**Partie 3** (S. Guillot)

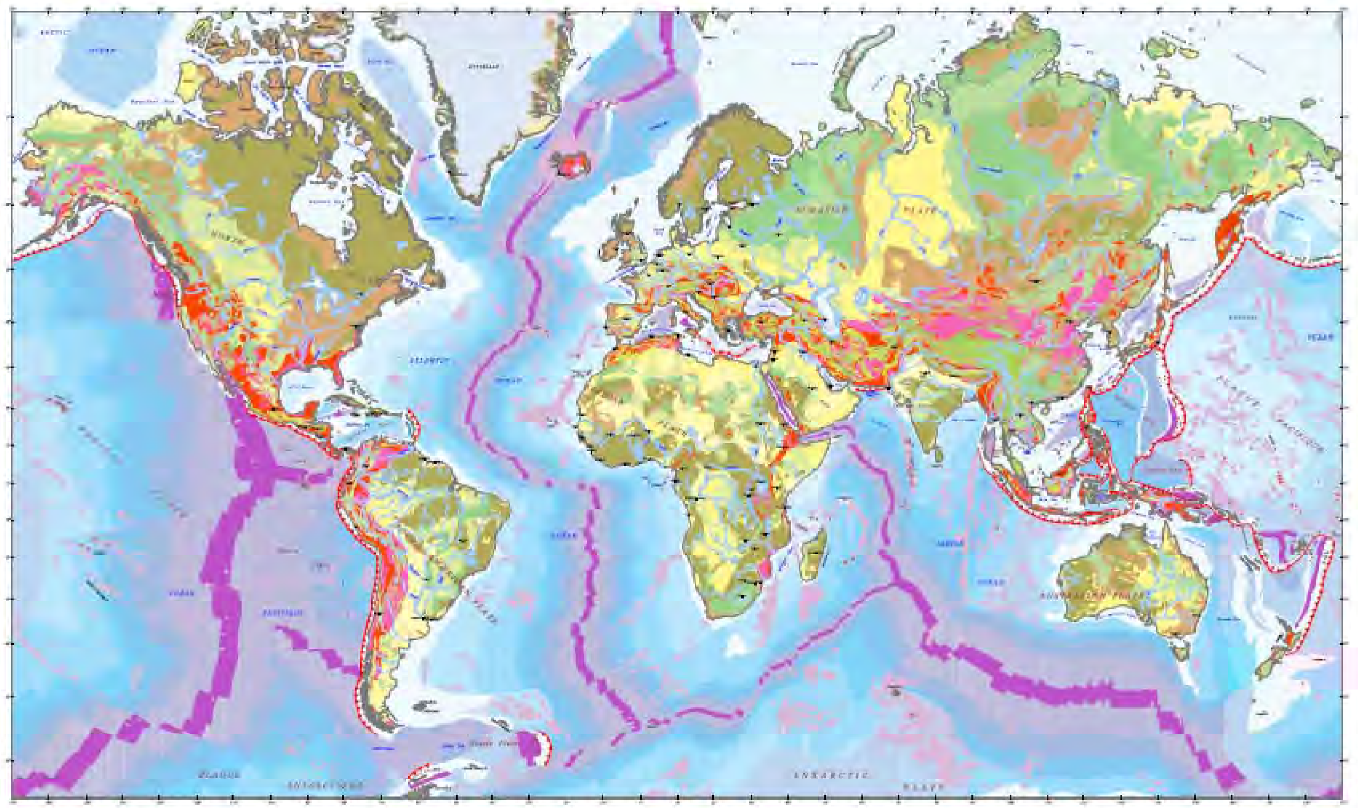
## Tectonique et Pétrologie métamorphique : la signature thermo-mécanique de l'évolution géodynamique d'une chaîne

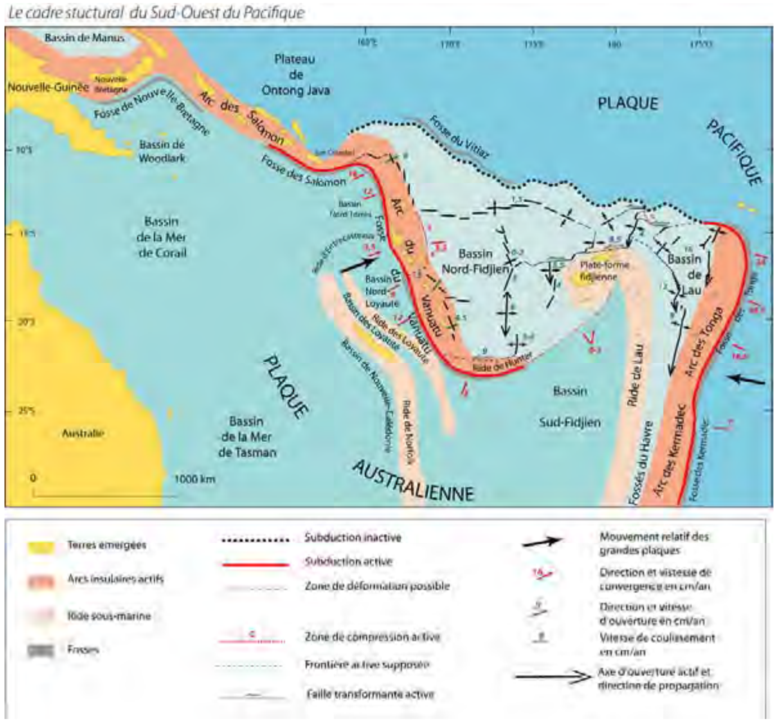
Mécanisme d’exhumation des roches de HP et UHP: apport de la géophysique, de la pétrologie et des modélisations thermo-mécaniques

Chemins P-Tp-t déduits de l'étude des roches métamorphiques et de la thermochronologie, leur interprétation : exemple de l'Himalaya-Karakorum (A. Pêcher)

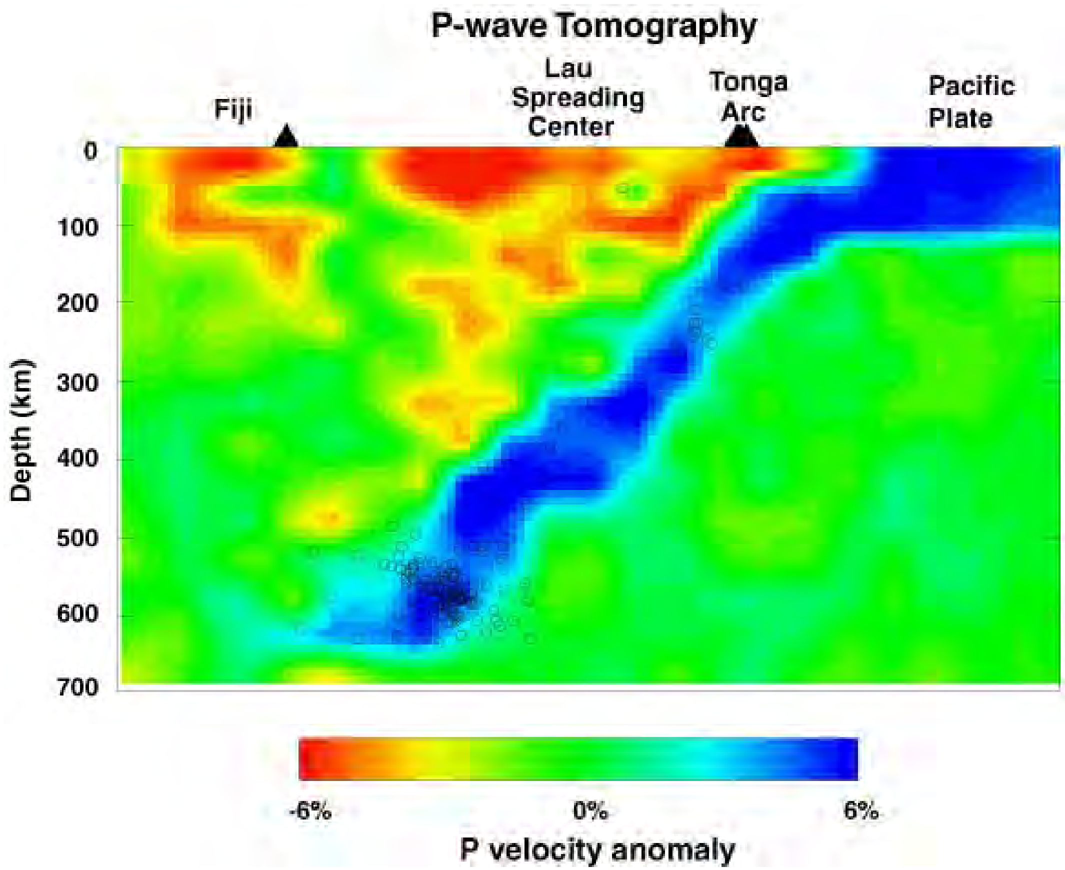
Cours M2R  2010
Processus d'exhumation en contexte de subduction
2 types de subduction
Océanique et continentale

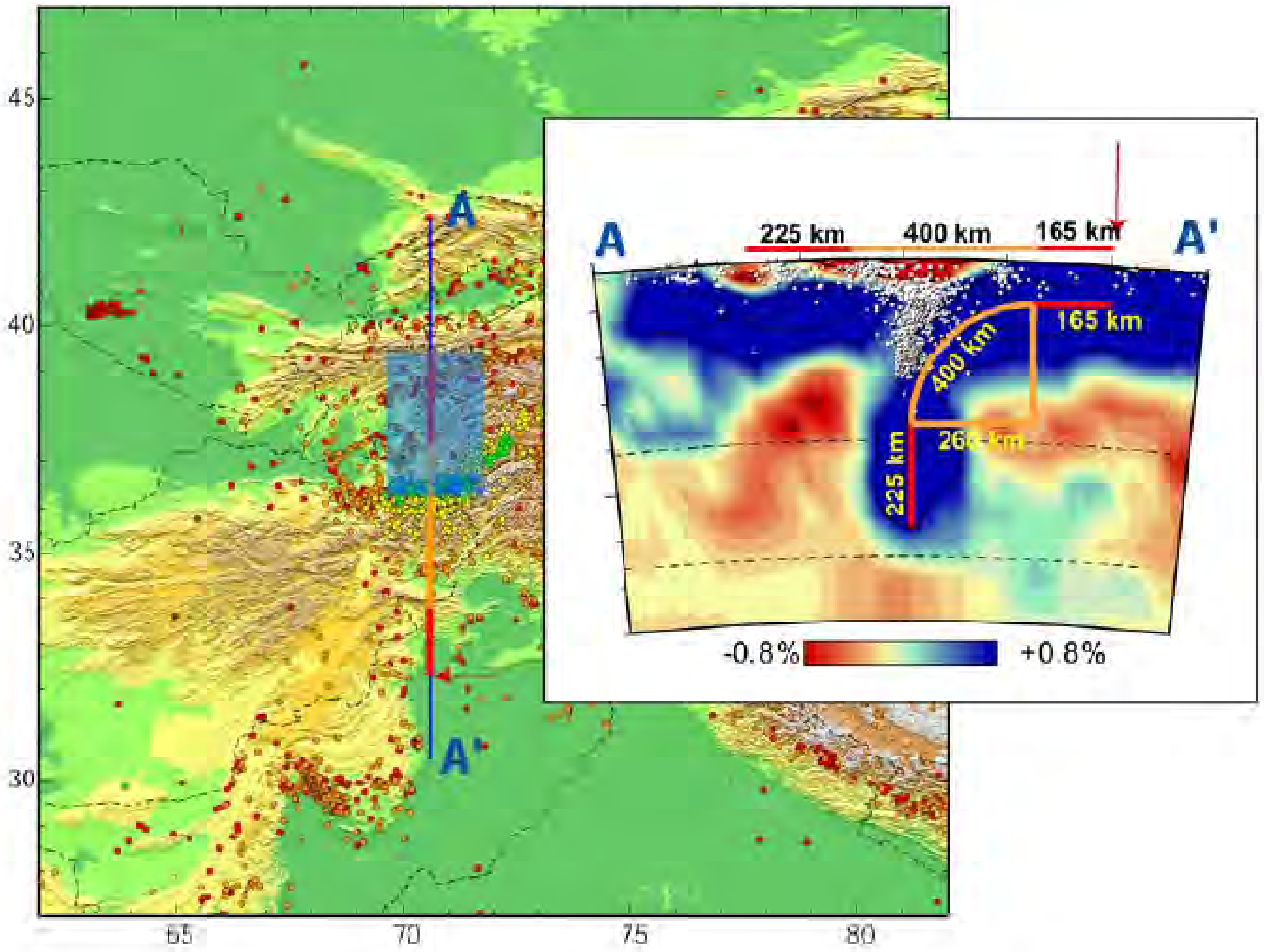
Stéphane Guillot – CNRS – LGCA - Grenoble



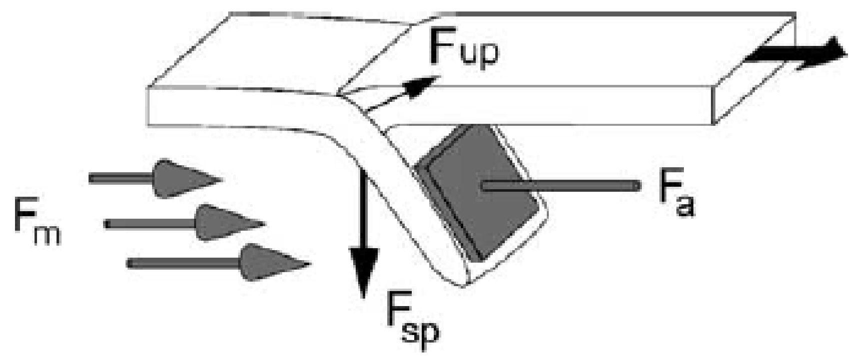



Subduction du pacifique sous l'arc des Tonga



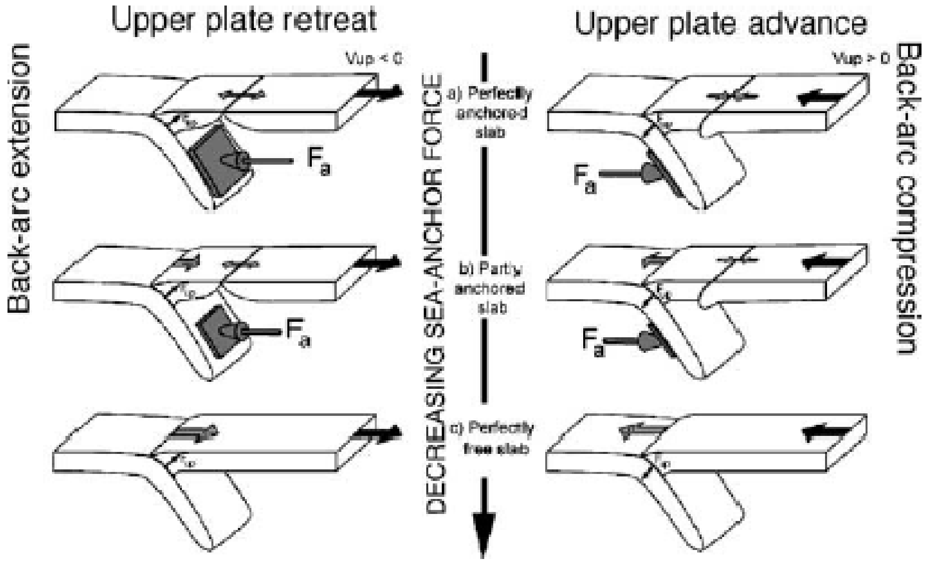



Subduction de l'Inde sous le Pamir




Fm : flux mantellique
Fa: force d’encrage (anchoring F.)
Fup:  force de succion de la plaque sup
Fsp: force de traction (slab pull)

Huret et Lallemand, 2005



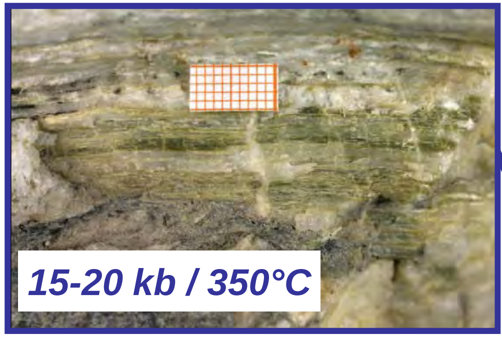

On distingue deux régimes de subduction, dépendant en particulier de la densité du panneau plongeant et de la viscosité du manteau .

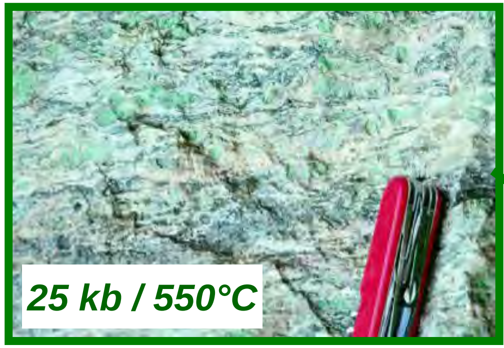
Un régime compressif qui se produit lorsque la densité du slab est inférieure à celle de l'asthénosphère. Dans ce cas la pression intraplaque Fa est supérieure au slab pull Fsp. **La plaque chevauchante est en compression**

Un régime extensif, qui se produit lorsque la densité du slab est supérieure à celle de l'asthénosphère, dans ce cas la pression intraplaque Fa est inférieure au slab pull, **la plaque chevauchante est alors en extension (cas 2).**

