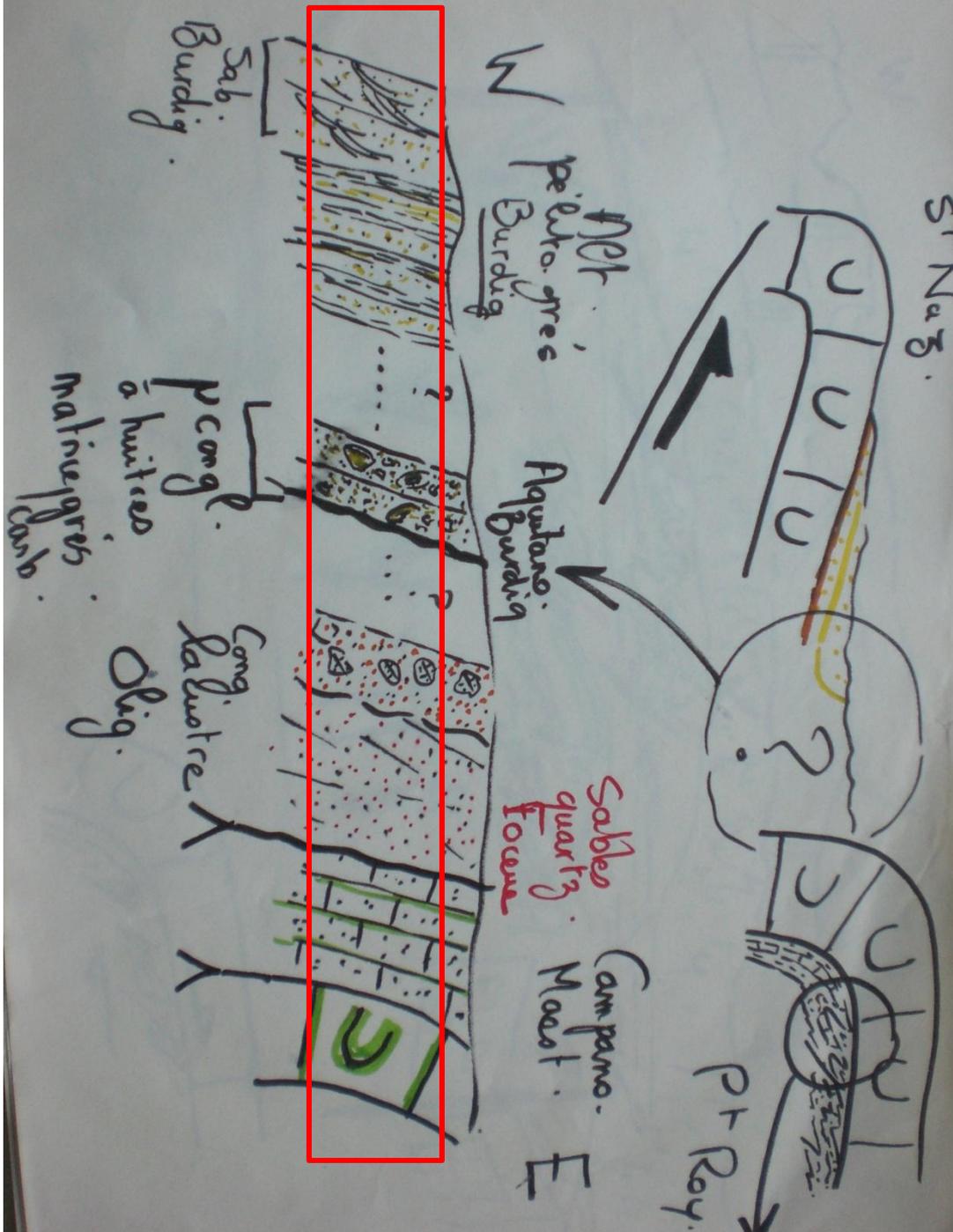
Sables  
quartz.  
Eocene

Campano.  
Maest.

W  
E

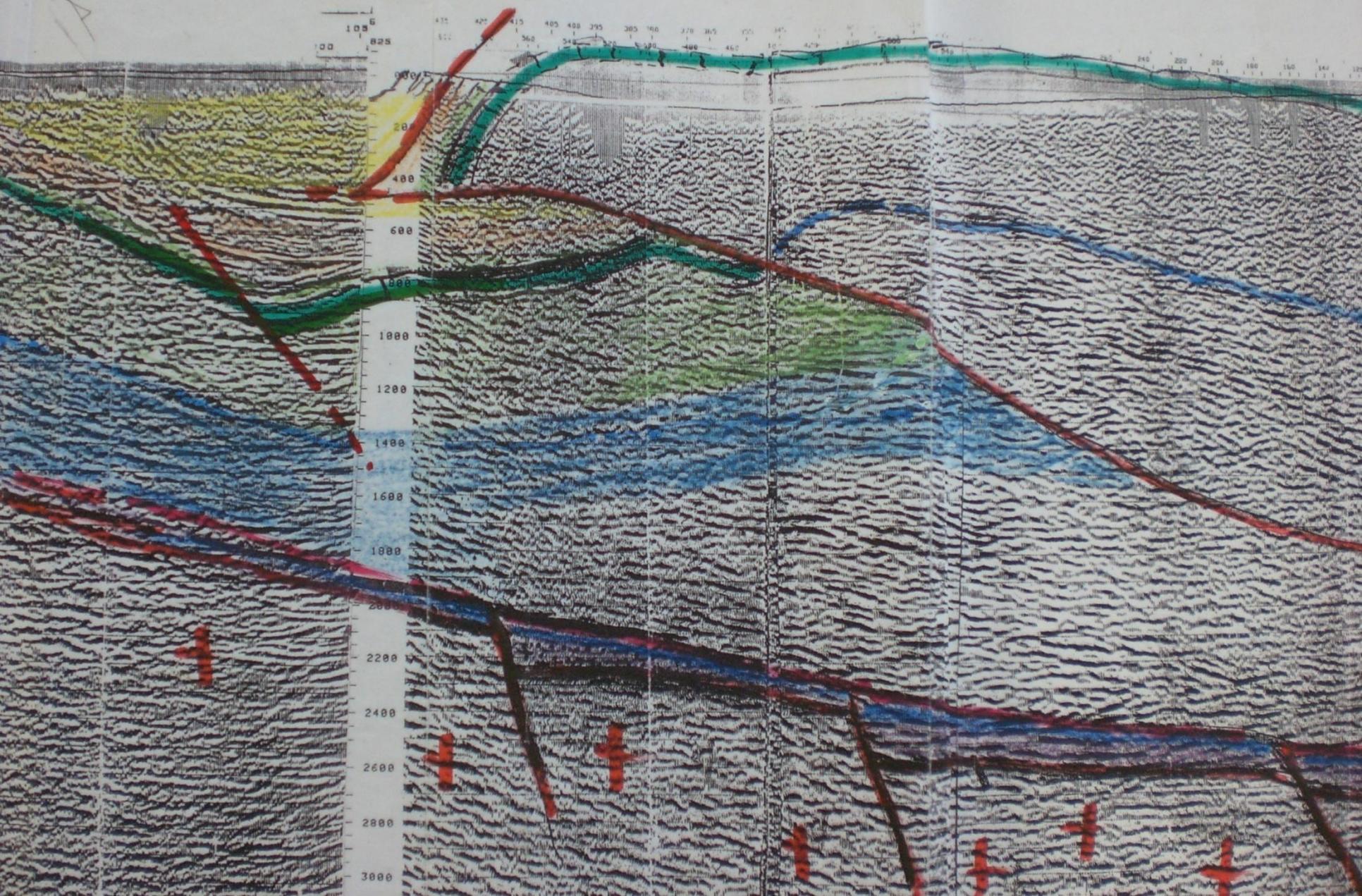


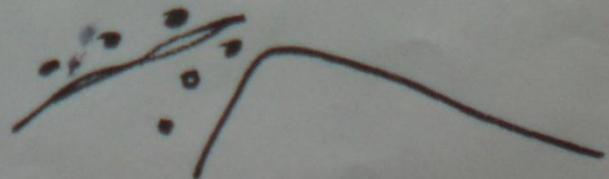
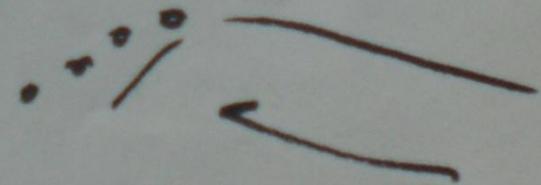
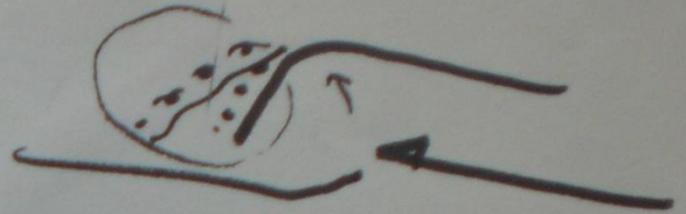
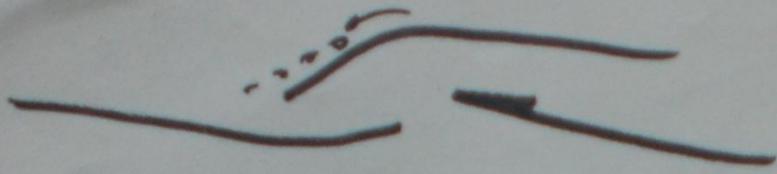
ST N<sub>2</sub> 3.





# PONT. EN. ROYALS





*Front de l'anticlinal de Pont-en-Royans*

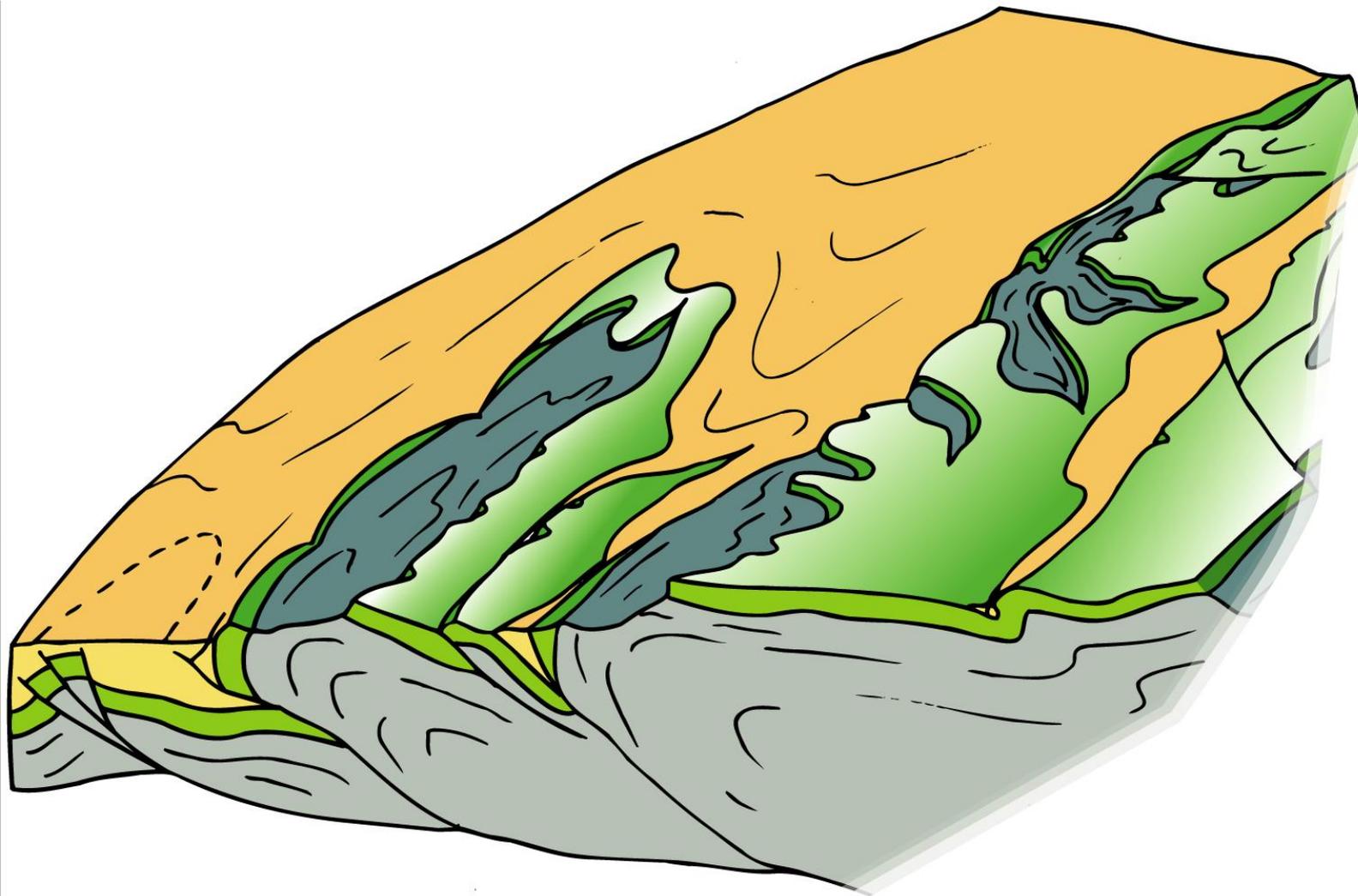
**Front de chevauchement du Vercors  
sur les molasses**



*Front de l'anticlinal de Pont-en-Royans*



# Le style tectonique du Vercors

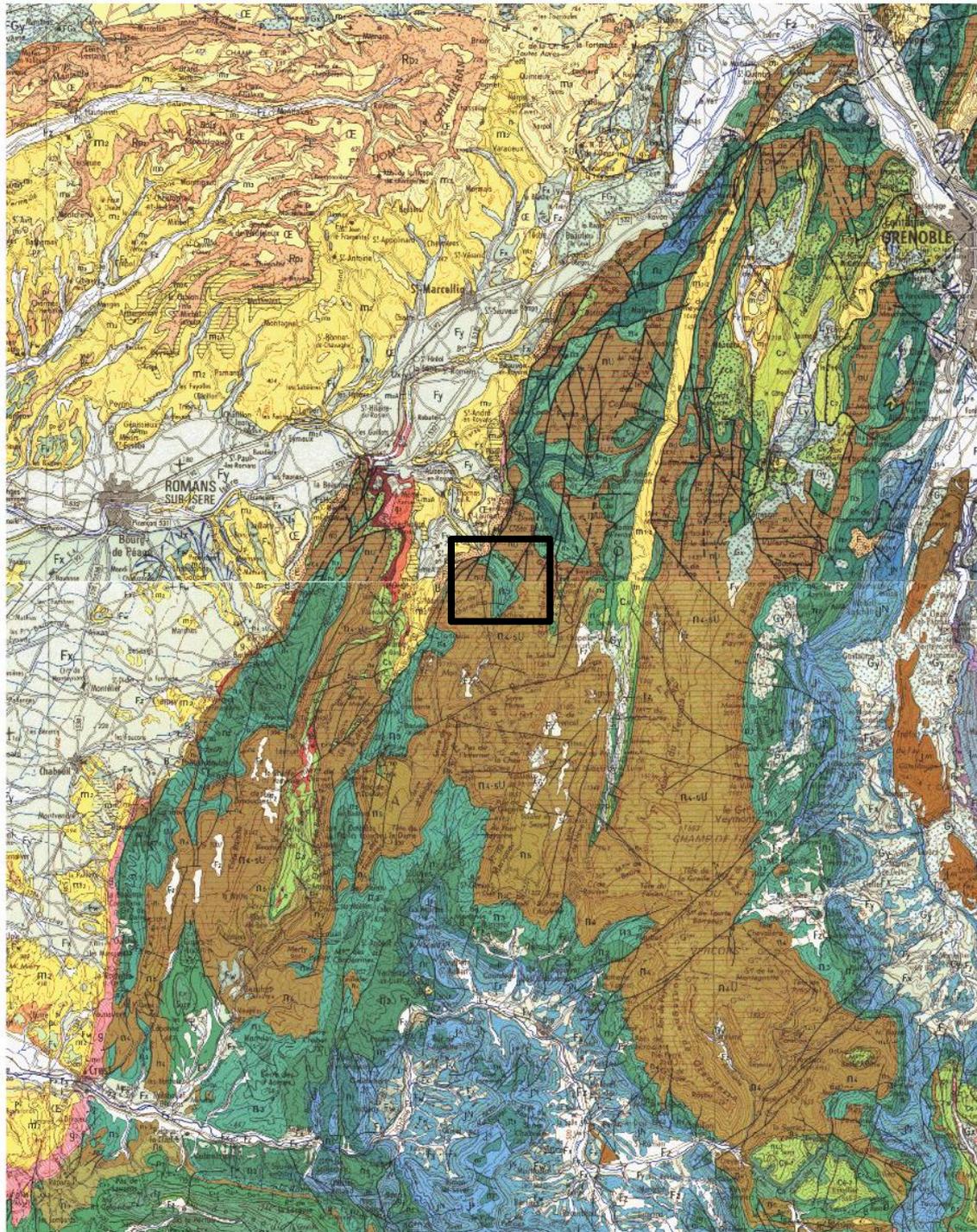


*Dysharmonie, Anticlinal de Pont-en-Royans, Urganien/Hauterivien*









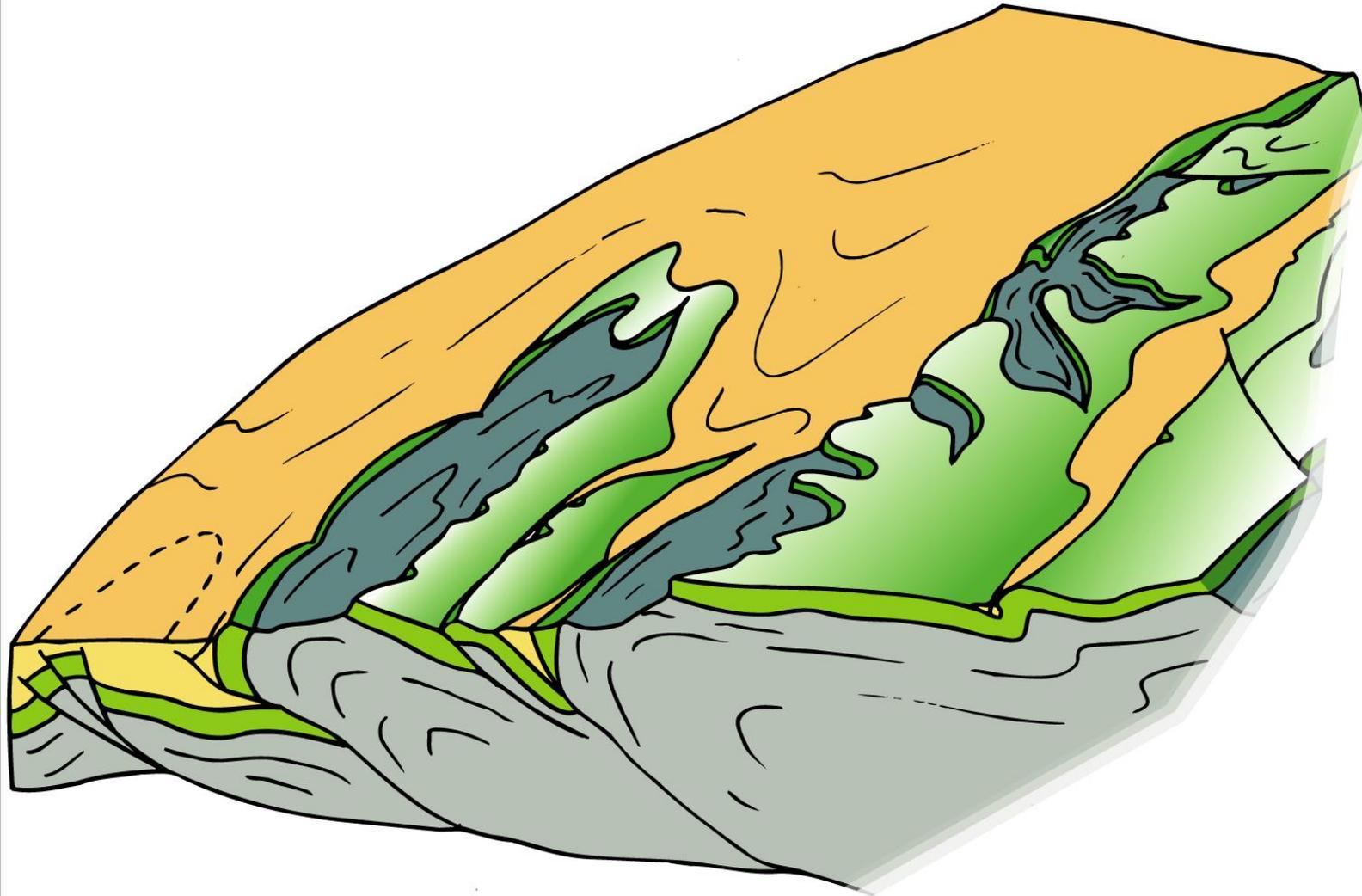
*Anticlinal de Pont-en-Royans, Combe Laval*