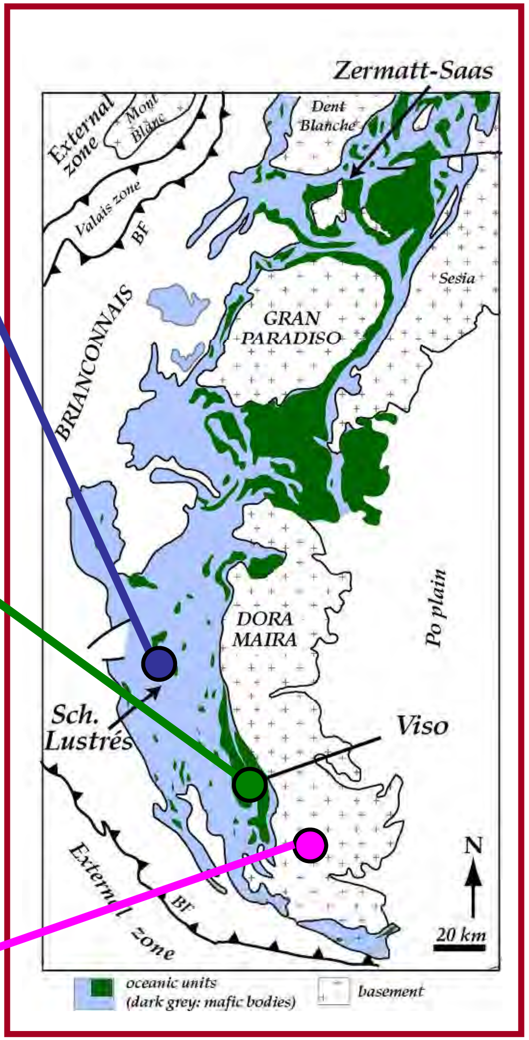
Huret et Lallemand, 2005

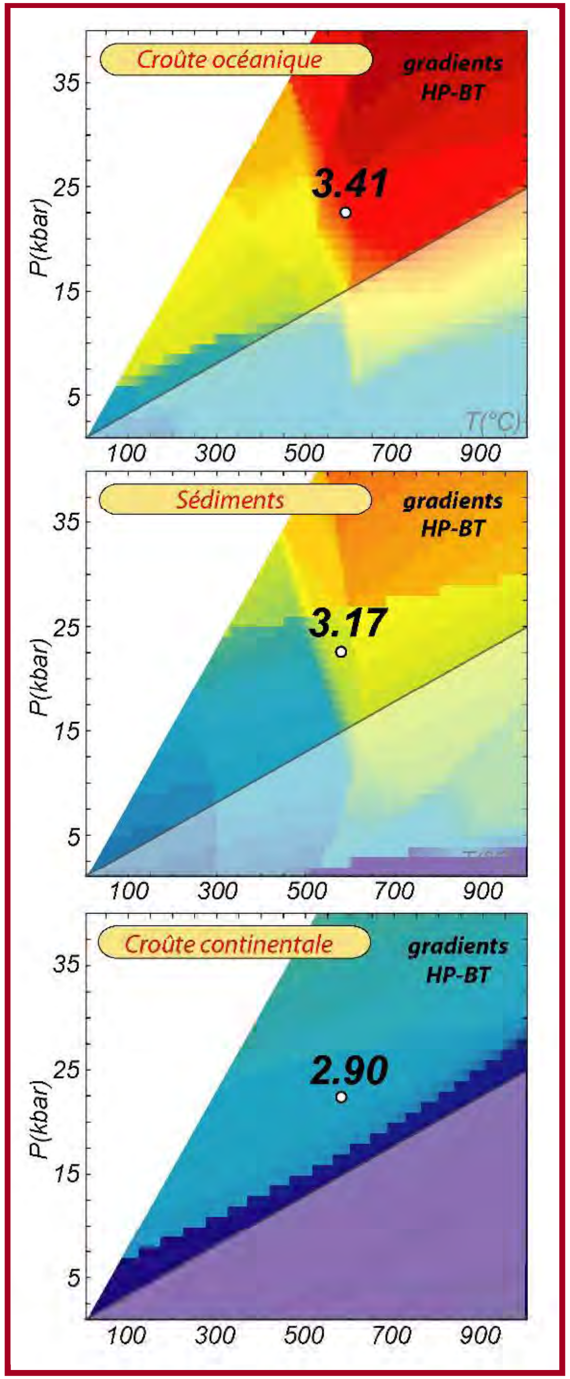
# Des matériaux mis en jeu différents



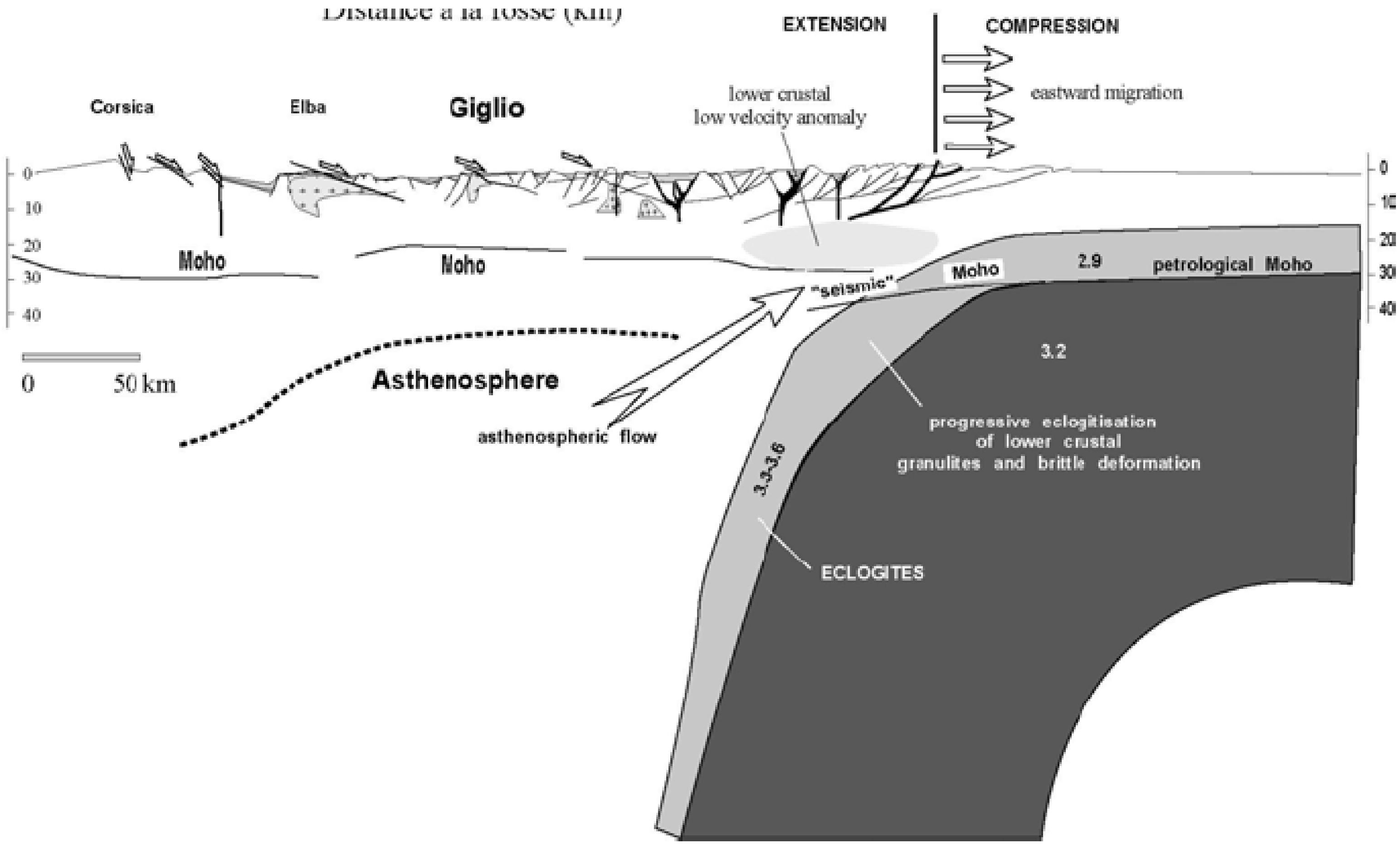




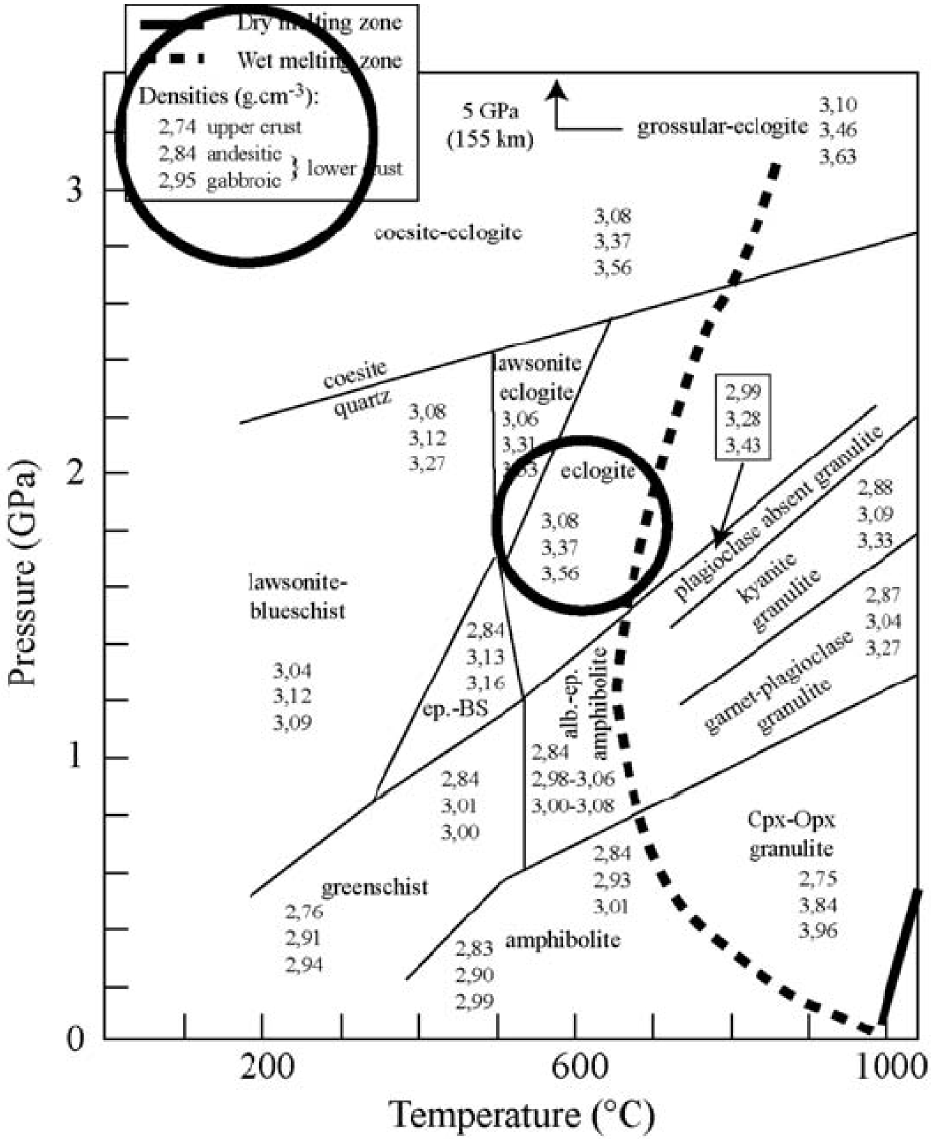

… avec des densités bien particulières

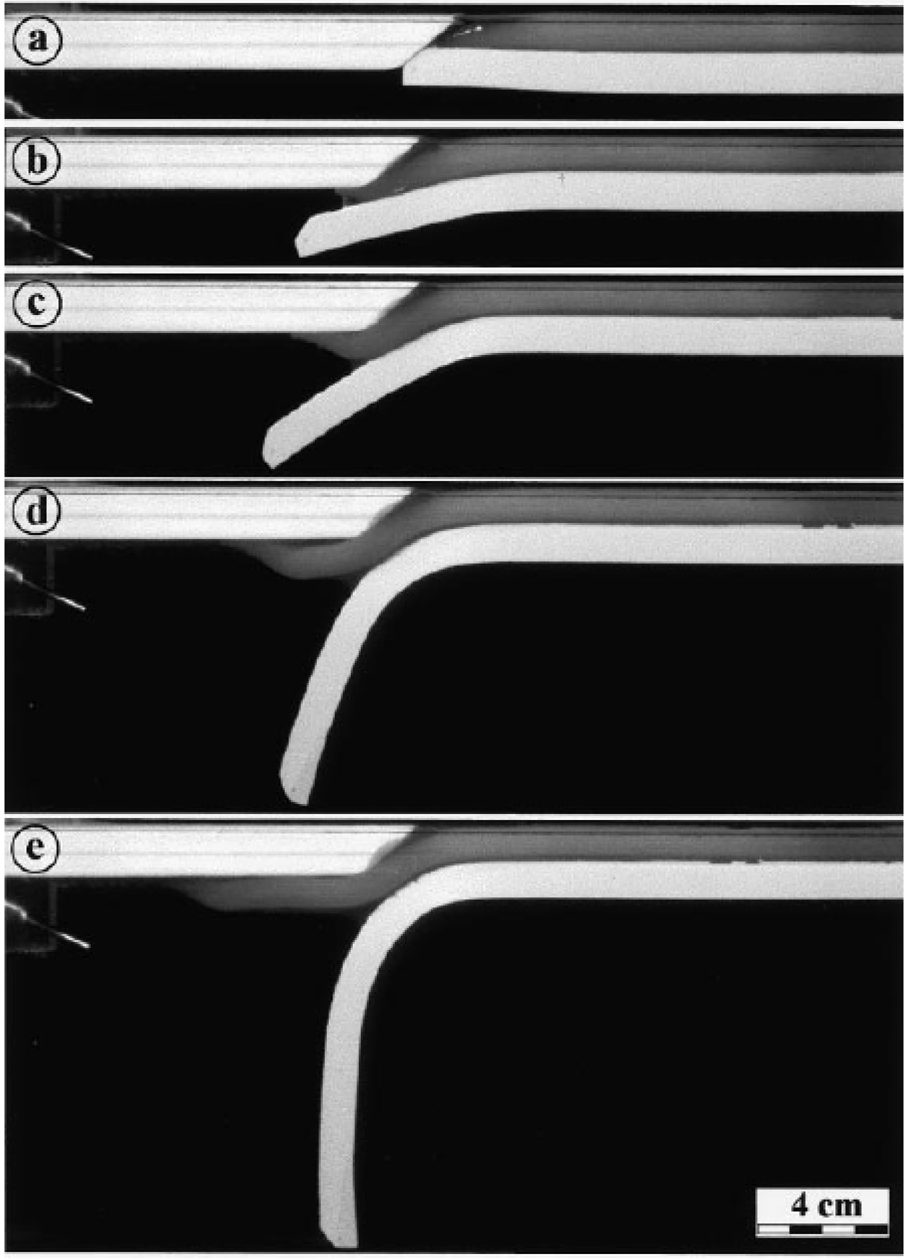
Yamato, 2007

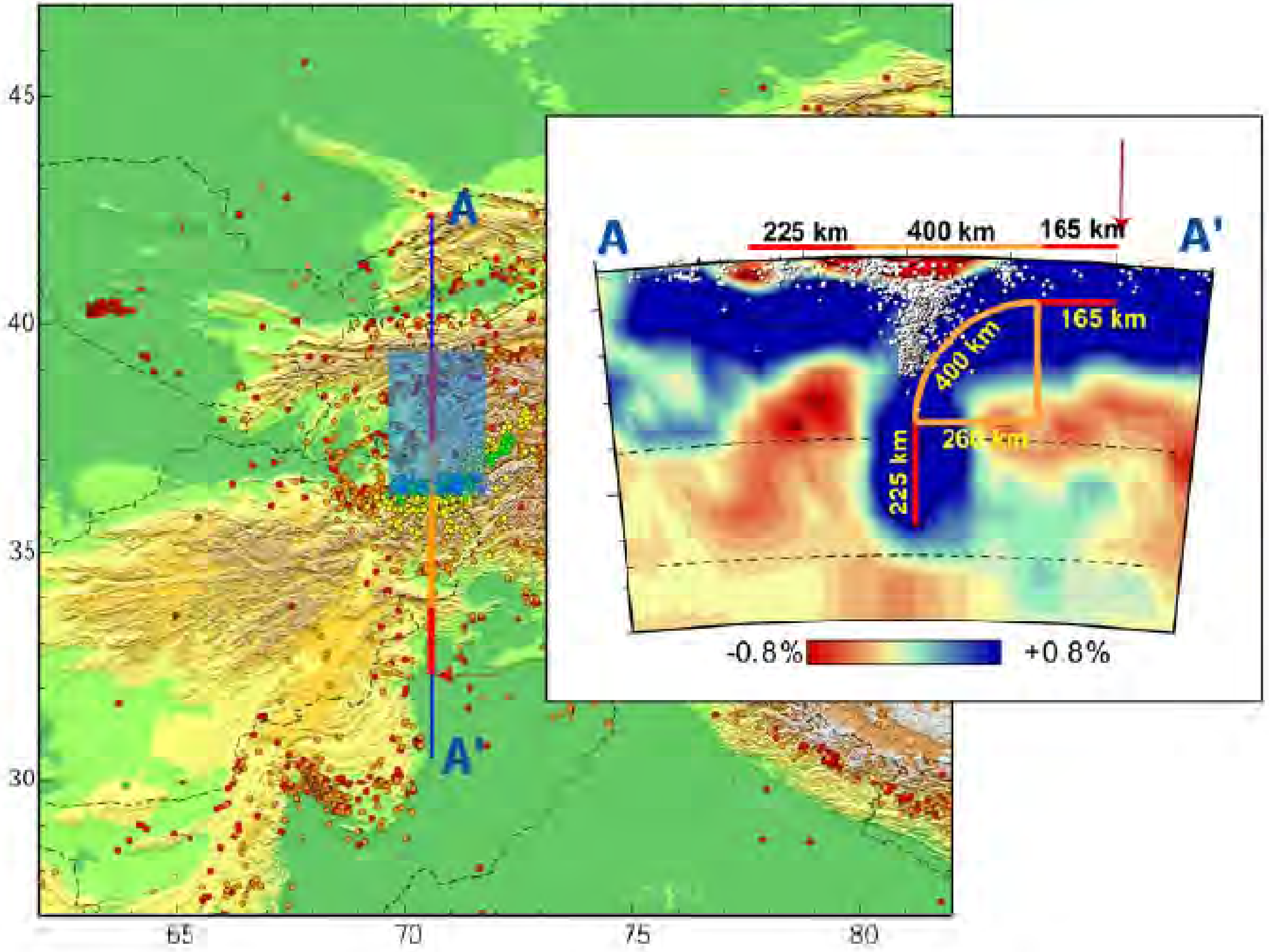



**Cas de la croute océanique**

# Cas de la croûte continentale

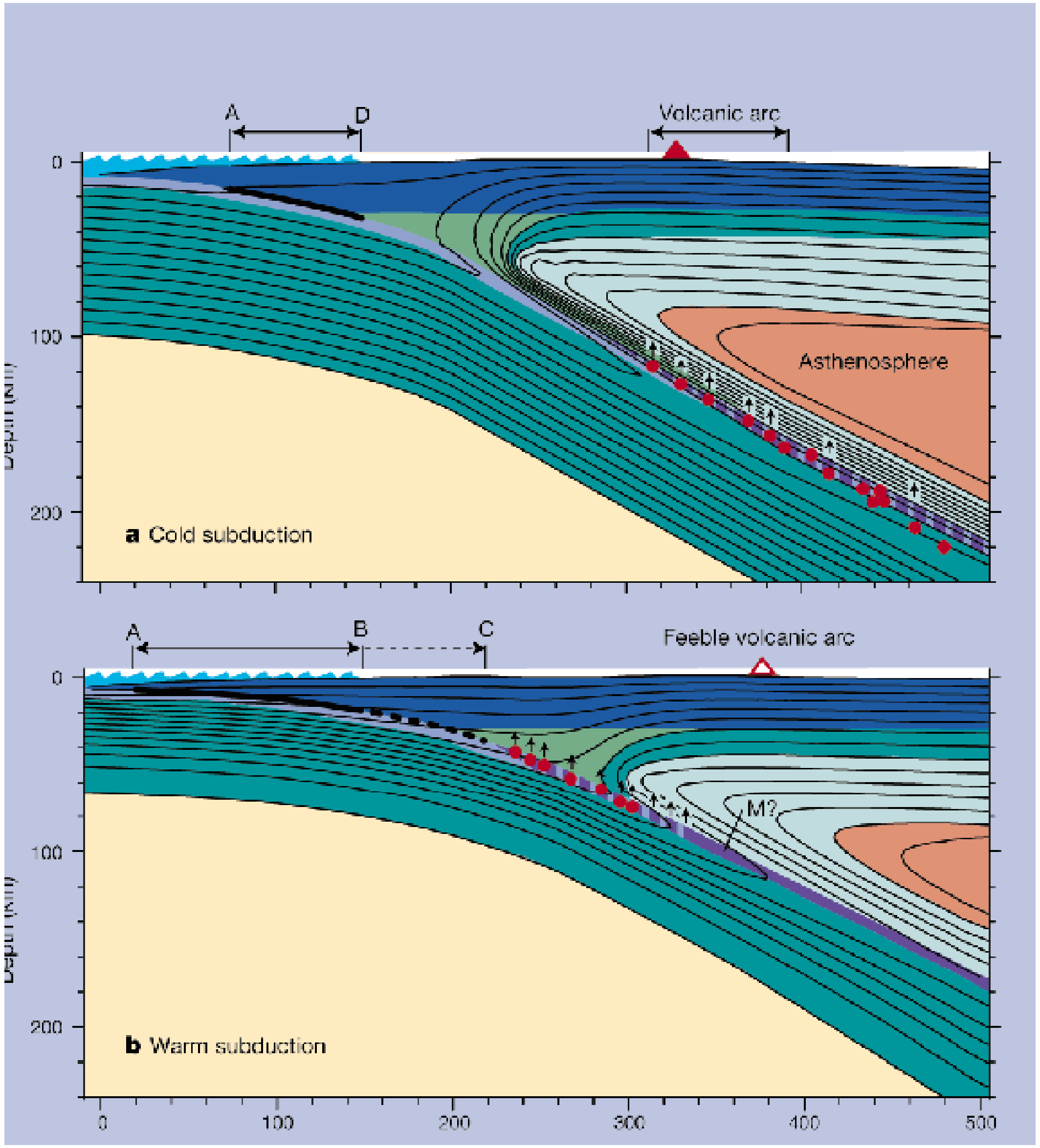



a
b
c
d
e
4 cm



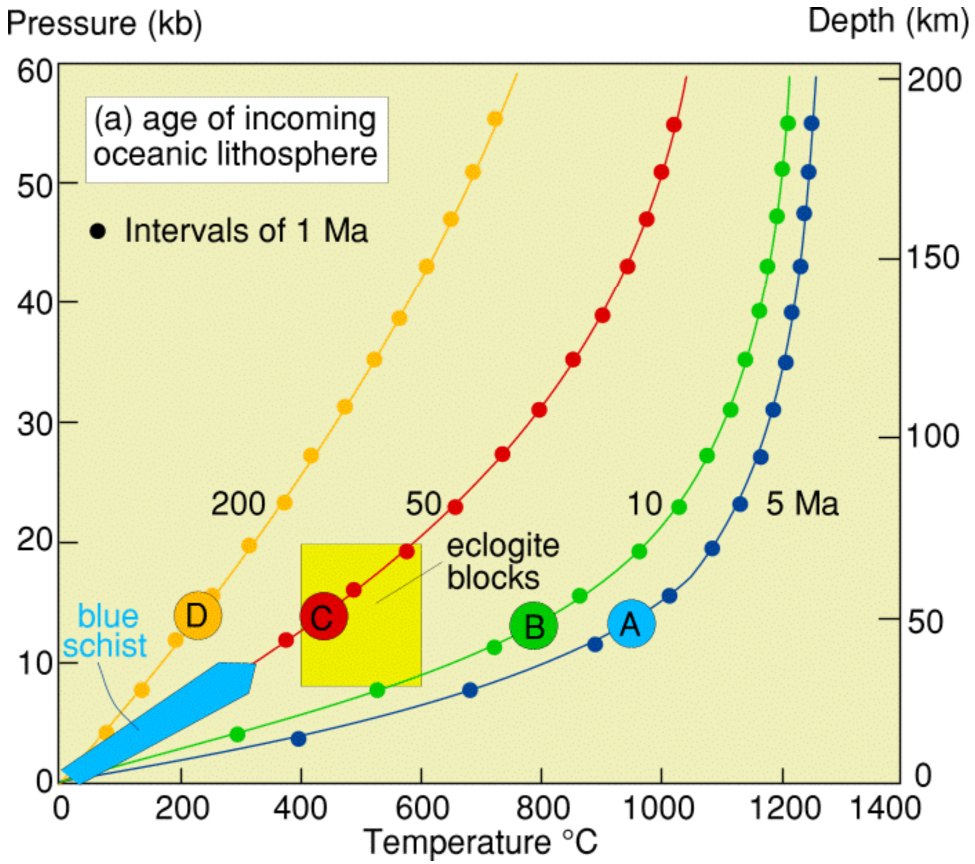

Subduction de l'Inde sous le Pamir

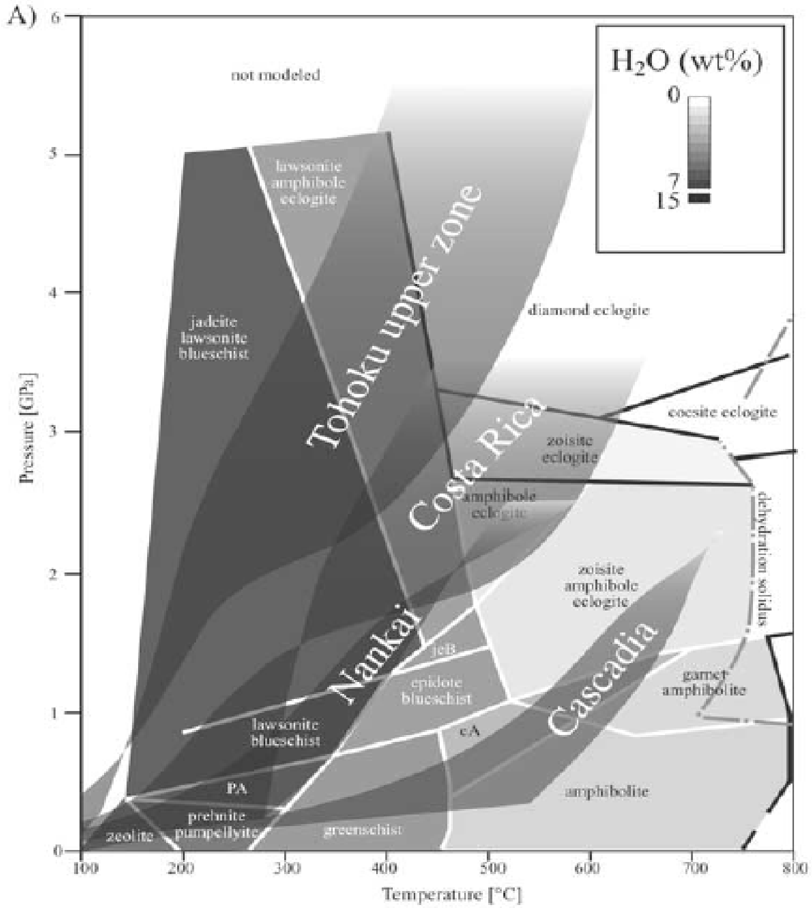
$$\frac{dT}{dt} = \kappa\left(\frac{d^2T}{dx^2} + \frac{d^2T}{dy^2}\right) - V(x,y)\left(\frac{dT}{dx} + \frac{dT}{dy}\right) + \frac{A(x,y)}{\rho C}$$




**Gradient de subduction**

Equation de la Chaleur en 2D



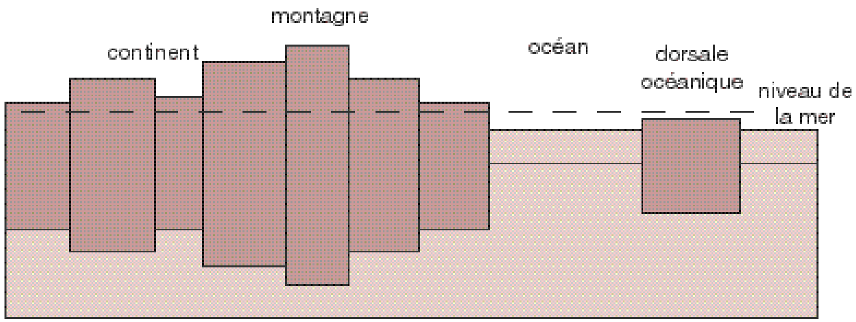




# Géothermes et âge des plaques

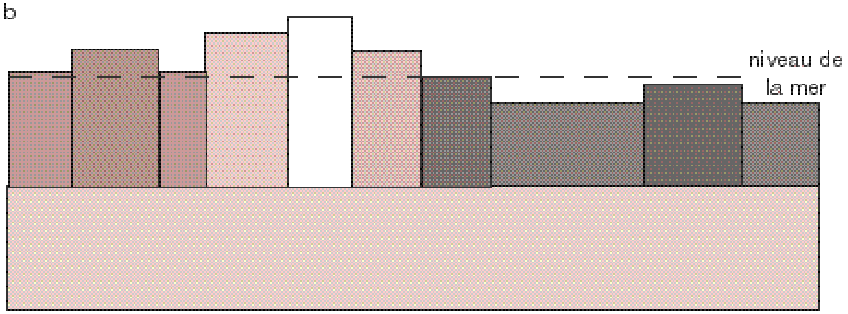
# Exhumation des roches métamorphiques en contexte de subduction

# Compensation isostatique, Uplift et Exhumation

a




b

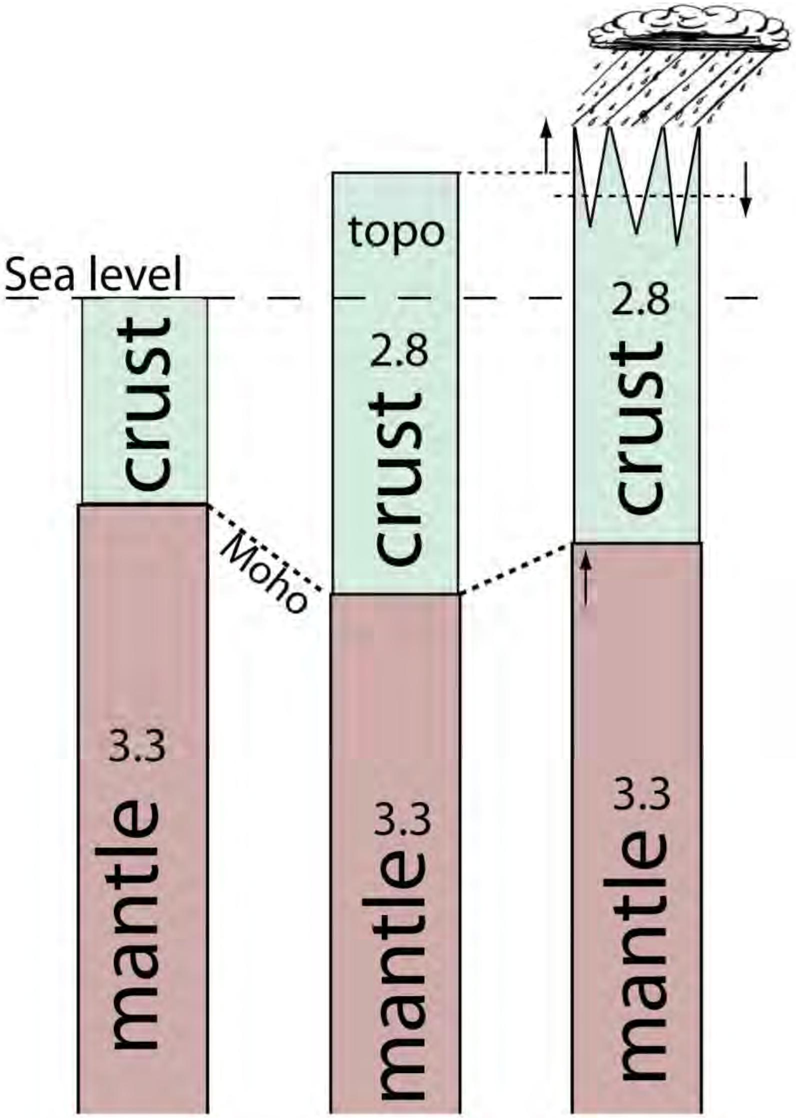



Deux interprétations du même profil topographique suivant les hypothèses isostatiques de Airy et Pratt.

(a) Modèle d'Airy : la croûte est d'épaisseur variable mais de densité constante, et est plus épaisse sous les terrains élevés que sous les dépressions - les océans par exemple ; la profondeur de la " racine " est fonction de l'altitude de la topographie.