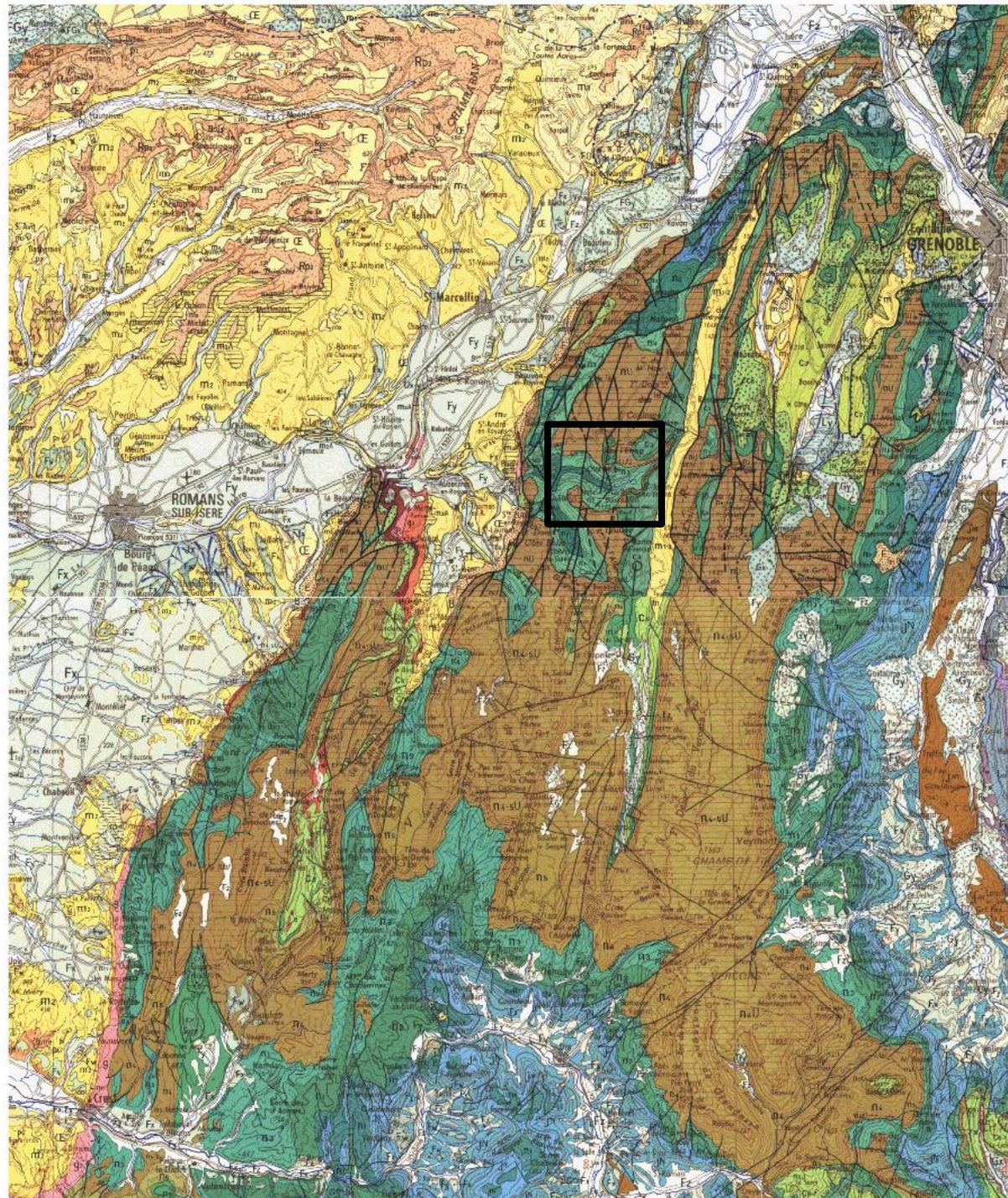


*Anticlinal de Pont-en-Royans, Combe Laval*



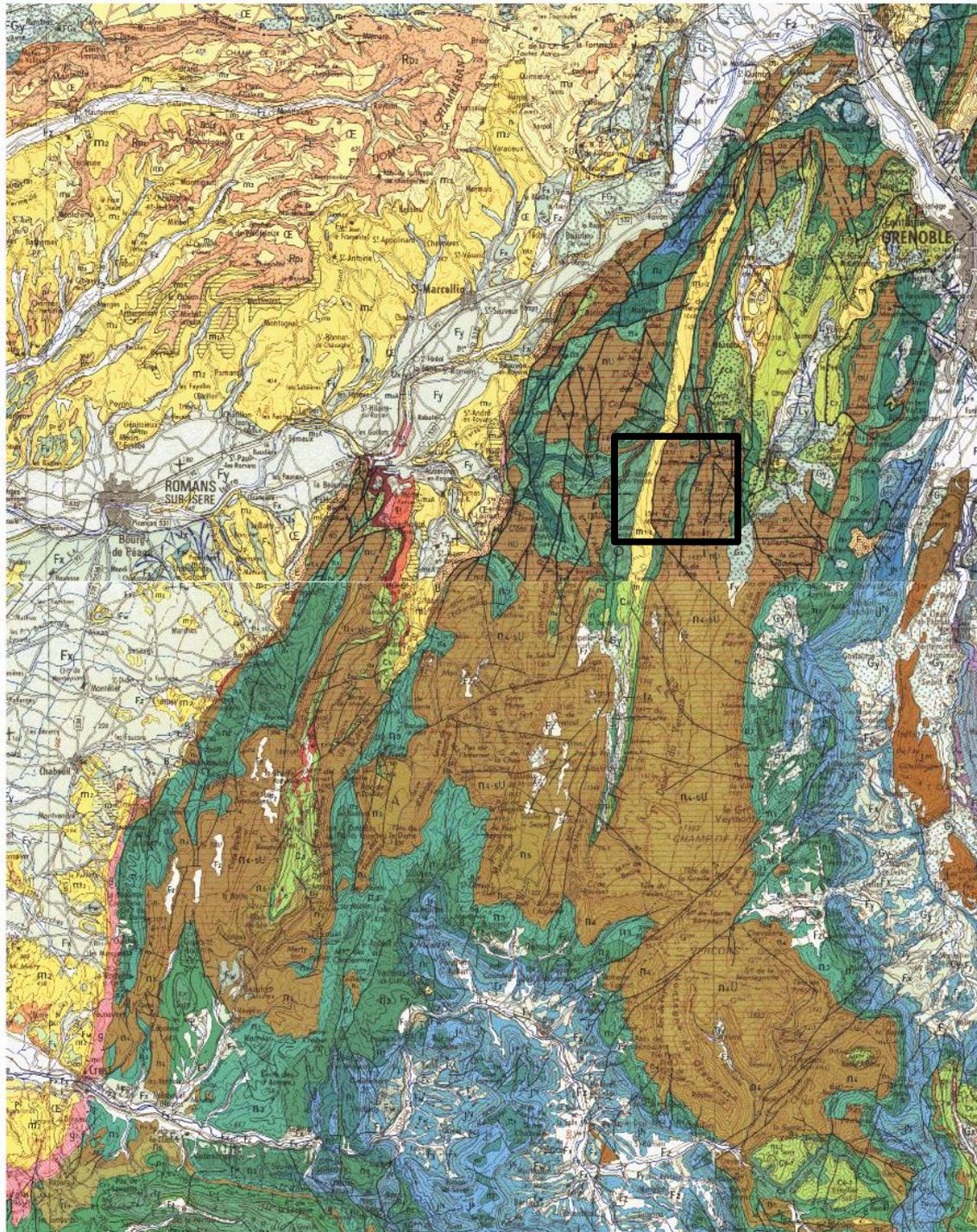
# Le style tectonique du Vercors





*Faille inverse, Choranche, Anticlinal de Pont-en-Royans, Urganien*



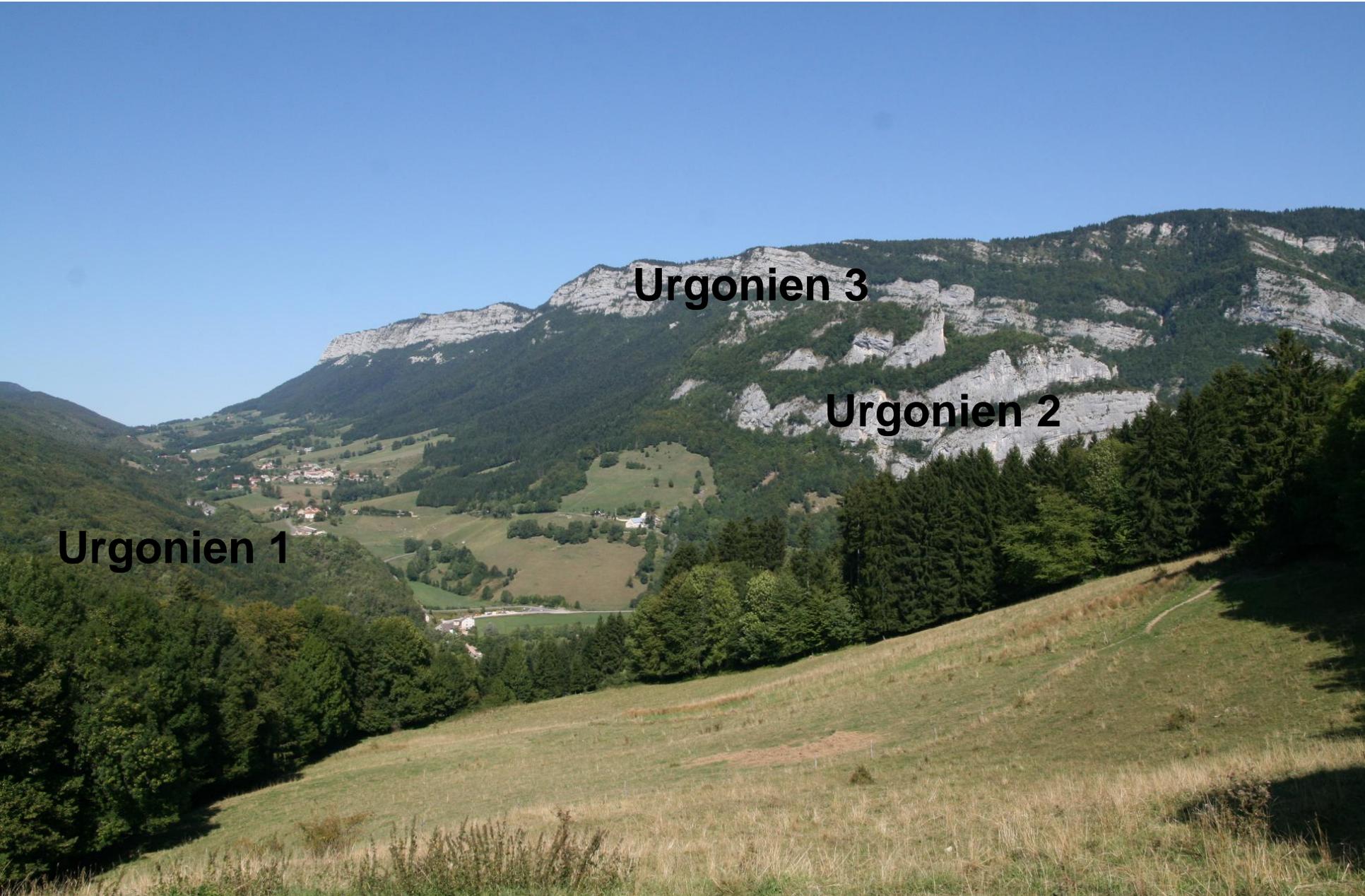


*Le synclinal à cœur de Miocène de Rencurel*



**Le chevauchement de l'Urgonien sur les molasses miocènes  
à la Balme de Rencurel.**



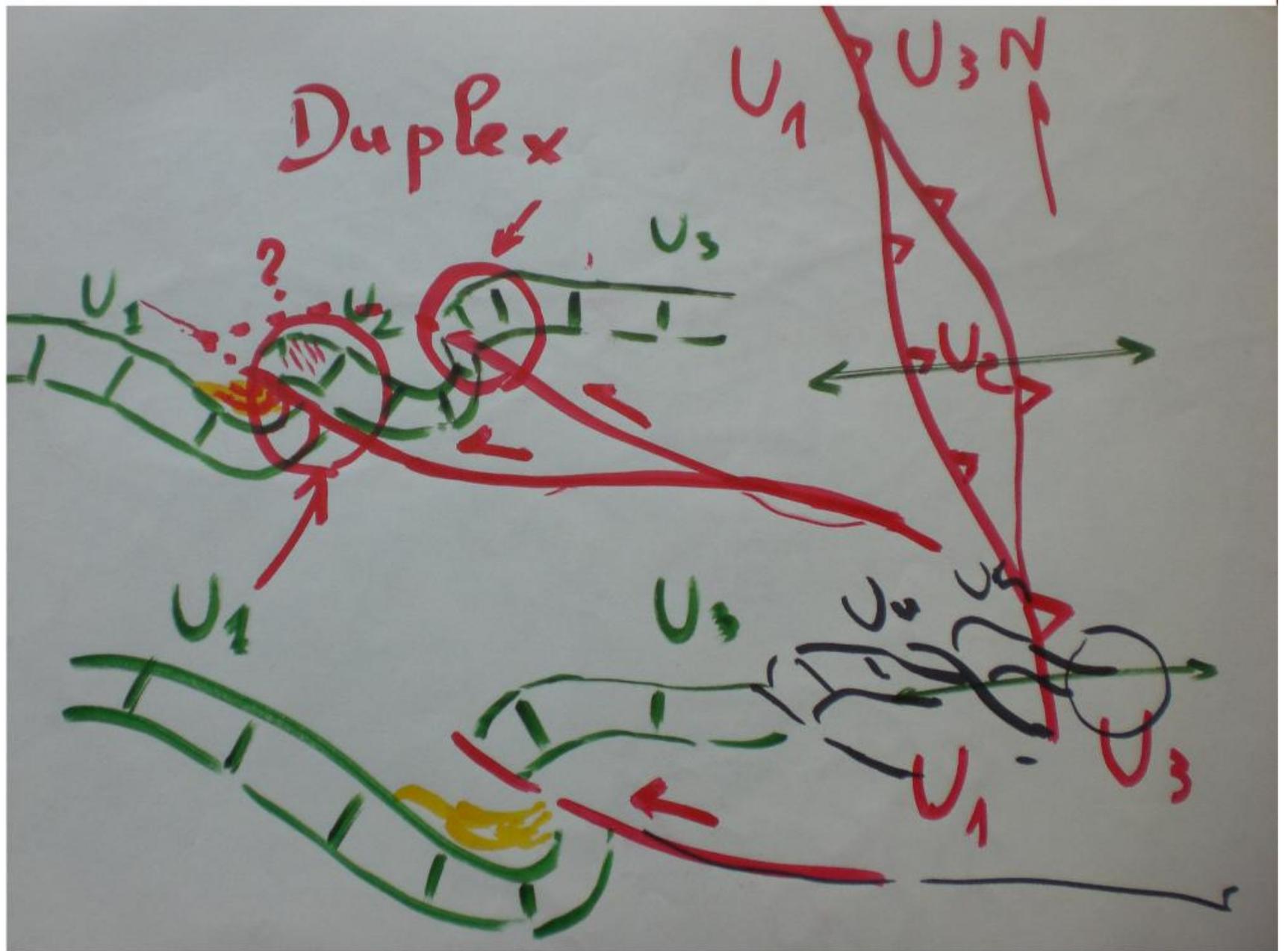


**Urgonien 1**

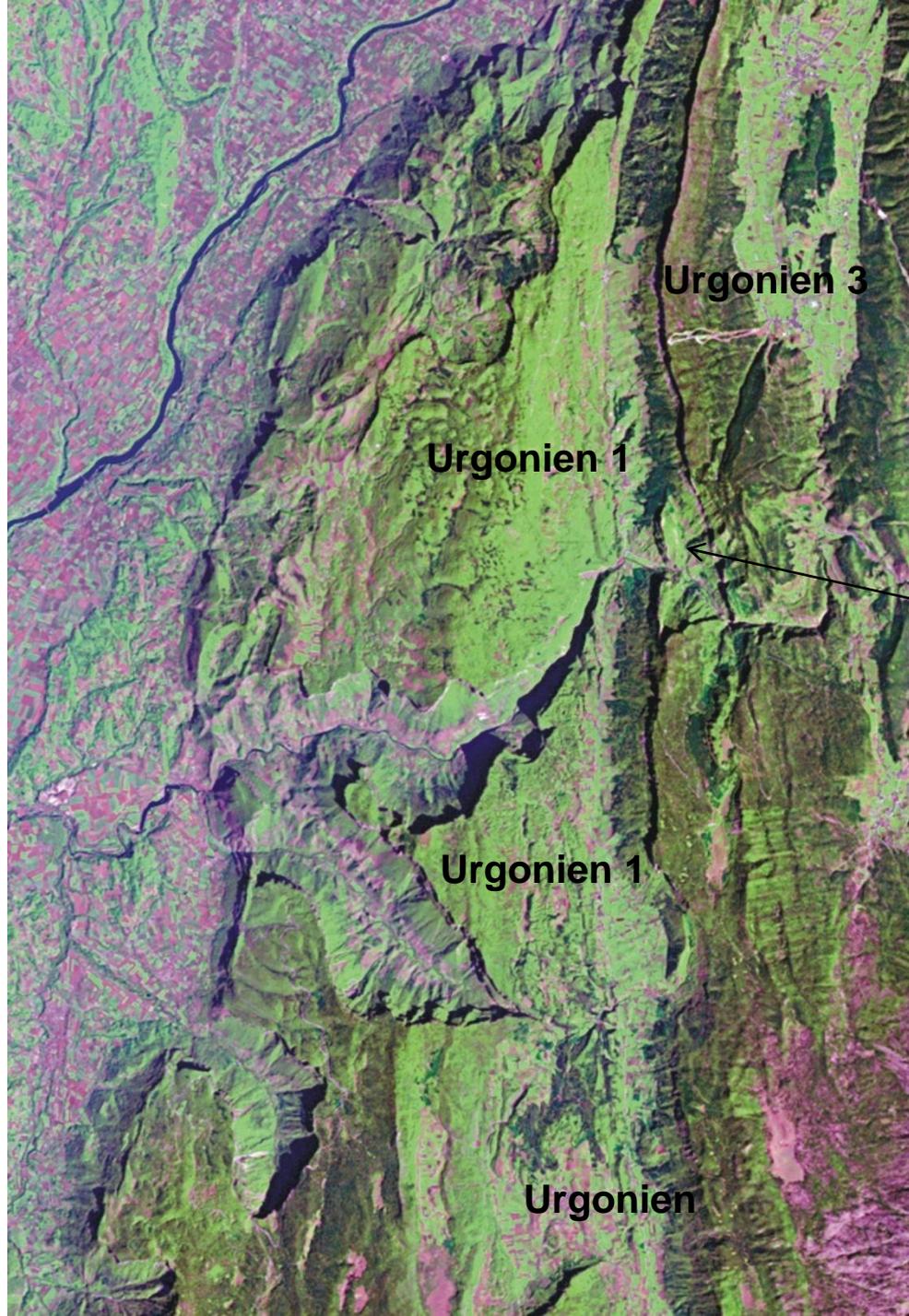
**Urgonien 3**

**Urgonien 2**

Duplex







**Urganien 3**

**Urganien 1**

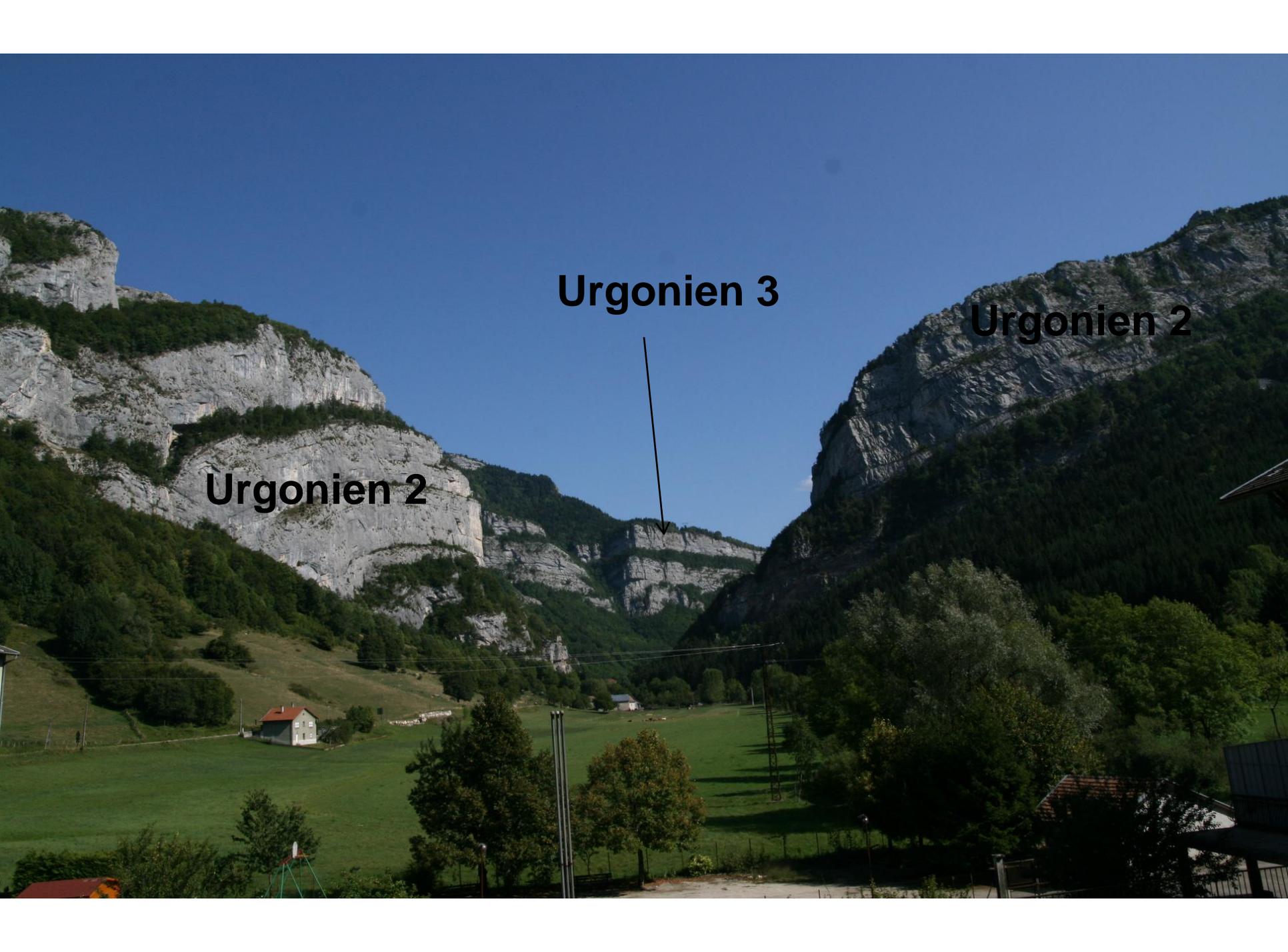
**Urganien 2**

**Urganien 1**

**Urganien**



## Urgonien 2



**Urgonien 3**

**Urgonien 2**

**Urgonien 2**



## Urgonien 2



# Urgonien 2 chevauchant sur les molasses miocènes



*Chevauchement de l'Urgonien 2 sur les molasses langhiennes du synclinal de Rencurel*

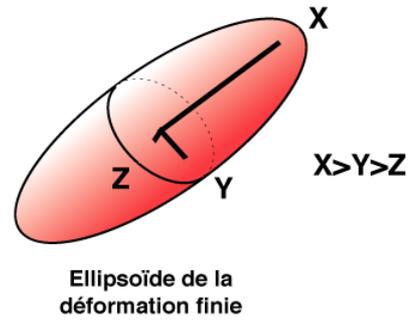
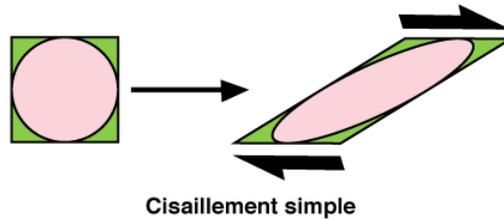
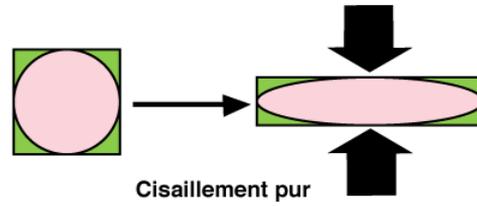


*Chevauchement de l'Urgonien 2 sur les molasses langhiennes du synclinal de Rencurel*





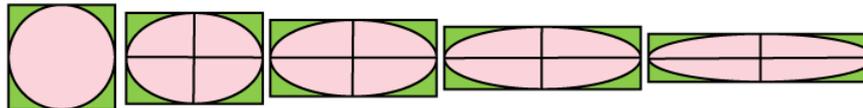




**Etude  
"microtectonique"**

**EVOLUTION DES AXES PRINCIPAUX  
DE LA DEFORMATION**

**cisaillement pur, déformation coaxiale**



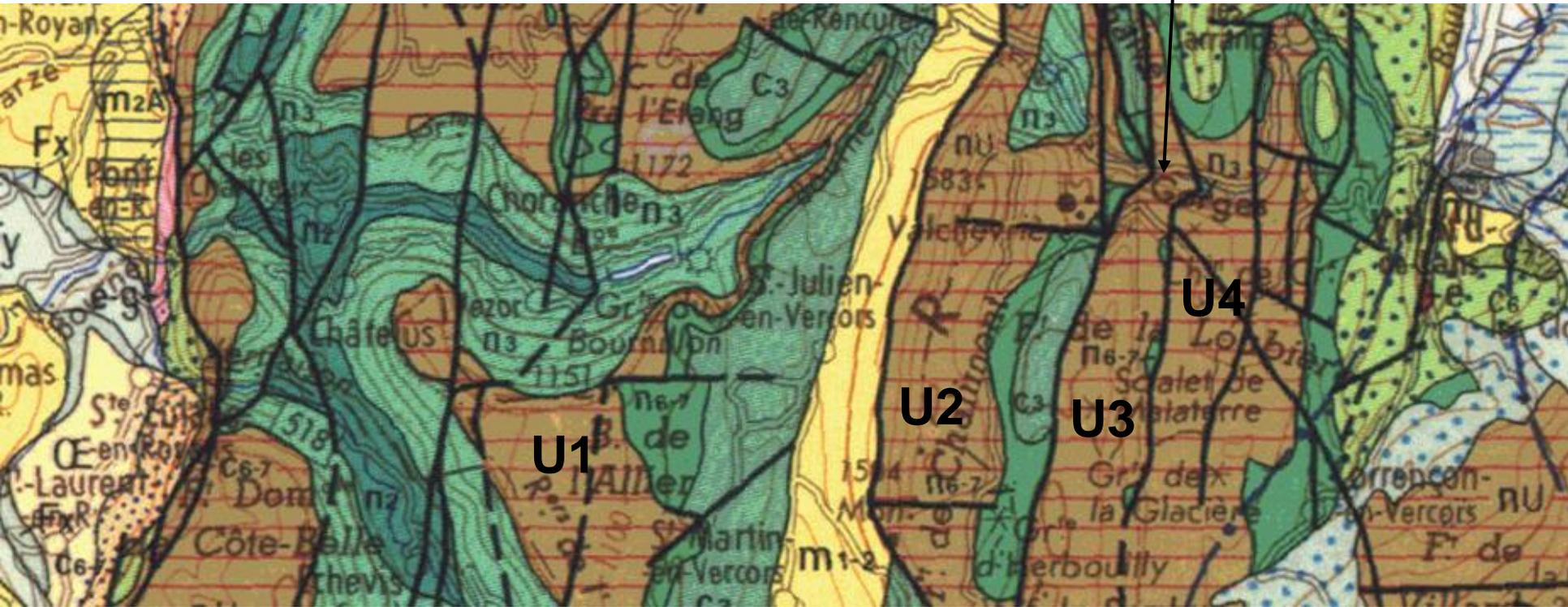
**cisaillement simple, déformation non coaxiale**



*Déformation ductile dans les alternances pélito-gréseuses langhiennes du synclinal de Rencurel juste sous le chevauchement*

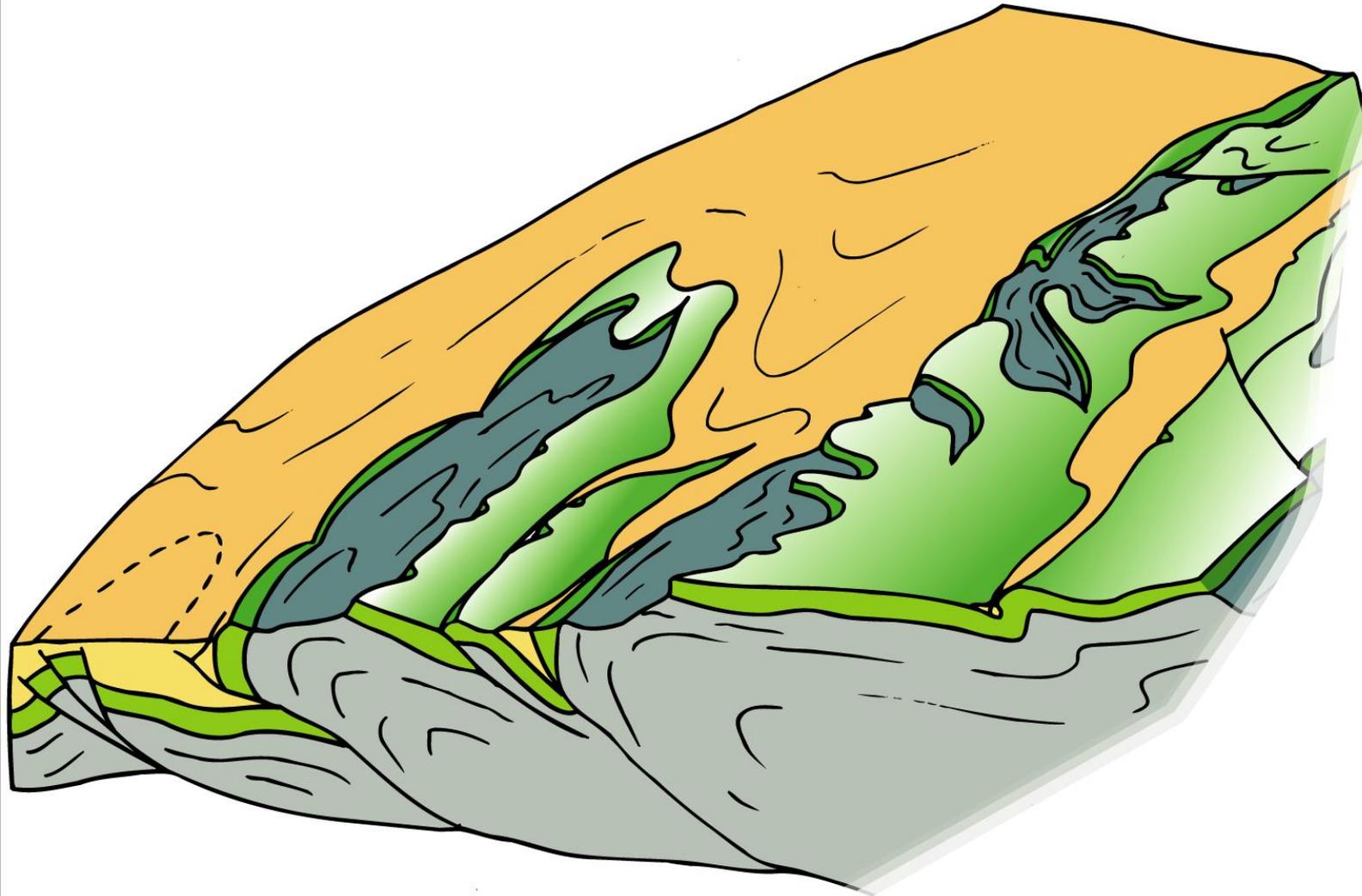


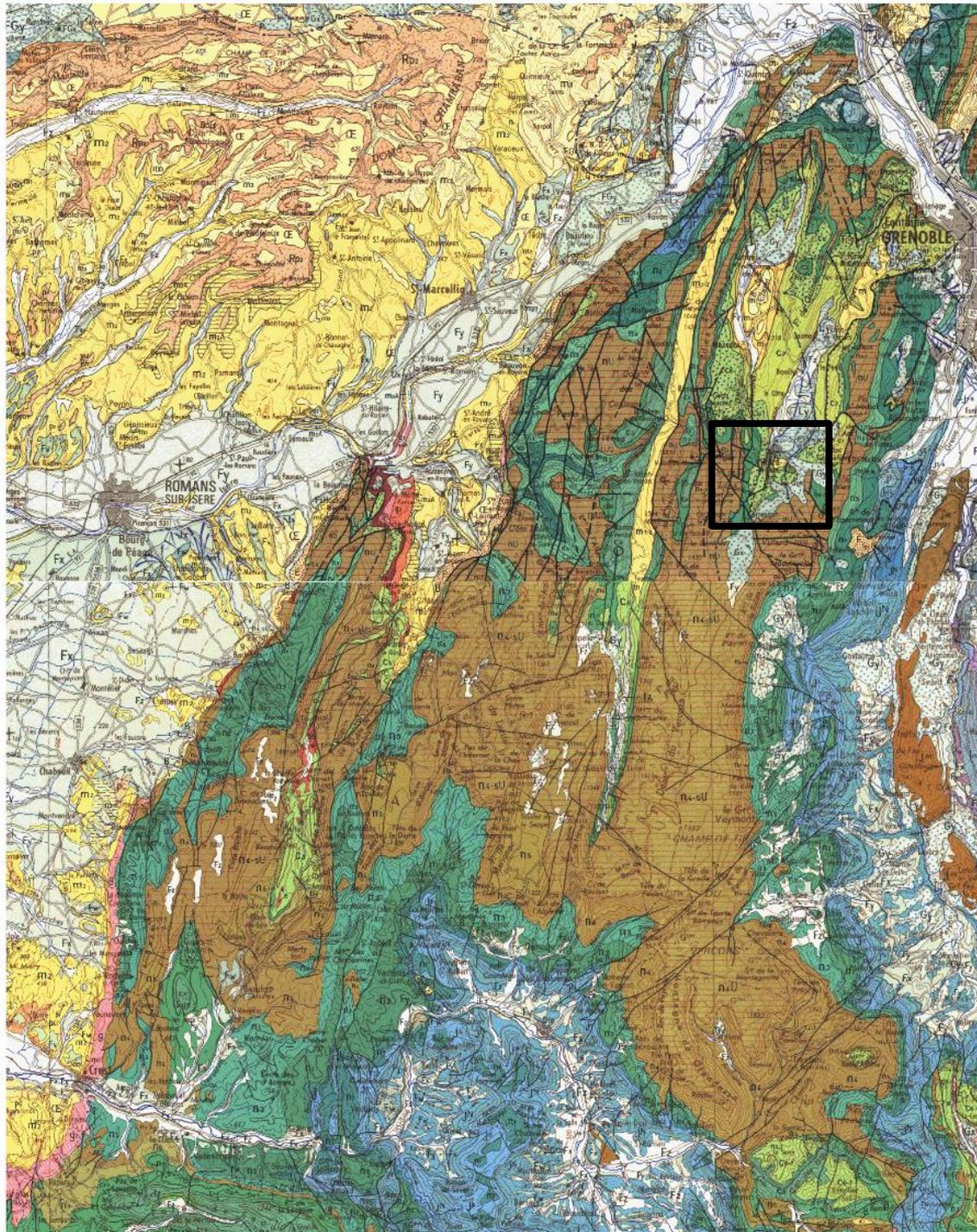
# Urgonien 4 chevauchant sur Urgonien 3





# Le style tectonique du Vercors





*Synclinal de Villard de Lans*



**Urgonien x**

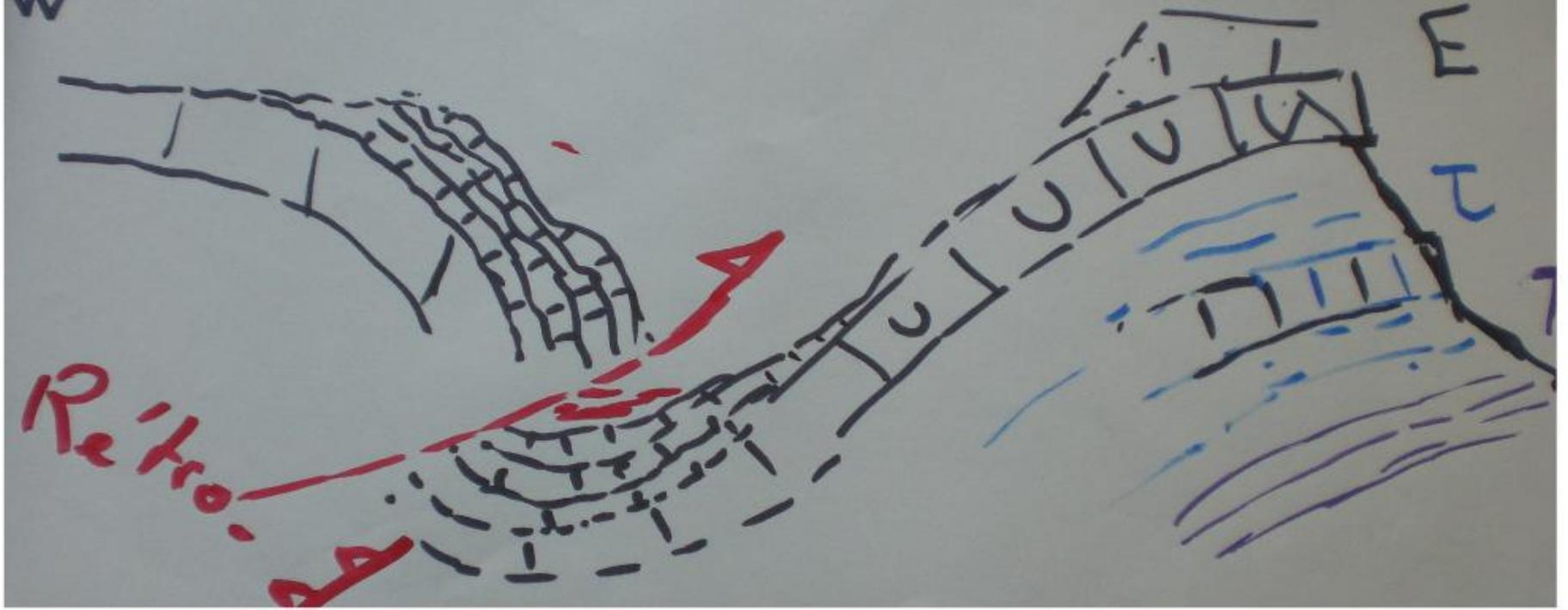


*Rétro-chevauchement de Villard de Lans*



# Villard-de-Lans

W U5

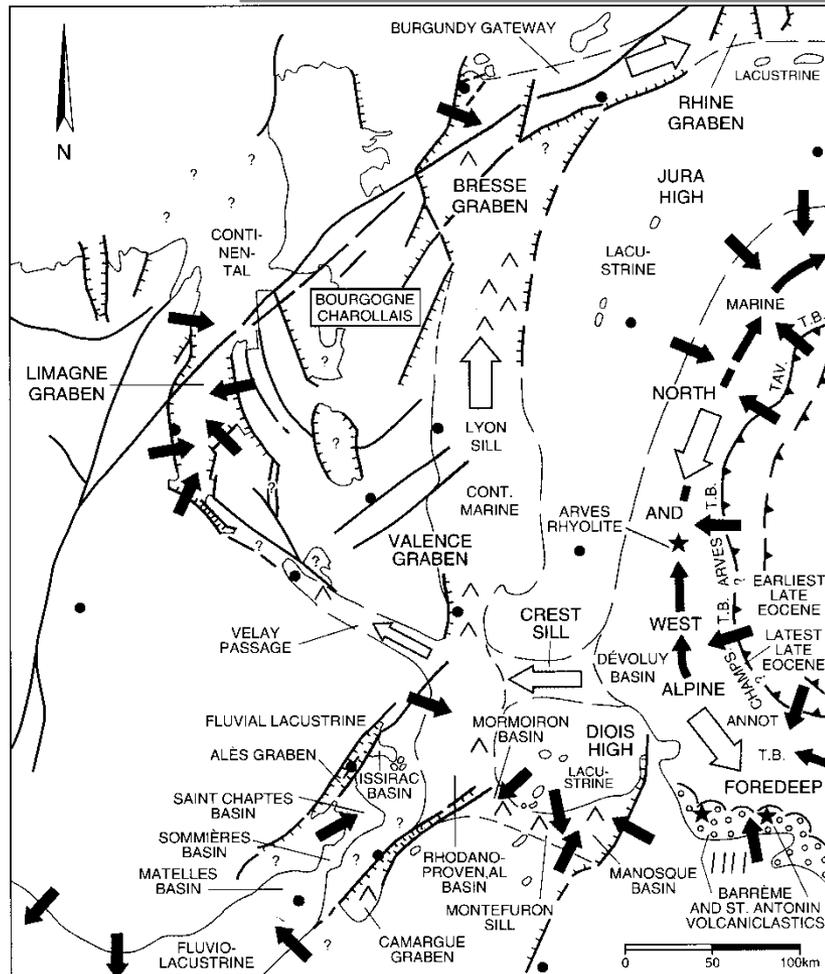


*Molasse marine conglomératique  
Langhienne, Croix de Lichou*





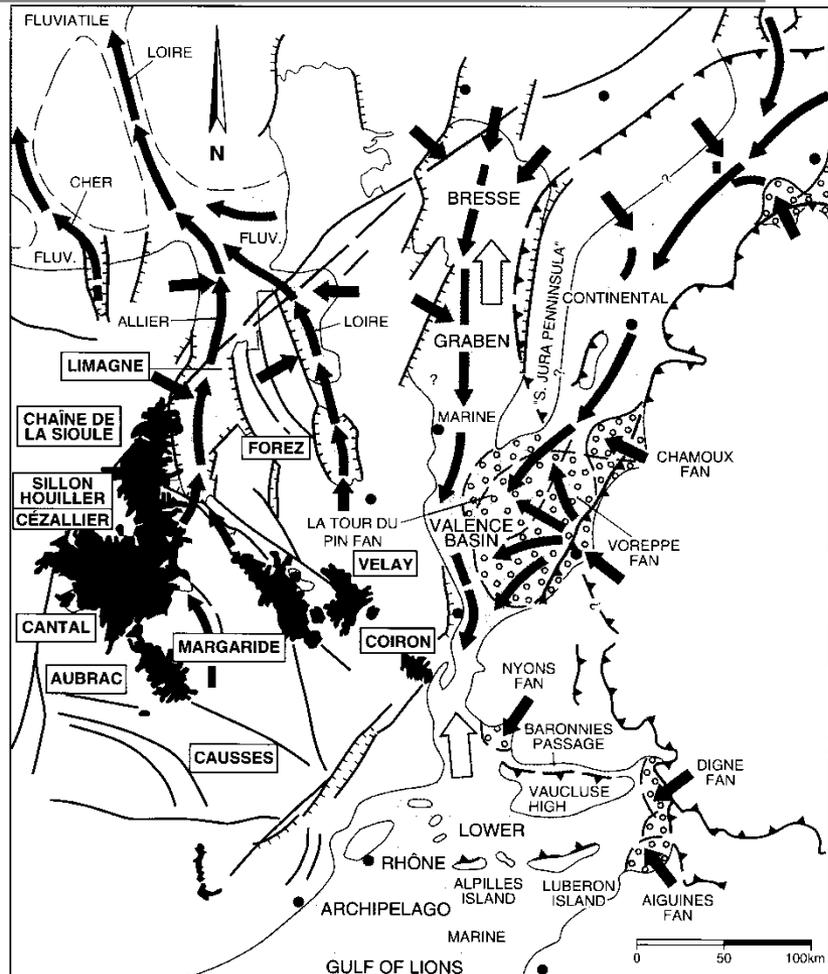
# Paléogéographie de l'avant-pays alpin : des flyschs éocènes aux molasses oligo-miocènes



### LATE EOCENE: PRIABONIAN

- |  |  |
|--|--|
| <ul style="list-style-type: none"> <li> GENERAL DIRECTION OF MARINE INCURSION</li> <li> LOCAL DIRECTION OF CLASTIC SUPPLY</li> <li> REGIONAL DIRECTION OF CLASTIC TRANSPORT</li> </ul> | <ul style="list-style-type: none"> <li> EVAPORITES</li> <li> ORGANIC (ANOXIC)</li> <li> THRUST FRONT</li> <li> ACTIVE VOLCANIC AREA OF MASSIF CENTRAL</li> </ul> |
|--|--|

(b)



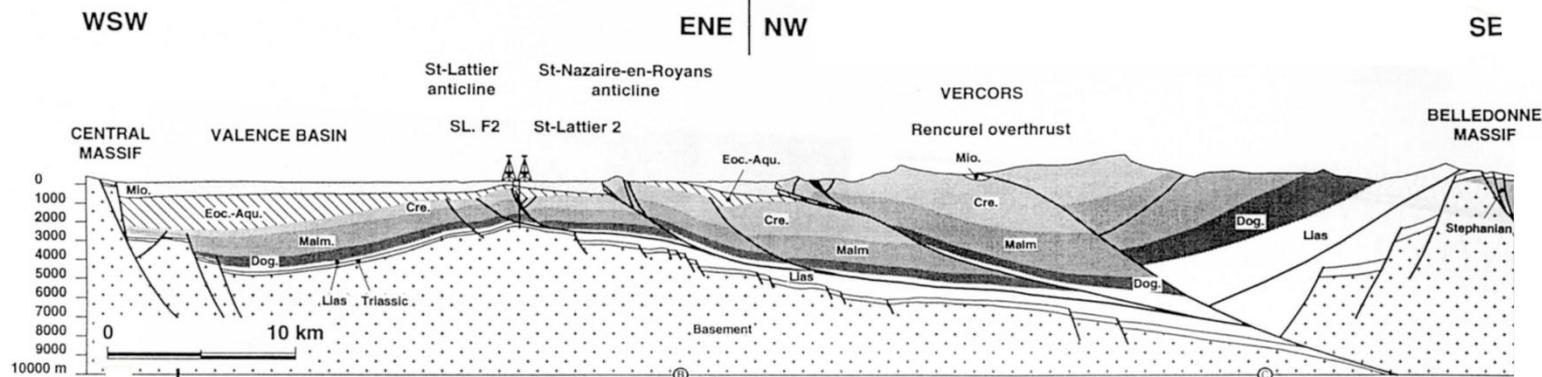
### MIDDLE-LATE MIOCENE P.P.: LANGHIAN-TORTONIAN

- |  |   |
|--|---|
| <ul style="list-style-type: none"> <li> GENERAL DIRECTION OF MARINE INCURSION</li> <li> LOCAL DIRECTION OF CLASTIC SUPPLY</li> <li> REGIONAL DIRECTION OF CLASTIC TRANSPORT</li> </ul> | <ul style="list-style-type: none"> <li> (POSSIBLE) ISLAND AND / OR SHOAL</li> <li> THRUST FRONT</li> <li> LATE CENOZOIC VOLCANOES UNDIFF.</li> <li> ACTIVE VOLCANIC AREA OF MASSIF CENTRAL</li> </ul> |
|--|---|

(b)

**Le Vercors :**  
**Une chaîne de couverture Miocène**





### VERCORS

Massif Central

Bassin de Valence

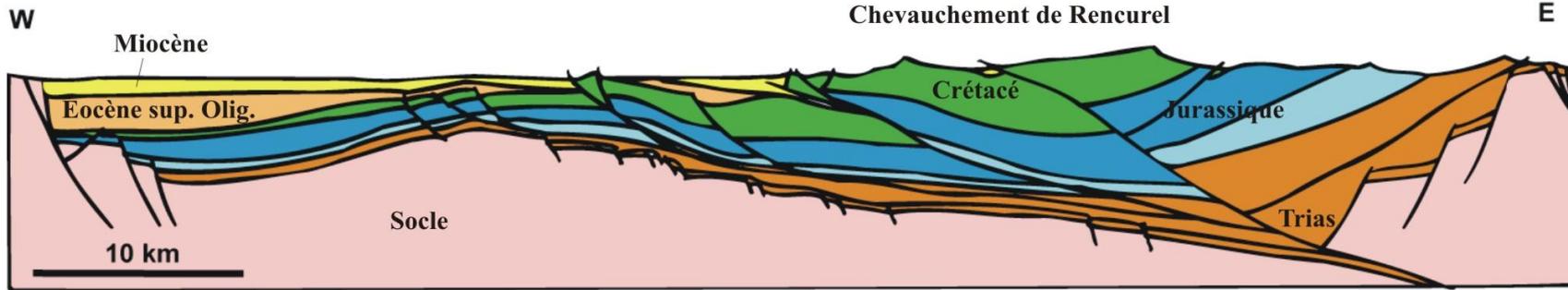
Anticlinal de Saint-Lattier

Anticlinal de Saint Nazaire en Royans

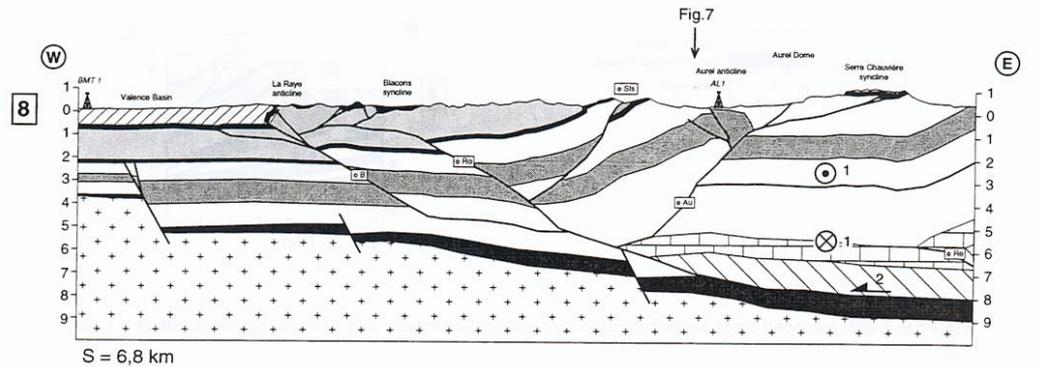
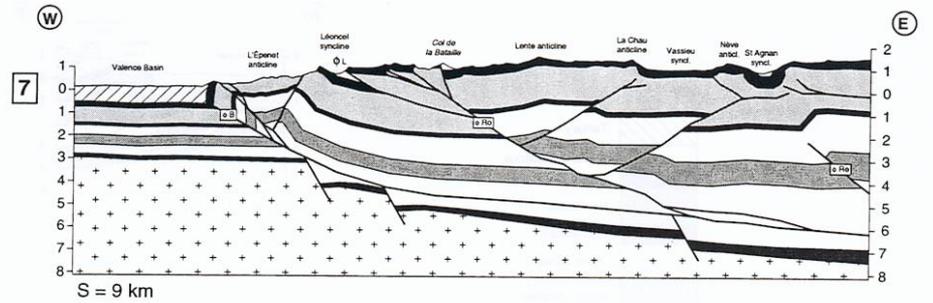
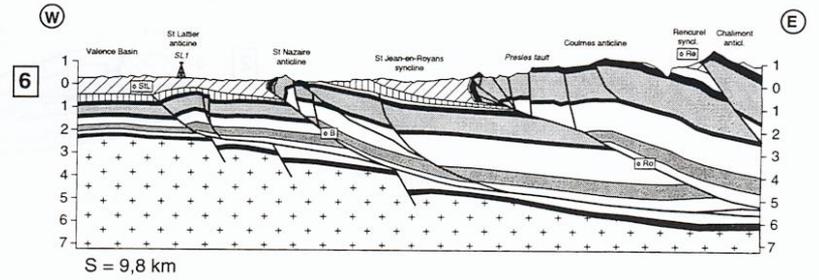
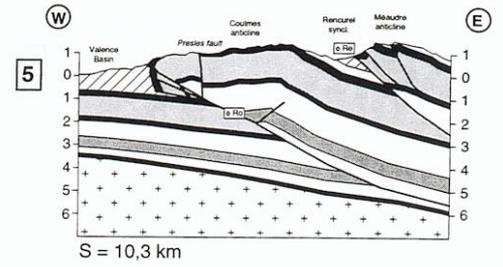
Anticlinal de Pont-en-Royans