(b) Modèle de Pratt, dans lequel la croûte est de densité variable, sa base se trouvant à une profondeur constante. L'altitude de la topographie est ici fonction de la densité de la croûte en un point donné.

# 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

**Uplift of rocks** (soulèvement des roches) : Déplacement des roches par rapport au géoïde : phénomène Eulérien

**Exhumation** : déplacement des roches par rapport à la surface : phénomène Lagrangien

**Exhumation** : soulèvement des roches – soulèvement de la surface

Surface Uplift (soulèvement de la surface) : déplacement de la surface par rapport au géoïde sur de grandes longueurs d’onde de 10 3 à 104 km2

Exemple : Mt Everest : 8850 mètres : mais topographie moyenne : 5000 mètres/géoïde

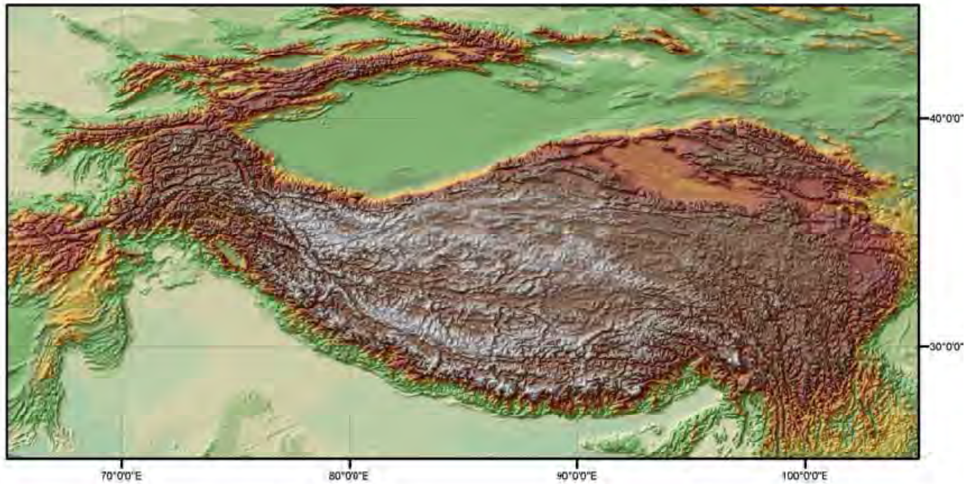
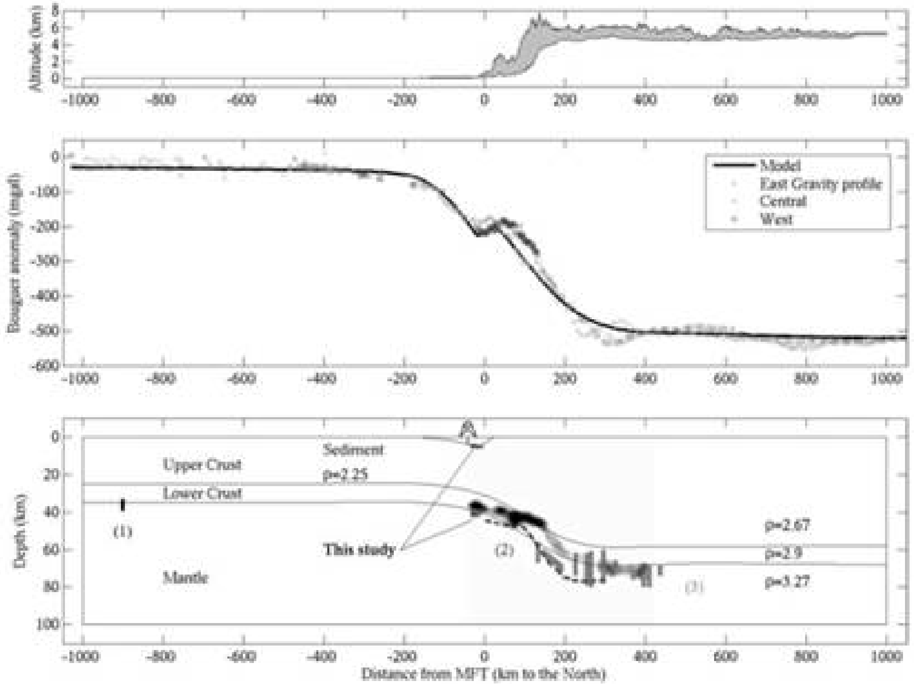
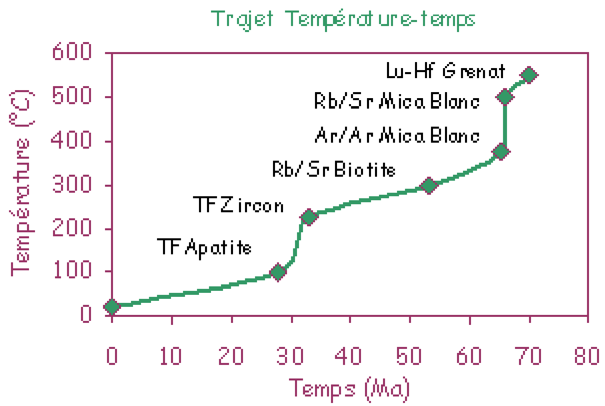


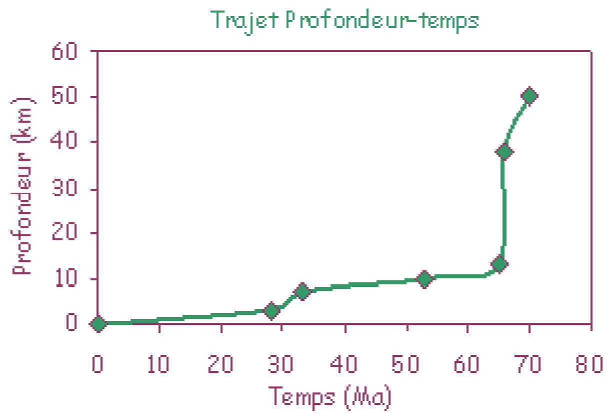

*Fig.1: Topographie du Tibet.*



# Les roches métamorphiques en contexte de subduction

Vitesse d’exhumation par etapes
Dz/dt = dT/dt .dP/dt
Nécessite de combiner le trajet T-t et Z-t

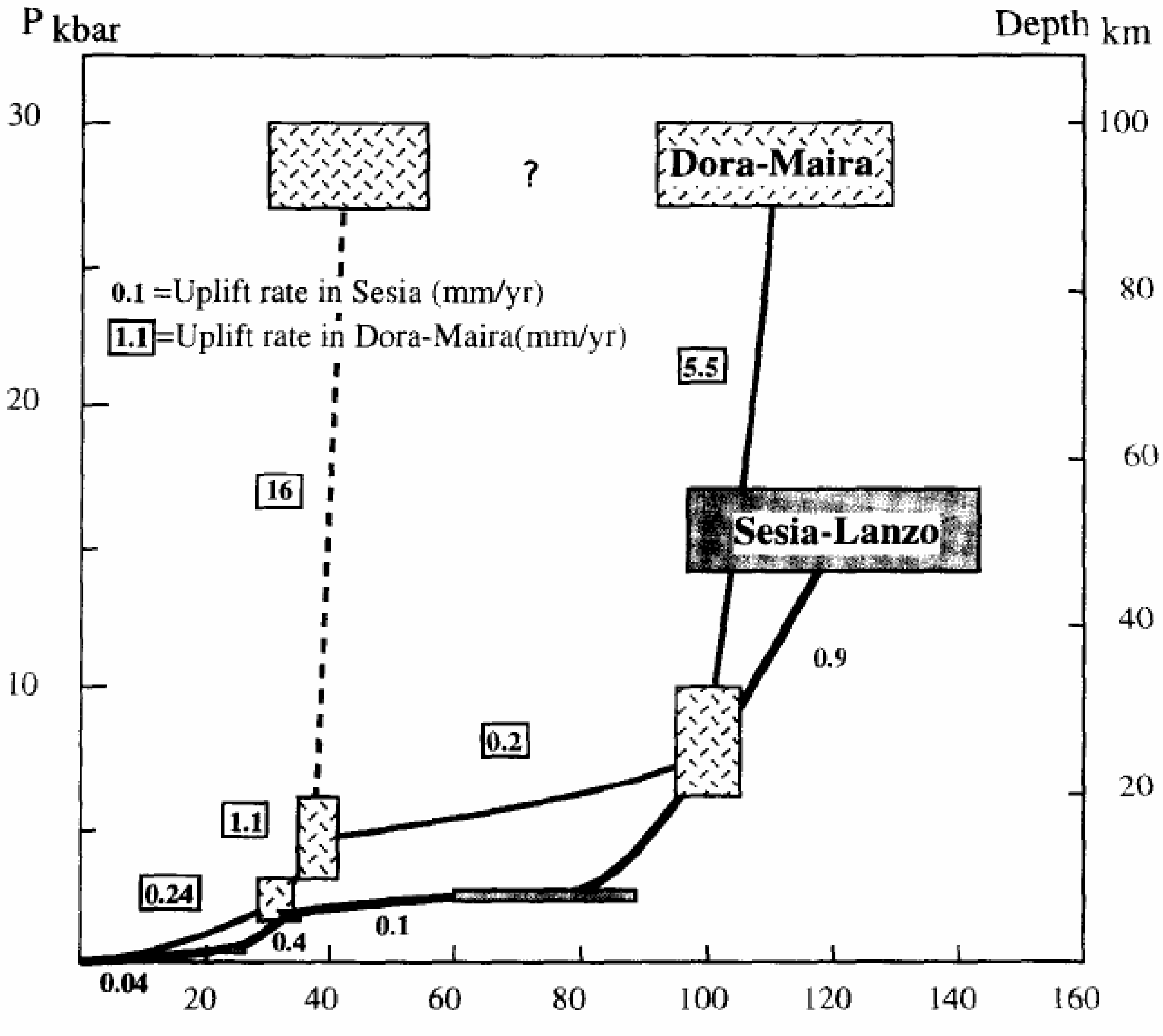


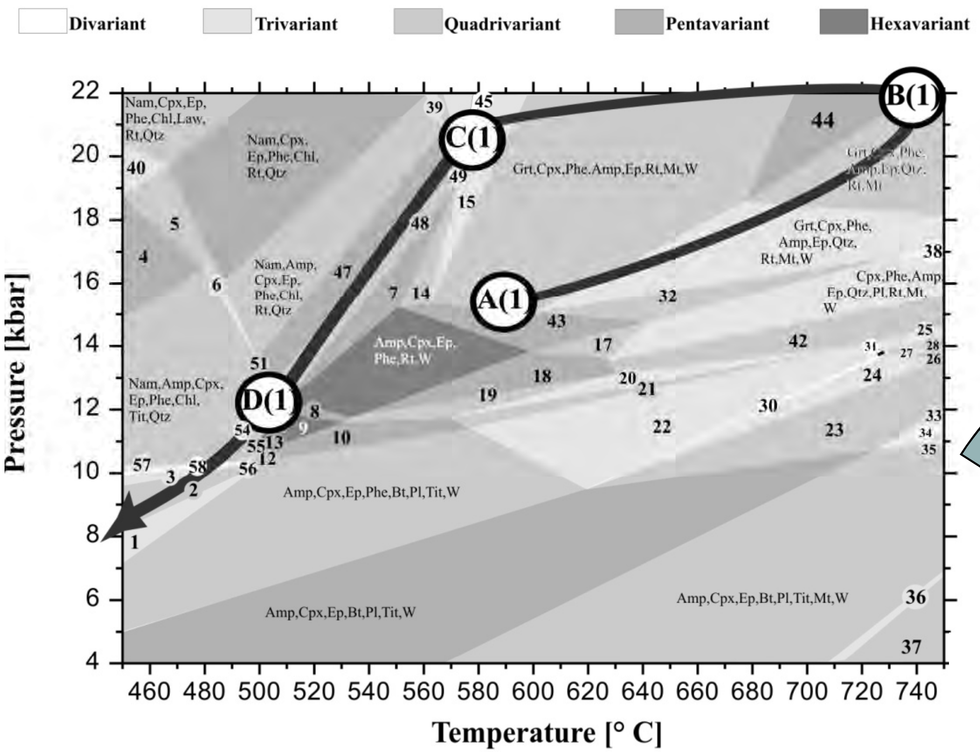

On peut par exemple déduire de ces diagrammes:
- que la vitesse de refroidissement a diminué au cours de la remontée