Belledonne

Chevauchement de Rencurel



0 km 5

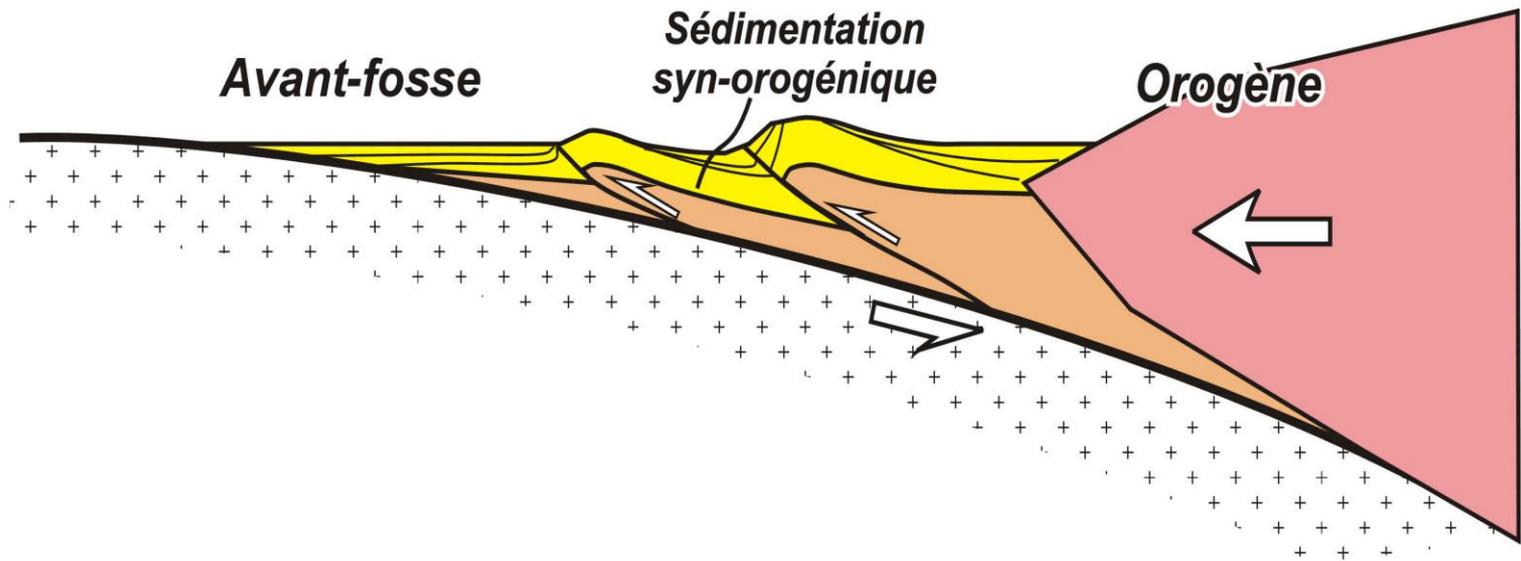


(Philippe, 1995)

**Lien avec les Massifs Cristallins Externes**

Bassin d'avant-pays

Prisme orogénique



Massif Central

Bassin de Valence

Chaînes subalpines septentrionales VERCORS

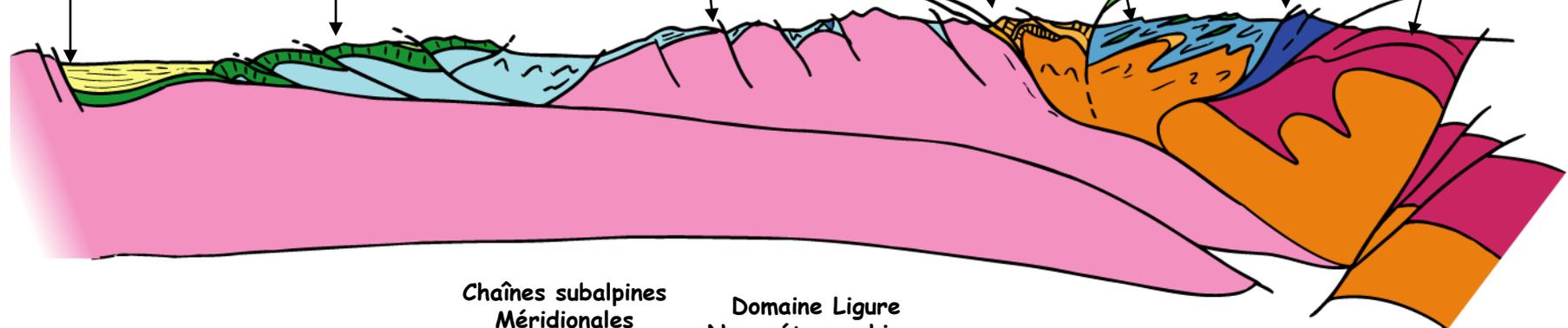
Massifs cristallins externes OISANS

Briançonnais

Domaine Ligure Schistes Lustrés Schistes Bleus

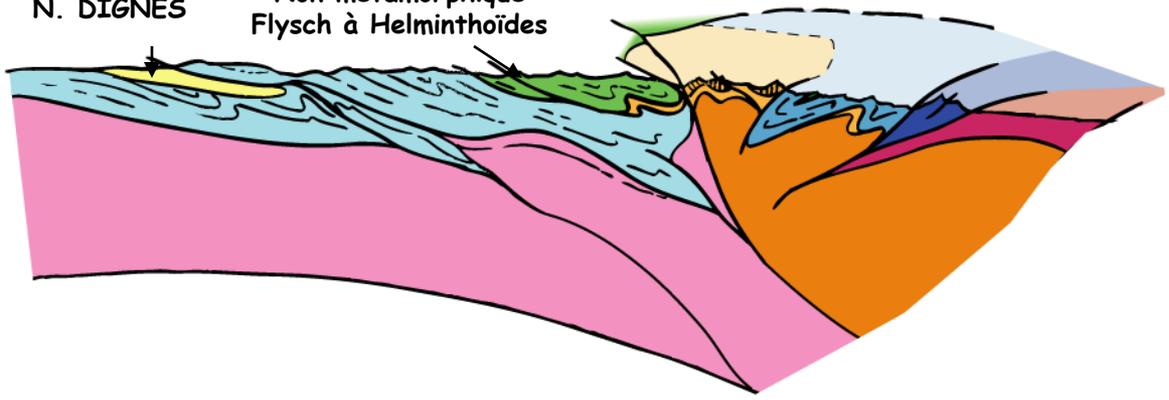
Domaine Ligure Mont Viso Eclogites

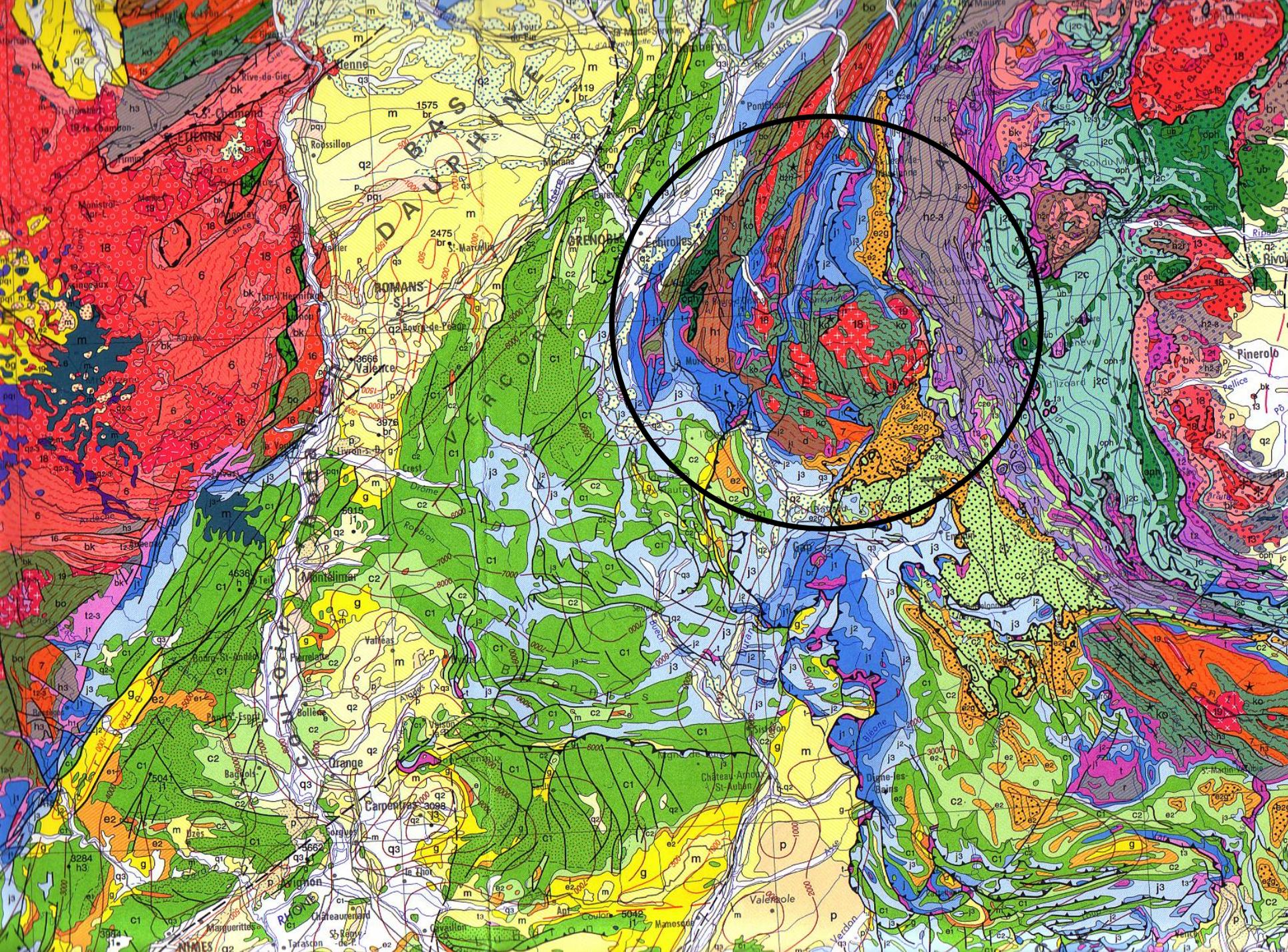
Dora Maira Très Haute pression



Chaînes subalpines Méridionales N. DIGNES

Domaine Ligure Non métamorphique Flysch à Helminthoïdes

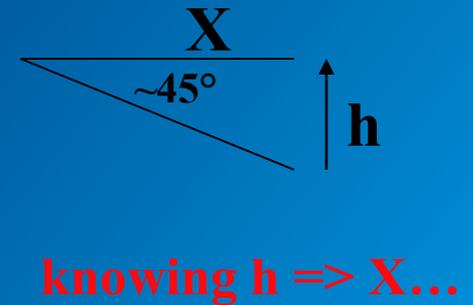
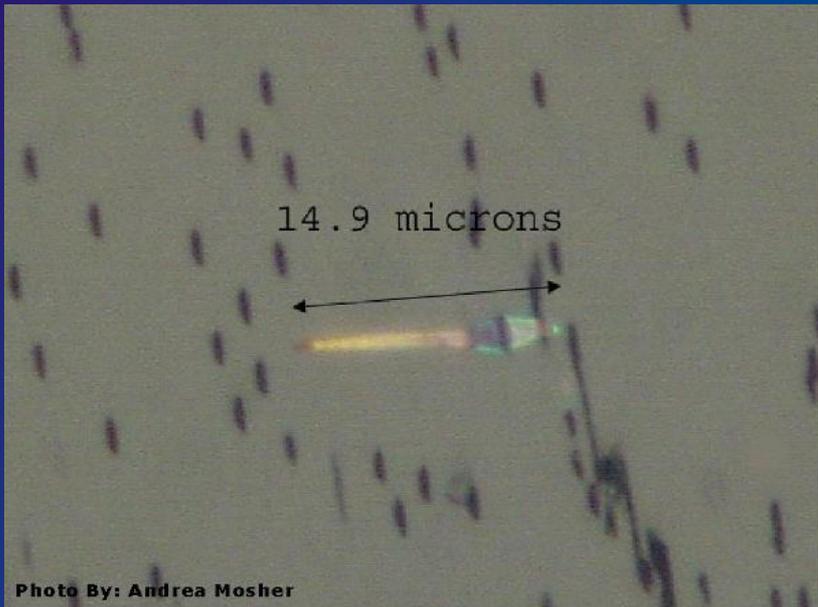
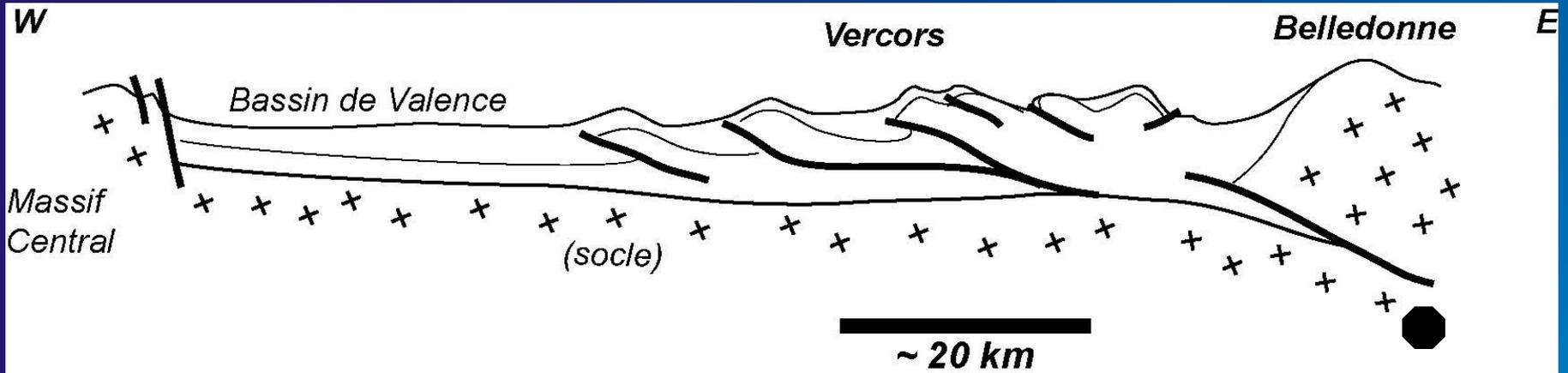




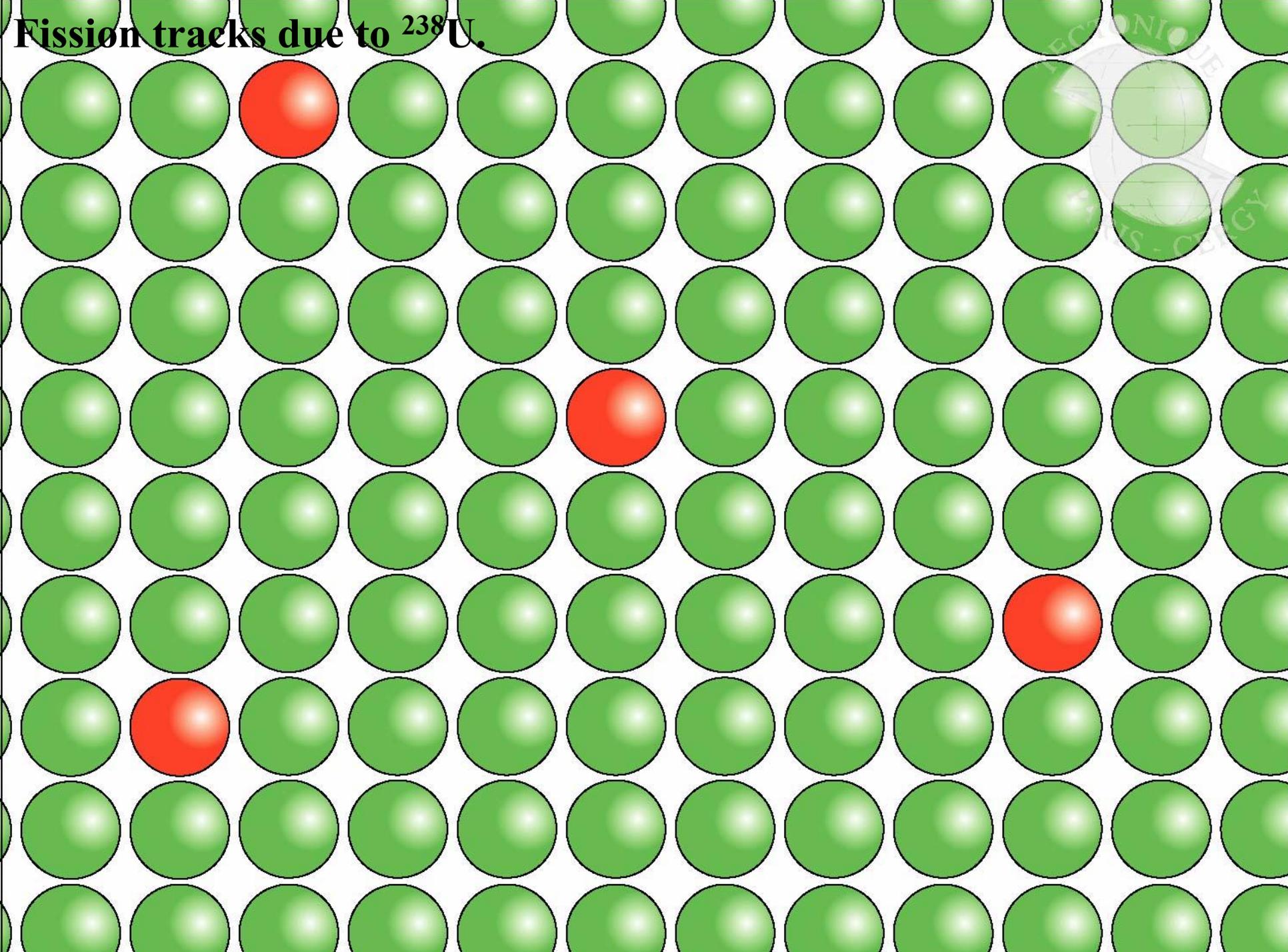


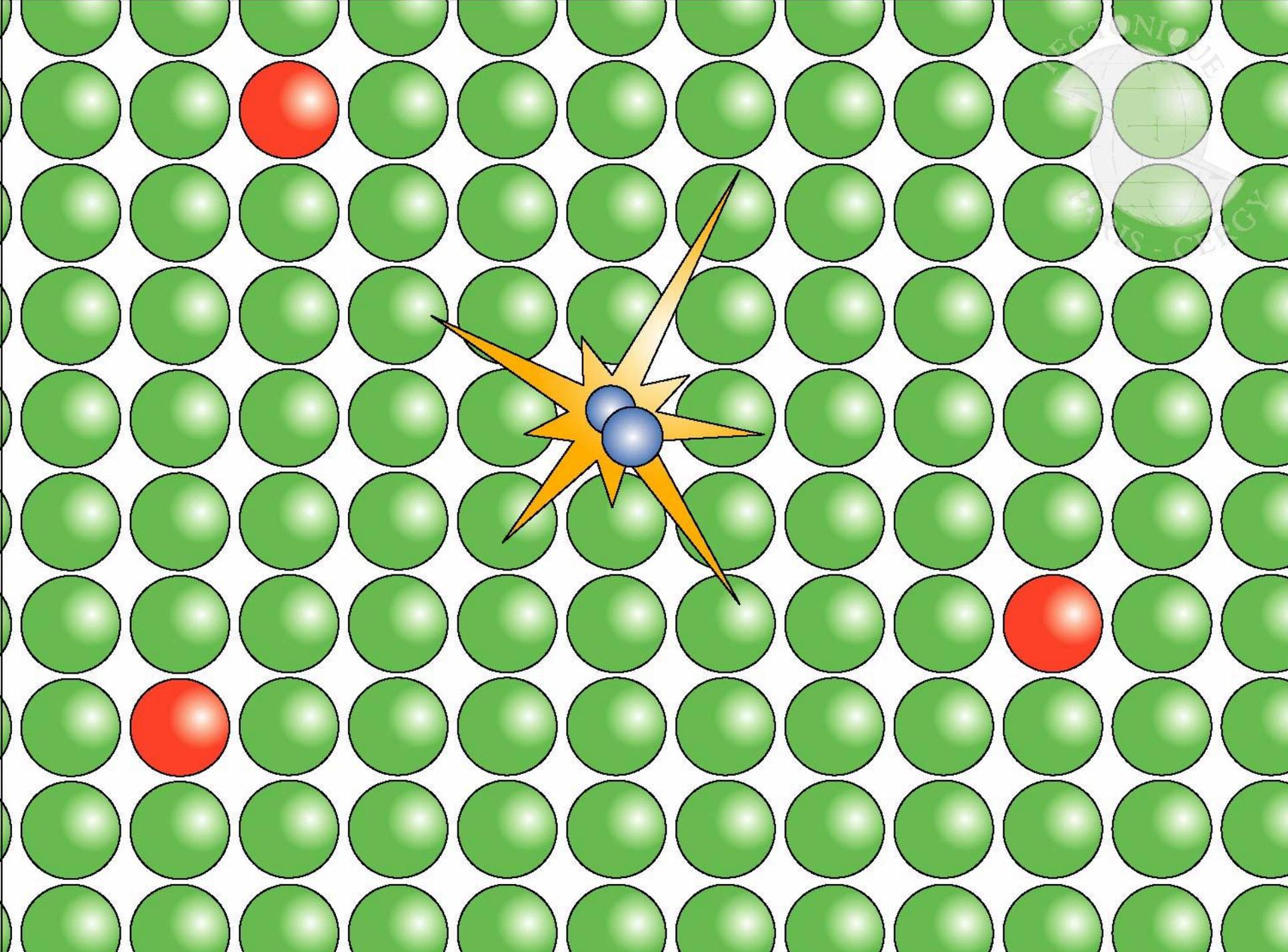
**LA MEIJE**  
**3983 m**

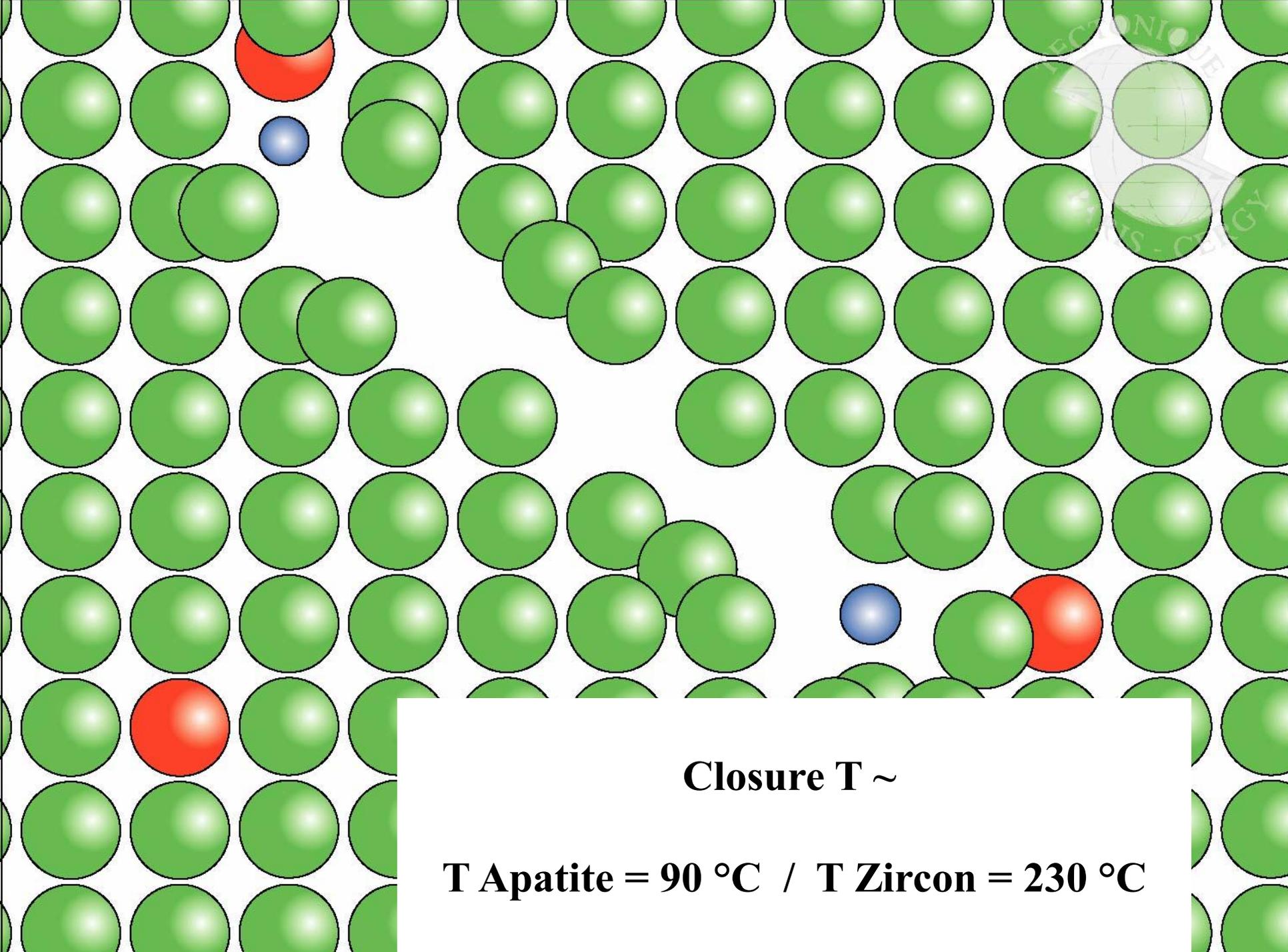
*10 km of shortening in the cover since 10 Ma  
0 in the basement !...*



Fission tracks due to  $^{238}\text{U}$ .

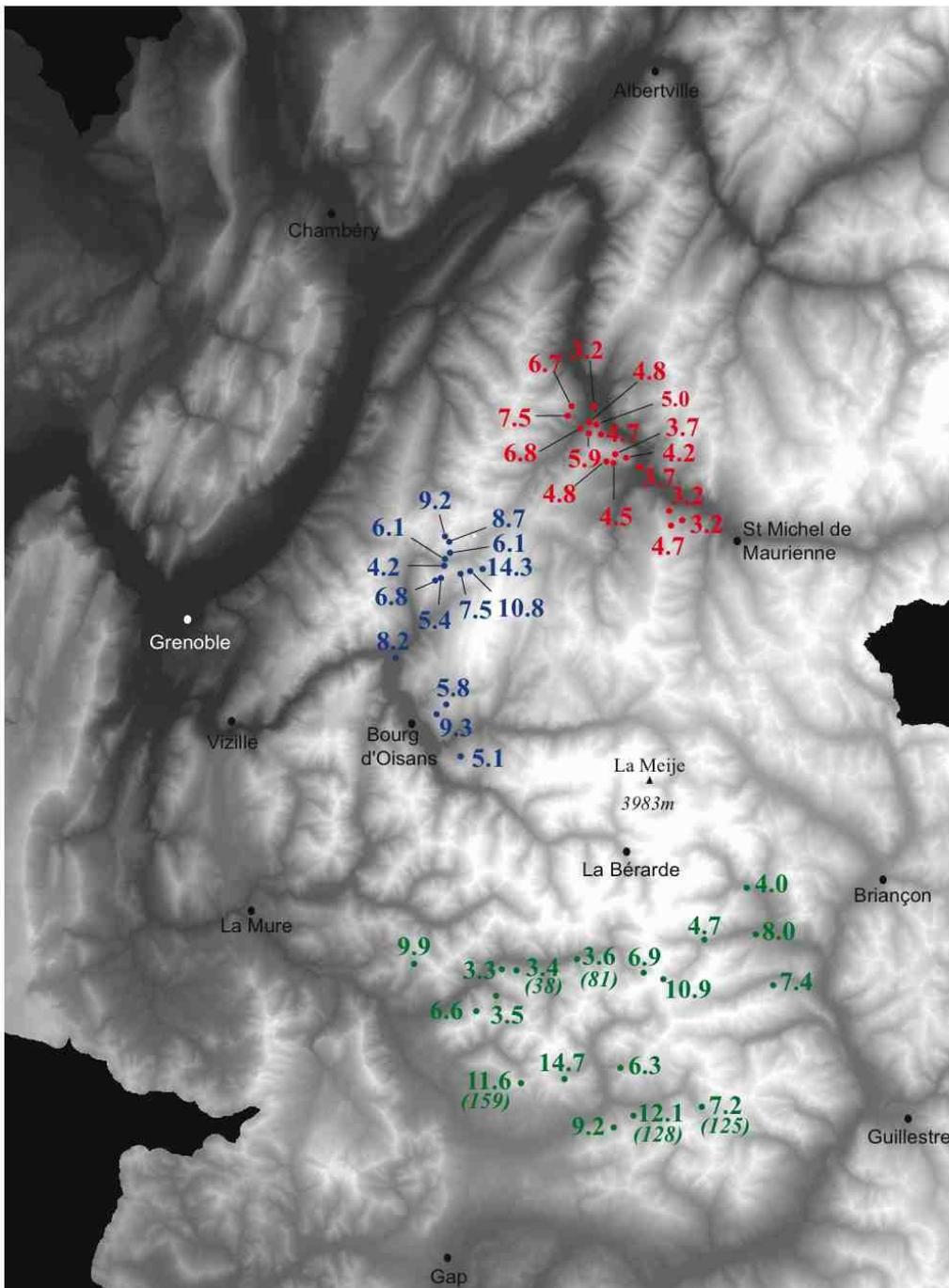




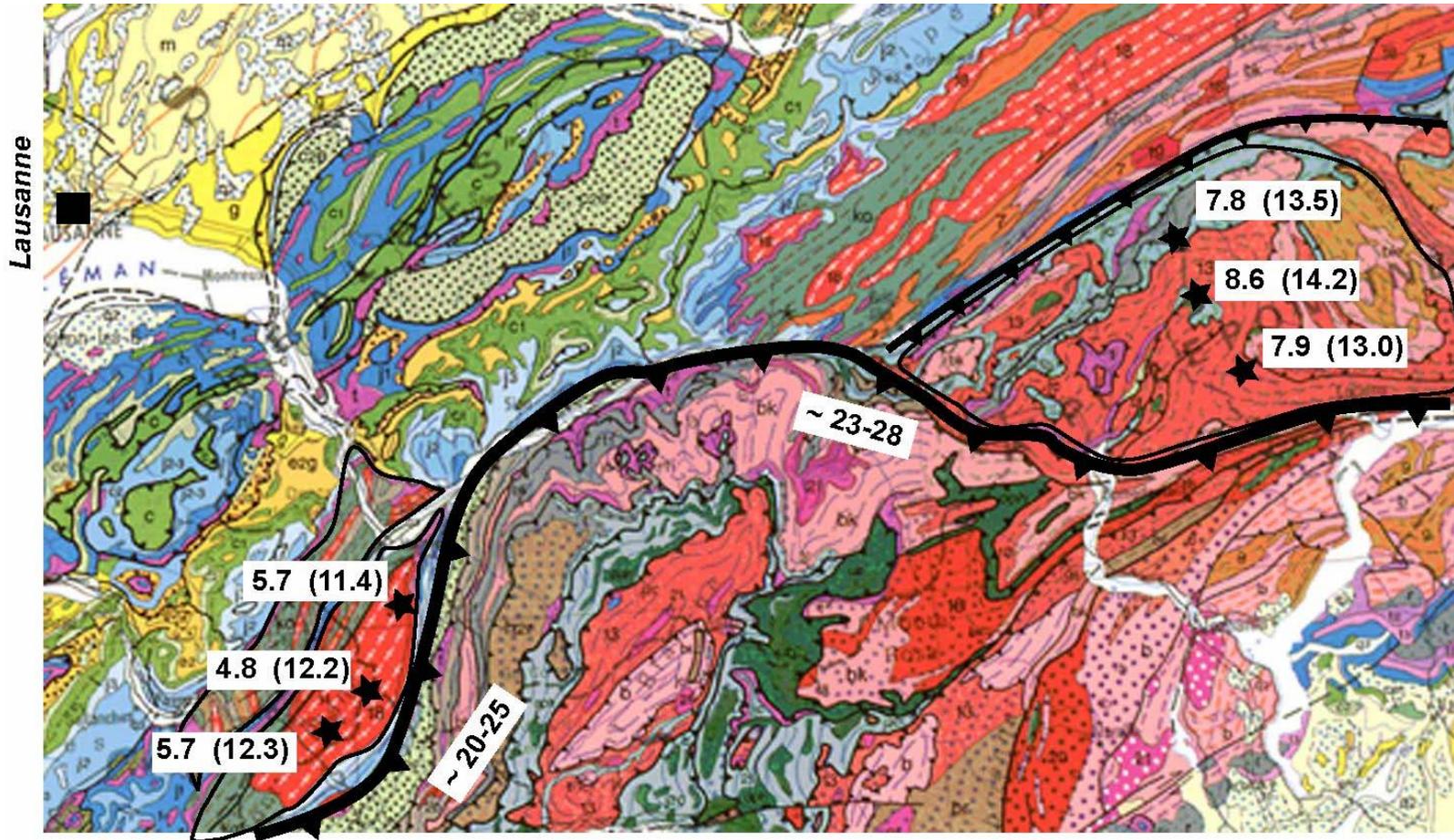


**Closure T ~**

**T Apatite = 90 °C / T Zircon = 230 °C**

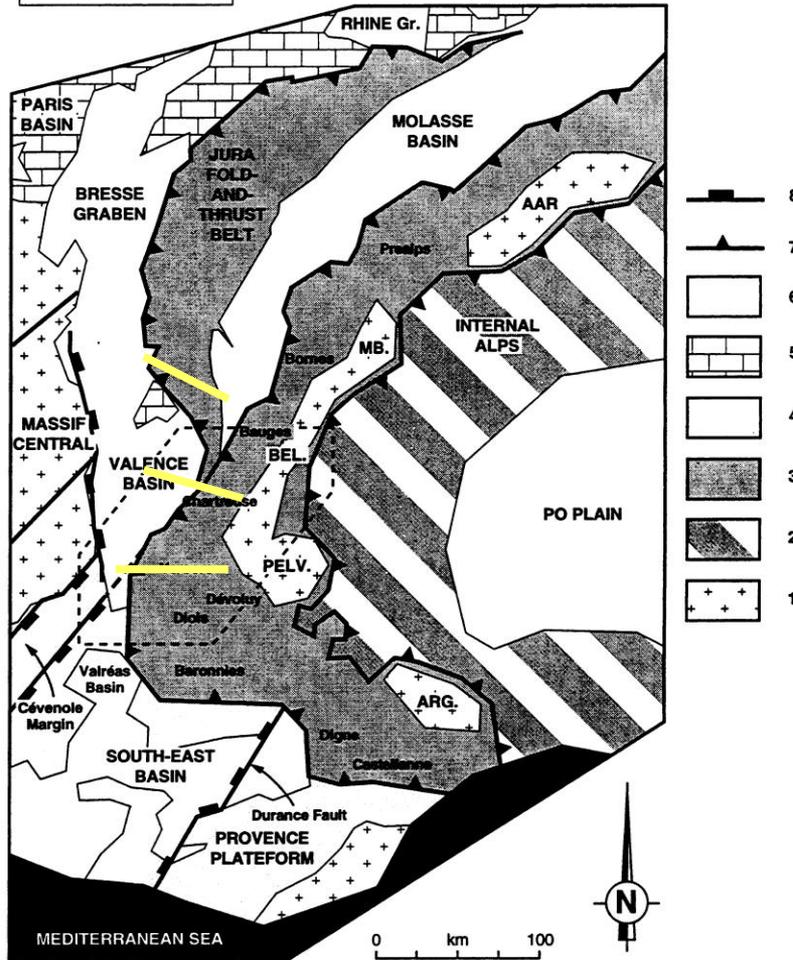


*FT ages : apatite (zircon), Ma*



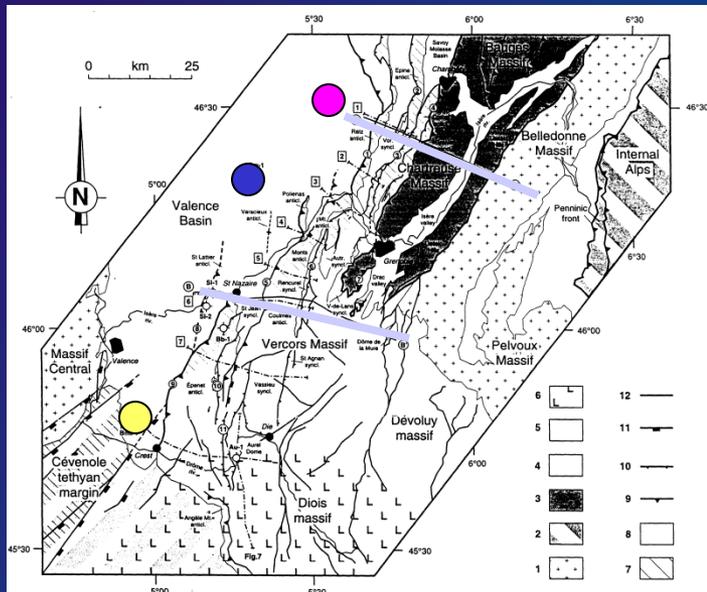
*=> 140°C in 6 Ma, with a gradient of 25°C/km => ~1mm/yr*