- que la phase principale de refroidissement et de remonté a immédiatement suivi l'enfouissement

- que la phase principale de refroidissement et de remonté a eu lieu avant la collision alpine d'âge oligocène



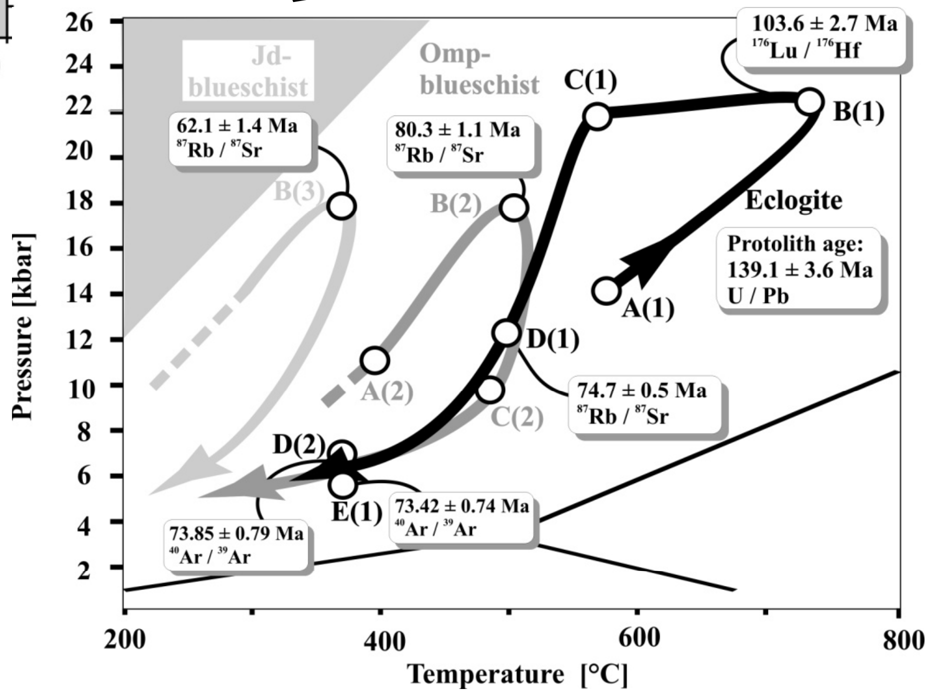

**Pressure-time paths**




Modern thermobarometric tools :

Multi-equilibria P-T calculations or energy minimizing
(Holland and Powell, 1998; Berman, 1990 Connolly, 1990; De Capitani, 1994, Vidal et al., 2006)

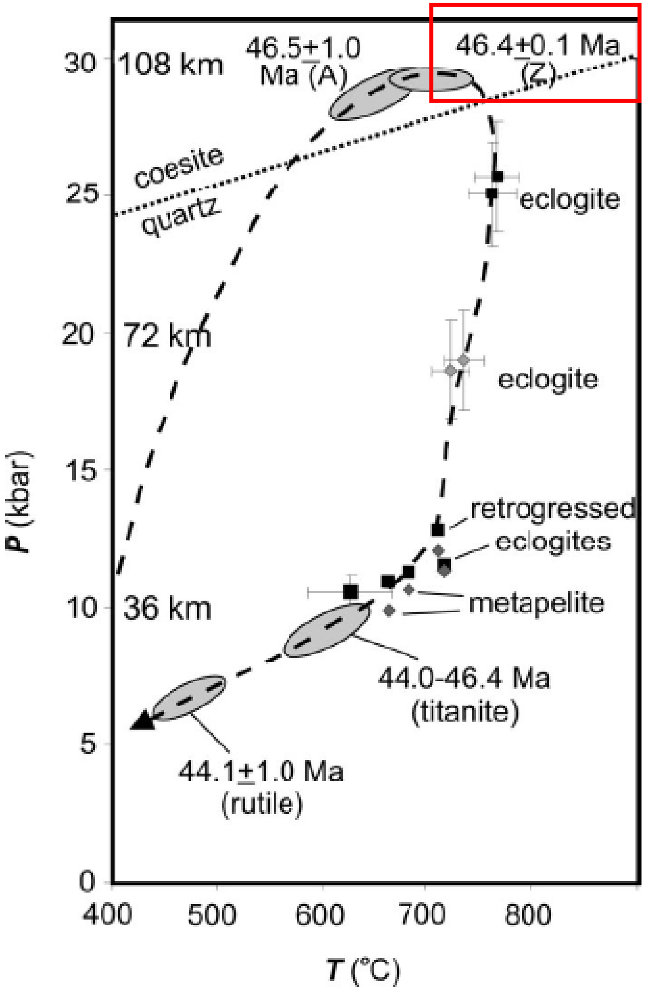
Krebs et al., in press.




Combining Modern Geochronological tools:

U-Th-Pb, Sm-Nd, Lu-Hf : High Temperature
Rb-Sr, Ar-Ar: Medium Temperature
FT and U-Th-He : low Temperature

More and more accurate datings !!



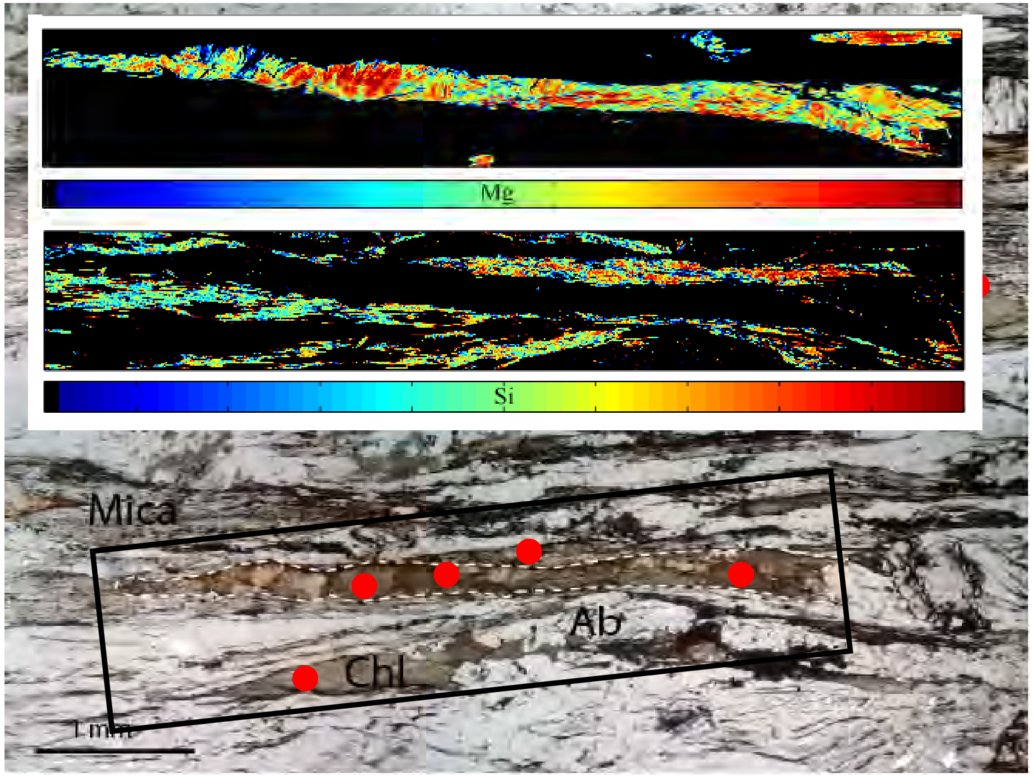

Précision: 0.1 Ma !!
Duration : 2 Ma !!