**Variations N-S :**  
**Comparaison avec la Chartreuse**

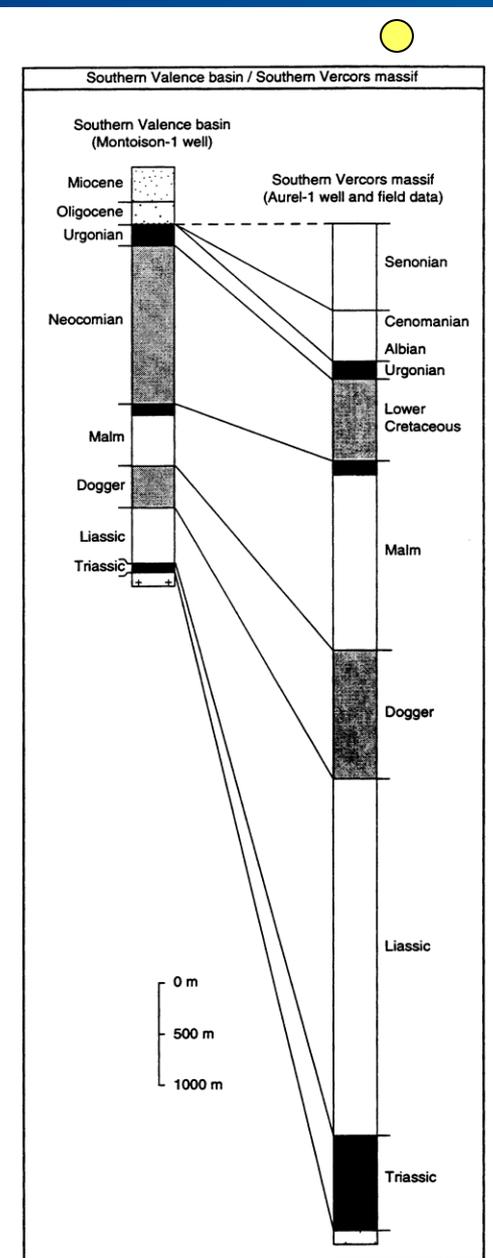
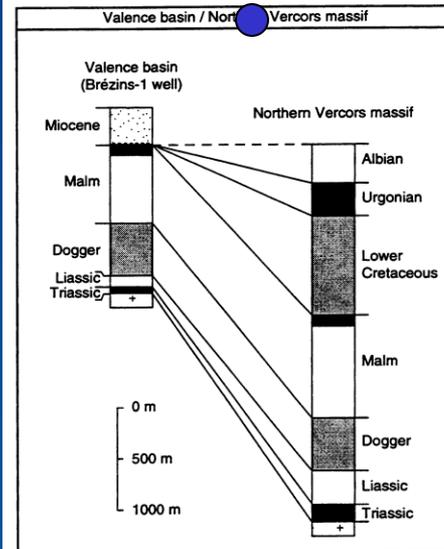
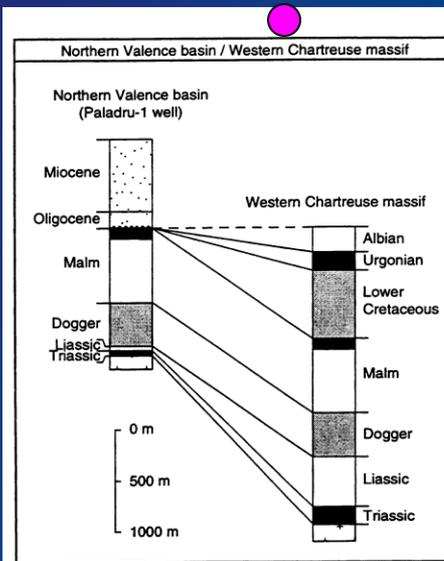


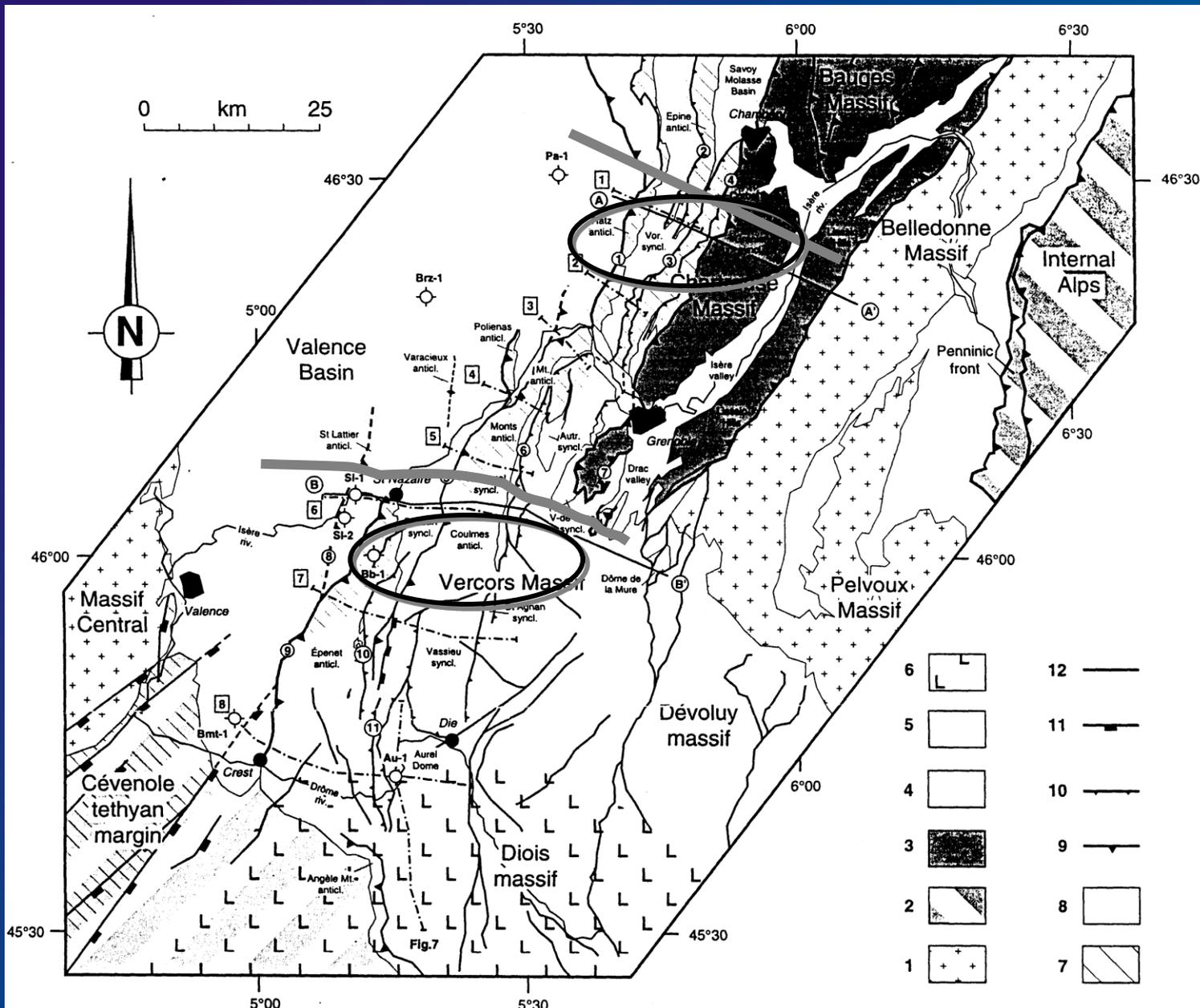
Chaînes plissées non cylindriques (variations de la largeur du prisme, du style structural)

# Epaisseur de la couverture sédimentaire de la Chartreuse au Vercors



(Philippe, 1995)







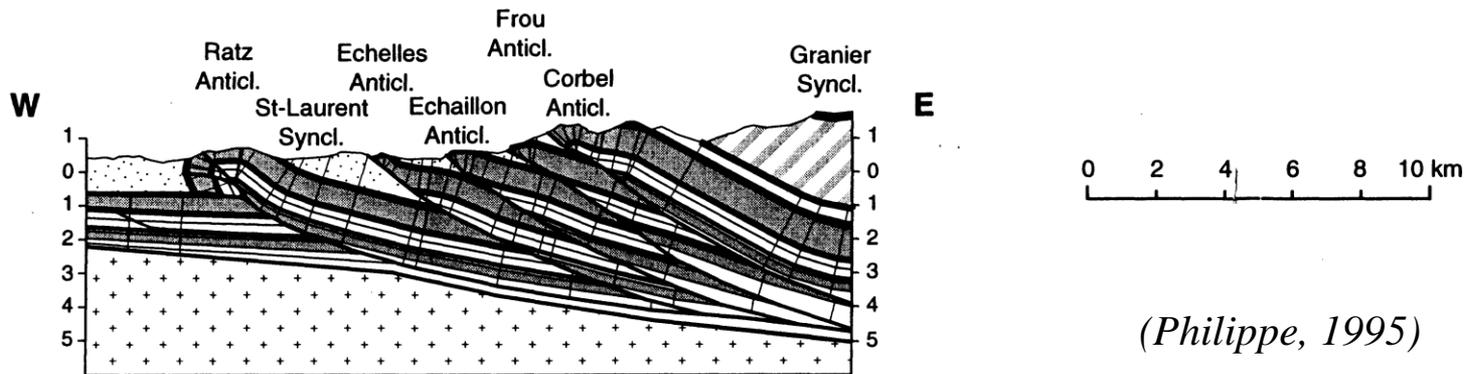


# La CHARTREUSE

BAS-DAUPHINÉ BASIN

JURASSIAN CHAÎNONS

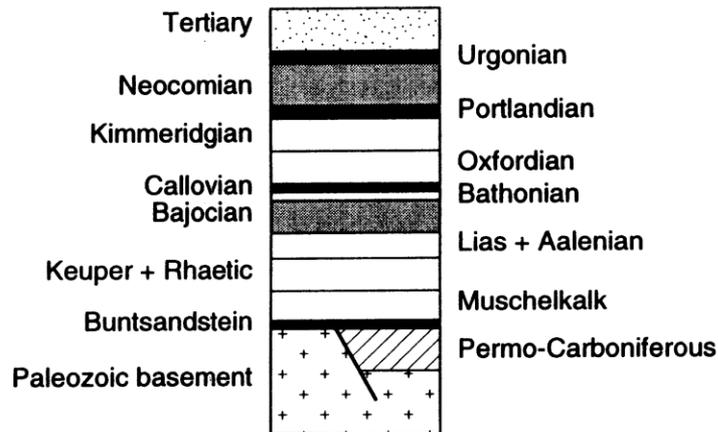
CHARTREUSE MASSIF

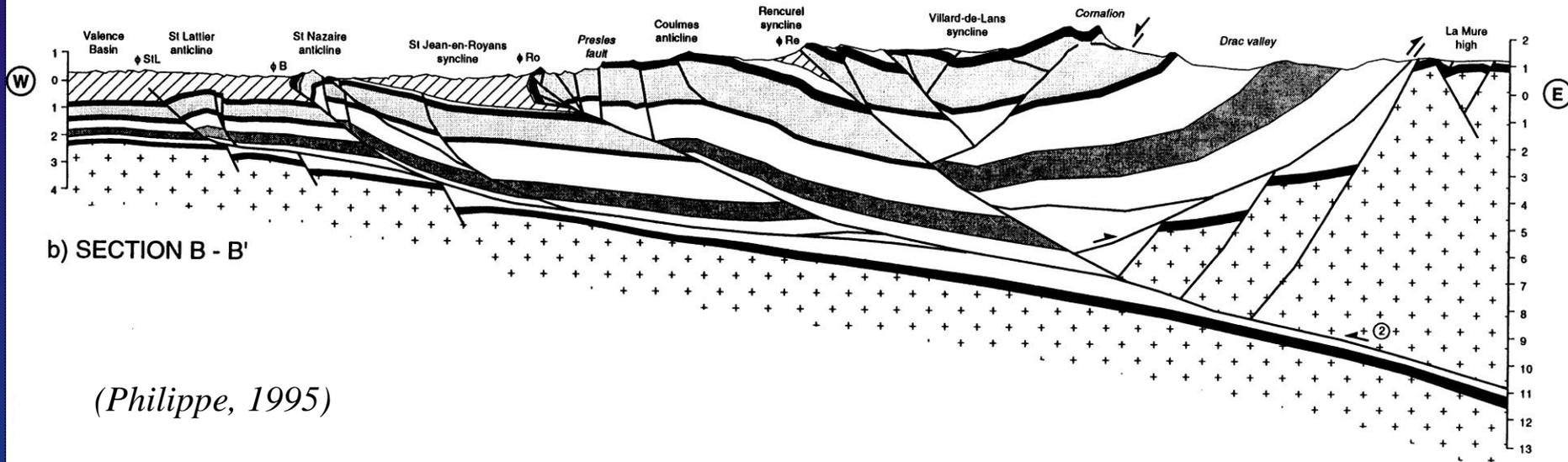
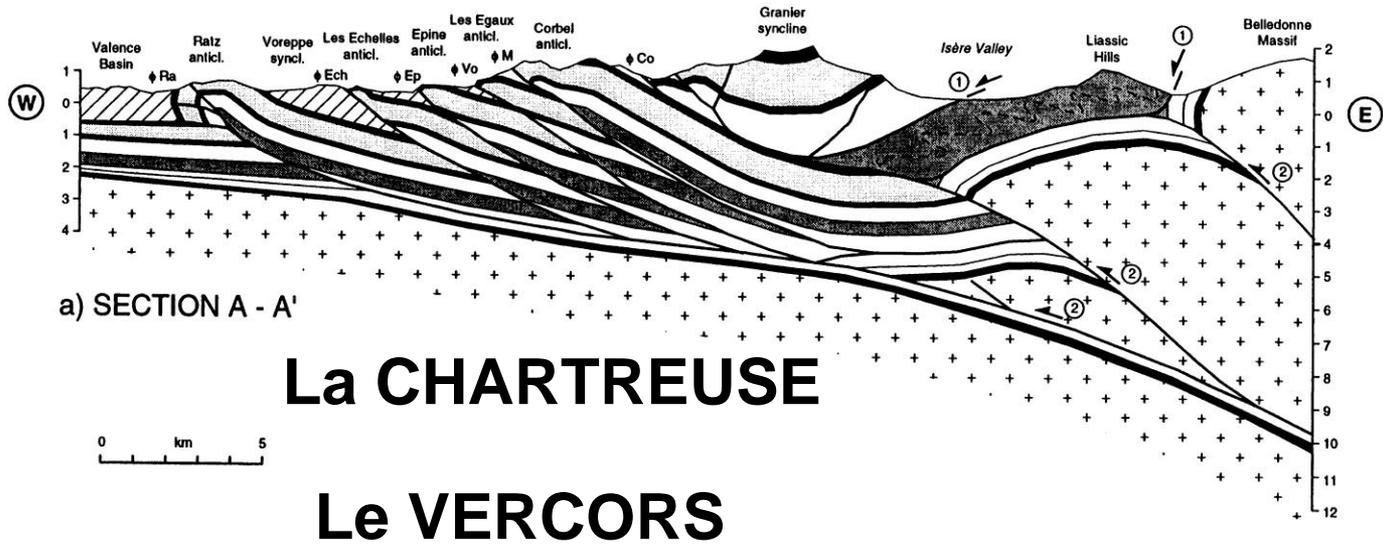
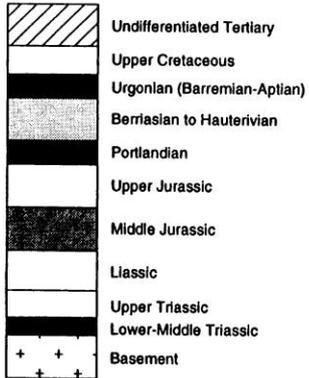


(Philippe, 1995)

Prisme épais

Flèche des  
chevauchements  
importante





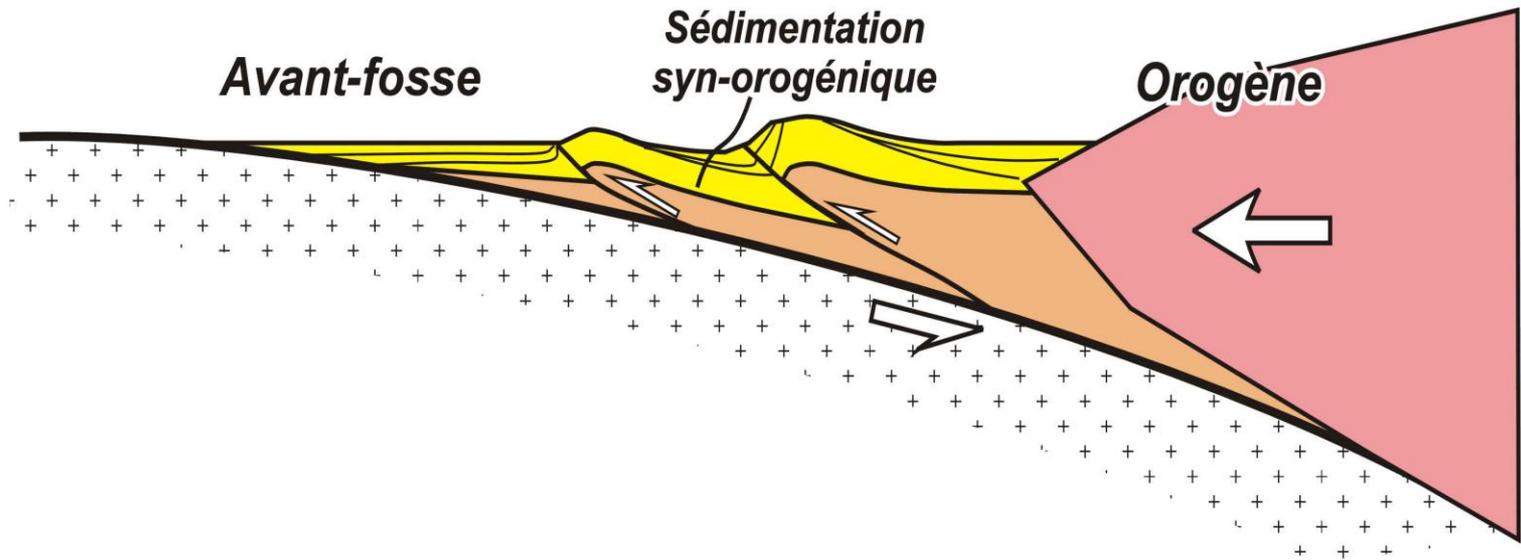
(Philippe, 1995)

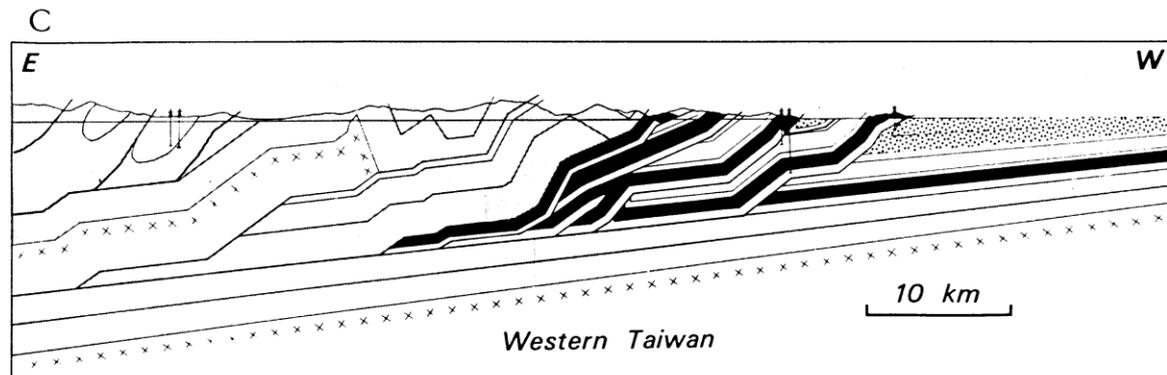
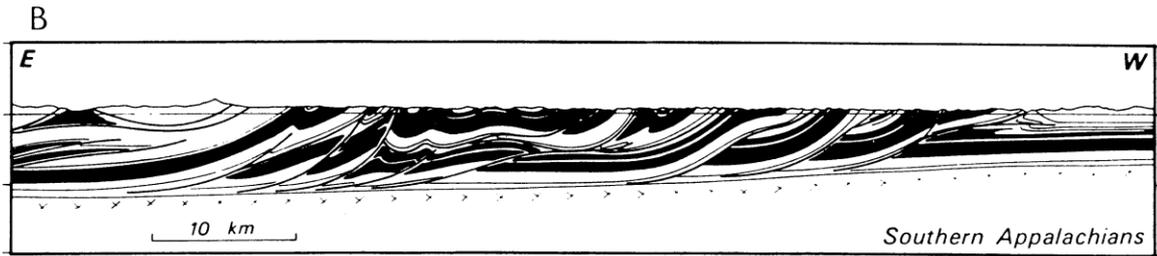
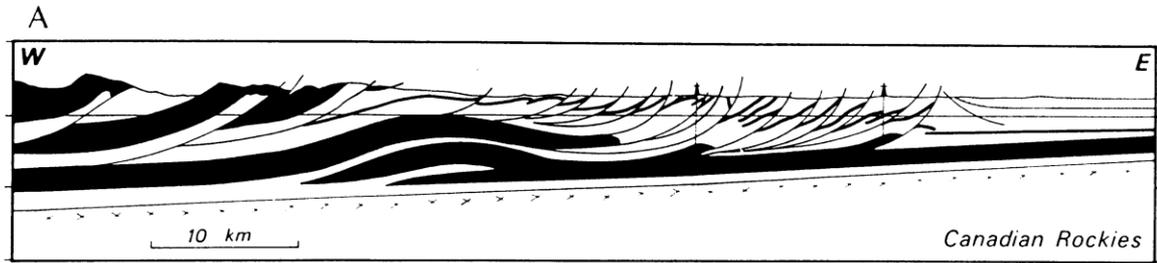
**Le Vercors :  
une chaîne de couverture Mio-Pliocène  
décollée au niveau du Lias...**

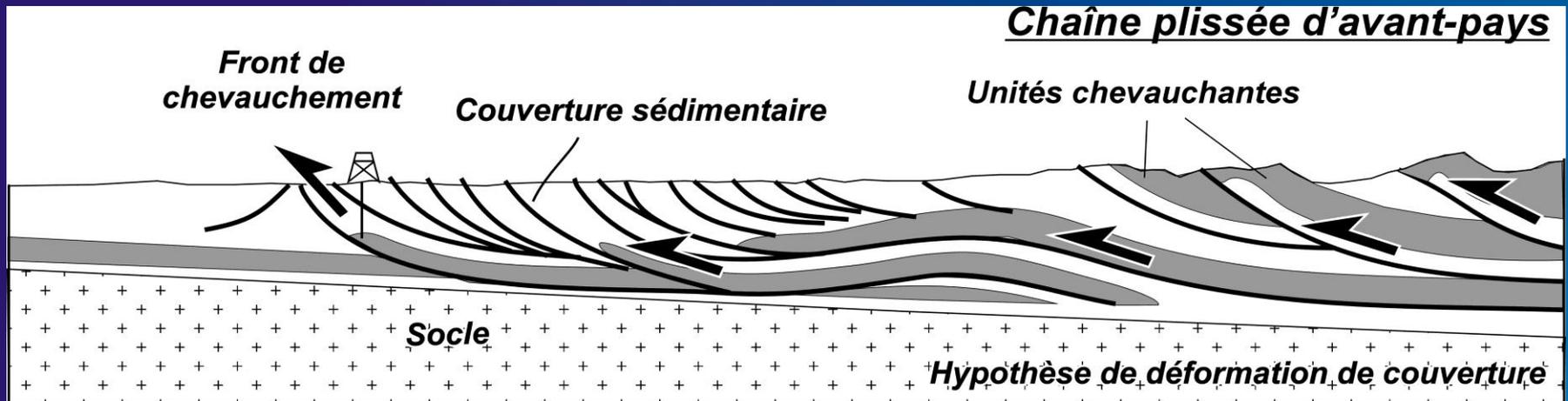
**... analogue à un prisme d'accrétion  
sédimentaire des zones de subduction ...**

Bassin d'avant-pays

Prisme orogénique





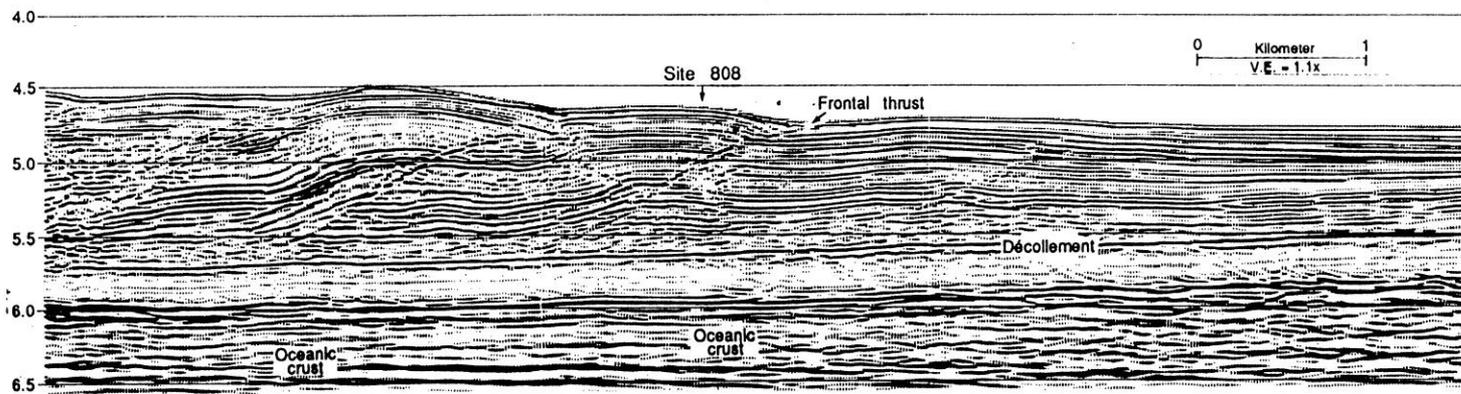


Le raccourcissement est accommodé dans les parties superficielles de la croûte au-dessus d'un décollement basal incliné vers l'intérieur de la chaîne

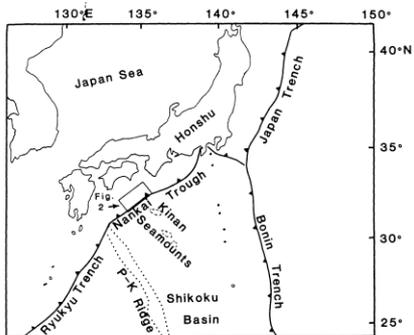
Hypothèse « implicite » de tectonique de couverture ou « thin-skin »

La pente topographique et le décollement basal définissent un prisme chevauchant

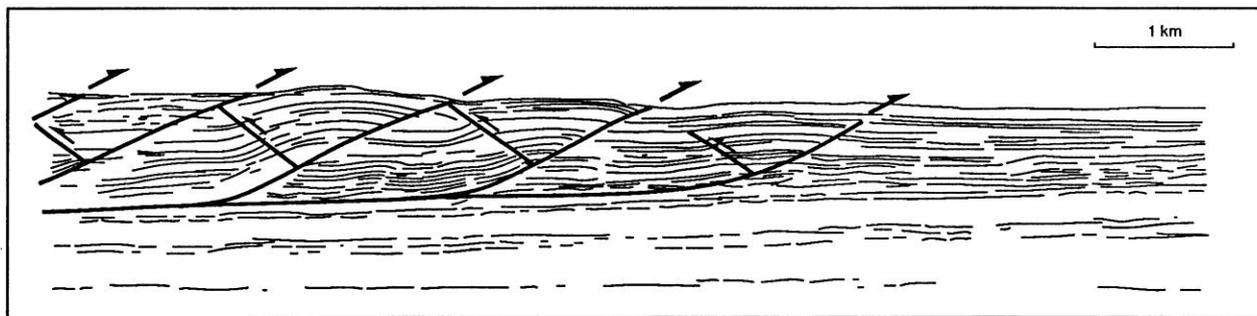
# Equivalents émergés des prismes d'accrétion océanique



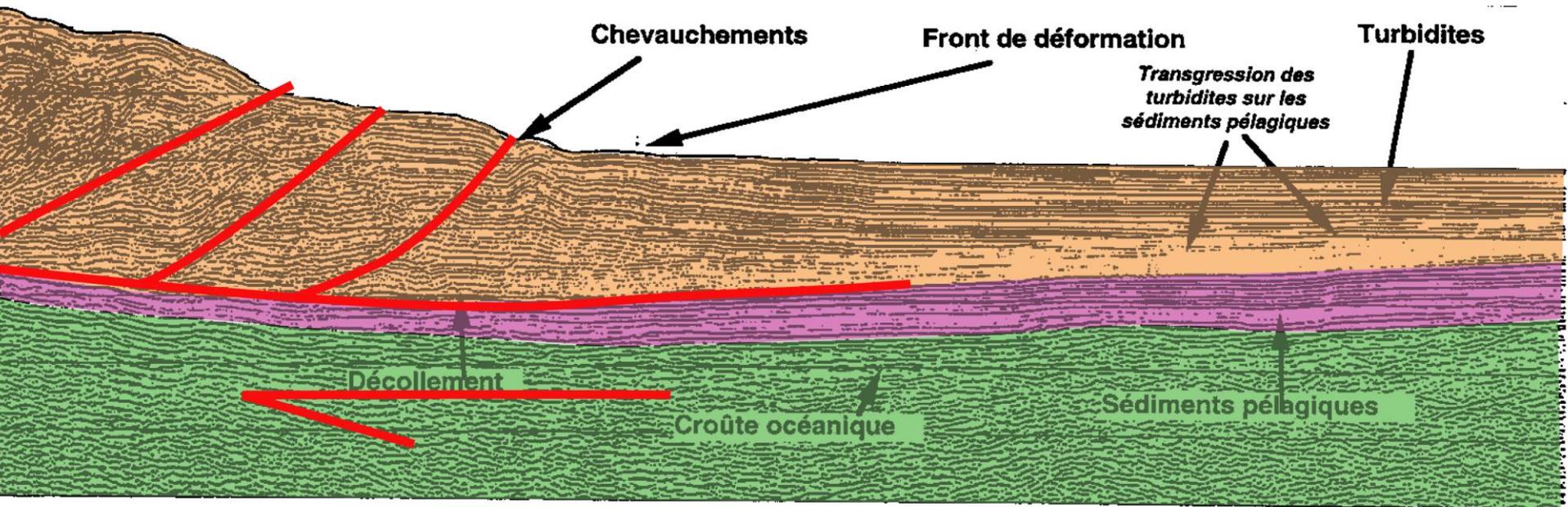
prisme de Nankai 2 (Moore *et al.*, 1991).



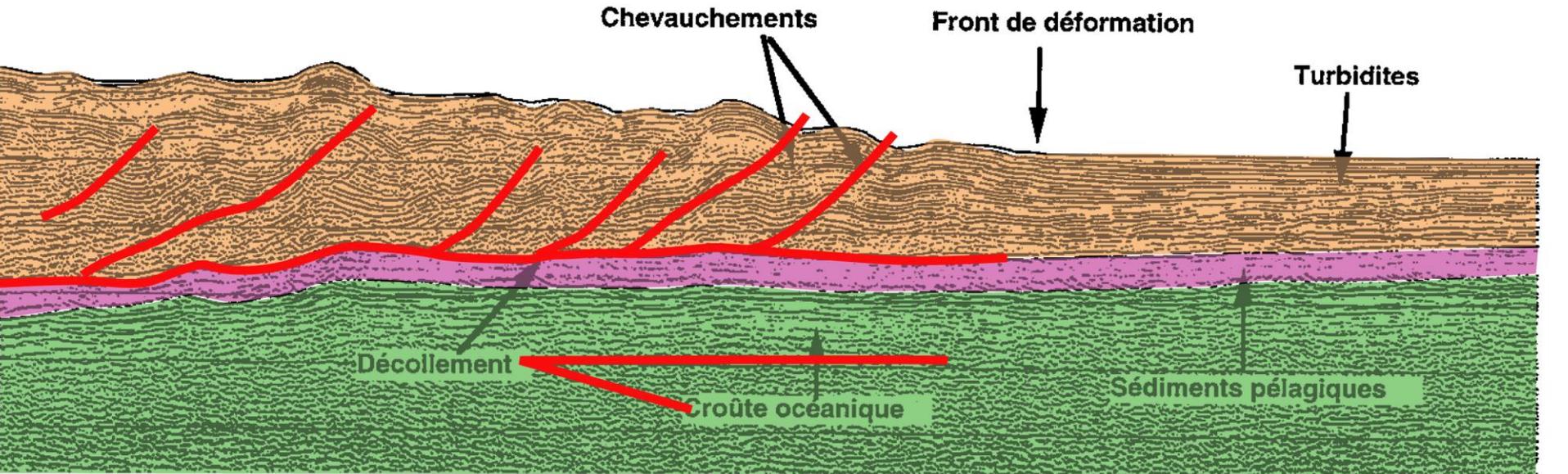
Regional tectonic map showing setting of the Nankai Trough study area (box labeled as Figure 2).