Parrish et al., 2006

***Difficulties of P-T-d estimates***

2) P-T calculation use the composition of minerals measured at points

*Point analyses not representative of the true range of composition*

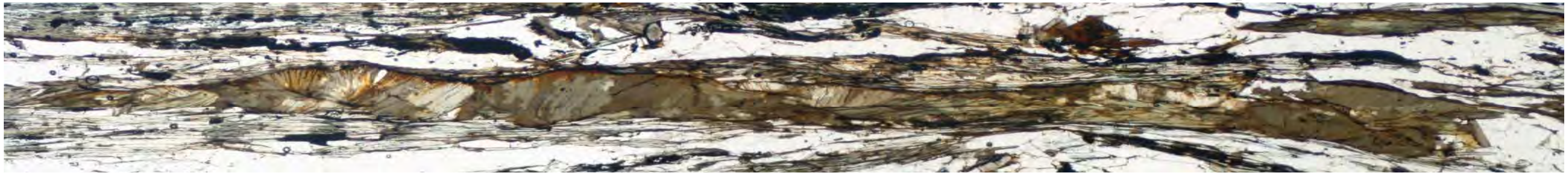



500 µm

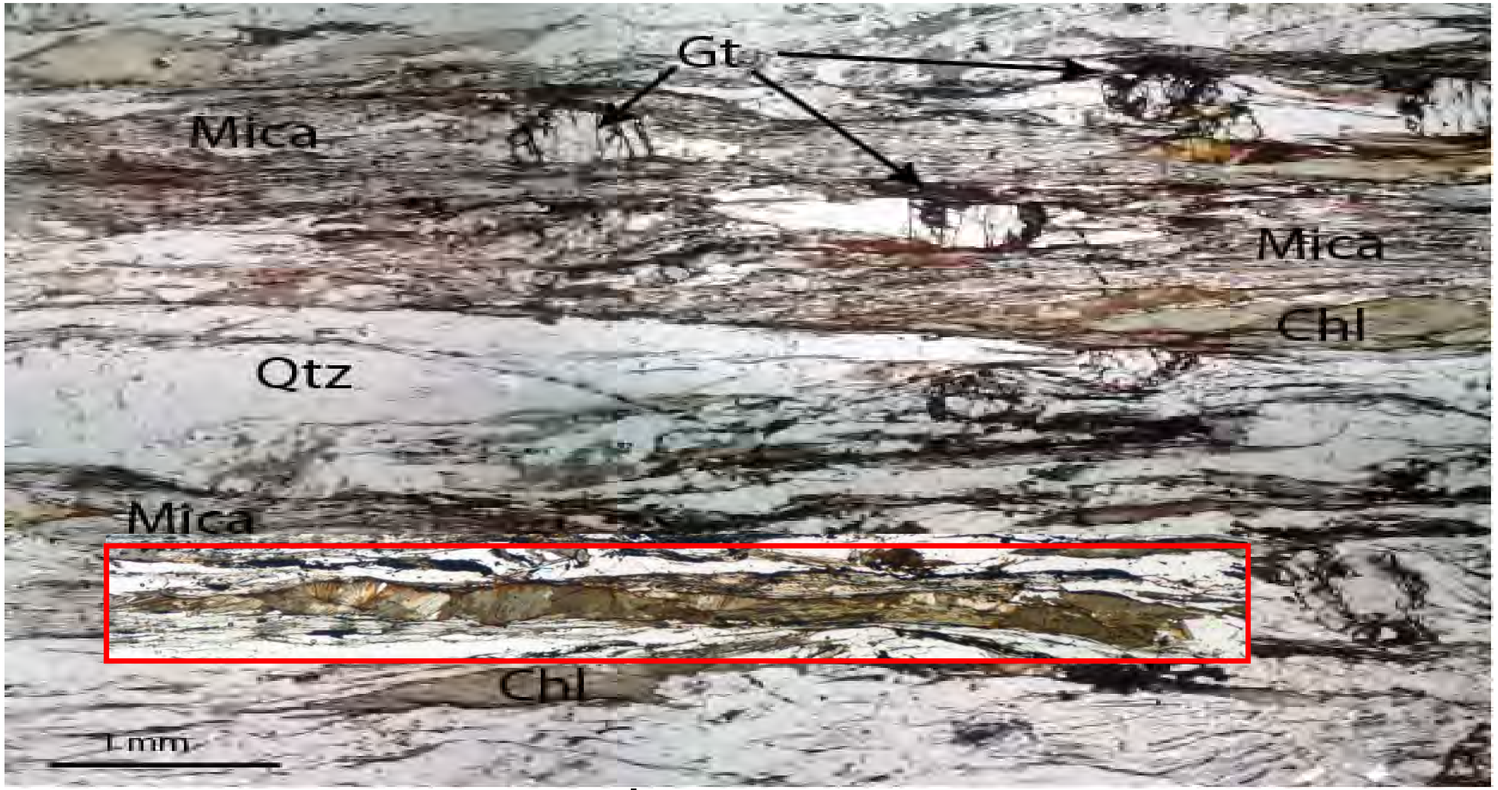
Vidal et al., 2006

*2. Quantification of X-ray maps*

***Upper Gt-bearing unit Sambagawa (Japan)***



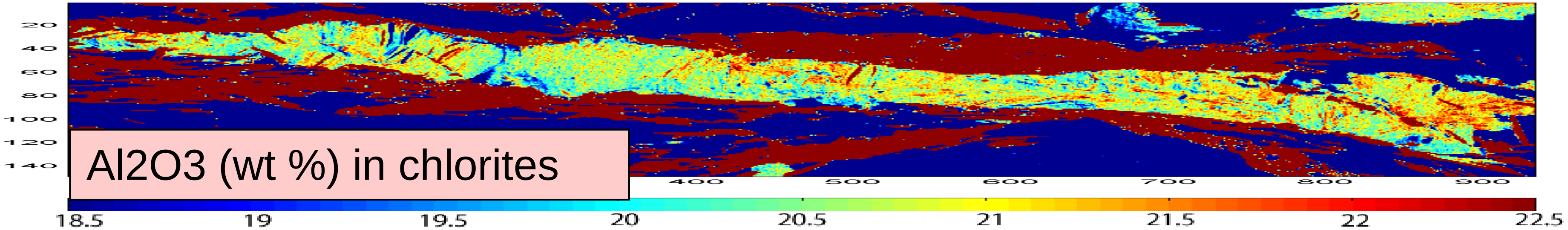
1 mm




Vidal et al., 2006

## 2.Quantification of X-ray maps

### *II. Standardization of raw data using point analyses*

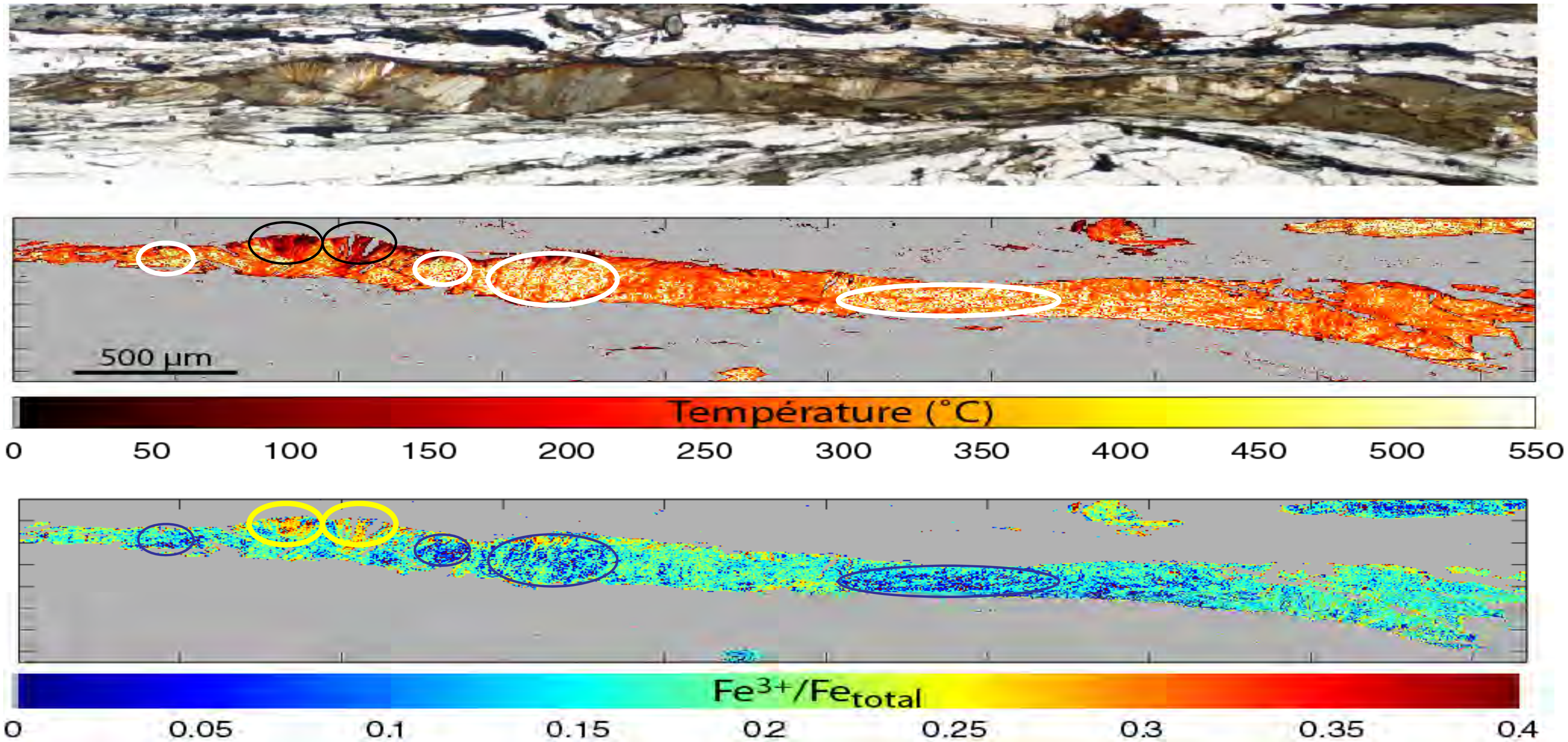



*Map of structural formulae (one for each pixel),*

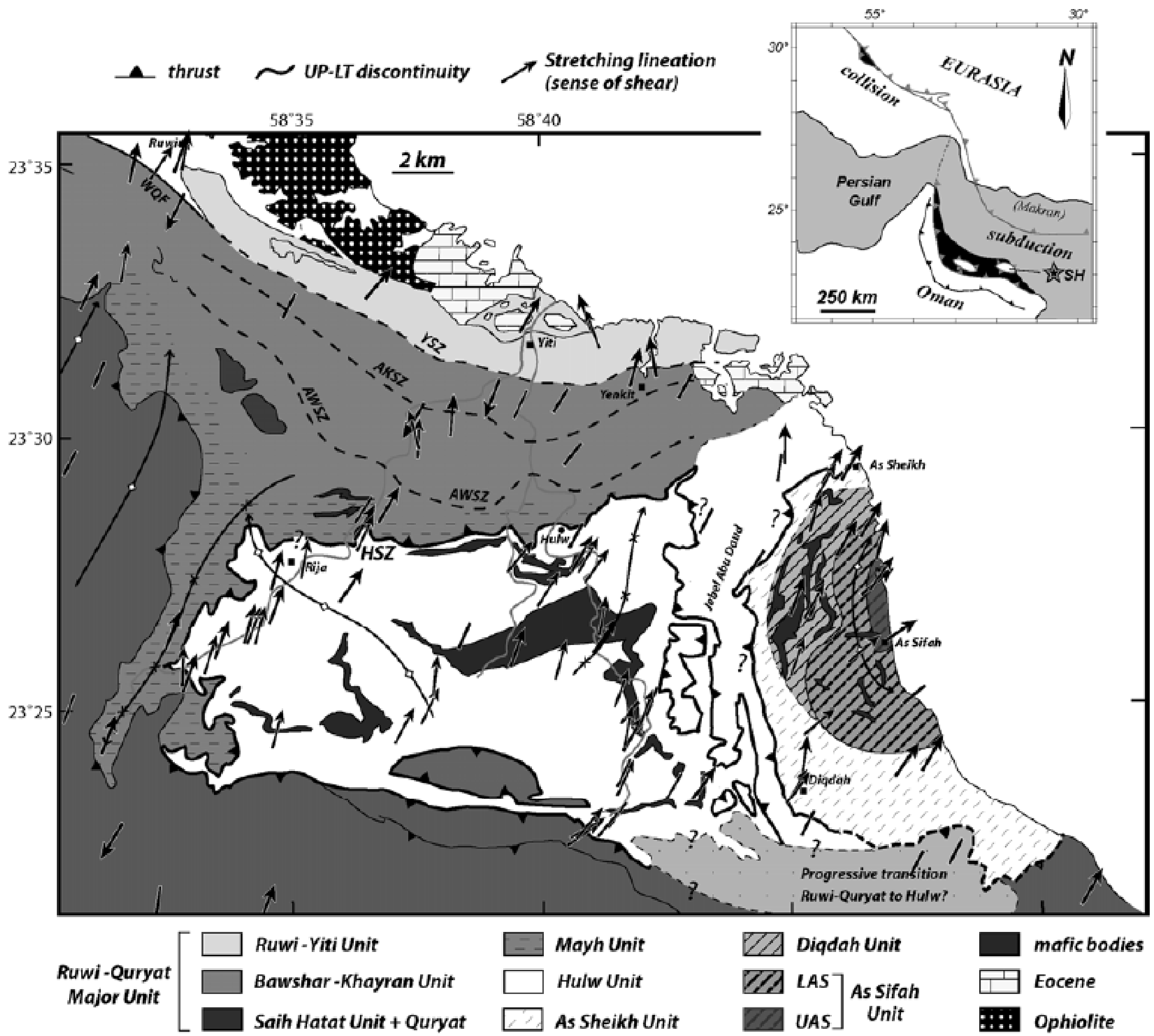
*=> One P-T estimate for each pixel*

Vidal et al., 2006

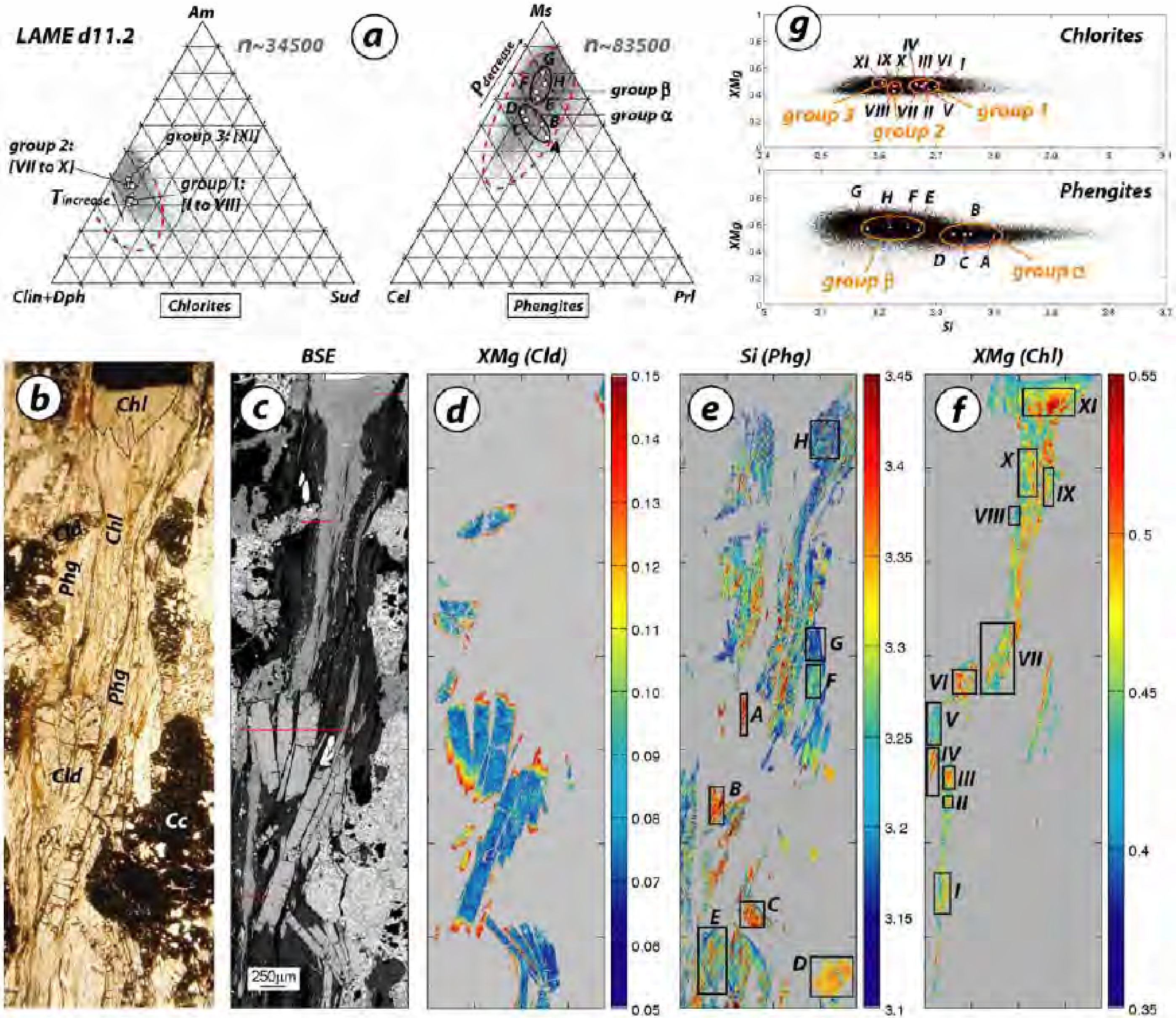
# *Chlorite formation temperature and Fe2+/Fe3+*