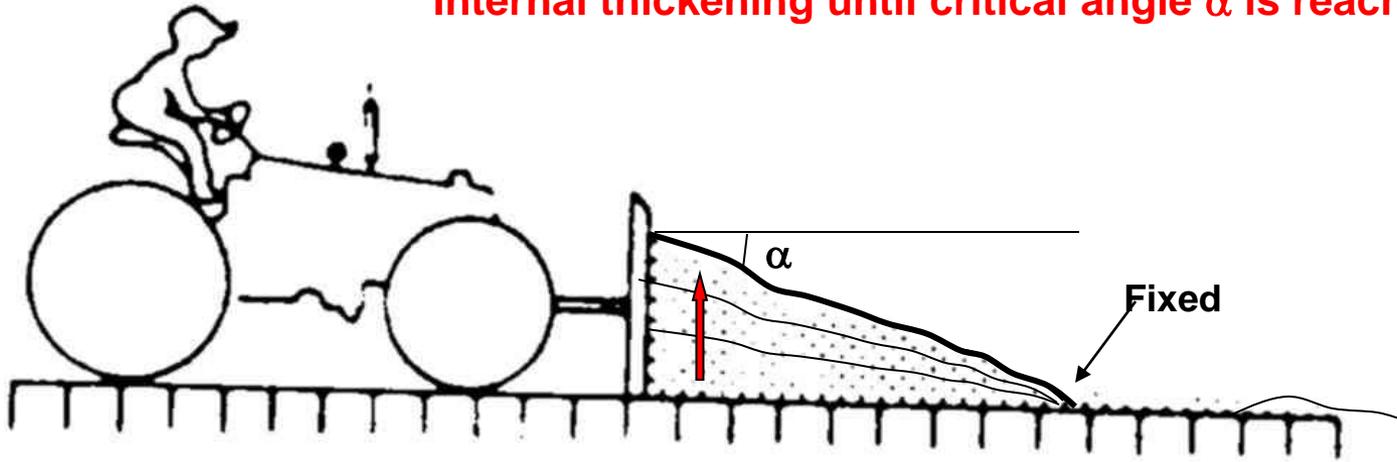
Line-drawing du profil Nankai 2



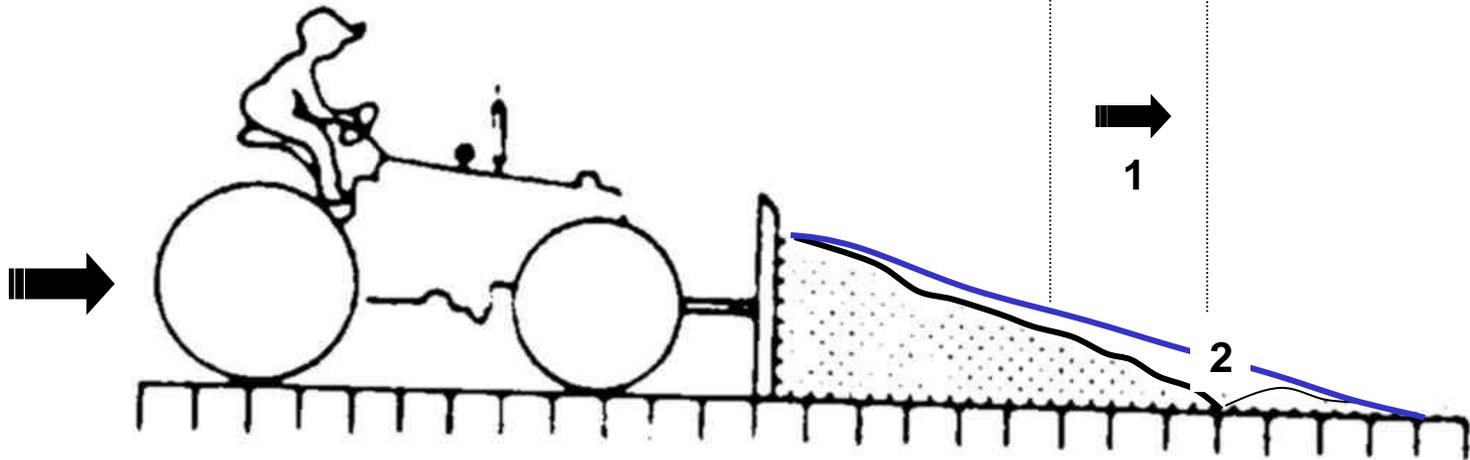
1 km



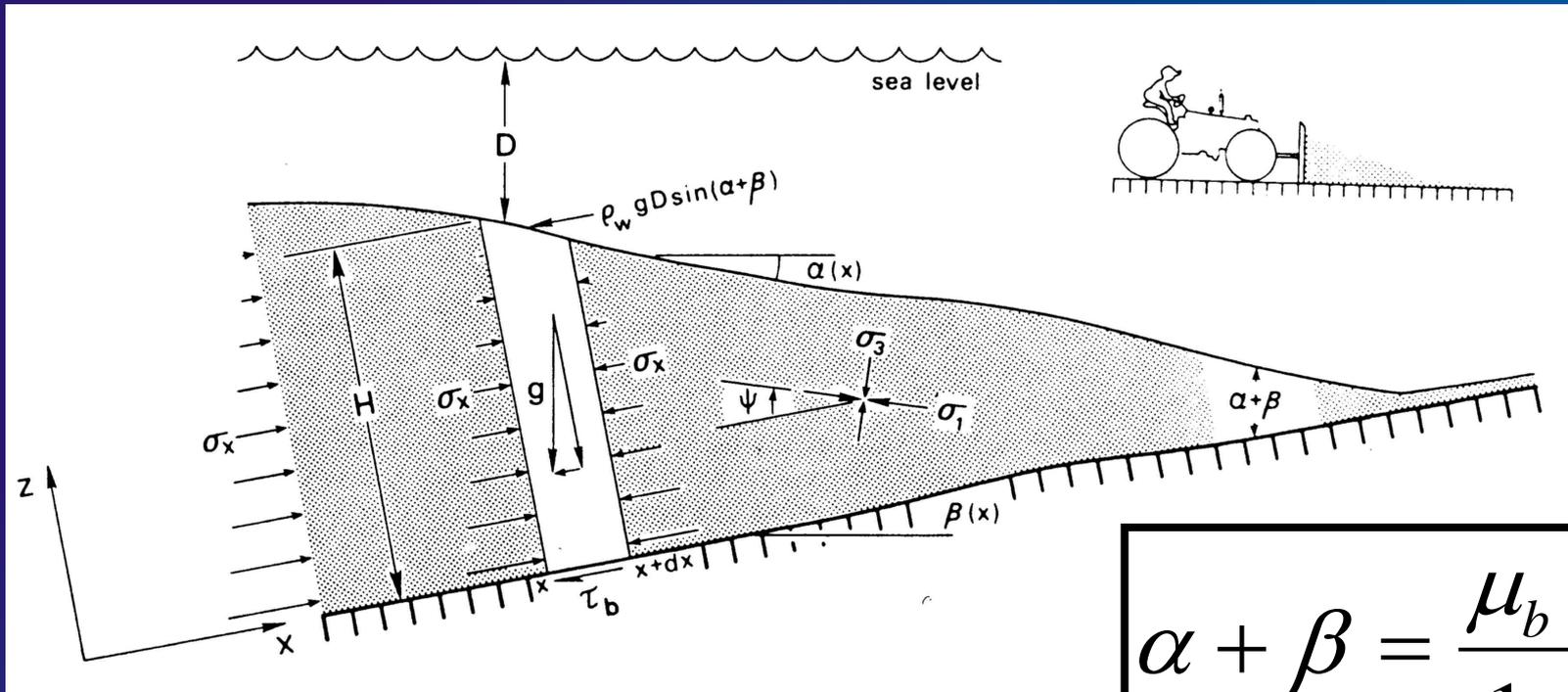
**Internal thickening until critical angle  $\alpha$  is reached**



1. Basal sliding without internal thickening, then
2. New snow is incorporated in the wedge,  $\alpha$  is lowered, then
3. The wedge will deform internally until  $\alpha$  is reached again, and so on



# Bilan des forces du prisme à l'équilibre



$$\alpha + \beta = \frac{\mu_b + \beta}{1 + K}$$

$K$  fonction de  $\phi$  et  $\phi_b$

$$\rho g H \beta + \rho_w g D (\alpha + \beta) + \tau_b + \frac{d}{dx} \int_0^H \sigma_x dz = 0$$

Poids de la colonne sédimentaire (pression lithostatique)

Poids de la colonne d'eau (pression de confinement)

Résistance au glissement (friction basale)

Somme des forces de poussée agissant sur les 2 côtés de la colonne en  $x$  et  $x + dx$

# Conditions de fracturation et état critique

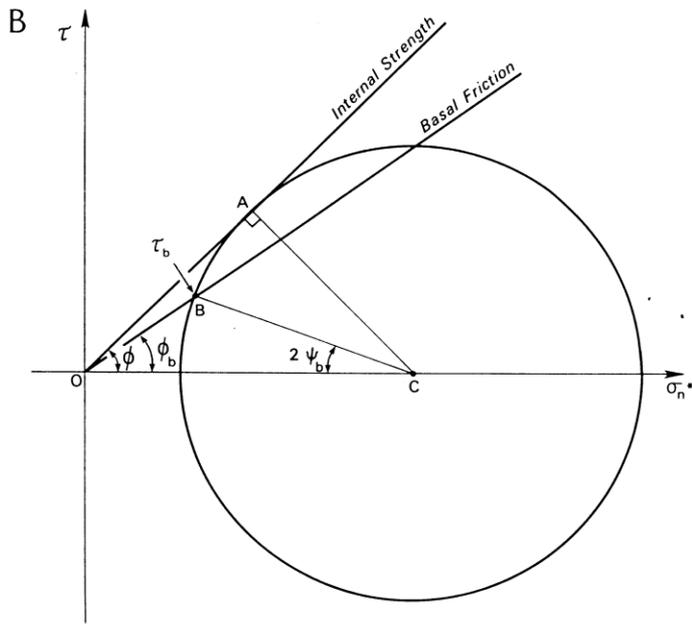
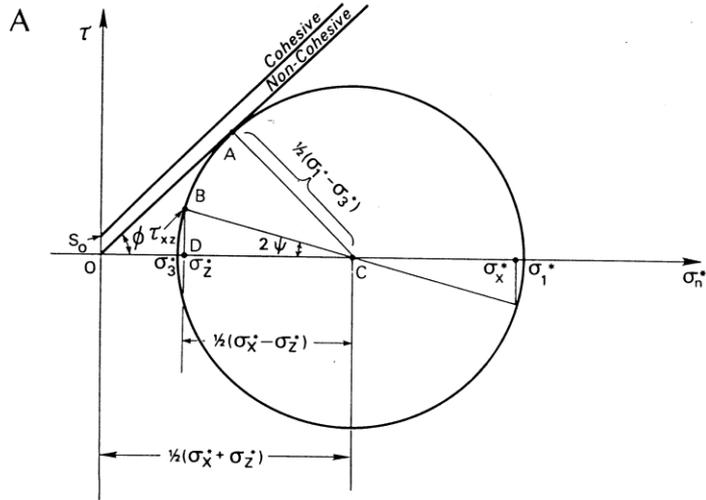
## Dans le prisme

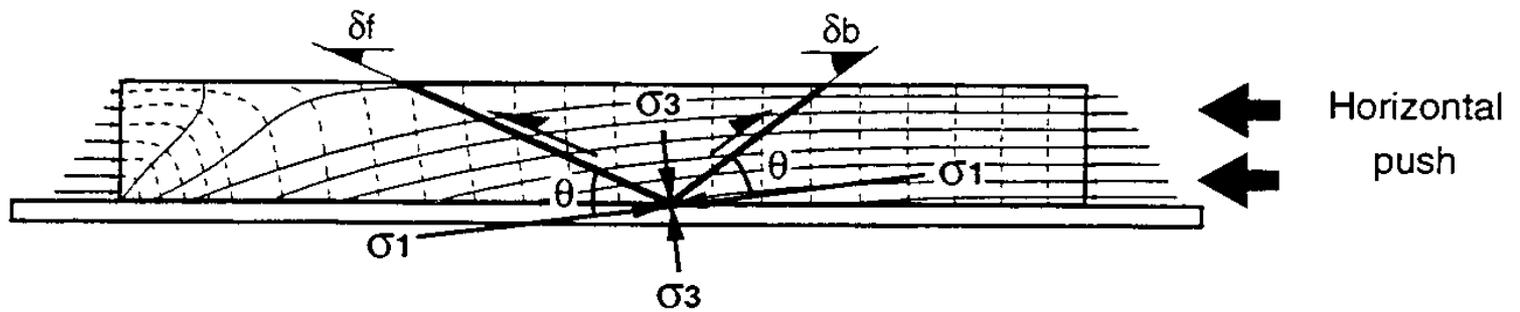
➔ **Critère de néorupture (Mohr-Coulomb)**

Le prisme est à l'état critique lorsque le cercle tangente la droite de néorupture

## Base du prisme

➔ **Critère de friction**





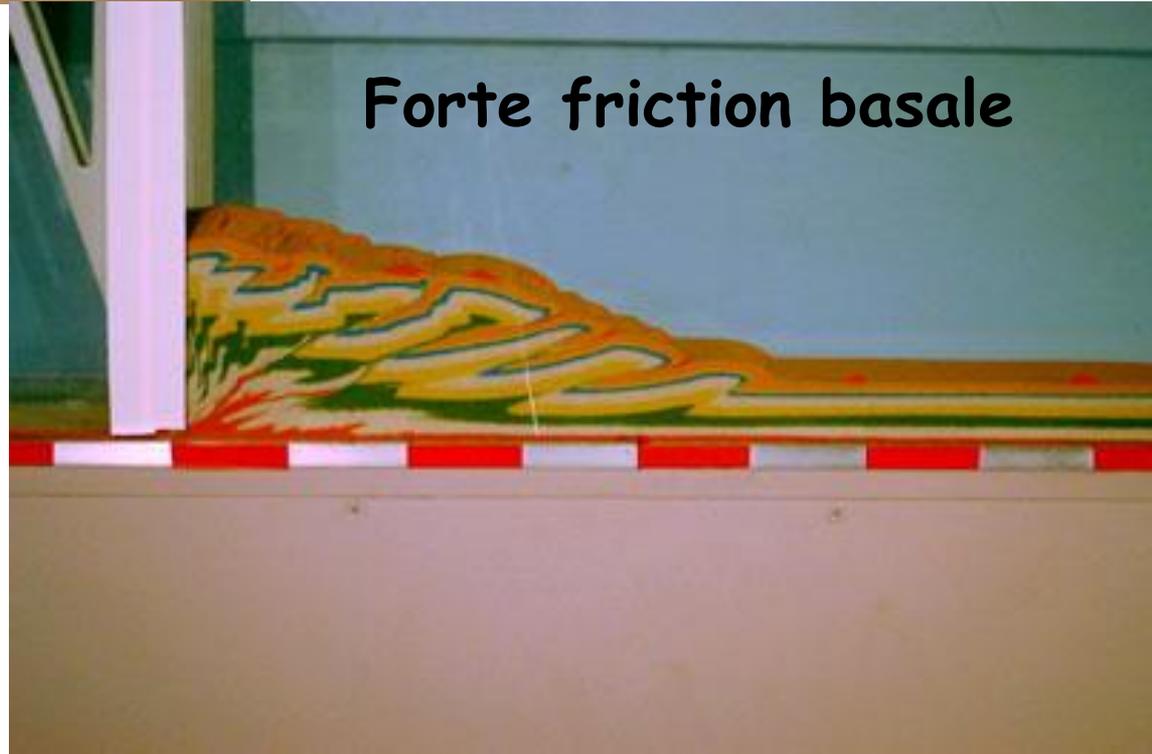
$$\text{tg } 2\theta = 2 \cdot \tau_b / (\sigma_h - \sigma_v)$$



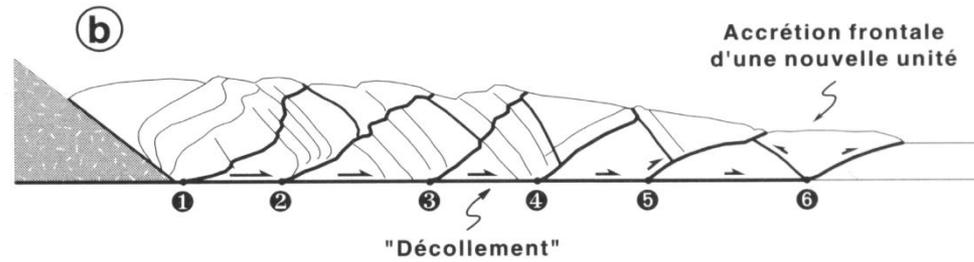
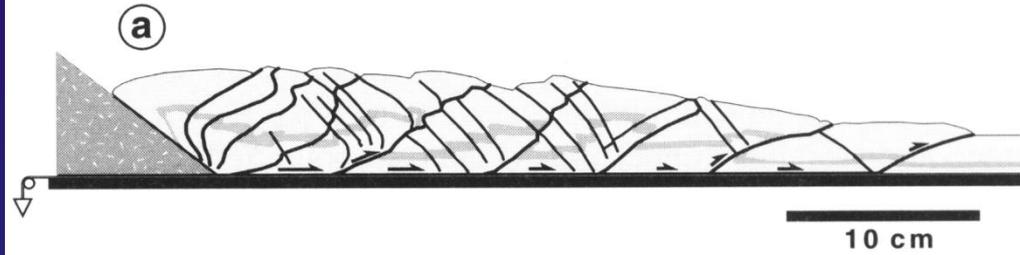
Faible friction basale



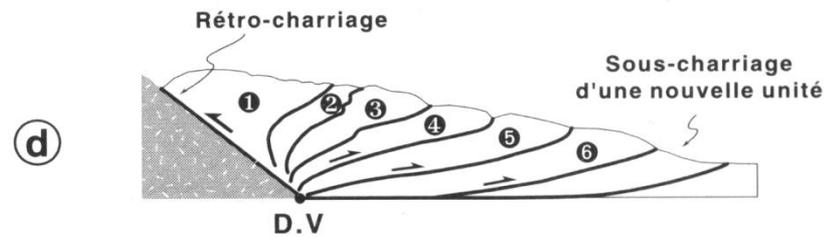
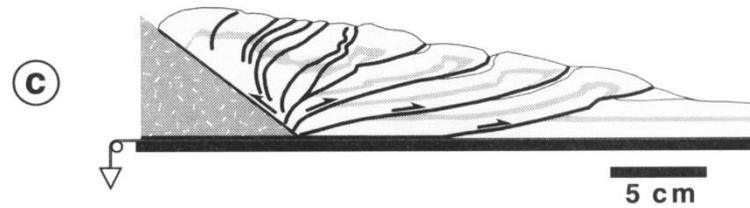
Forte friction basale



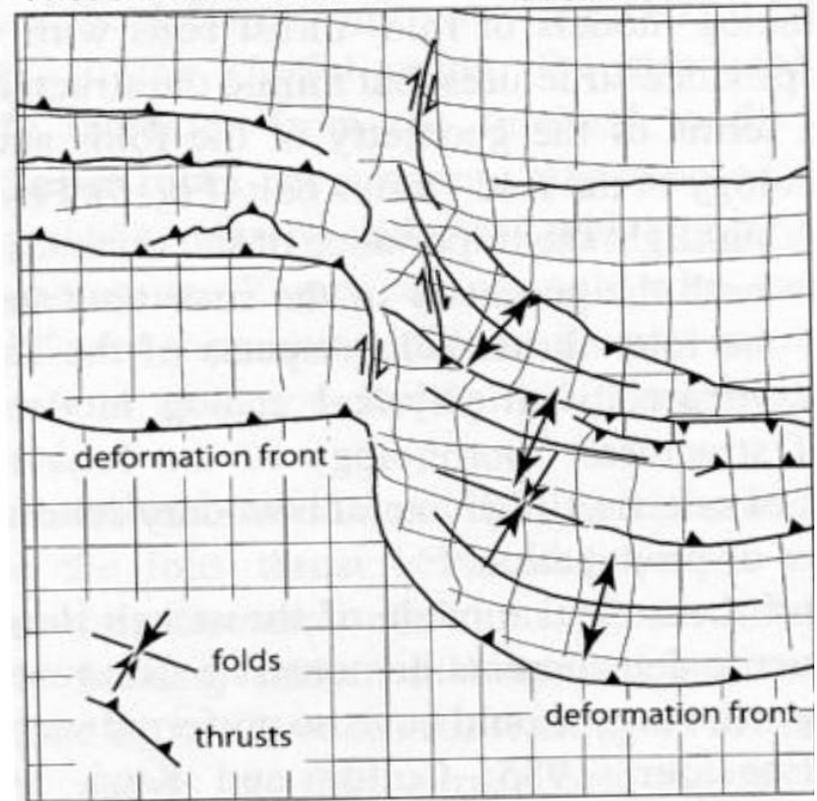
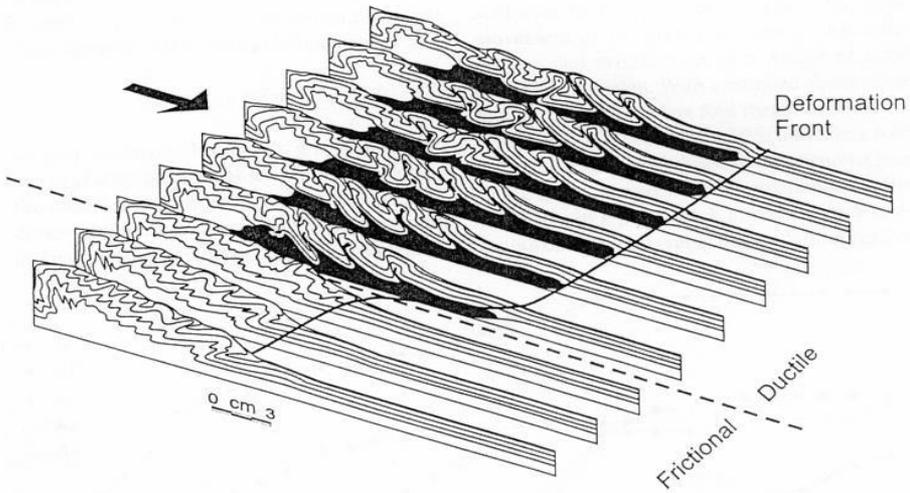
## FAIBLE FRICTION BASALE



## FORTE FRICTION BASALE



## Frictional decollement    Ductile decollement



(Cotton and Koyi, 2000)



| B | A

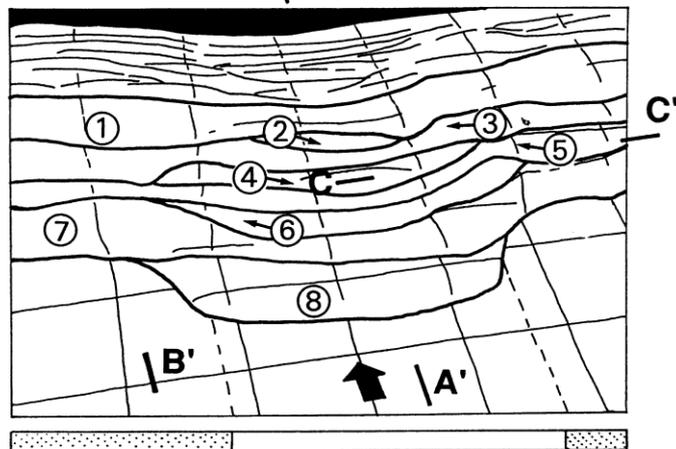
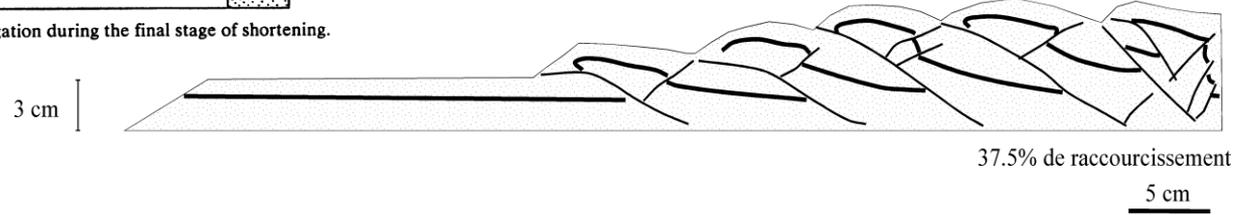
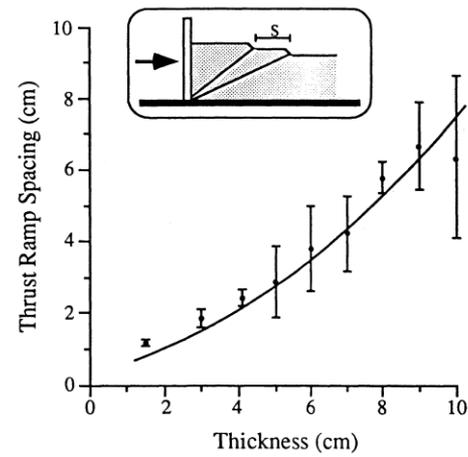
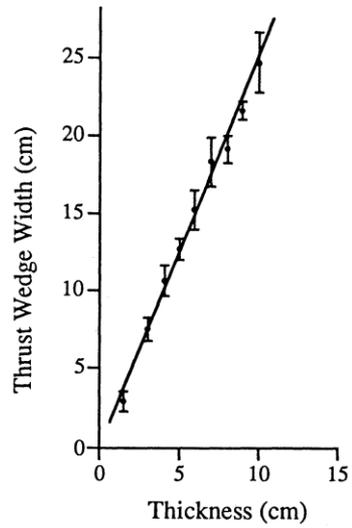


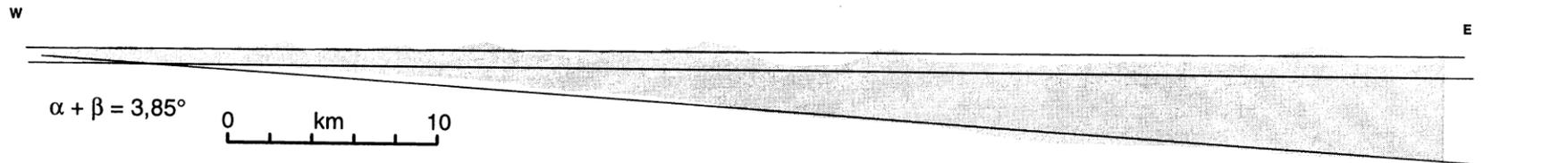
Fig. 12. The kinematics of thrust propagation during the final stage of shortening.



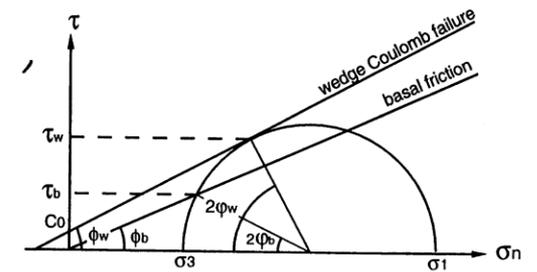
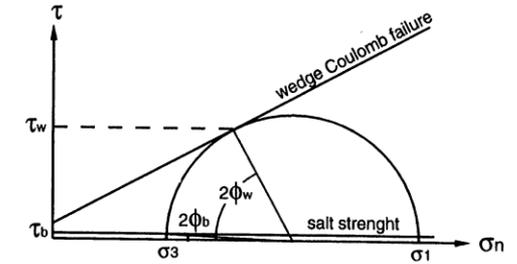
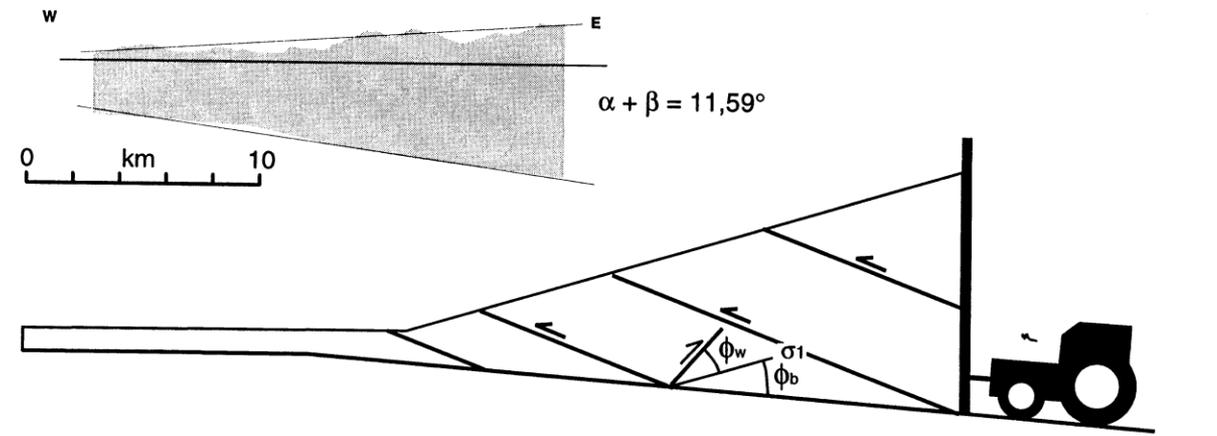
# Interprétation Jura (ou Vercors)/Chartreuse en termes de prisme critique (rôle de la friction basale)

(a) Jura fold-and-thrust belt and Molasse Basin: / Vercors

(Philippe, 1995)

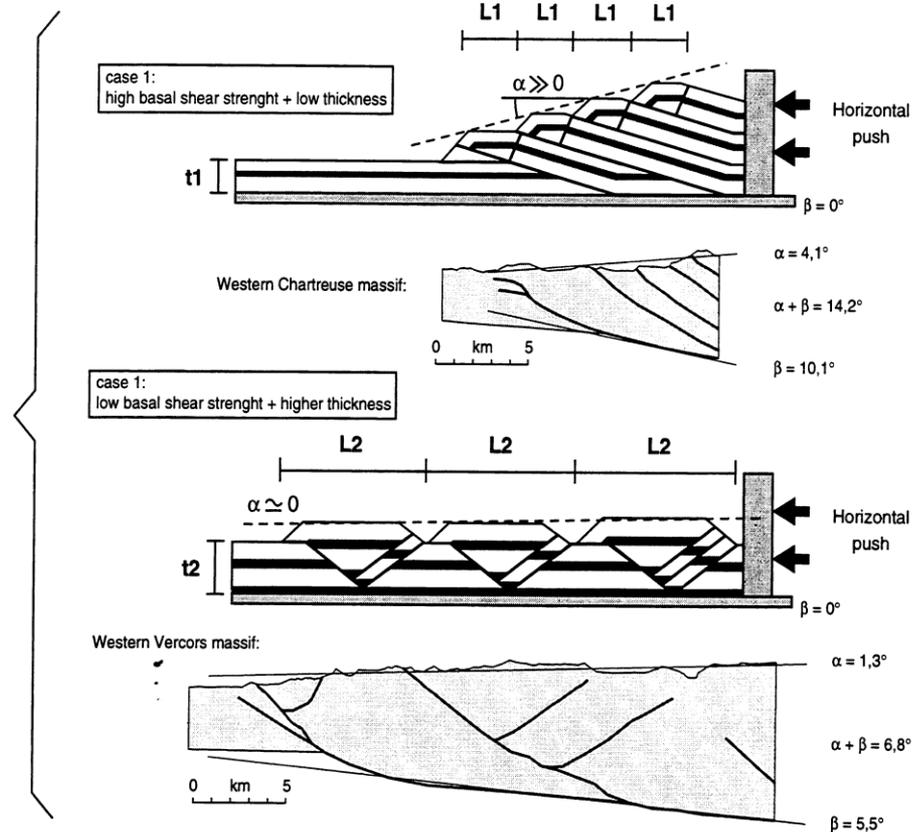


(b) Chartreuse fold-and-thrust belt:



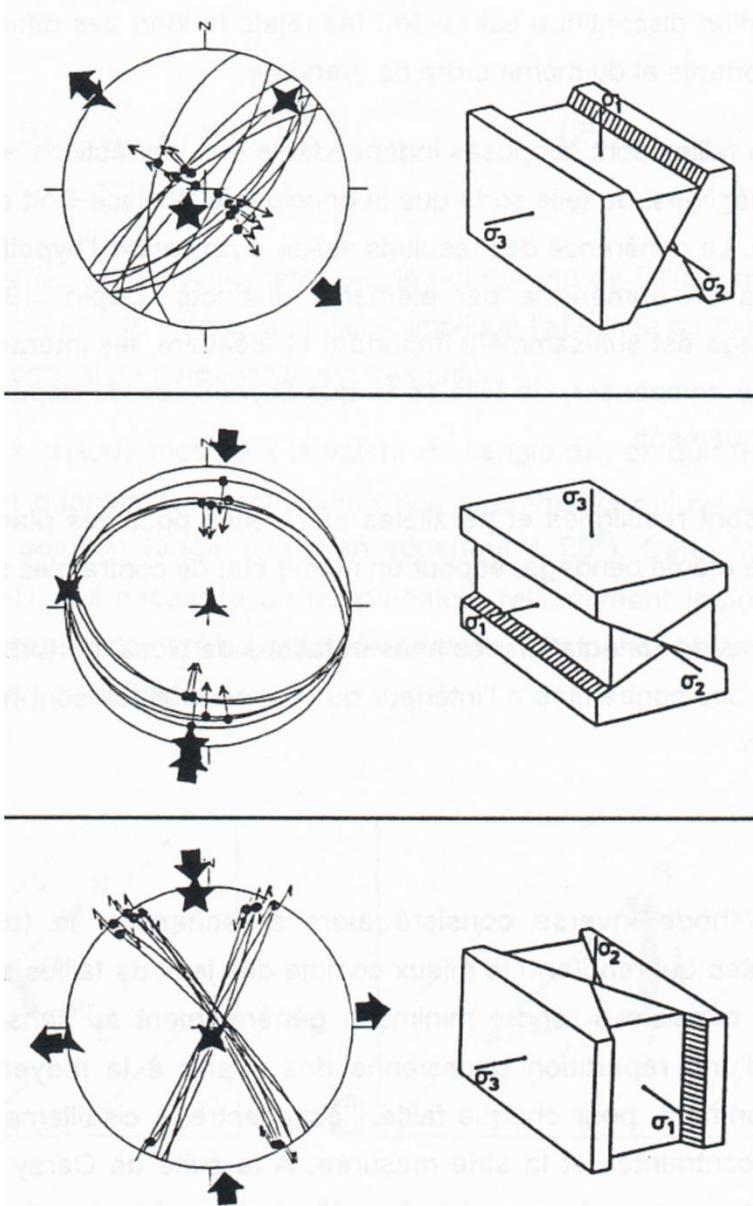
# Interprétation Chartreuse/Vercors en termes de prisme critique

(rôle de la friction  
basale et de l'épaisseur  
initiale)



(Philippe, 1995)

# **Histoire tectonique du Vercors**



Géométrie des systèmes conjugués (failles normales, inverses et décrochantes) en projection stéréographique et en blocs-diagrammes.