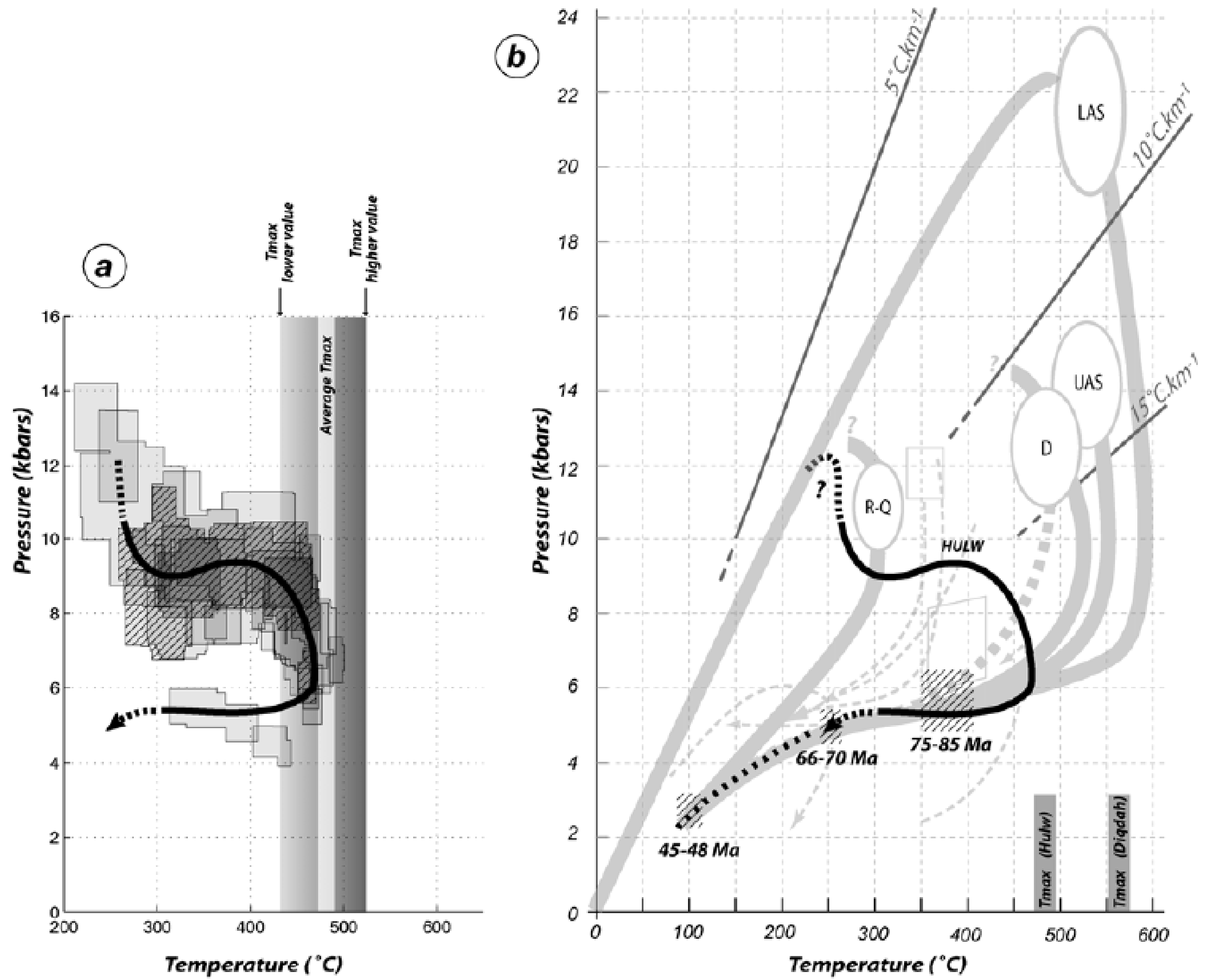

Vidal et al., 2006



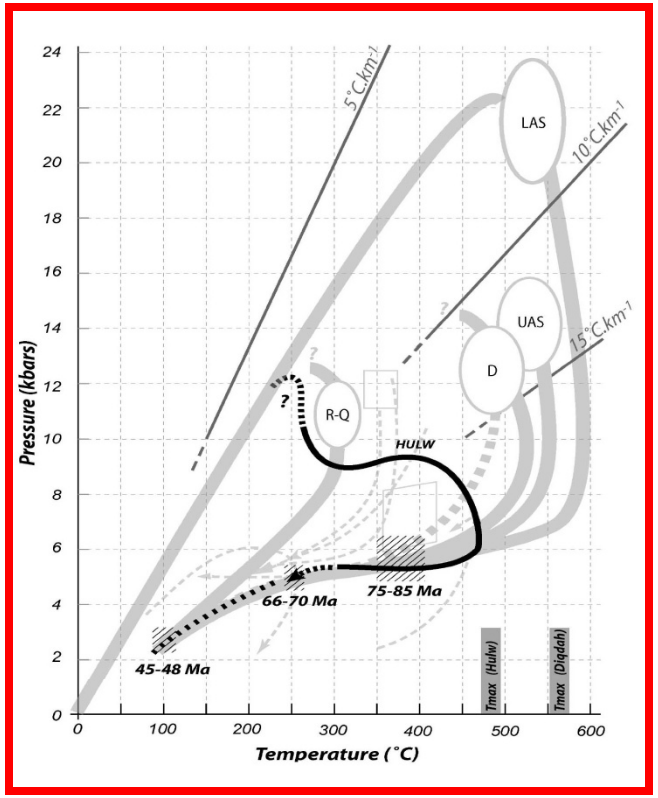

Yamato et al., 2007

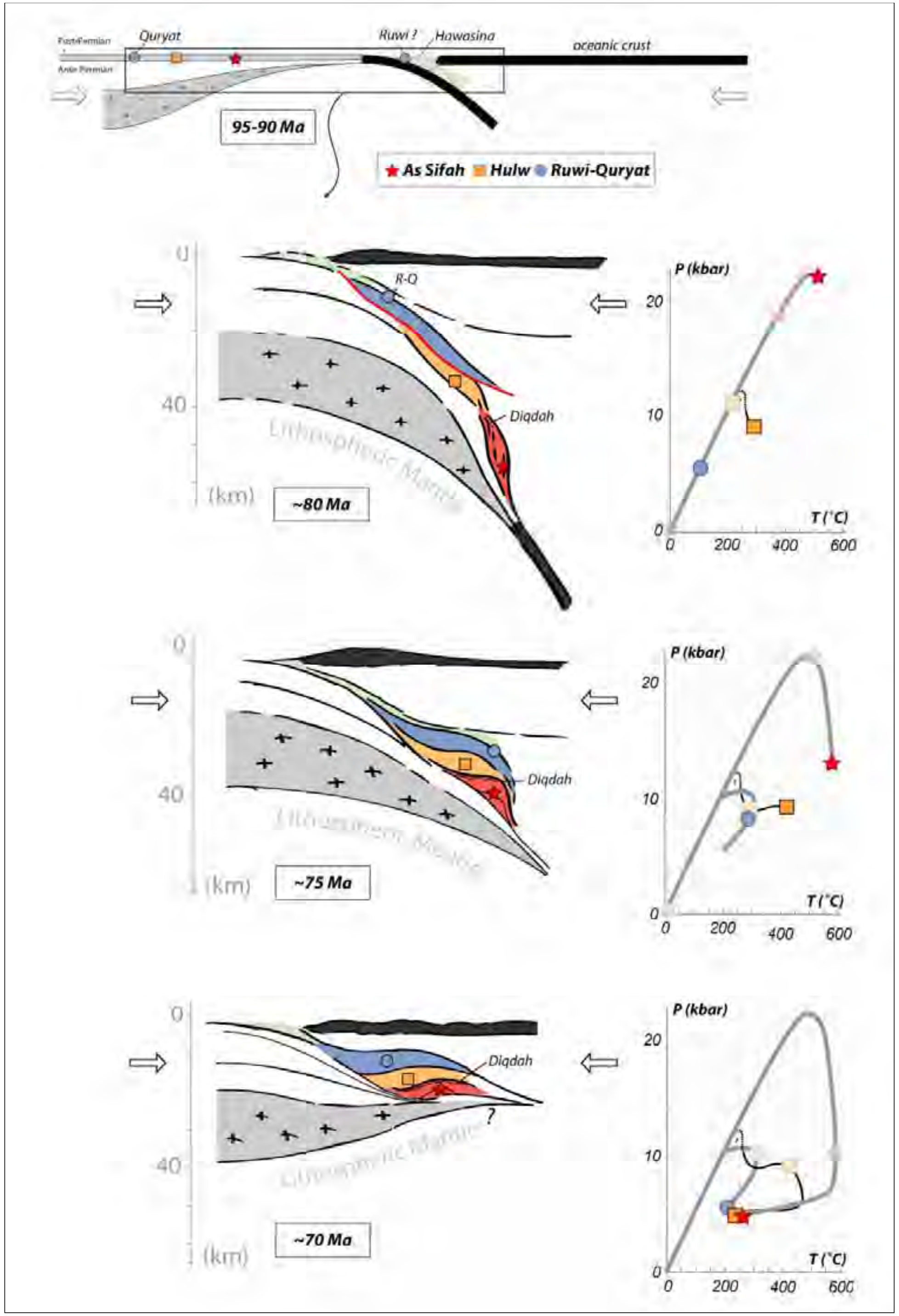



Yamato et al., 2007

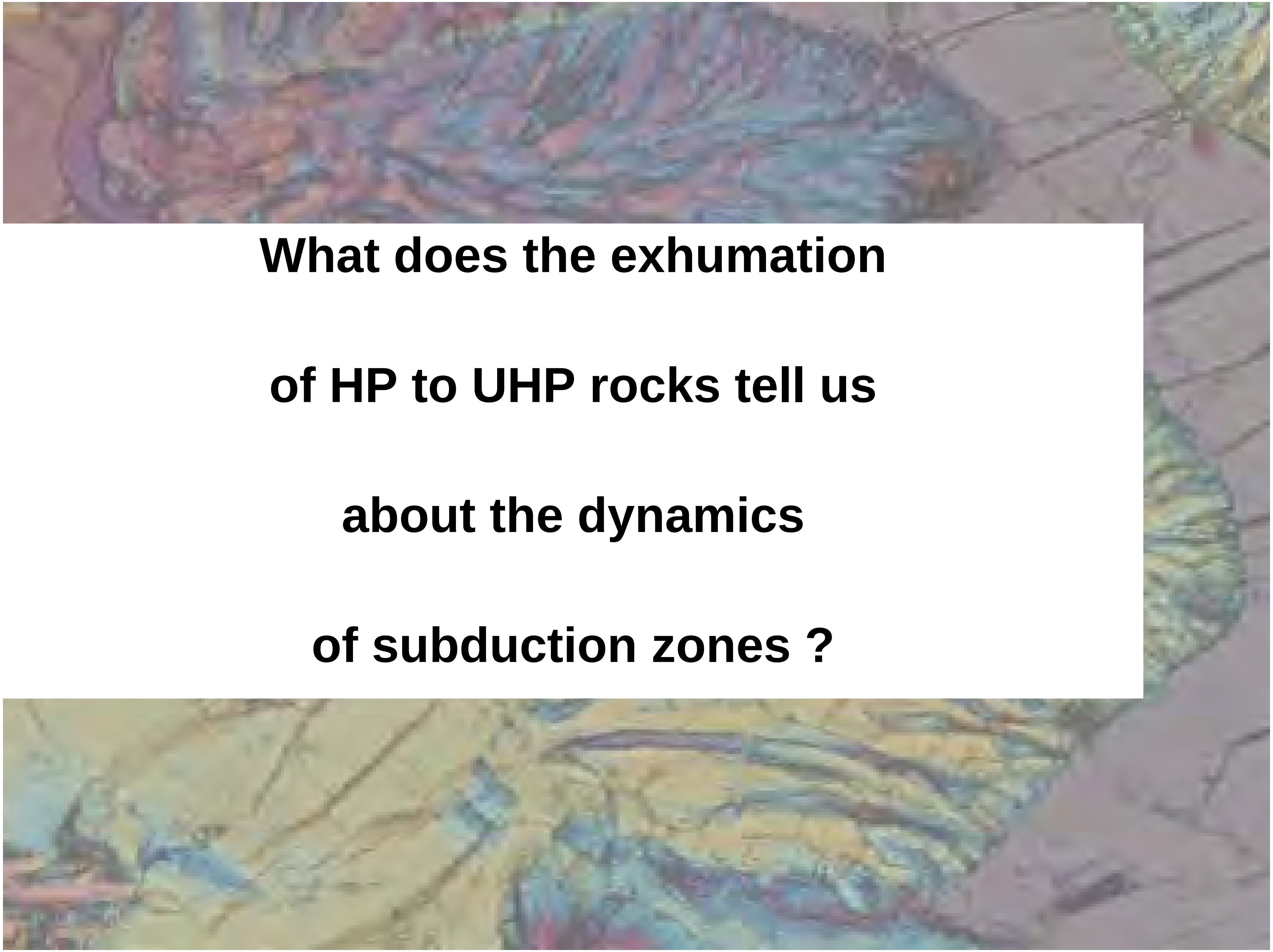



Yamato et al., 2007




Yamato et al., 2007

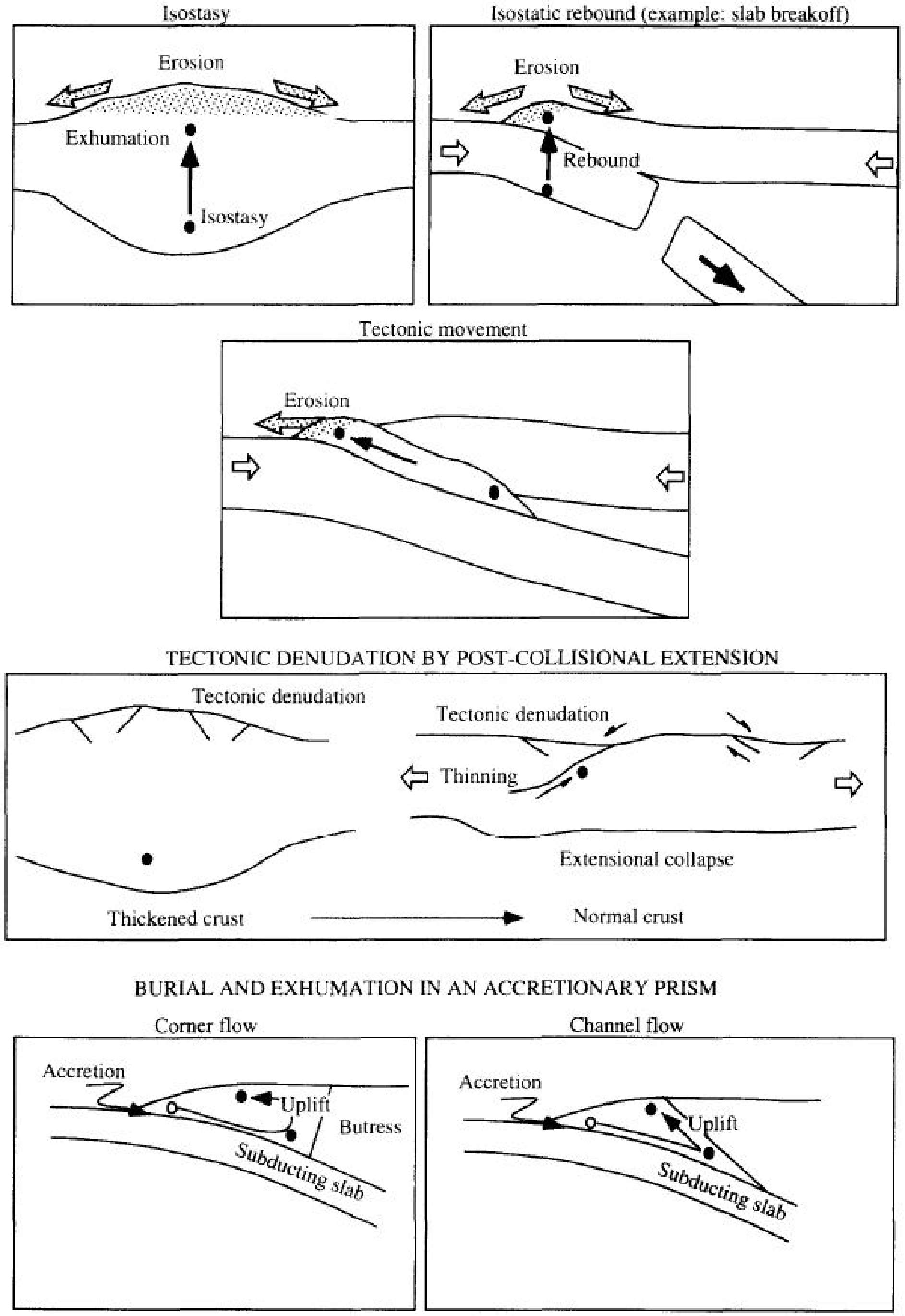


**What does the exhumation**

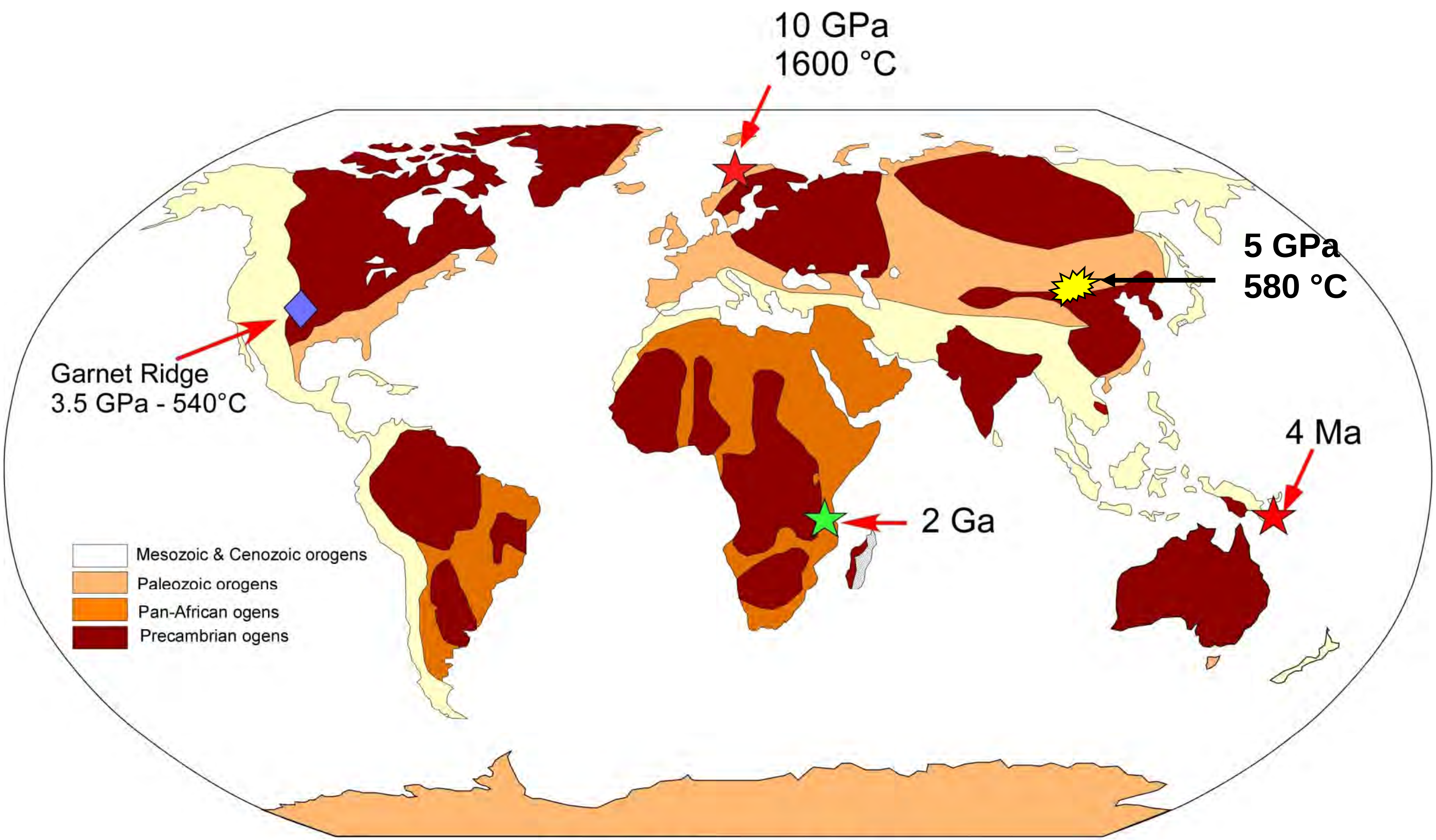
**of HP to UHP rocks tell us**

**about the dynamics**

**of subduction zones ?**

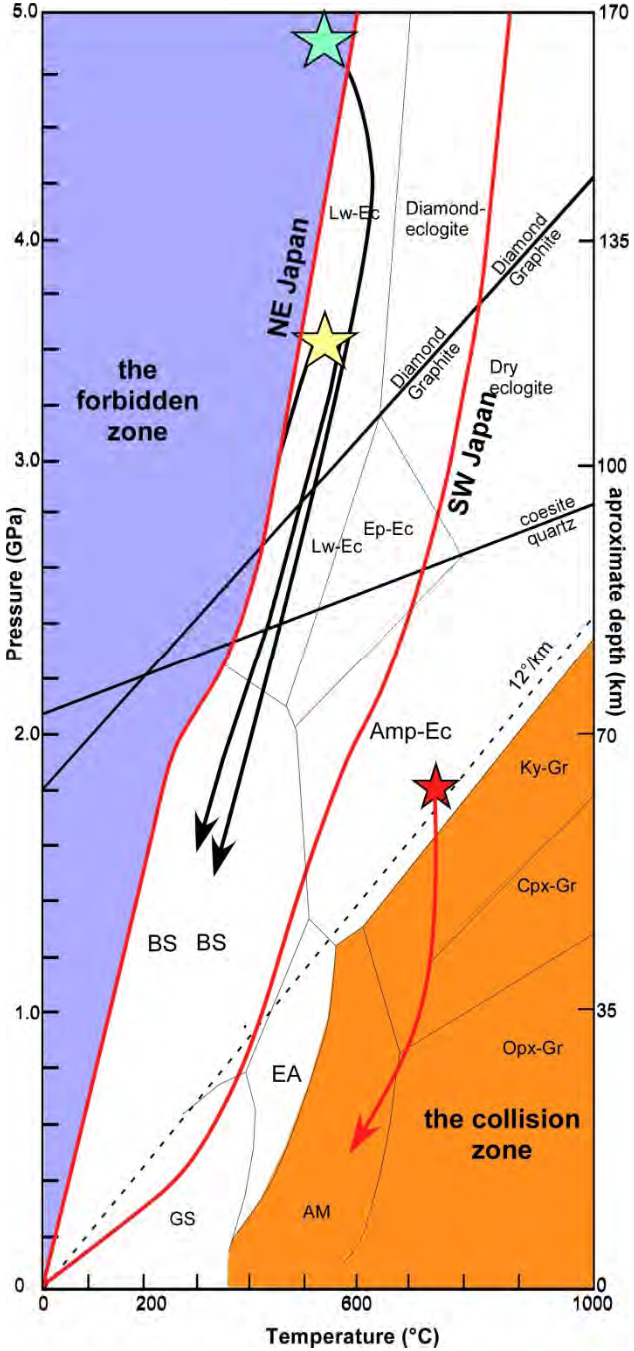



*Duchêne et al., 1997*




Extreme eclogites on Earth

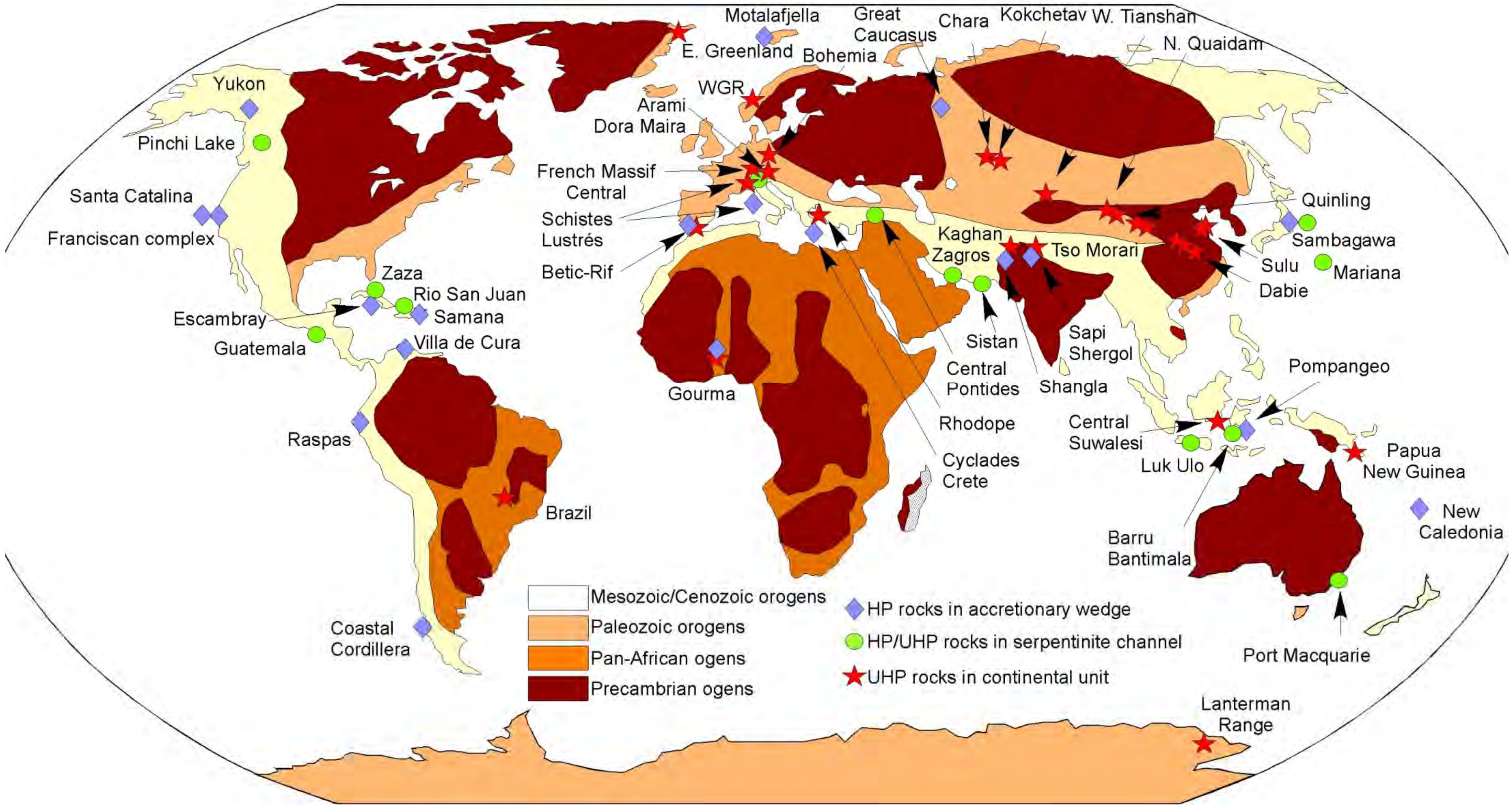
( after Van Roermund et al., 2004; Zhang et al., 2003; Collins et al., 2004, Baldwin et al., 2004)




At the first order
P-T data of eclogites from 2.0 Ga
to present day
match active subduction geotherm

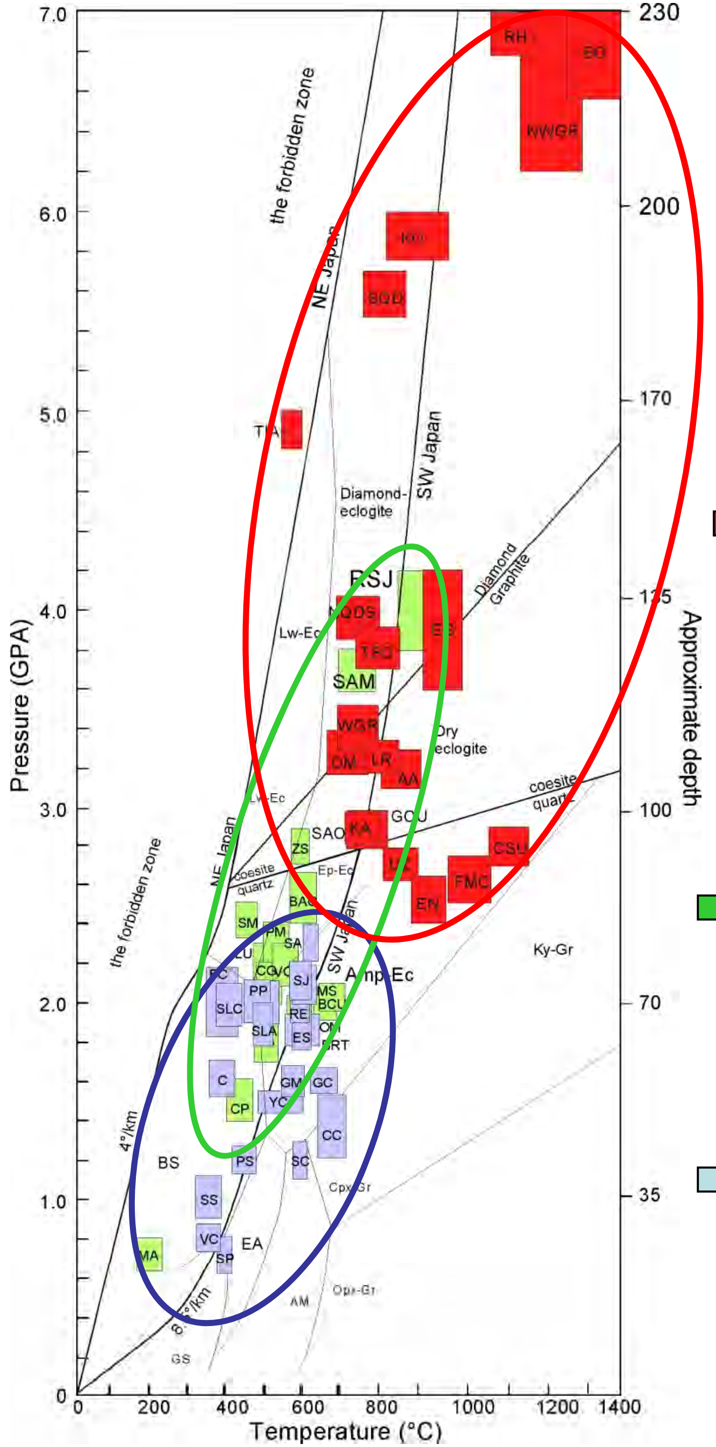
Petrological data can be used
to understanding subduction processes