**1. Compatibilité mécanique des structures**

**2. Datation « sédimentaire » des structures**

**Age des terrains affectés**

**Tectonique syn-sédimentaire**

**3. Datation relative des structures**

**Recoupement de structures**

**Superposition de stries**

**Datation par rapport au plissement**

**De la chronologie des structures à la chronologie des épisodes tectoniques**

**Une première phase de serrage N-S  
Crétacé sup ? Eocène ?**

*Pics stylolitiques  
~horizontaux N-S,  
Urgonien,  
Col de la Machine*

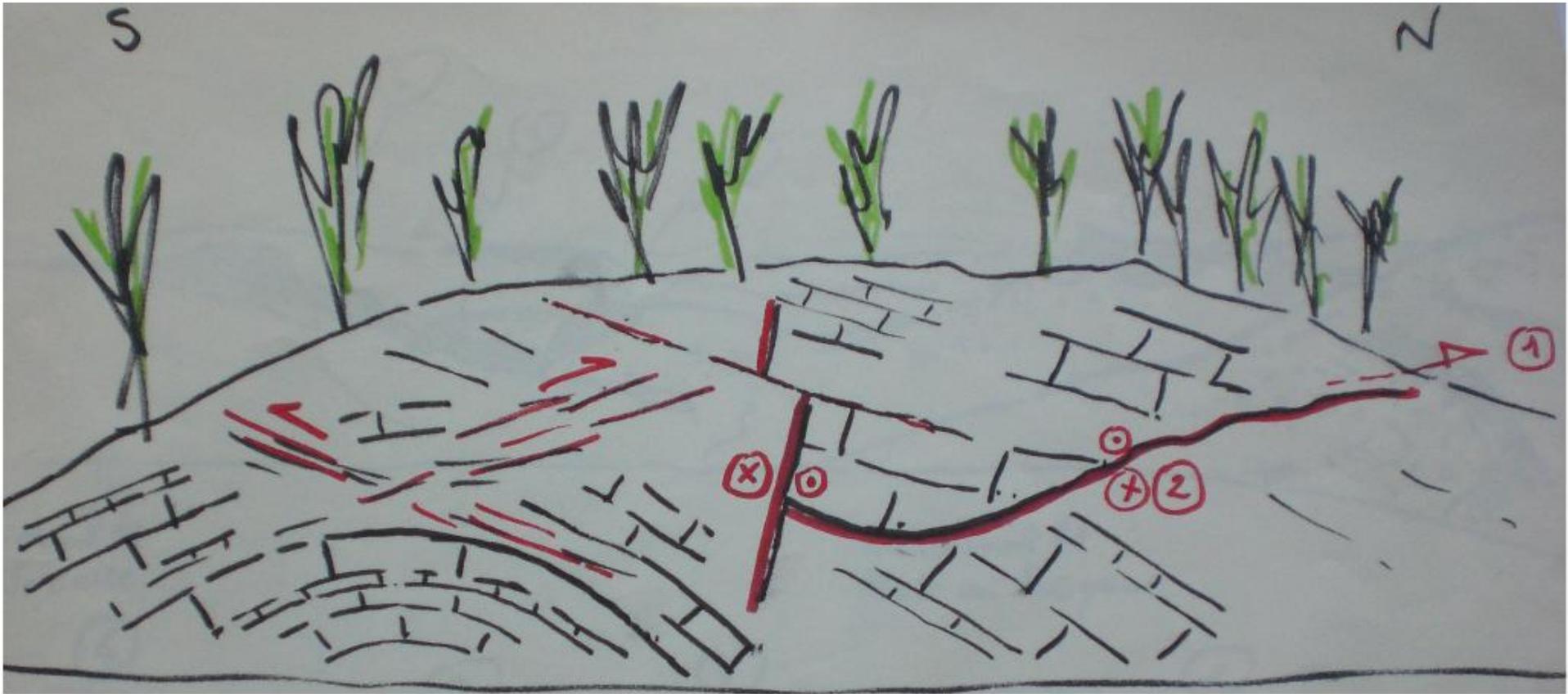


*Pics stylolitiques  
~horizontaux N-S,  
Urgonien,  
Col de la Machine*





*« Le tiroir » : pli d'axe E-W  
étêté par rétrochevauchement  
vers l'Est, Urgonien,  
Col de la Machine*



*Pli d'axe E-W repris par plissement d'axe N-S, Balme de Rencurel*



**Après l'extension oligocène,  
la phase régionale miocène de serrage alpin**

*Microtectonique,  
Col de la Bataille,  
Hauterivien*



*Microtectonique, Col de la Bataille, Hauterivien*



*Microtectonique, Col de la Bataille, Hauterivien*



*Microtectonique, Col de la Bataille, Hauterivien*



*Microtectonique, Col de la Bataille, Hauterivien*



*Microtectonique, plan strié*

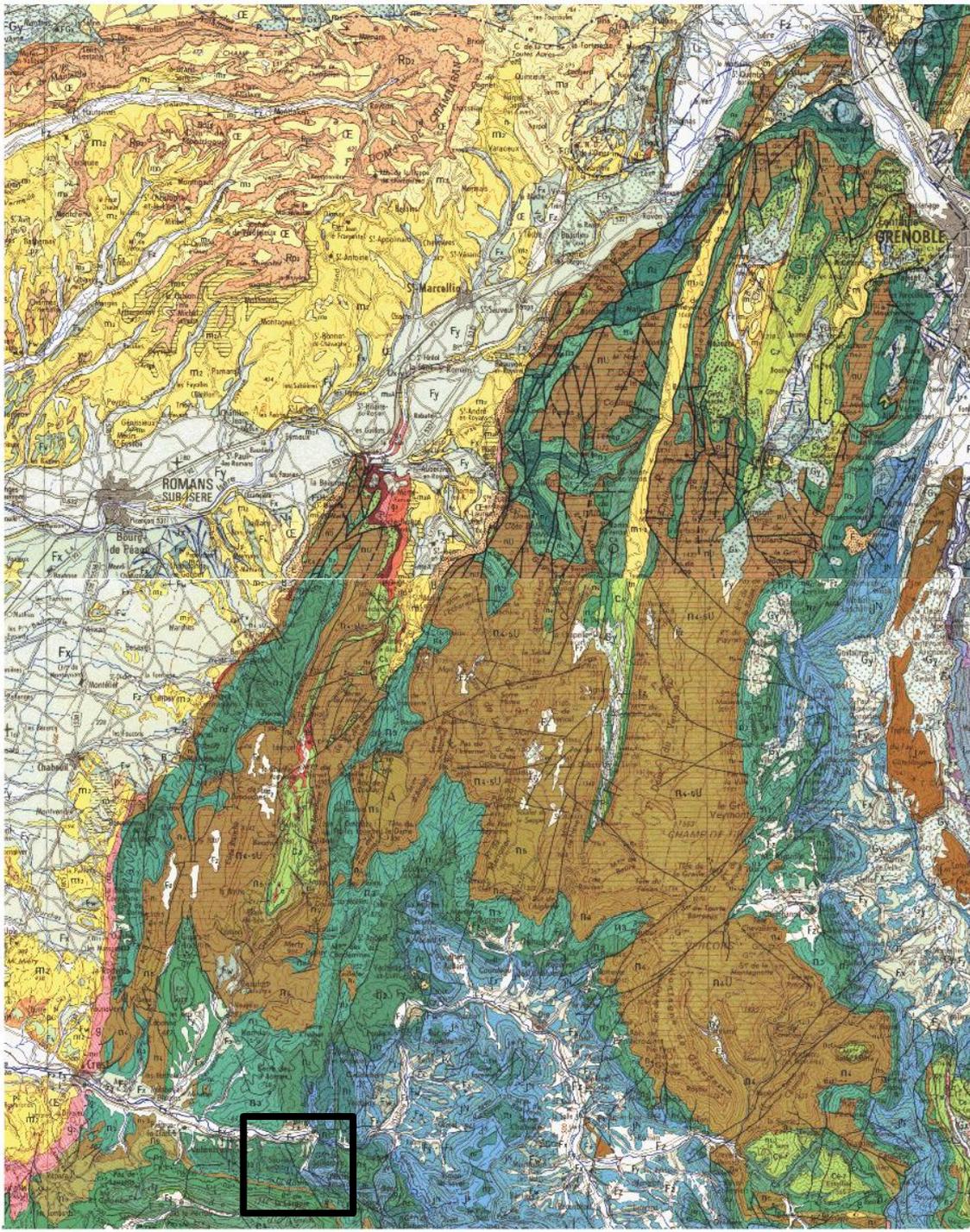


*Microtectonique, plan strié*



*Microtectonique, plan strié*





*Panorama, Saillans*



*Microtectonique, Saillans*



*Microtectonique, Saillans*



*Microtectonique, Saillans*



*Microtectonique, Saillans*



*Microtectonique, Saillans*

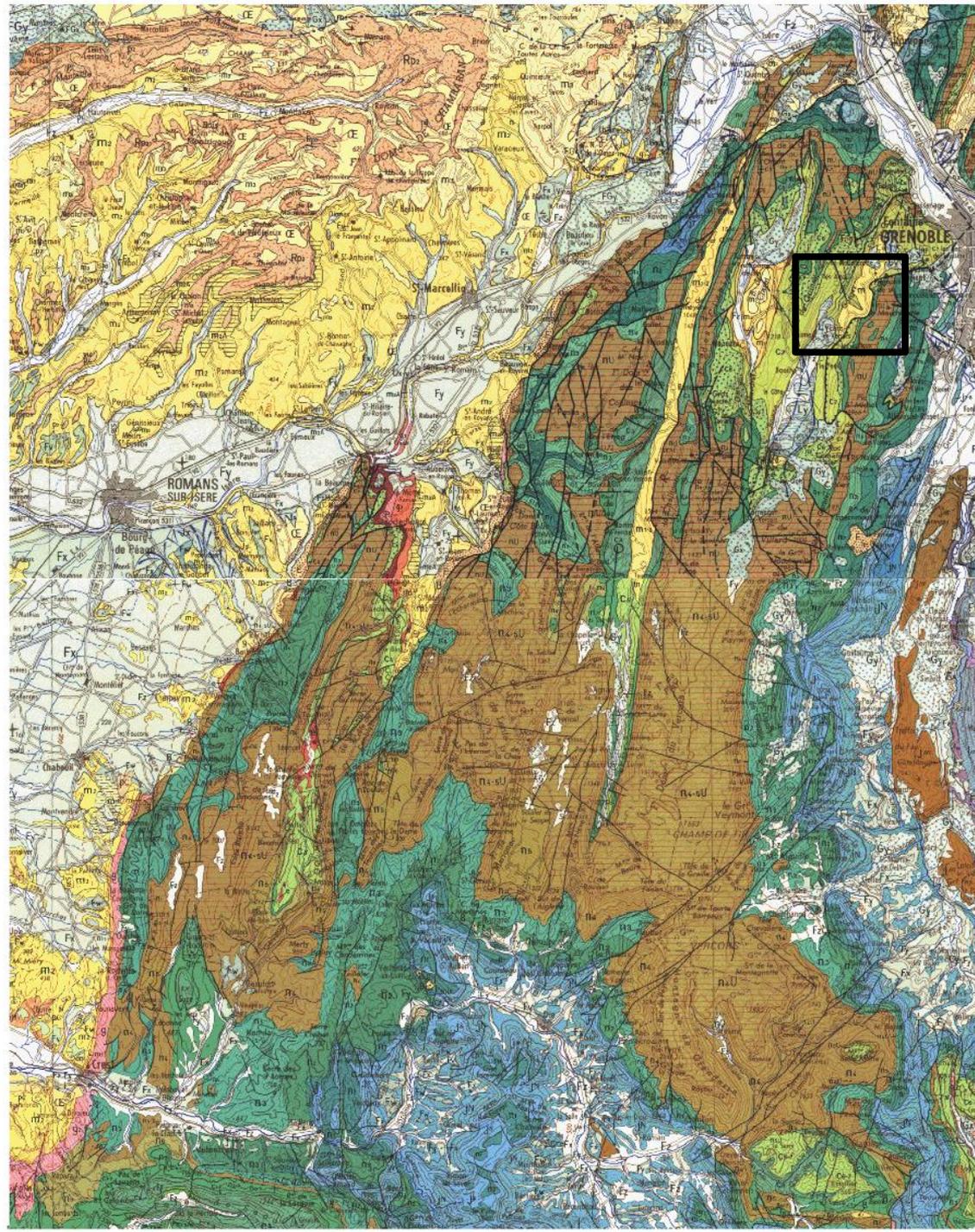


*Microtectonique, Saillans*



*Microtectonique, Saillans*







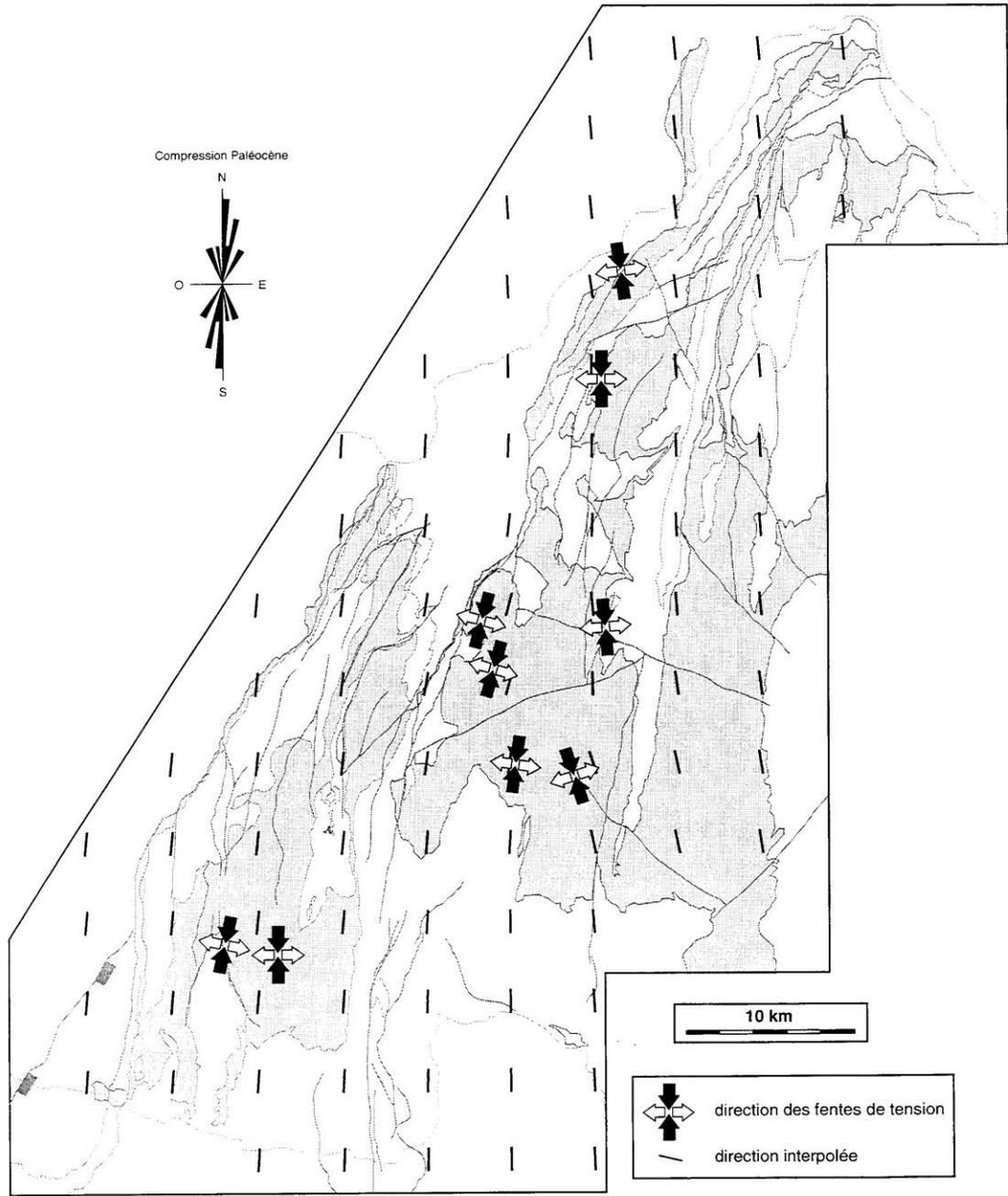
*Galets cisailés, Langhien,  
Croix de Lichou*

*Galets cisailés, Langhien, Croix de Lichou*

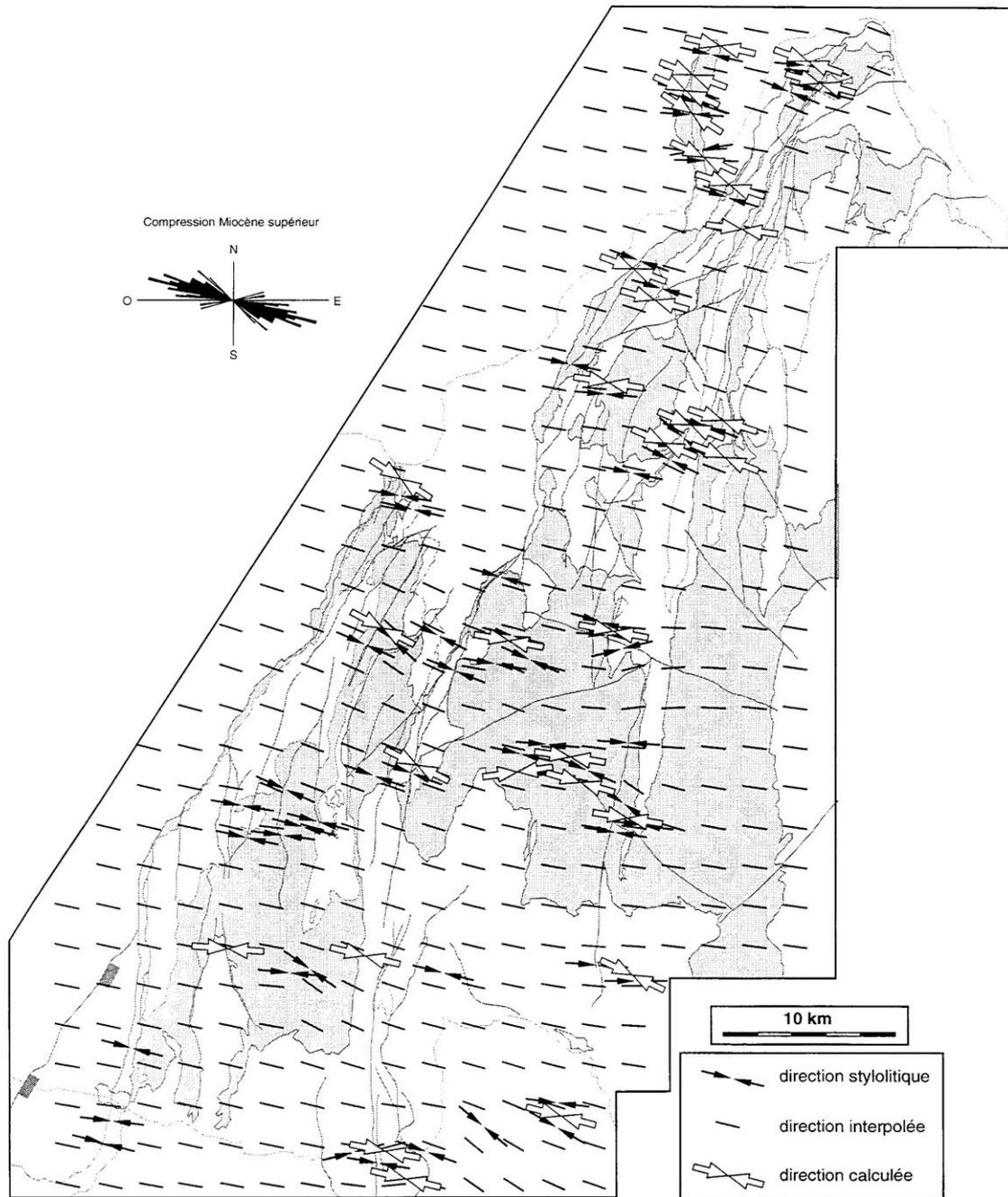


*Galets cisailés, Langhien, Croix de Lichou*

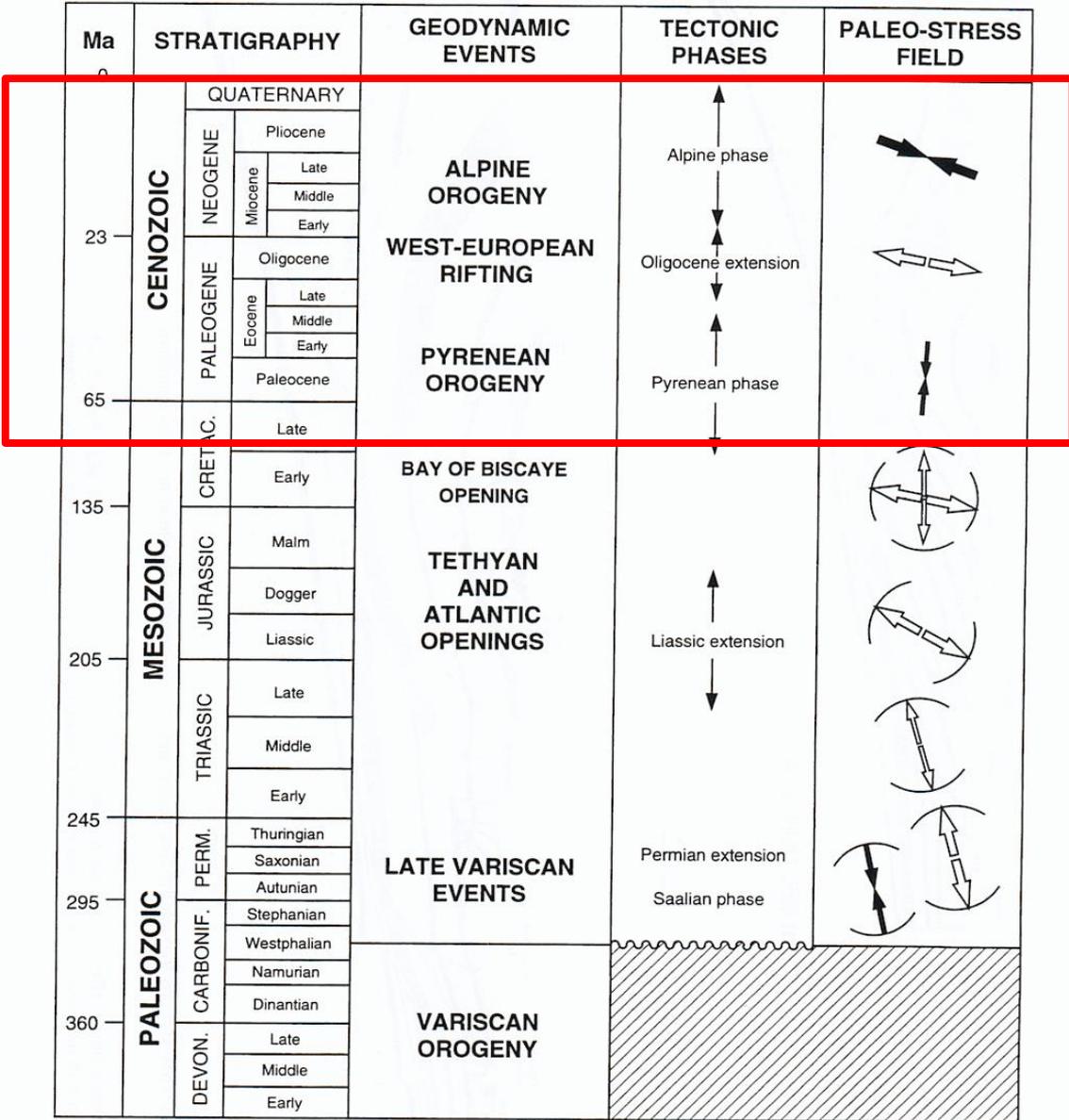




(Philippe, 1995)



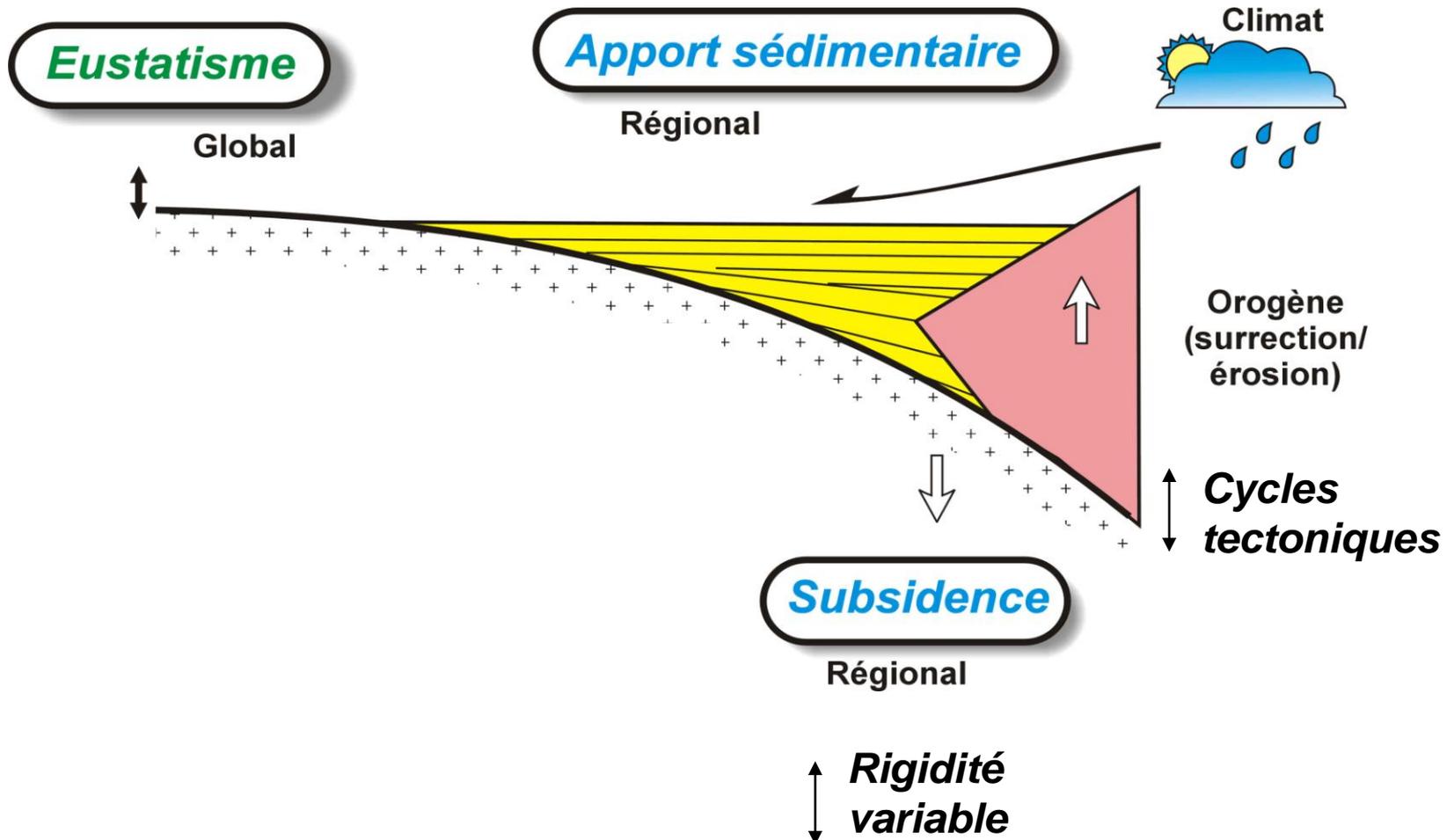
(Philippe, 1995)



(Philippe, 1995)

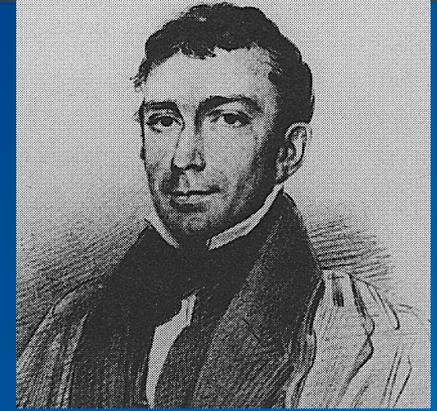
# **Le bassin molassique d'avant-pays**

**L'enregistrement sédimentaire est le résultat de l'interaction de facteurs tectoniques et eustatiques**



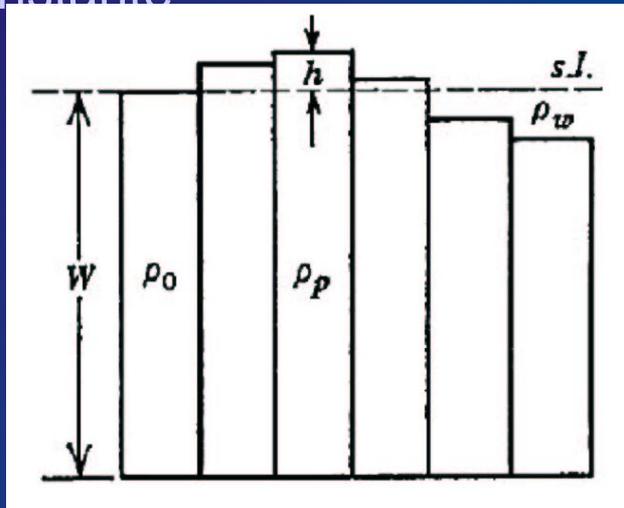
**Rappels sur l'isostasie  
et la flexure lithosphérique**

# Isostasie



## Pratt (1854)

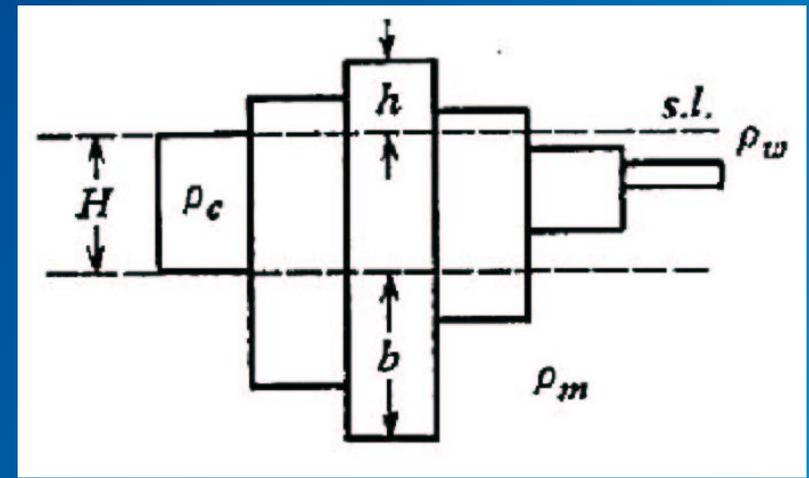
- $\rho$  diminue si  $h$  augmente
- profondeur de compensation constante



Exemple: dorsales océaniques

## Airy (1855)

- $\rho$  constant
- profondeur de compensation augmente si  $h$  augmente

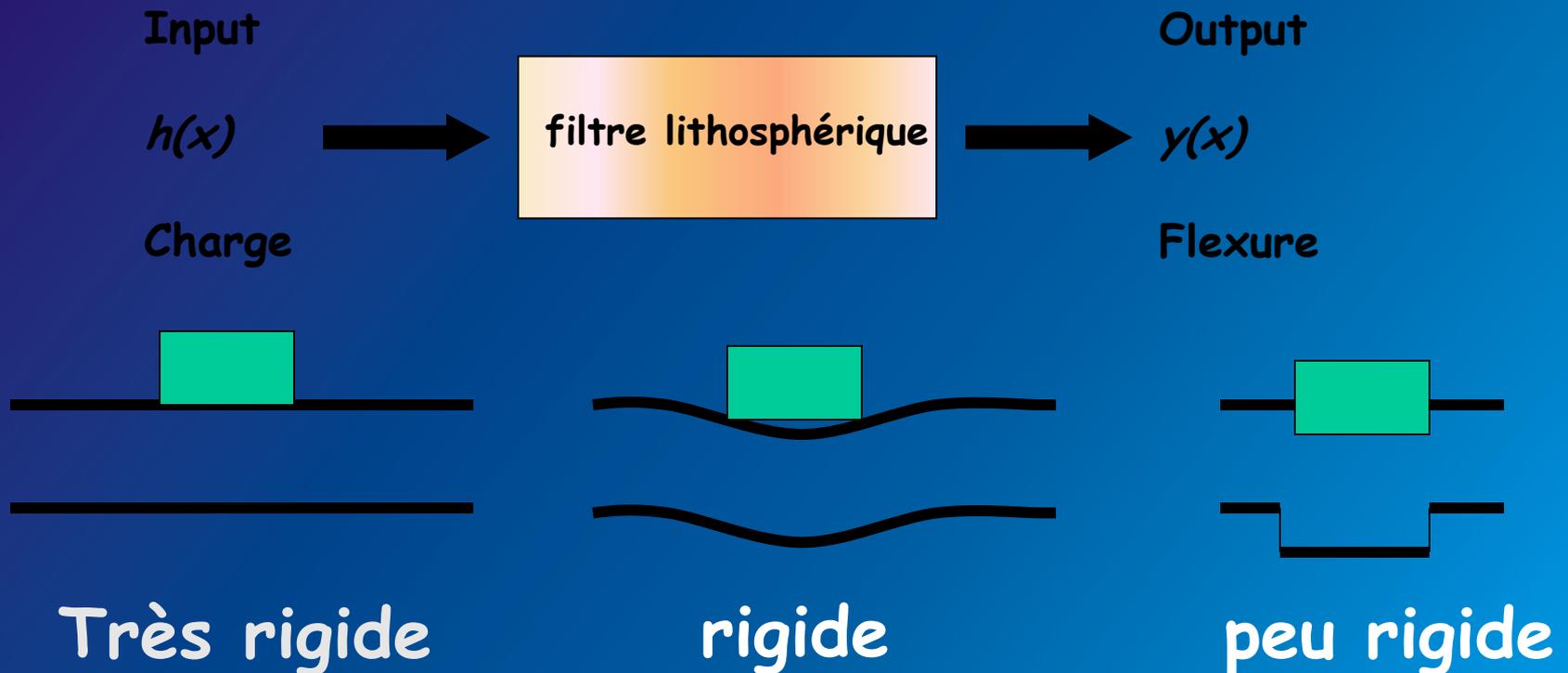


Exemple: Chaînes de montagnes

# Isostasie

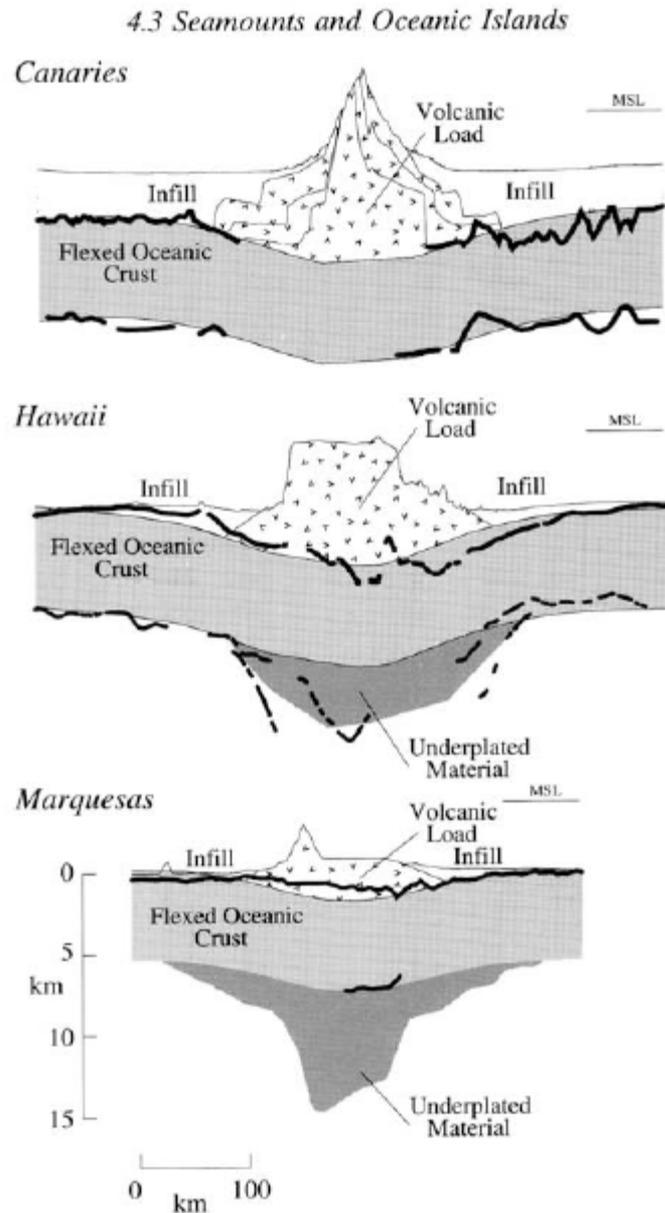
- Isostasie régionale

- Dépend de la rigidité de la lithosphère
- En étudiant le signal gravimétrique, on détermine le comportement mécanique de la lithosphère



# Plaque continue

Les « Seamounts »

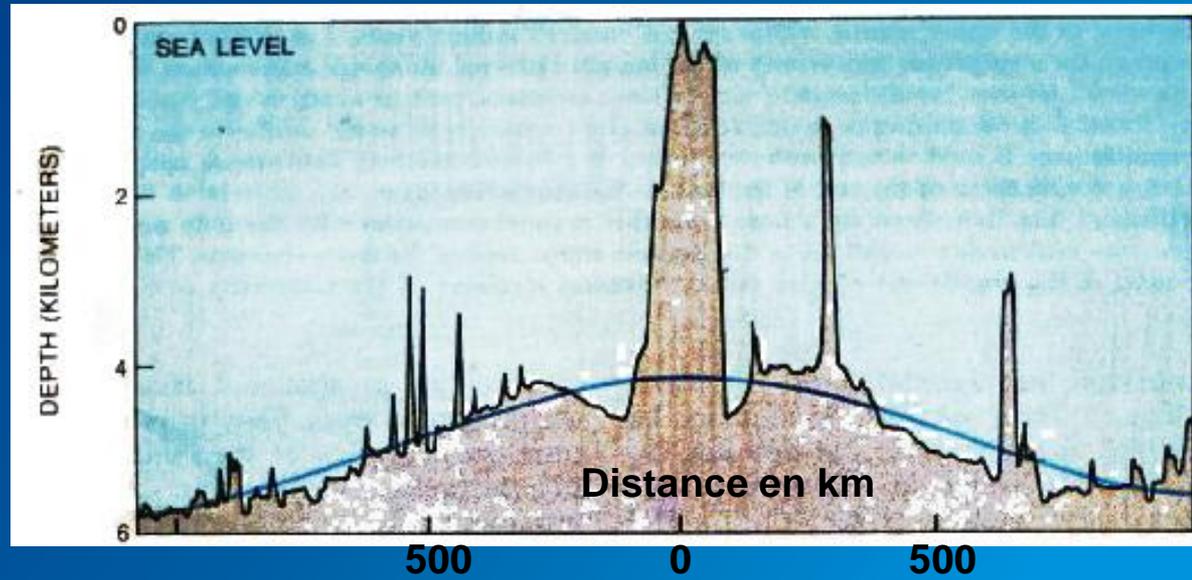


(D'après Watts)

Iles volcaniques

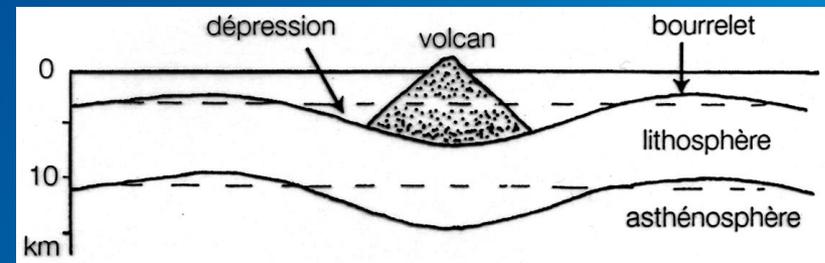
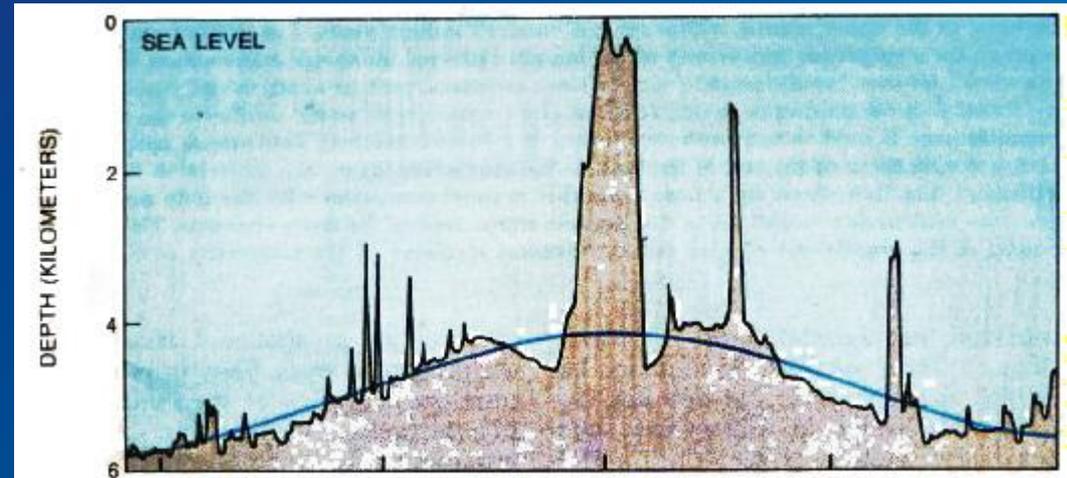
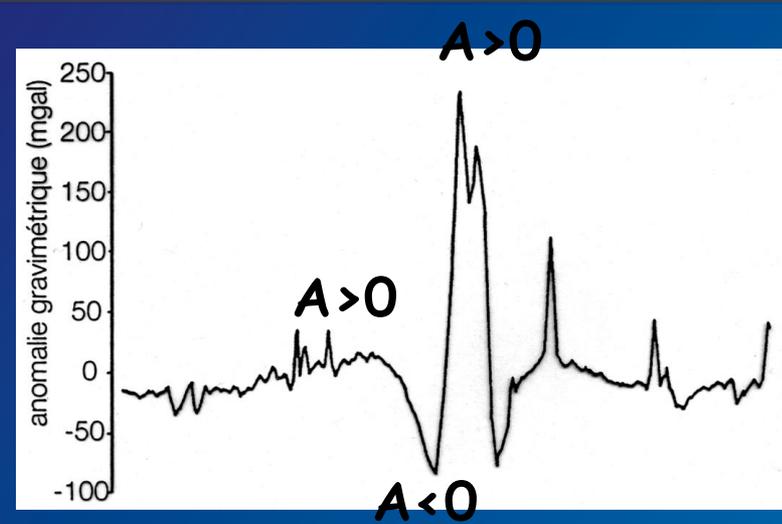


Flexure de la lithosphère  
Compensation régionale



$A > 0$  excès de masse

$A < 0$  défaut de masse

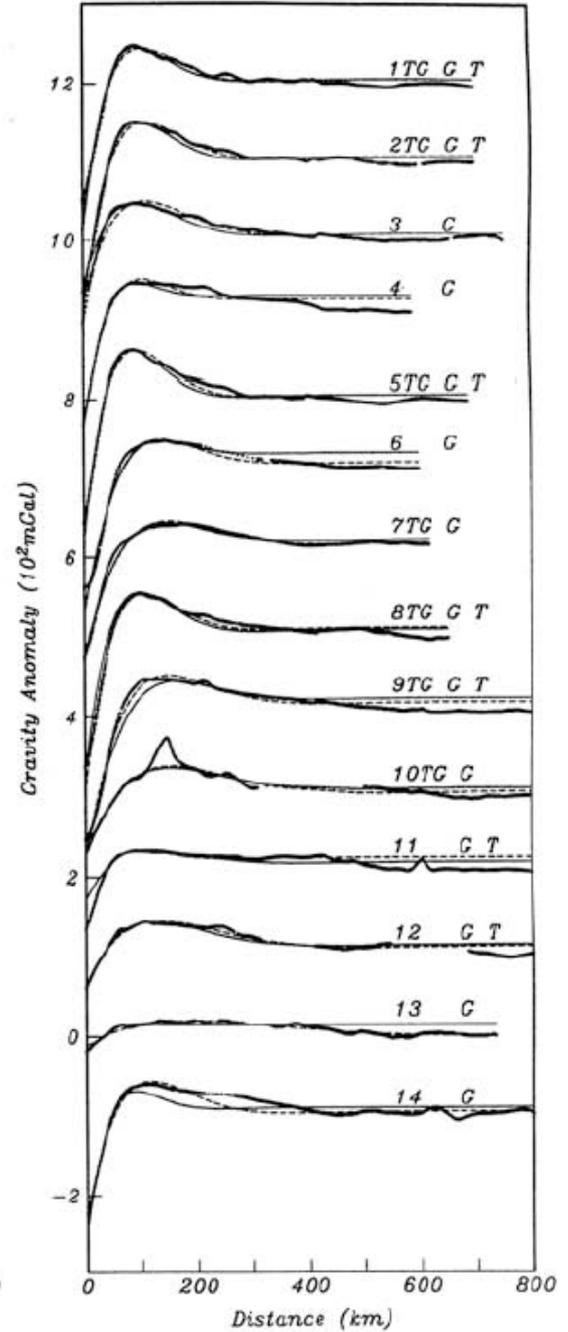
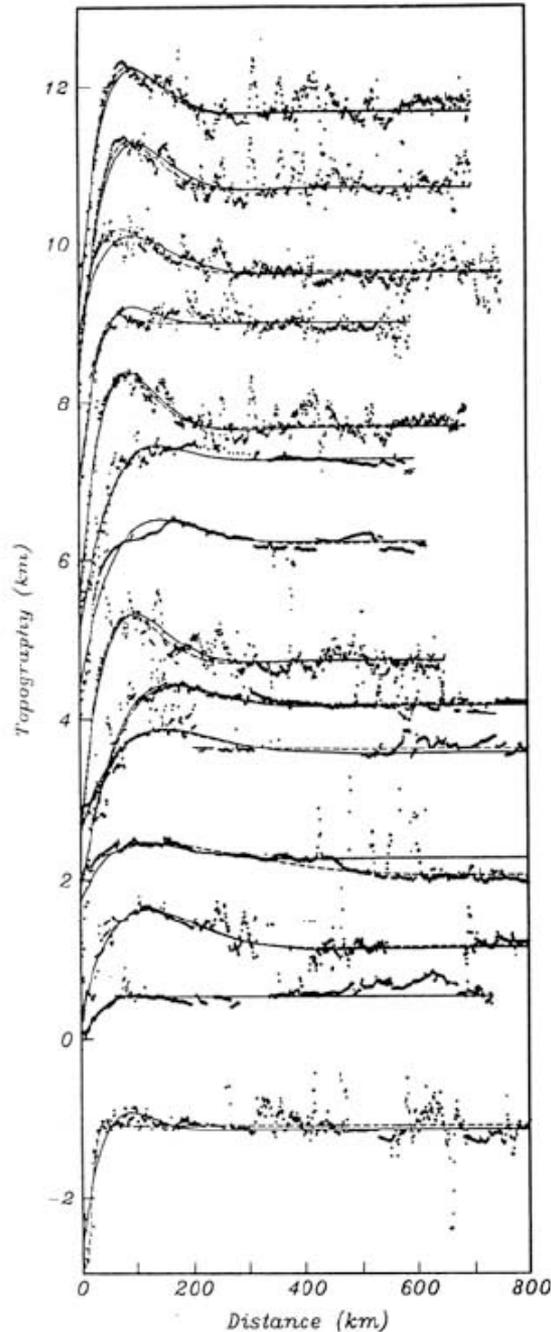


# Plaque cassée

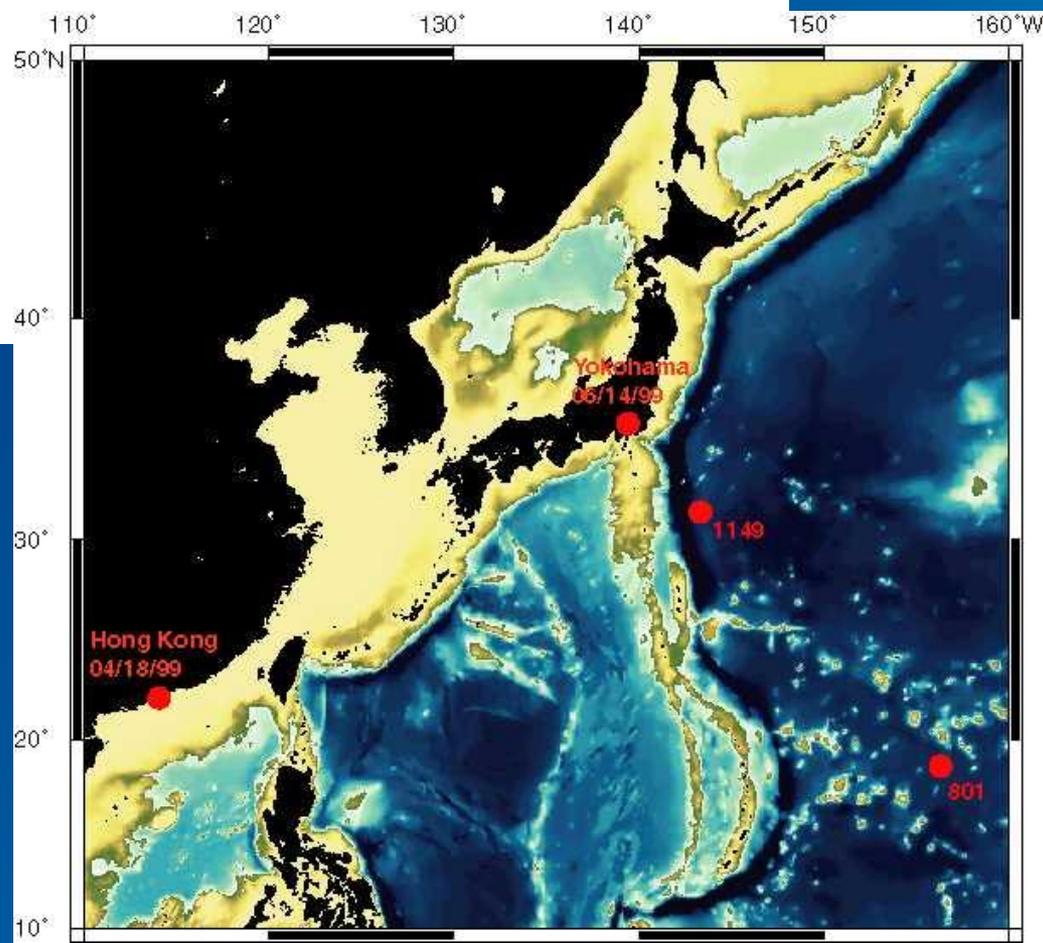
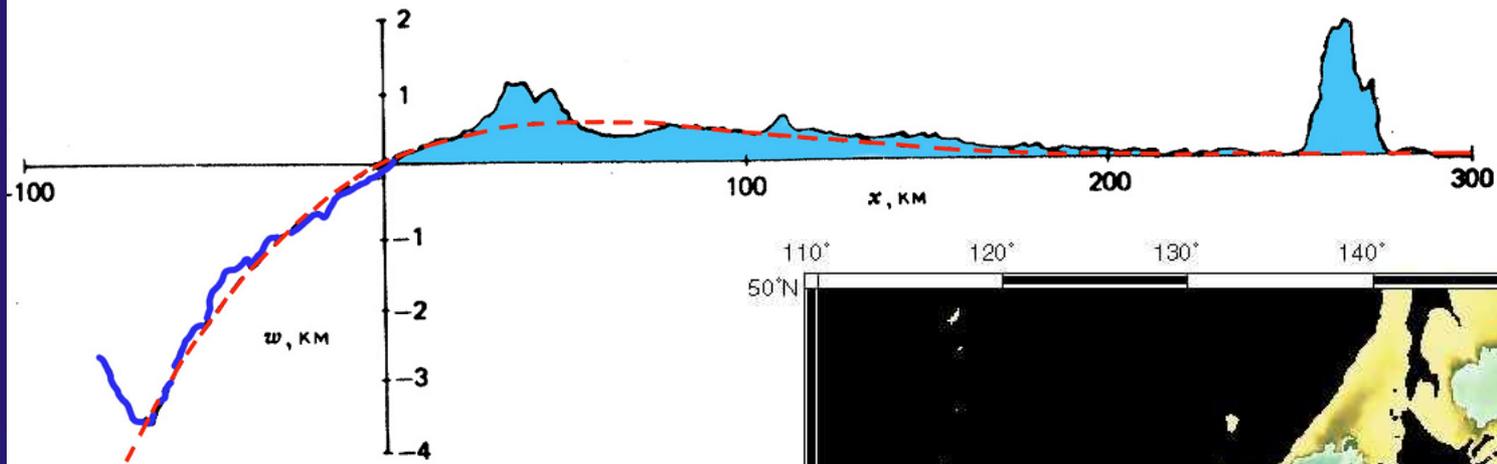
Les fosses  
« foredeeps »  
des zones  
de subduction

et les « forelands »  
des zones  
de collision

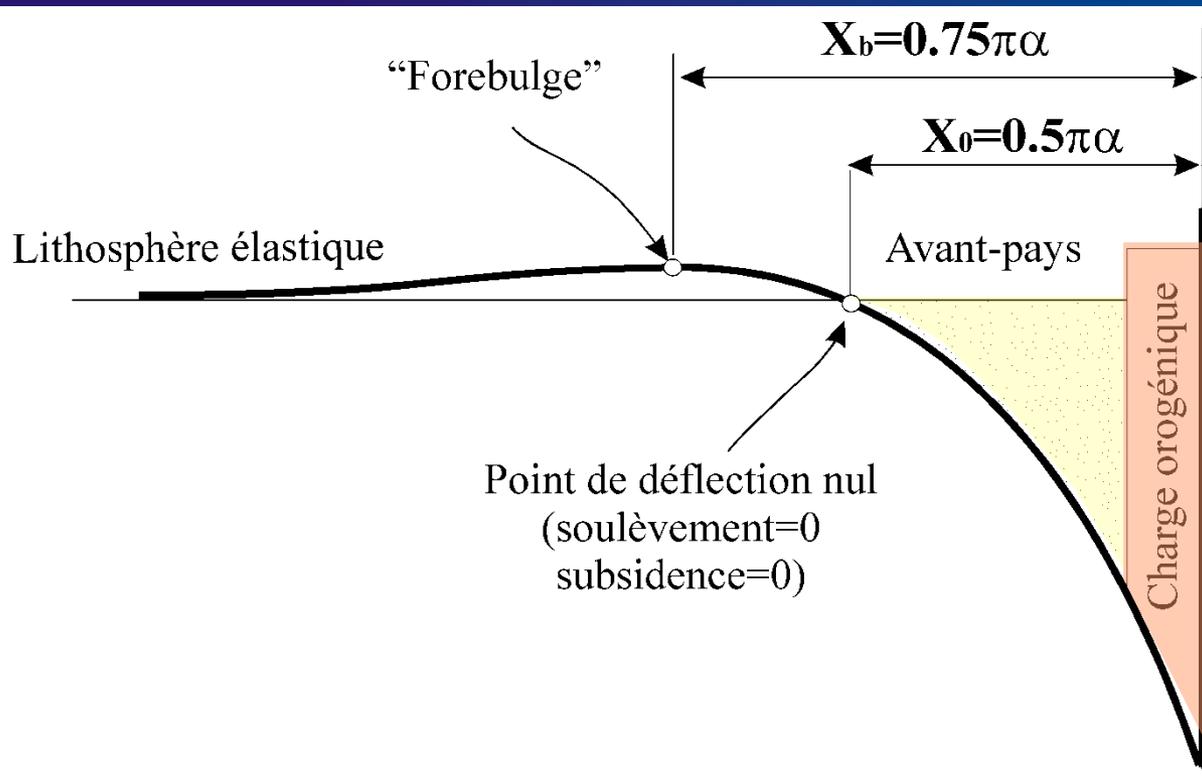
(D'après Watts)



# Mariana Trench



# Déflexion d'une lithosphère élastique (continentale ou océanique)



**Rigidité et épaisseur élastique équivalente d'une lithosphère**

**Paramètre flexural**

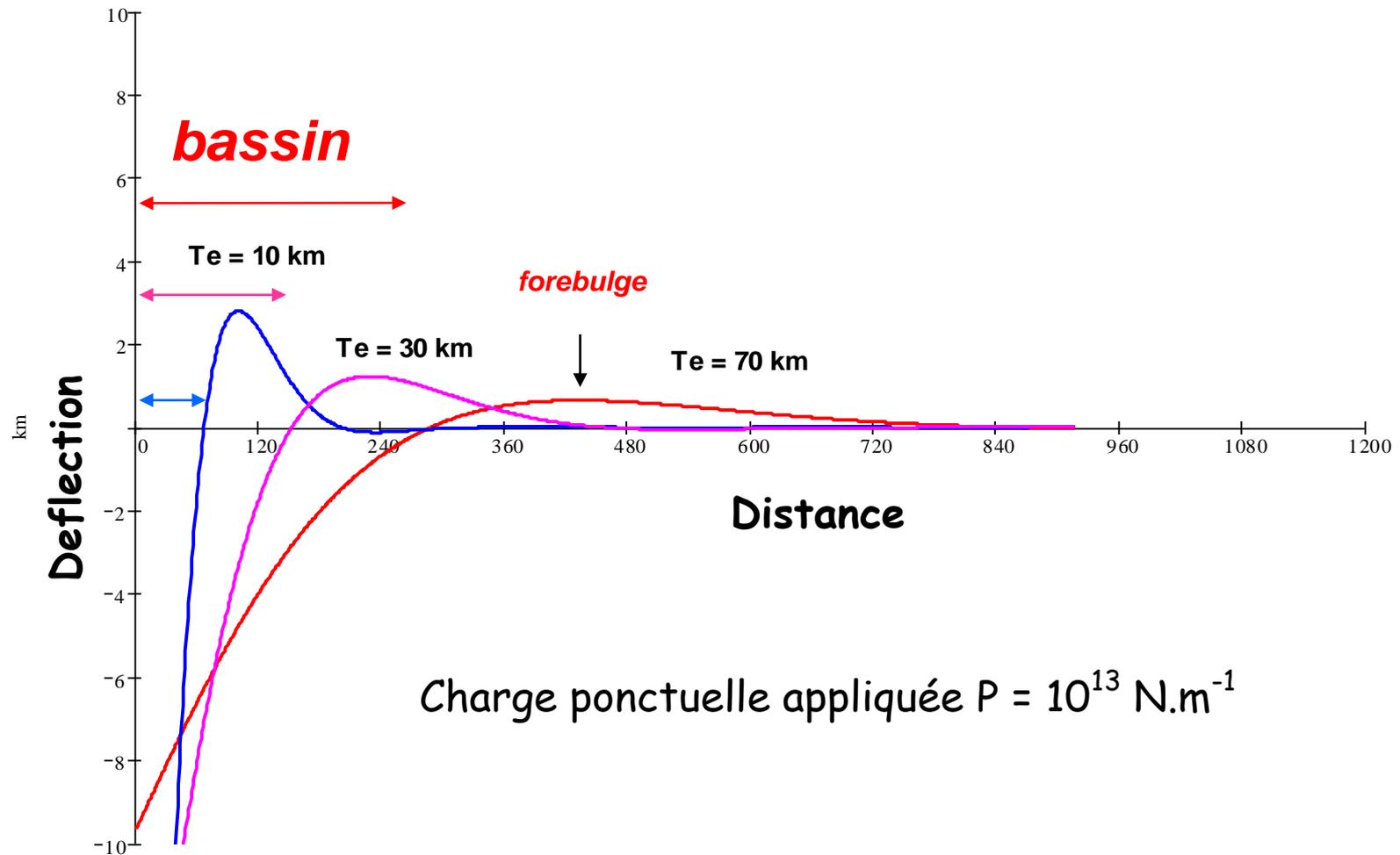
$$\alpha = \left( \frac{4D}{g(\rho_m - \rho_w / sed)} \right)^{1/4}$$

$$D = \frac{ET_e^3}{12(1-\nu^2)}$$

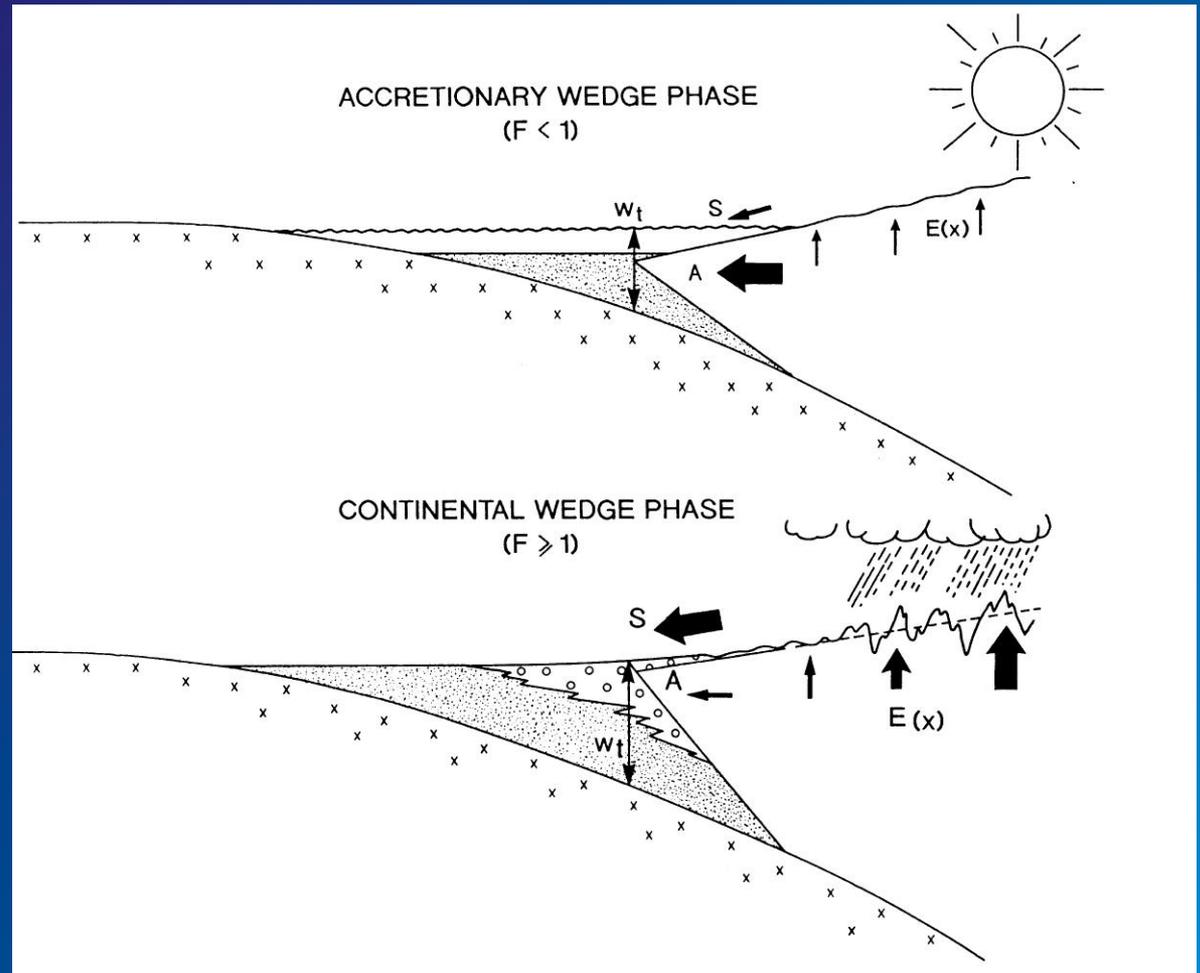
**$T_e$  (km)**  
 **$D$  (Nm)**

La subsidence est liée à la compensation isostatique régionale (flexurale) et non locale (Airy) de la surcharge tectonique et sédimentaire

# Plaque cassée



Bassin sous-alimenté  
stade « océanique »



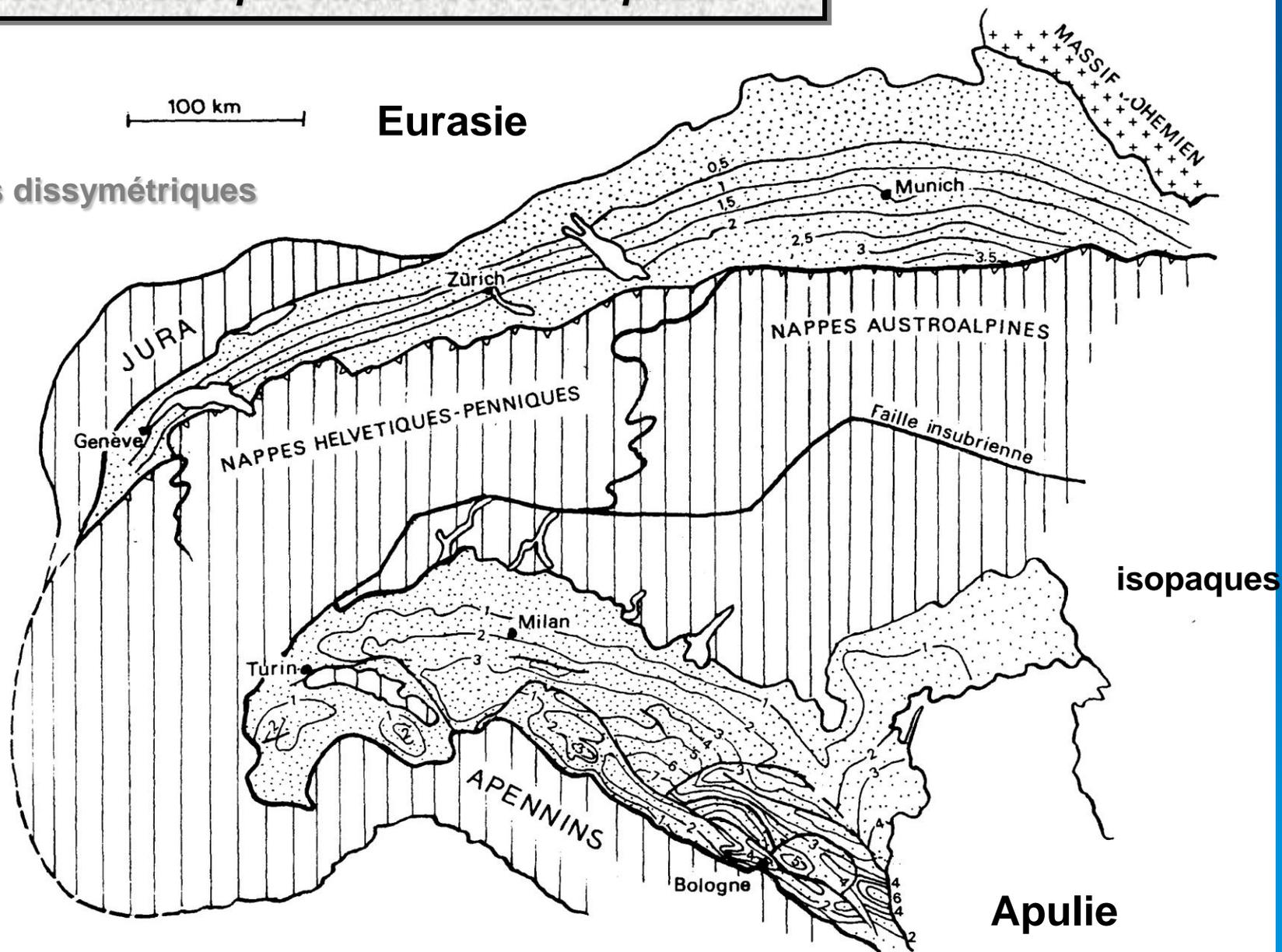
Bassin sur-alimenté  
stade « continental »

(d'après Sinclair)

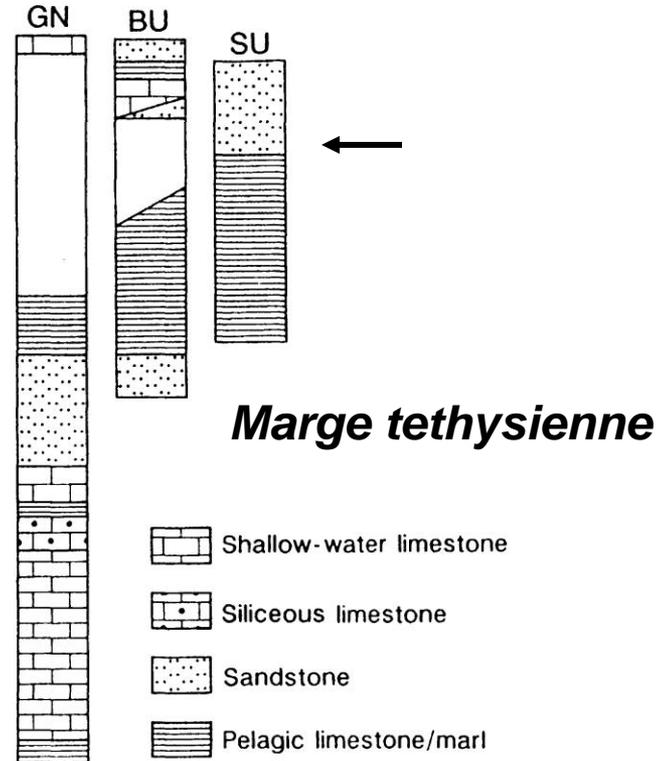
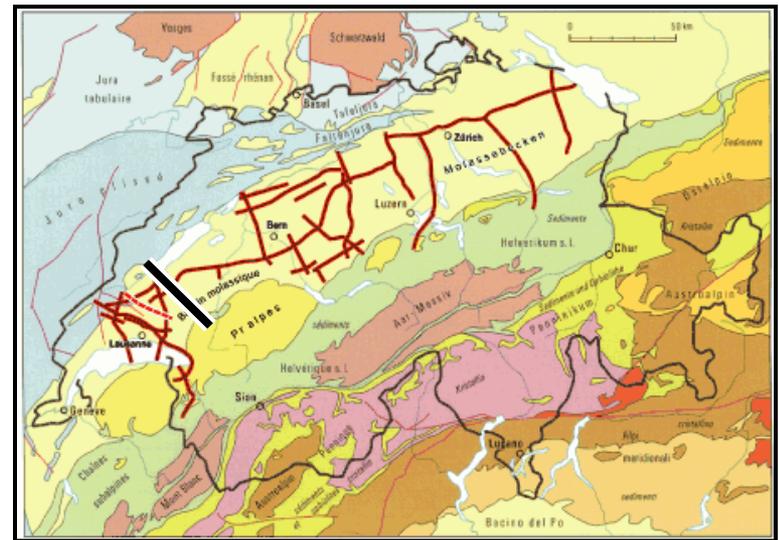
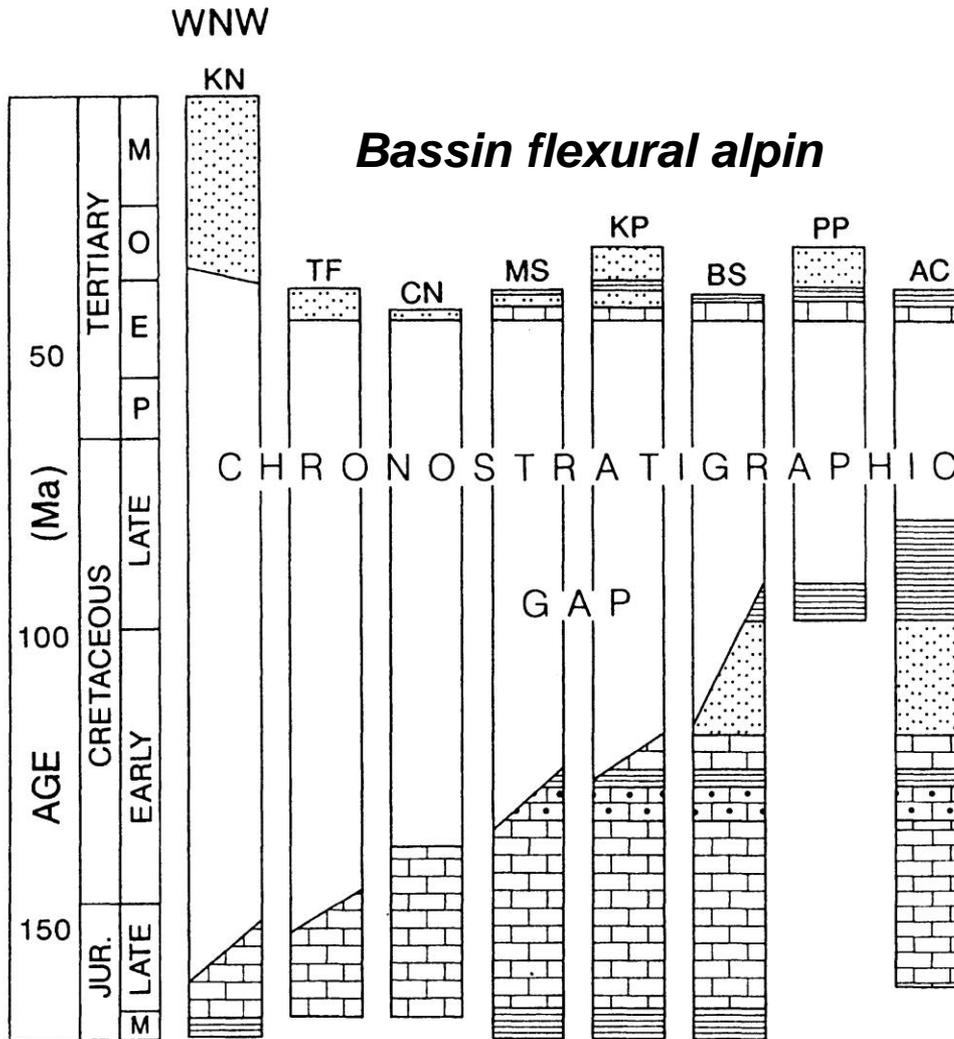
**Le bassin d'avant-pays,  
La transition flysch-molasse**