# 61 occurrences of Phanerozoic HP to UHP units




Guillot et al. 2008

# Les conditions Pressure-Température

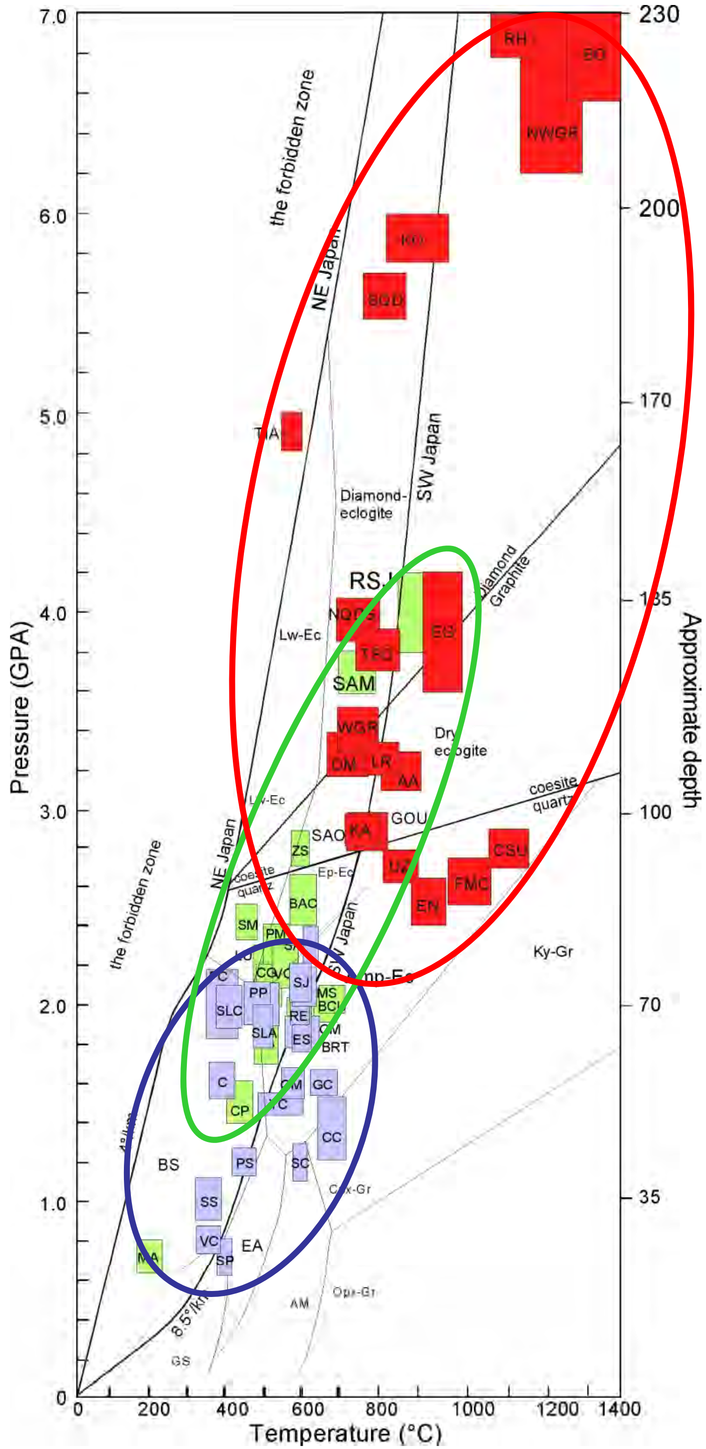



Subduction continentale

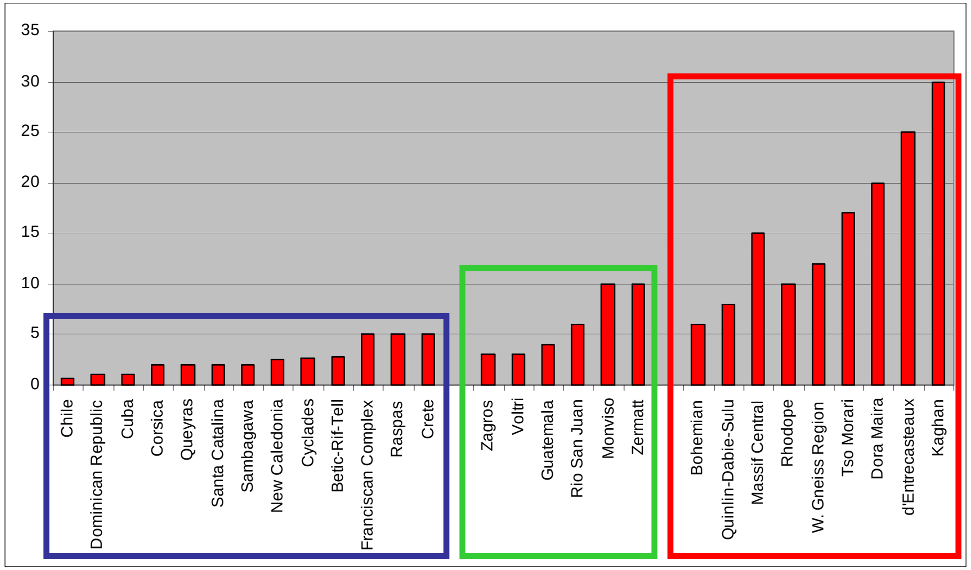
Chenal de serpentines

Prisme d’accrétion

Guillot et al. 2008




## Vitesse d'exhumation cm/yr




**Prisme D'accrétion**

**Chenal de serpentines**

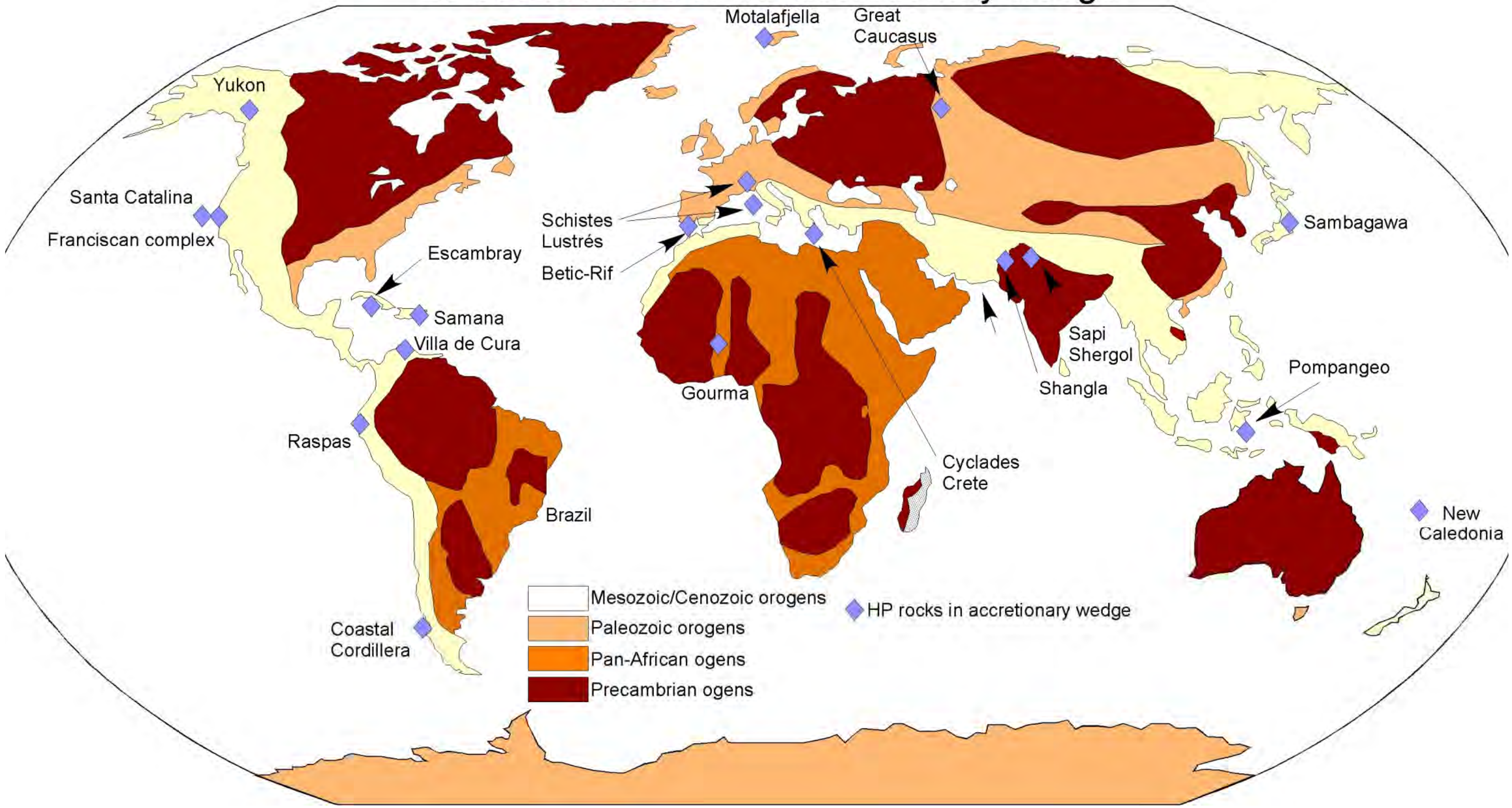
**Subduction continentale**

| faible $V_{exhum}$ (1-5 mm/yr) | int $V_{exhu}$ (0.5-1 cm/yr) | forte $V_{exhum}$ (0.7-3 cm/yr) |
|---|---|---|

Données P-T-t suggèrent
des mécanismes d'exhumation différents

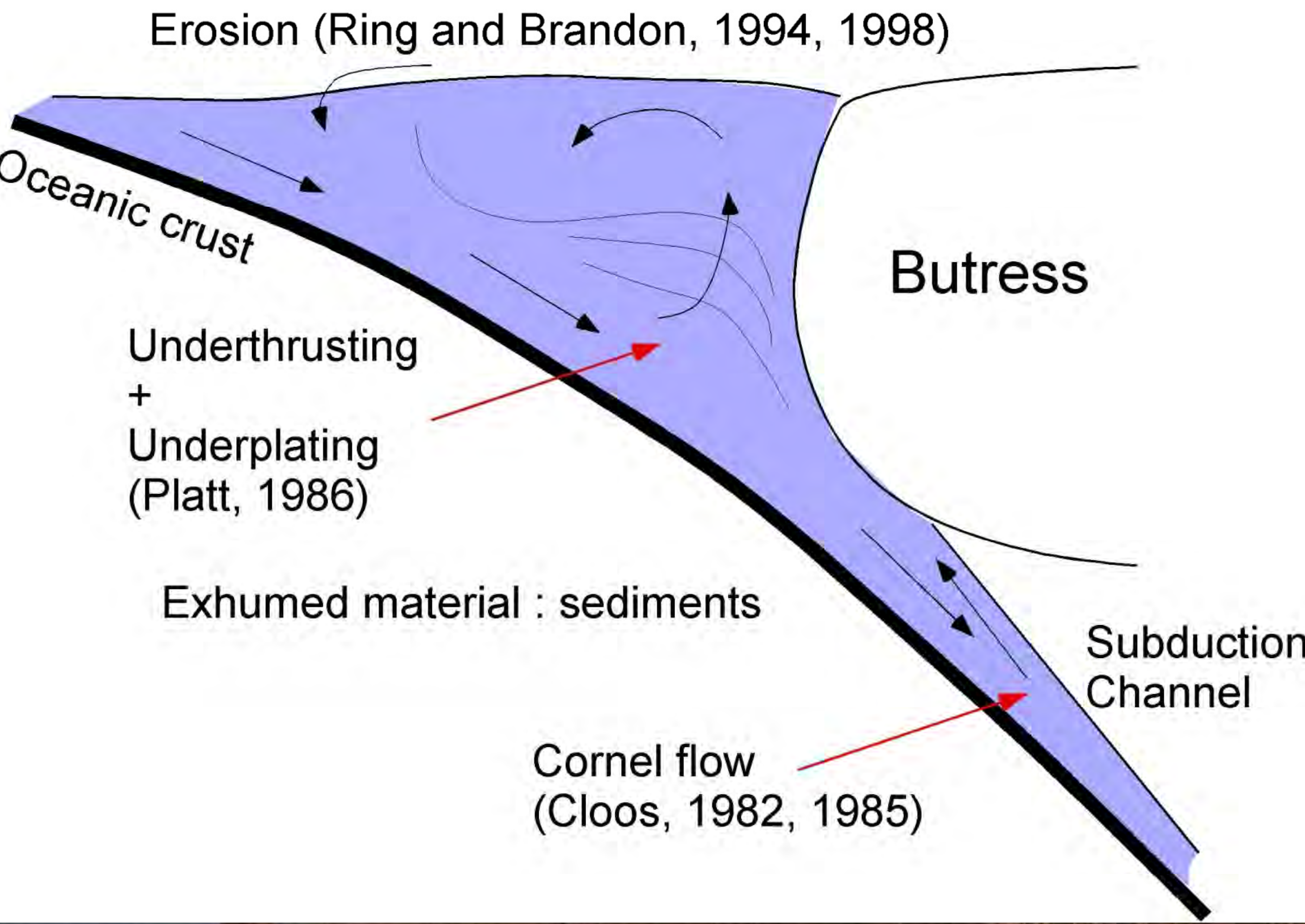
Guillot et al. 2008

# 20 occurrences of HP accretionary wedge

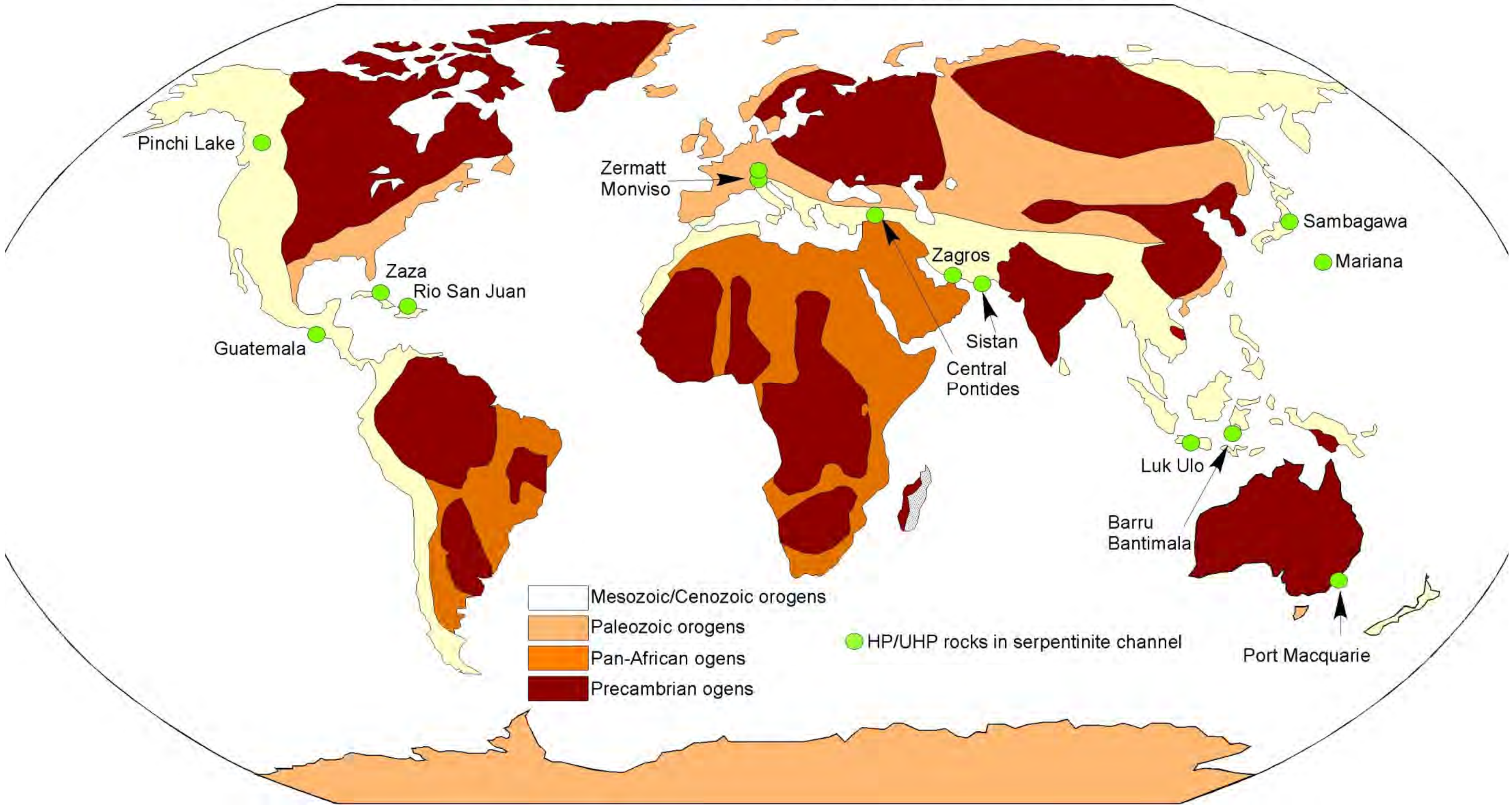


# Pacific-Type Subduction (Bally, 1981)

accretionary wedge system

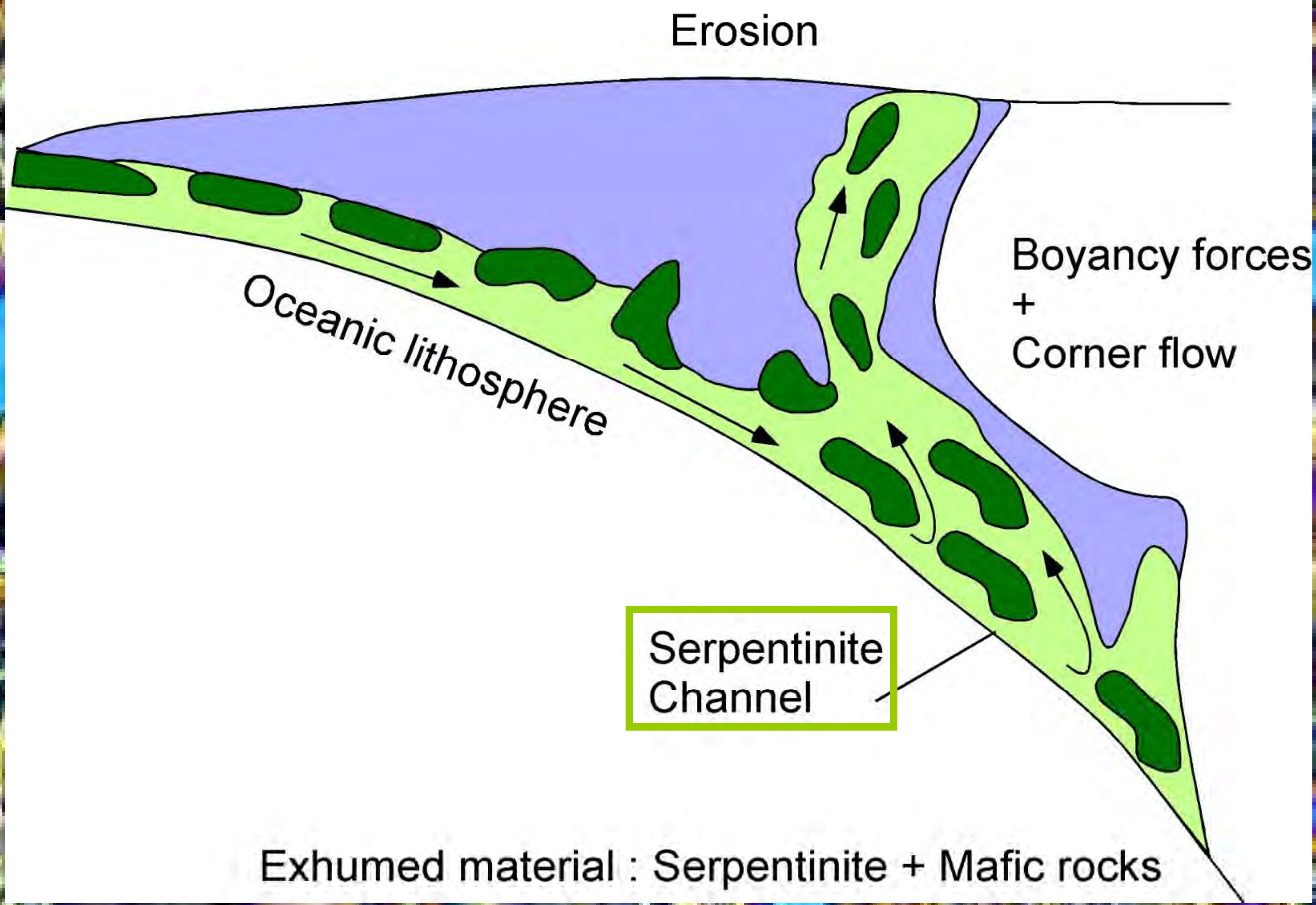


# 14 occurrences of HP-UHP rocks in serpentinite channel



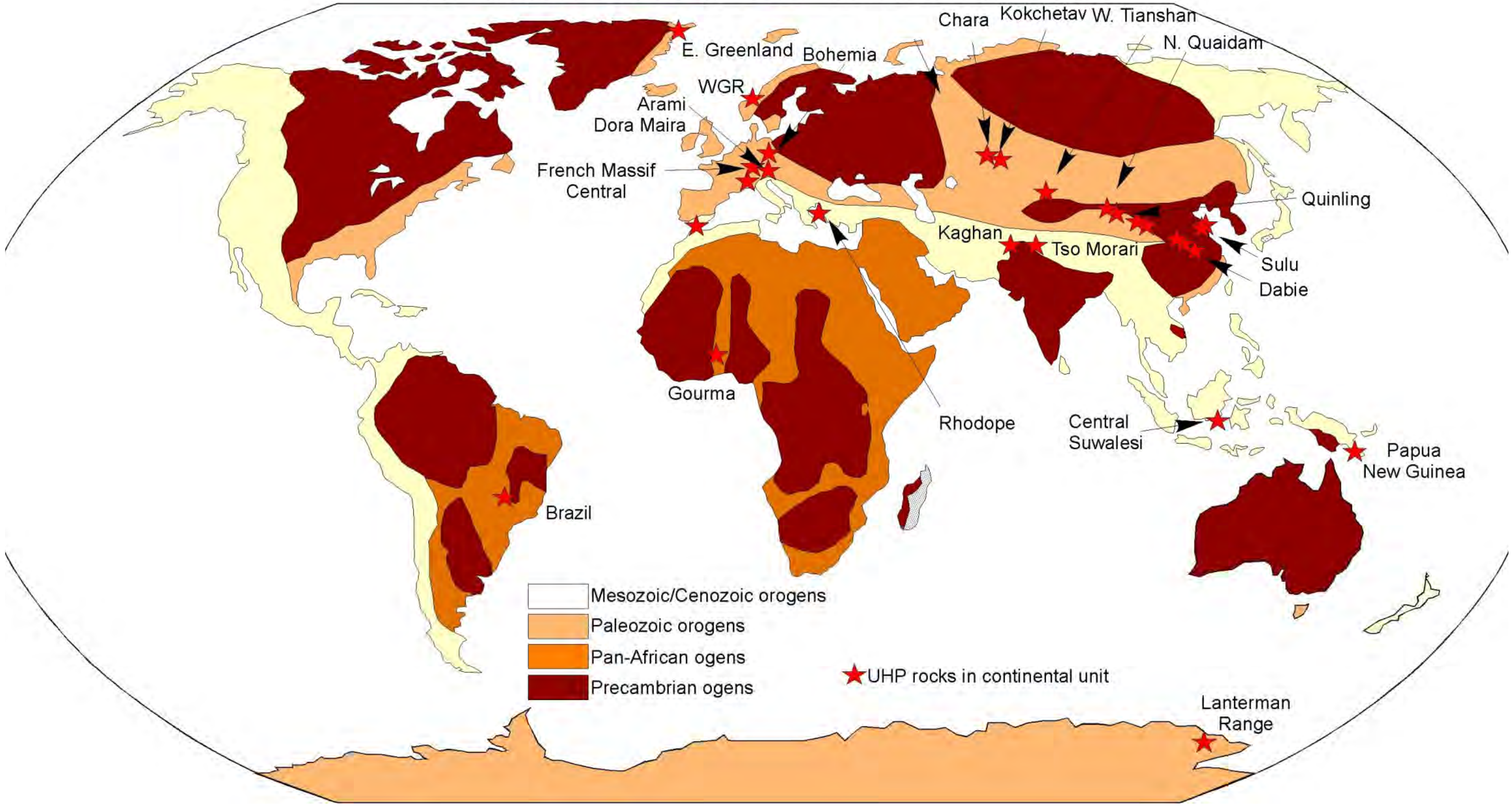
Serpentinite-Type Subduction
(Guillot et al., 2001; Gerya et al., 2002)