# Bassin molassique suisse et bassin padan

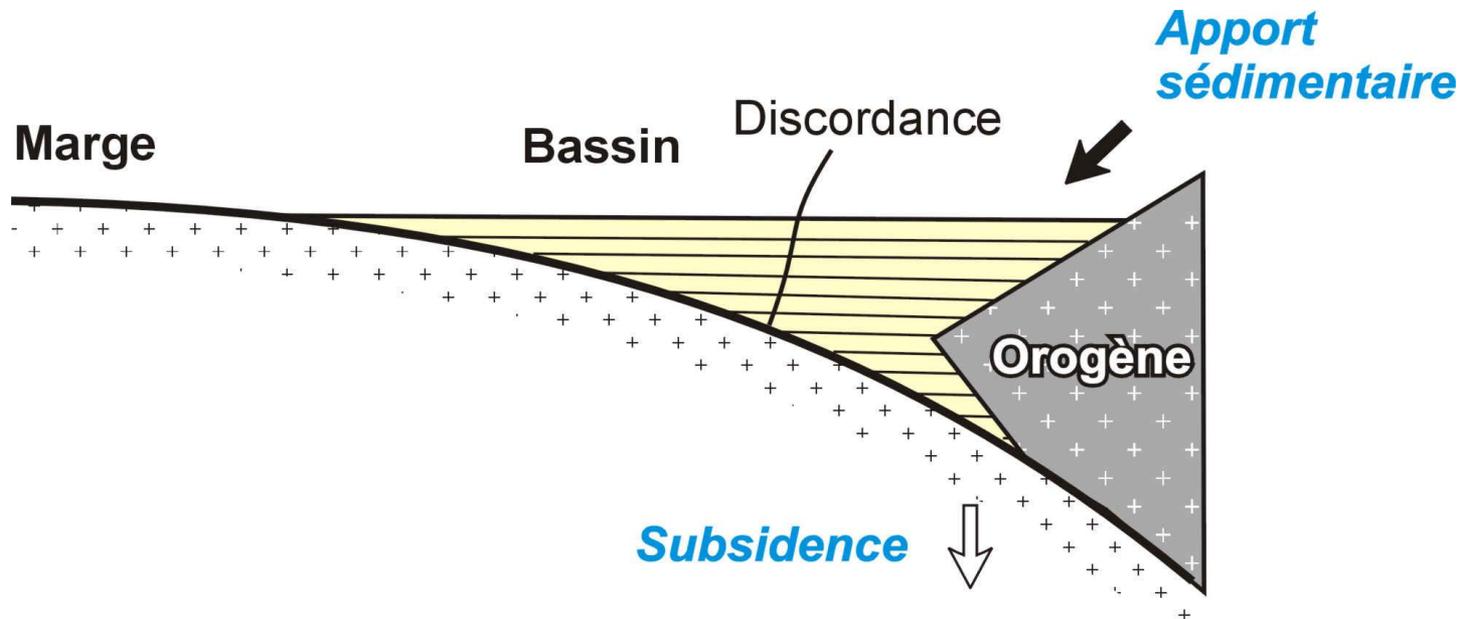
Bassins dissymétriques



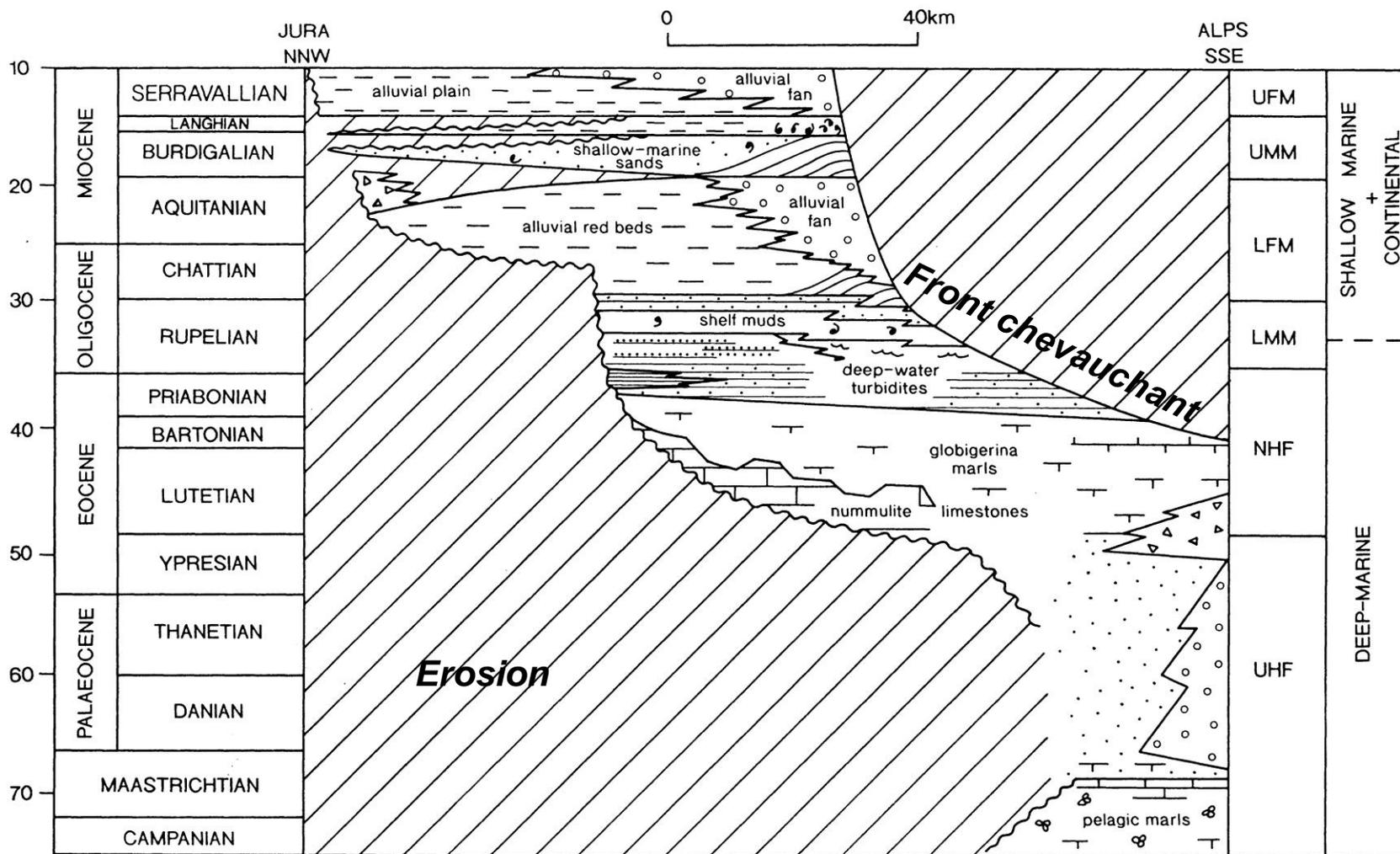
# Stratigraphie et géométrie du bassin molassique



# Remplissage sédimentaire discordant en onlaps sur la marge



# Stratigraphie et milieux de dépôts tertiaires dans le bassin alpin



## « *Flyschs* » *Eocène alpins* : les grès d'Annot



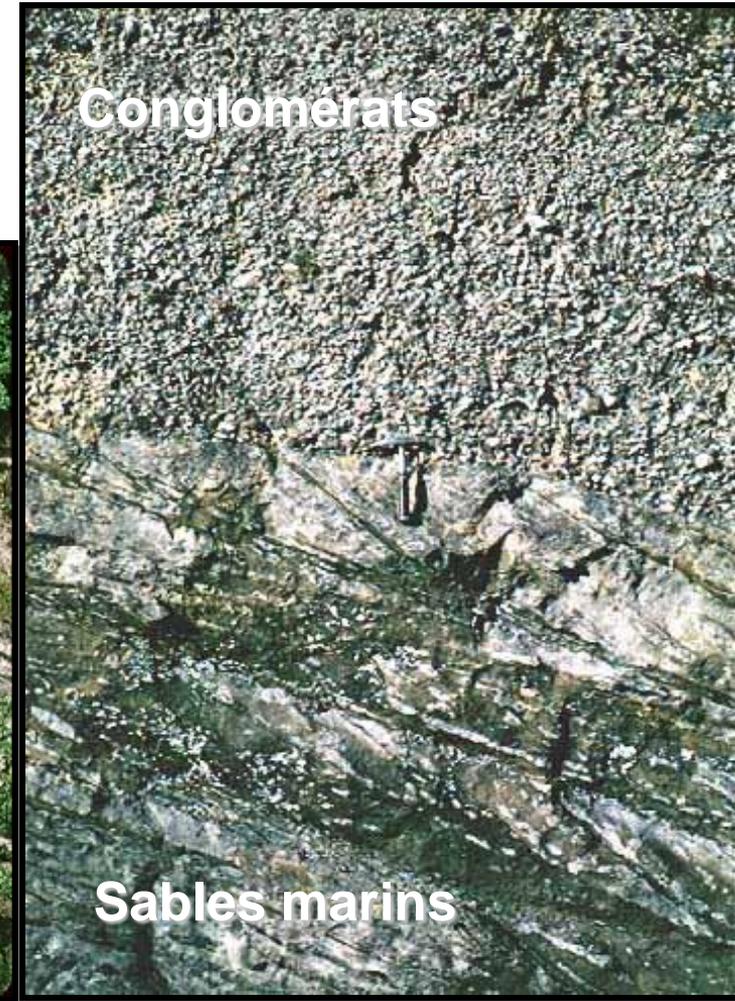
Dépôts marins profonds  
turbiditiques éocènes  
(Priabonien)

Souligne l'initiation du  
bassin flexural



## ***Molasse Alpine***

Dépôts fluvi-marins miocènes  
contemporains de la croissance de la chaîne

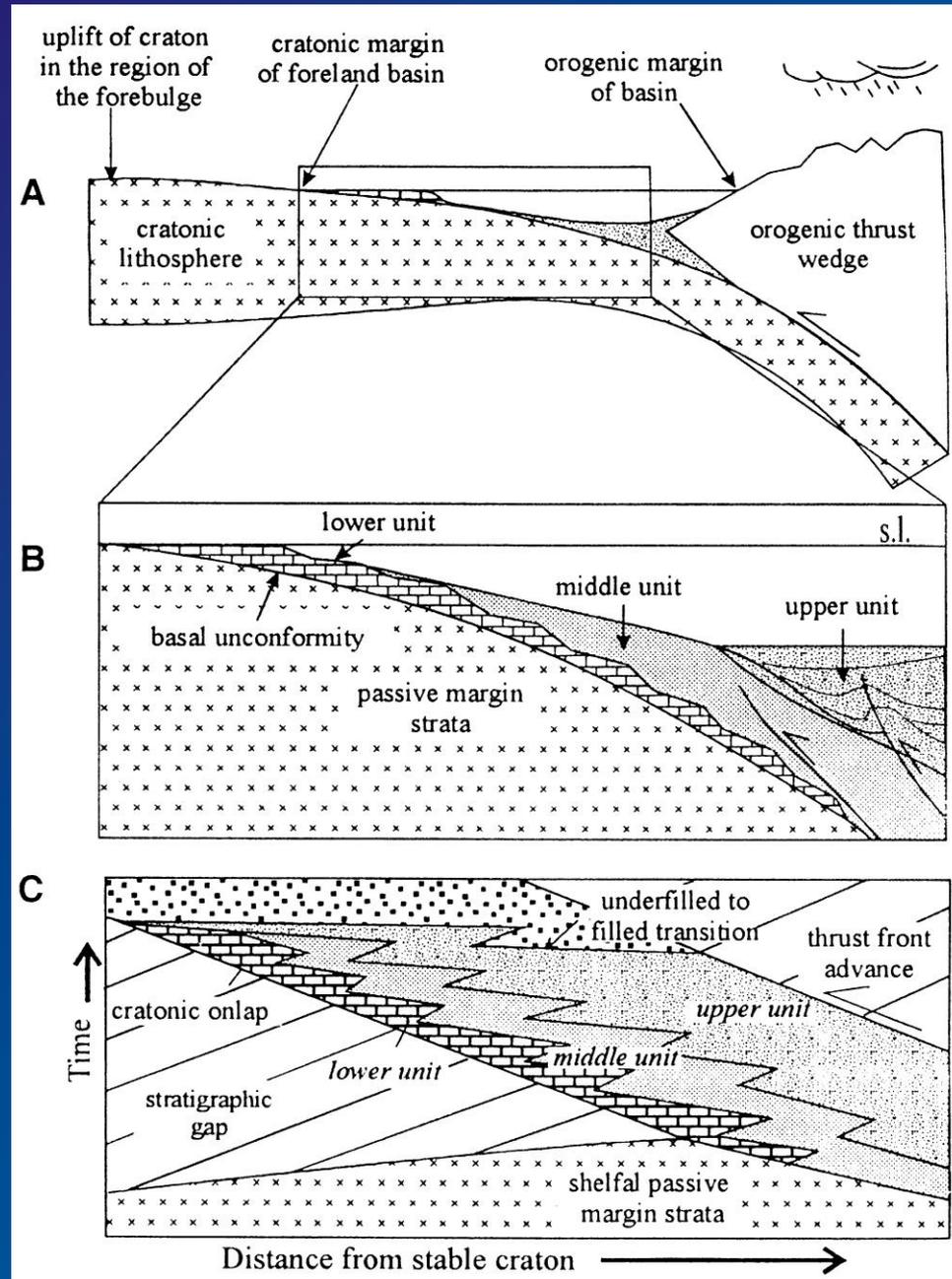


Dépôts d'avant-pays proximaux (source d'apport proche)

*Début du développement  
du bassin et migration  
sur la marge à l'Eocène*

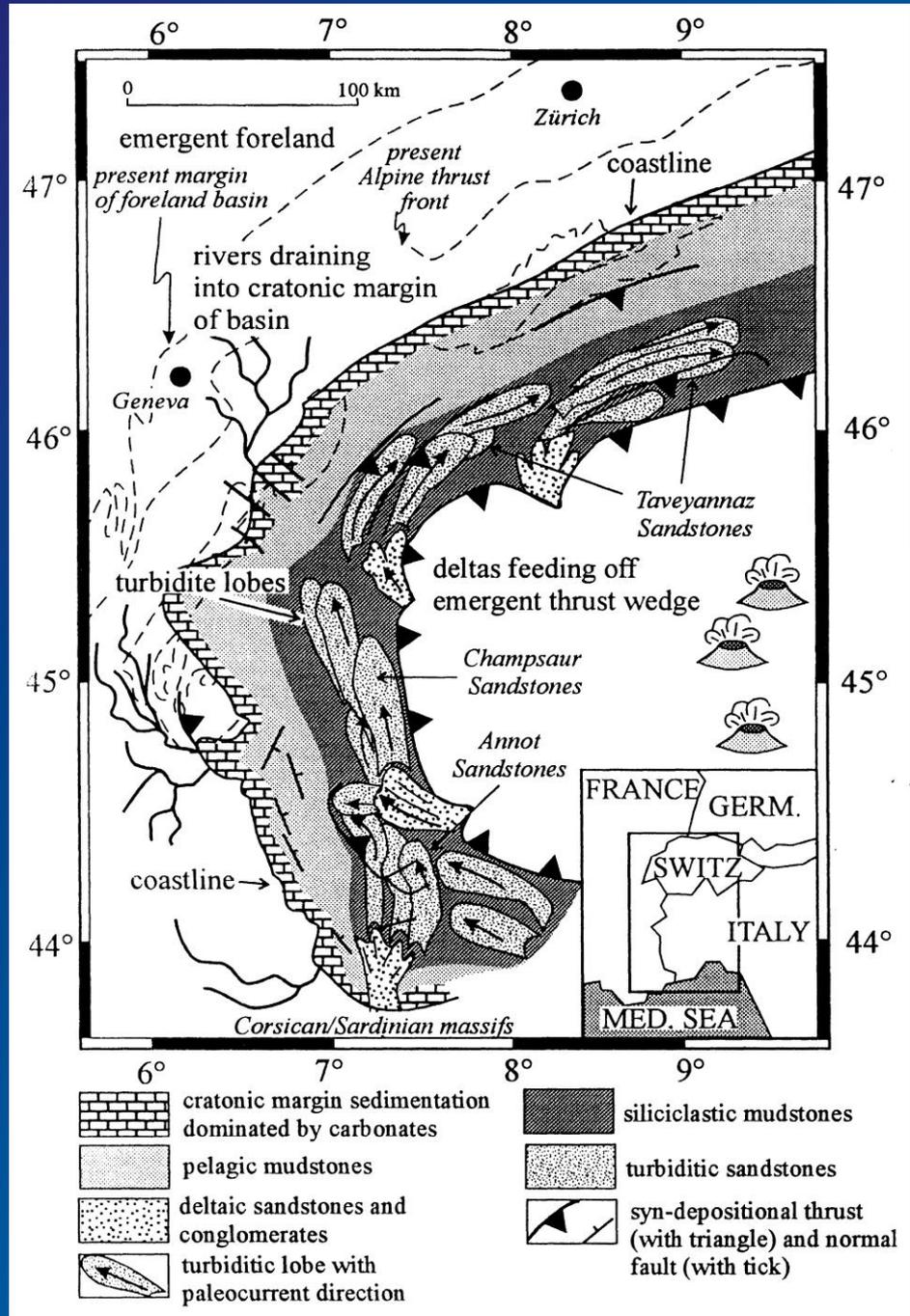
*Reconstitution  
du bassin  
au Priabonien*

*Stratigraphie*

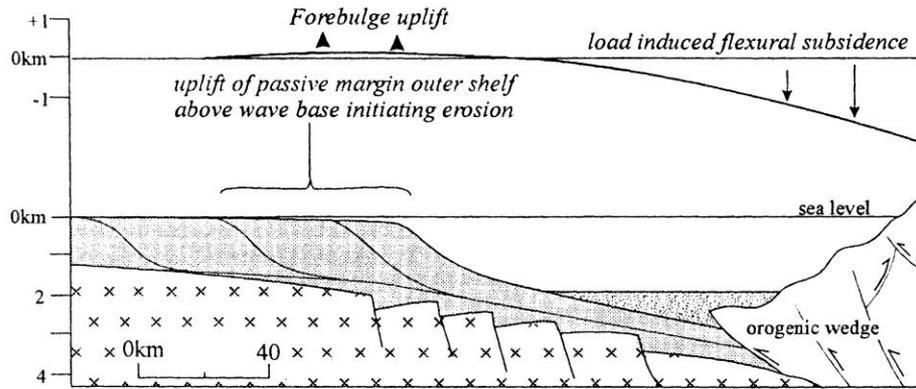


# L'avant-pays alpin à l'Eocène

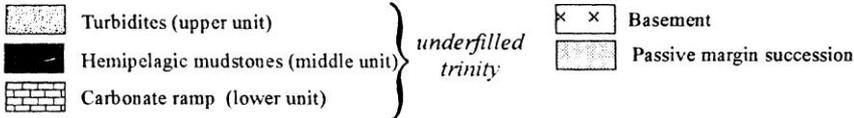
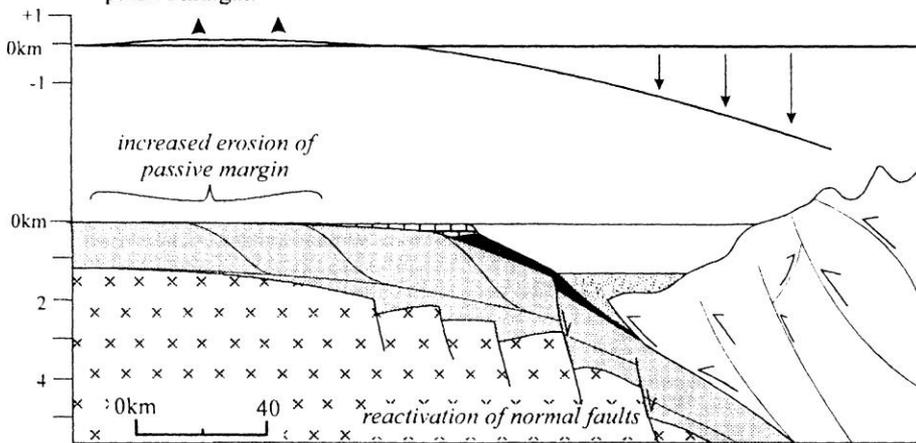
La trilogie calcaire/  
marnes/flyschs  
souligne la géométrie  
initiale du bassin



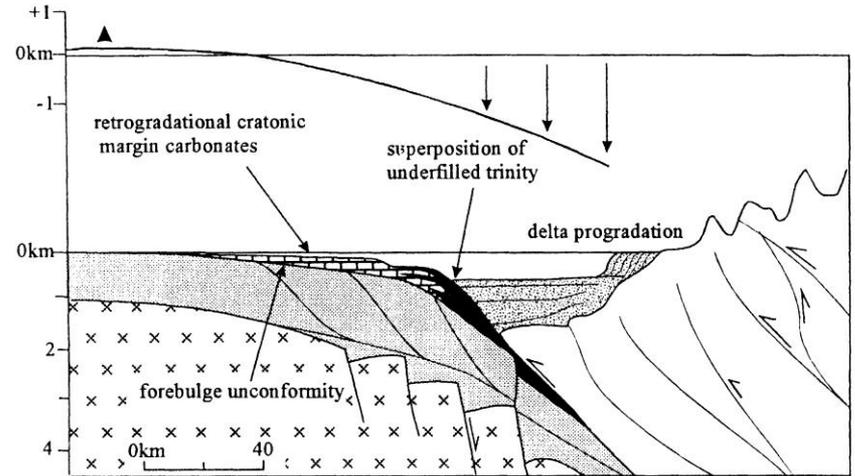
Stage 1. Initial loading of outer passive margin, eg., present day Taiwan, Timor and Papua New Guinea. Paleocene in the Alps.



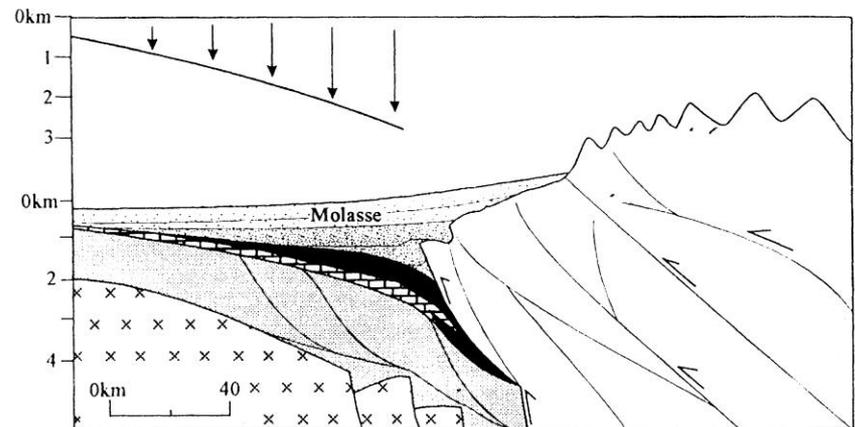
Stage 2. Development of underfilled trinity as flexural profile passes over passive margin.

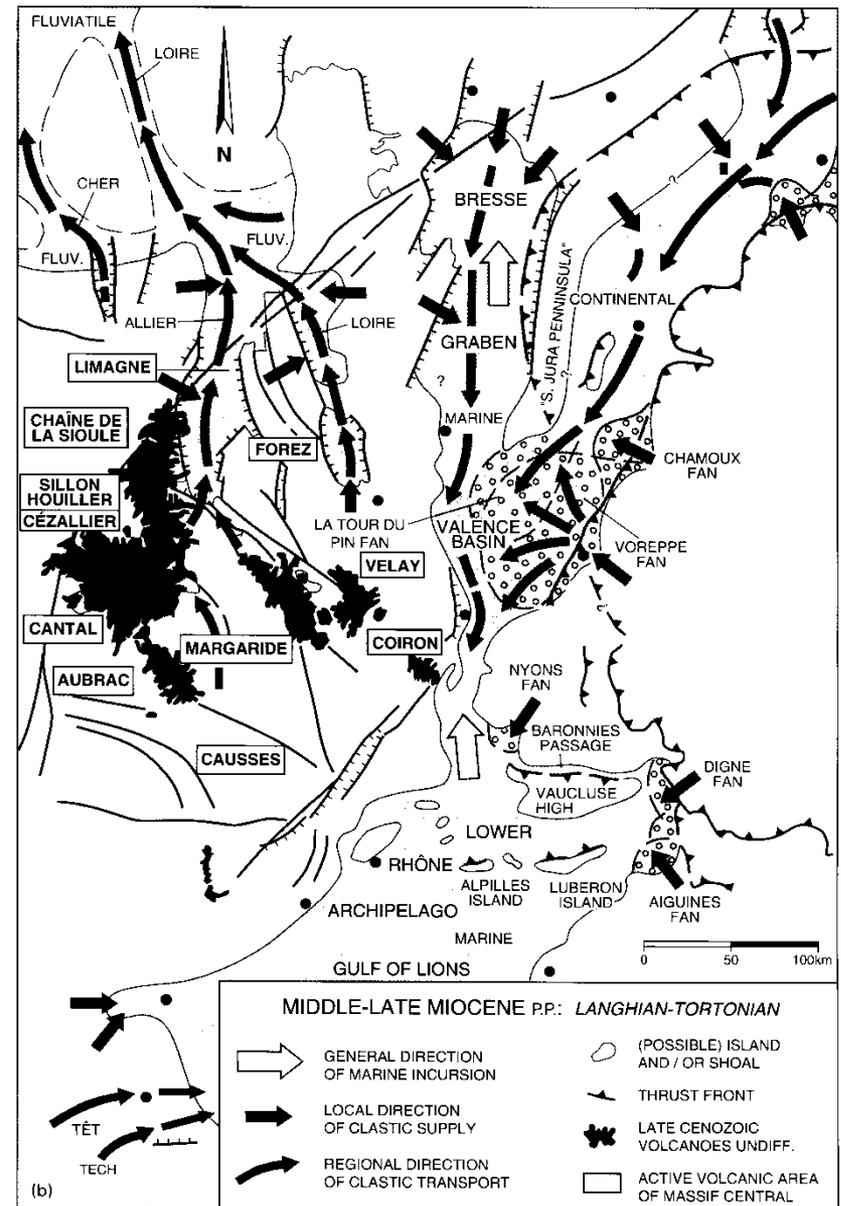
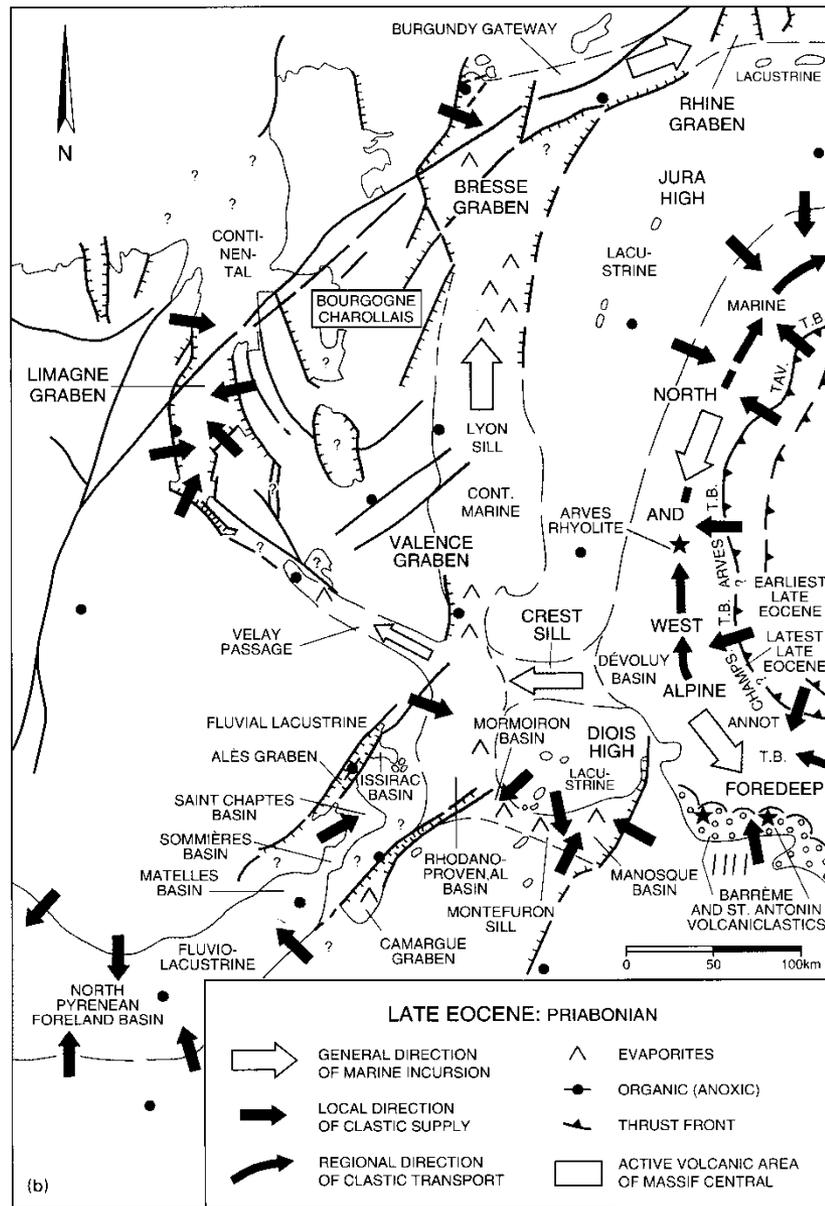


Stage 3. Steady state migration of the underfilled trinity over the craton i.e., rate of thrust front advance equals rate of cratonic onlap



Stage 4. Transition of foreland basin from an underfilled to a filled depositional state. Siliciclastics from orogen fill the basin, smothering the underfilled stratigraphy.

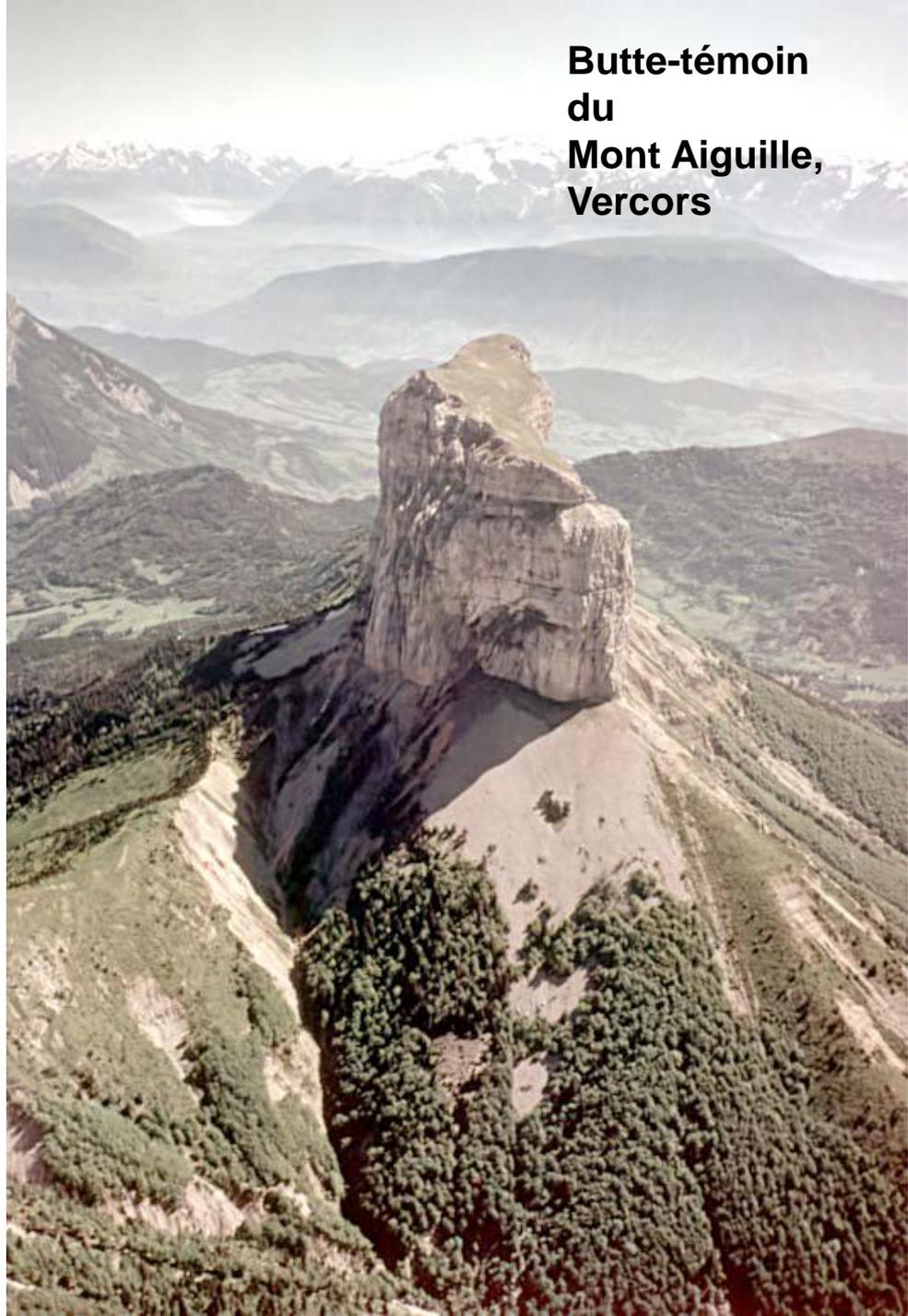




# **Le Vercors:**

- **Une géologie spectaculaire et « lisible »**
- **Des paysages splendides**
- **Un pays calcaire, avec ses morphologies karstiques**
- **Un haut-lieu de la résistance**
- ...

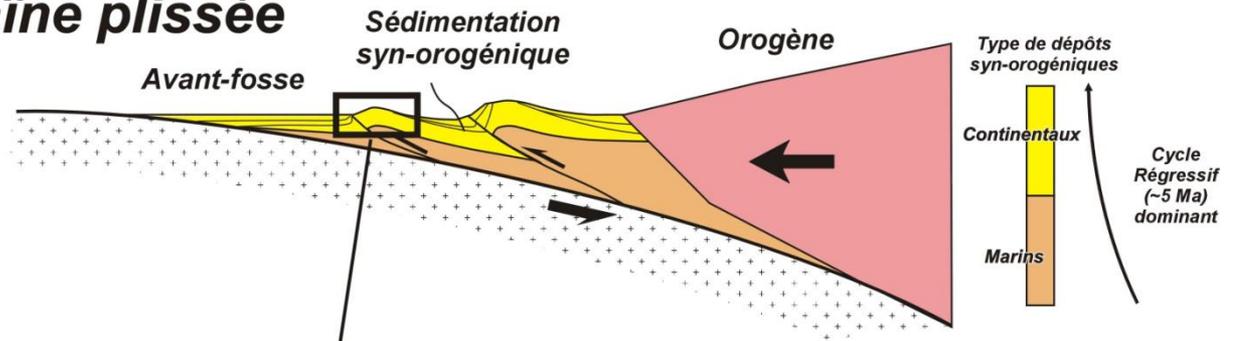
**Merci pour  
votre invitation...**



**Butte-témoin  
du  
Mont Aiguille,  
Vercors**



# La chaîne plissée



# L'unité chevauchante

**Eustatisme**