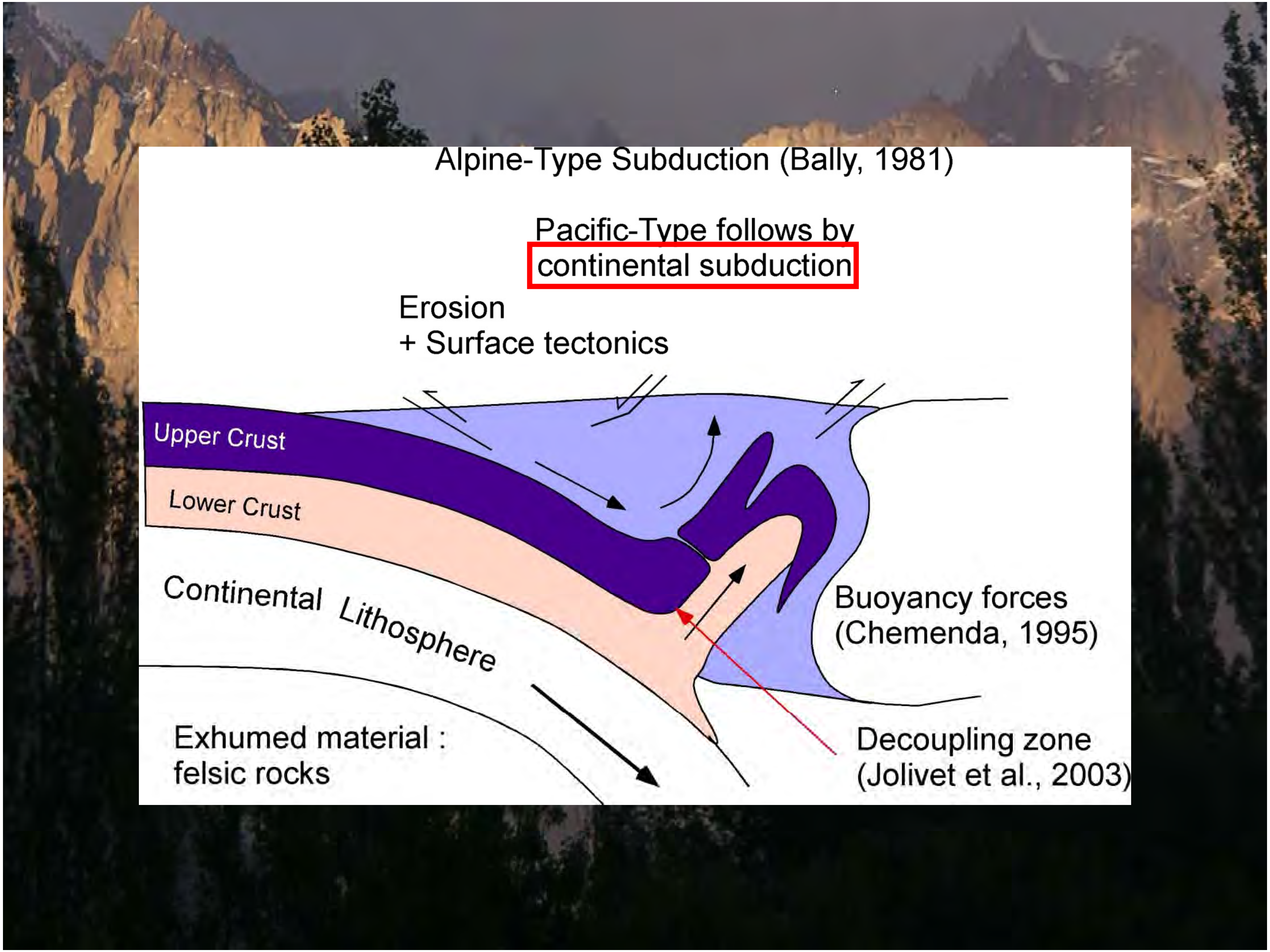
Sediments are replaced by serpentines



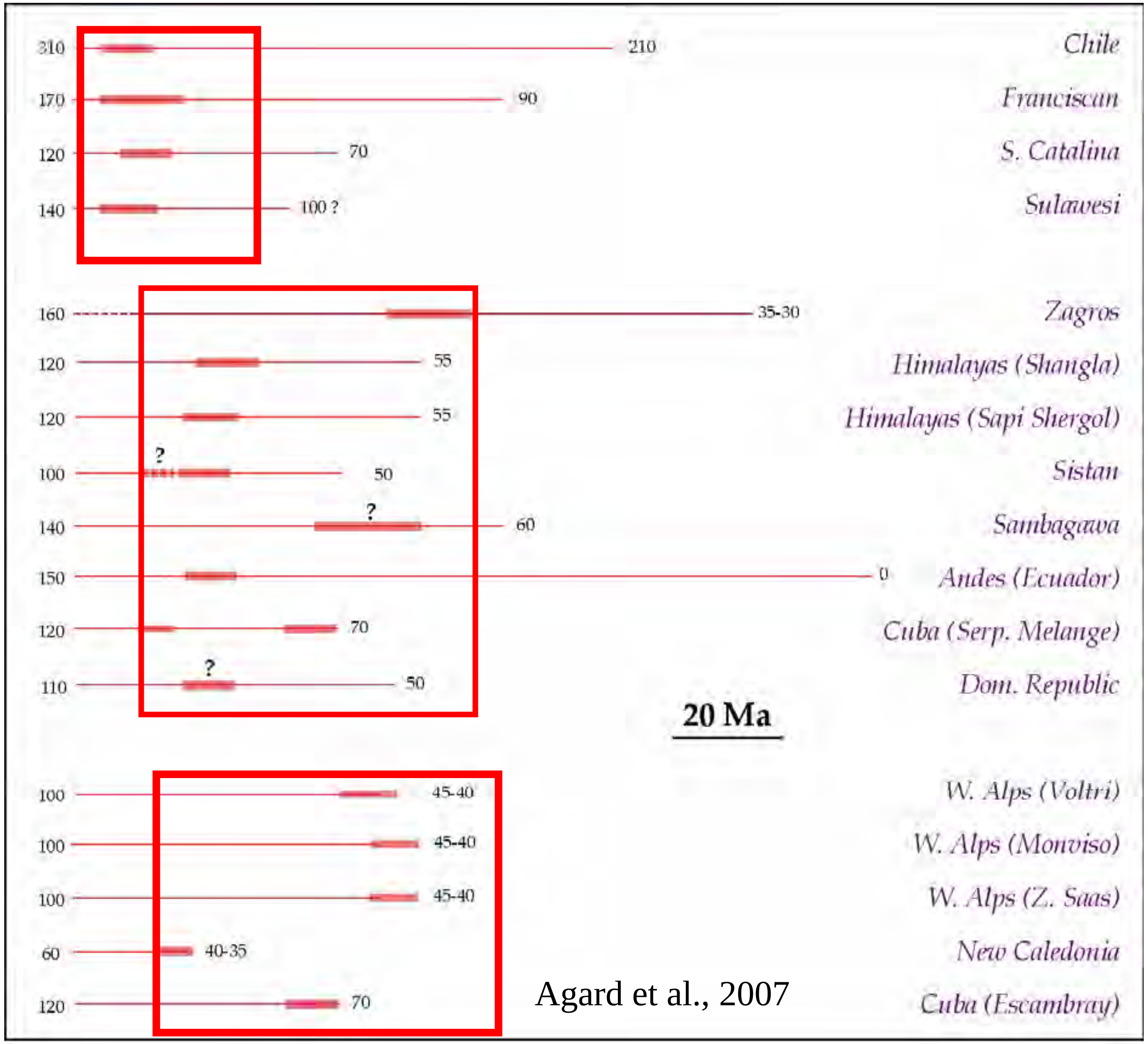

Exhumed material : Serpentinite + Mafic rocks

# 27 occurrences of UHP continental units

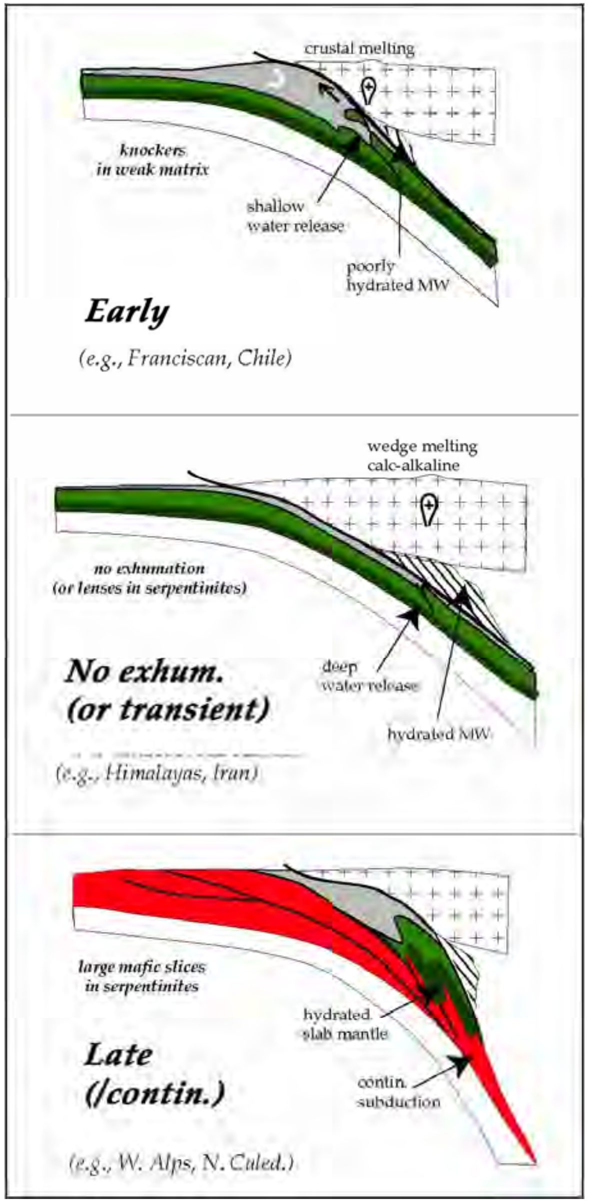



Alpine-Type Subduction (Bally, 1981)
Pacific-Type follows by
continental subduction
Erosion
+ Surface tectonics
Upper Crust
Lower Crust
Continental Lithosphere
Buoyancy forces
(Chemenda, 1995)
Exhumed material :
felsic rocks
Decoupling zone
(Jolivet et al., 2003)

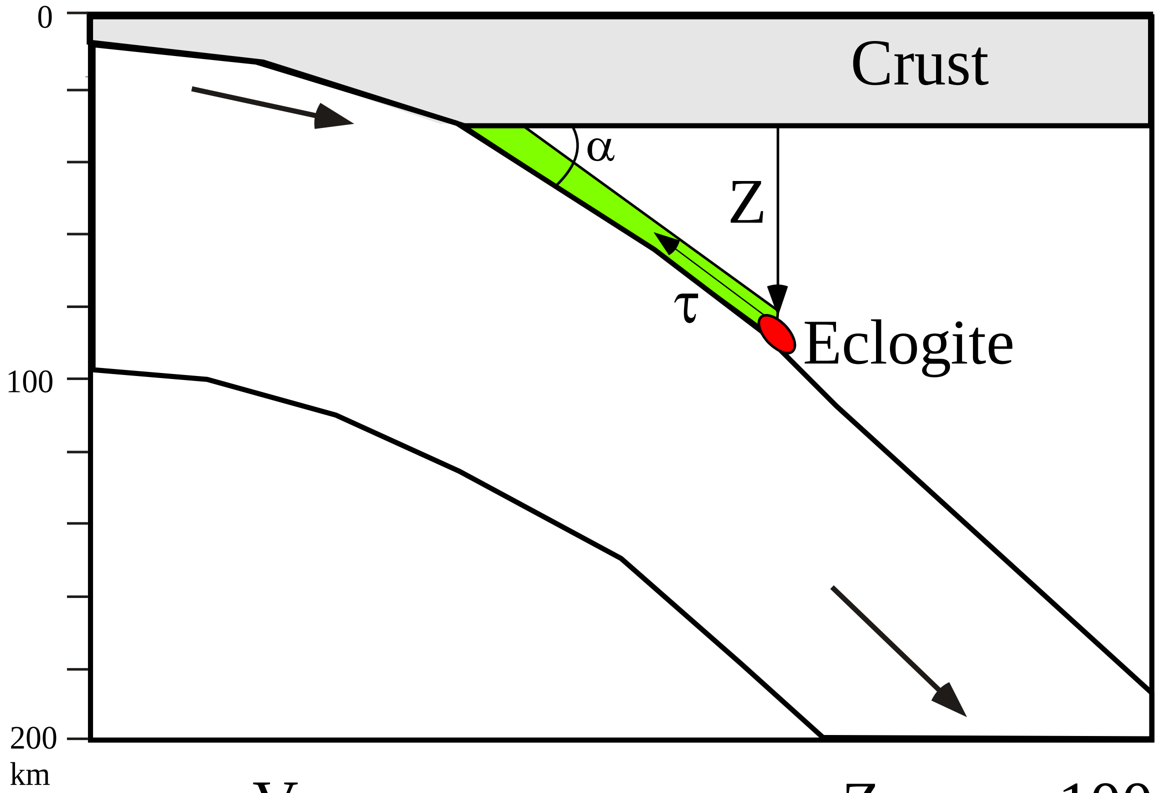
**⇒discontinuous exhumation during oceanic convergence !!**




Agard et al., 2007



What are the driving forces for the exhumation of HP oceanic units ?




$$\mathring{\varepsilon} = \frac{V}{Z\sin\alpha} = 5.10^{-13} s^{-1}$$

Zmax = 100 km

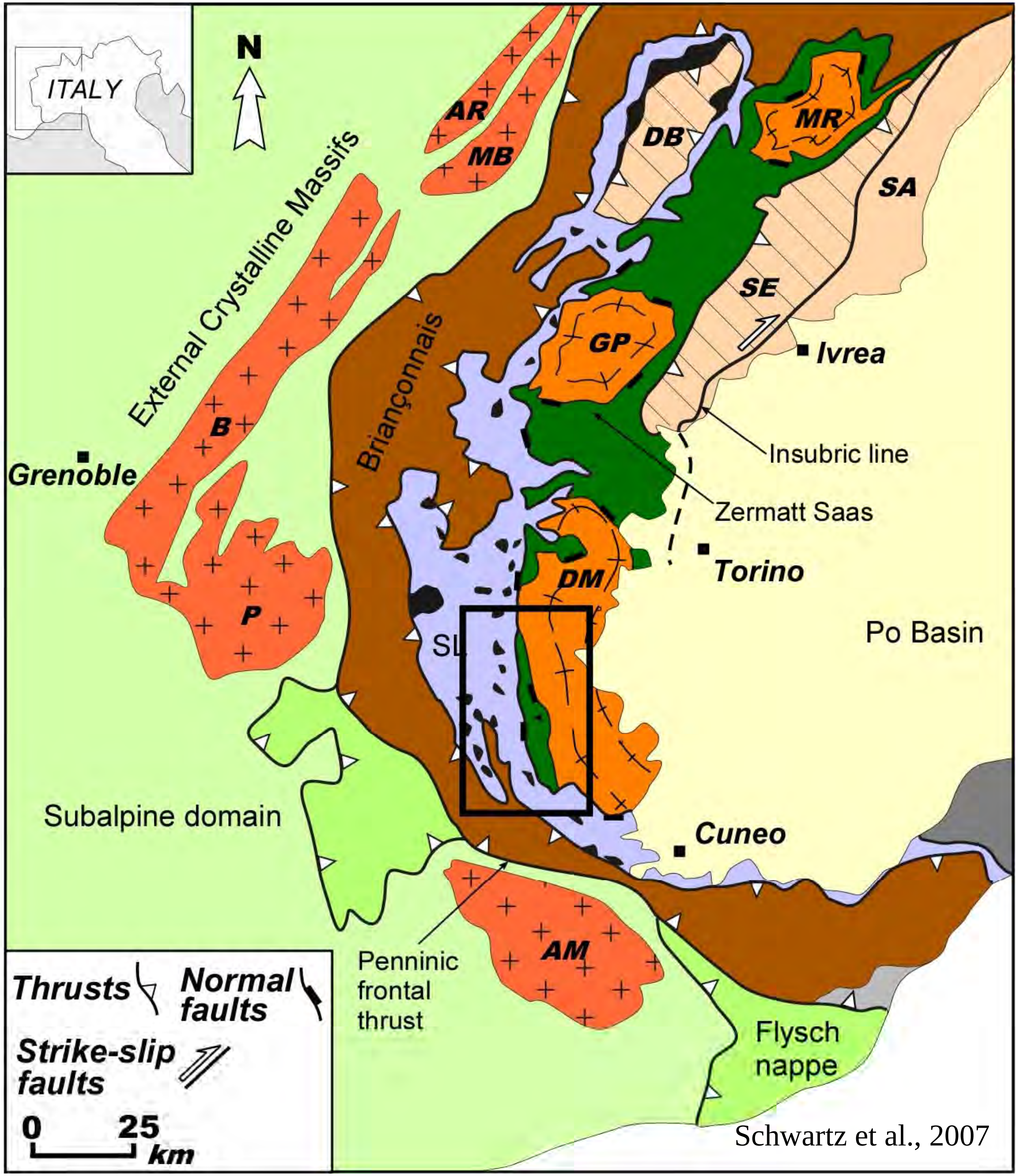
Vmax = 3 cm/yr

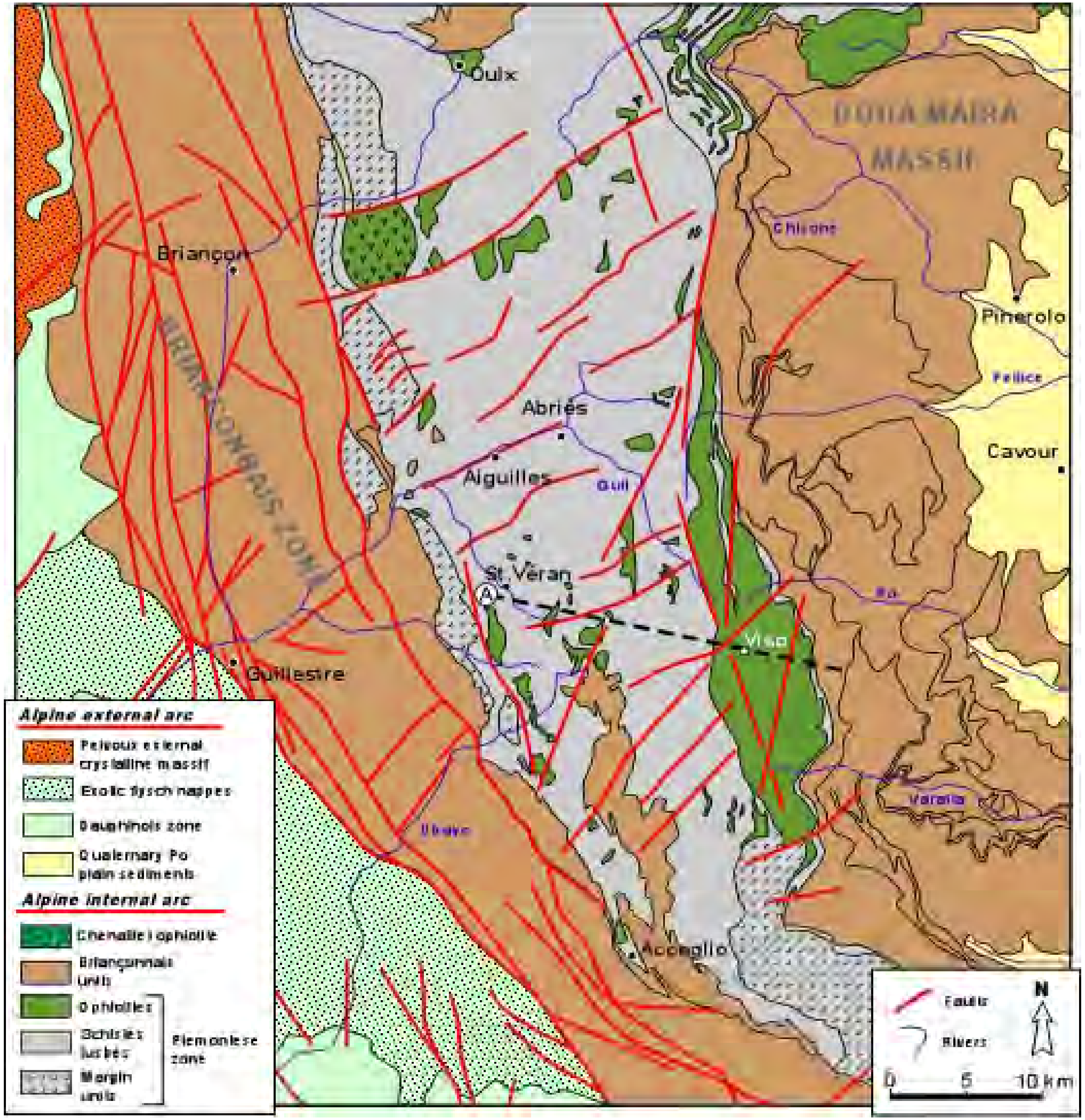
τ : 10 MPa

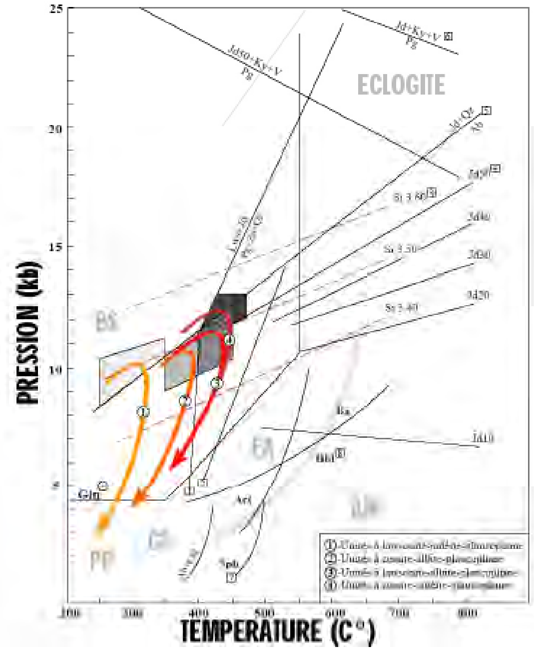
$$\boxed{\mu = \frac{\tau}{2\mathring{\varepsilon}} = 10^{19}\ \text{Pa.s}}$$

Guillot et al., 2001

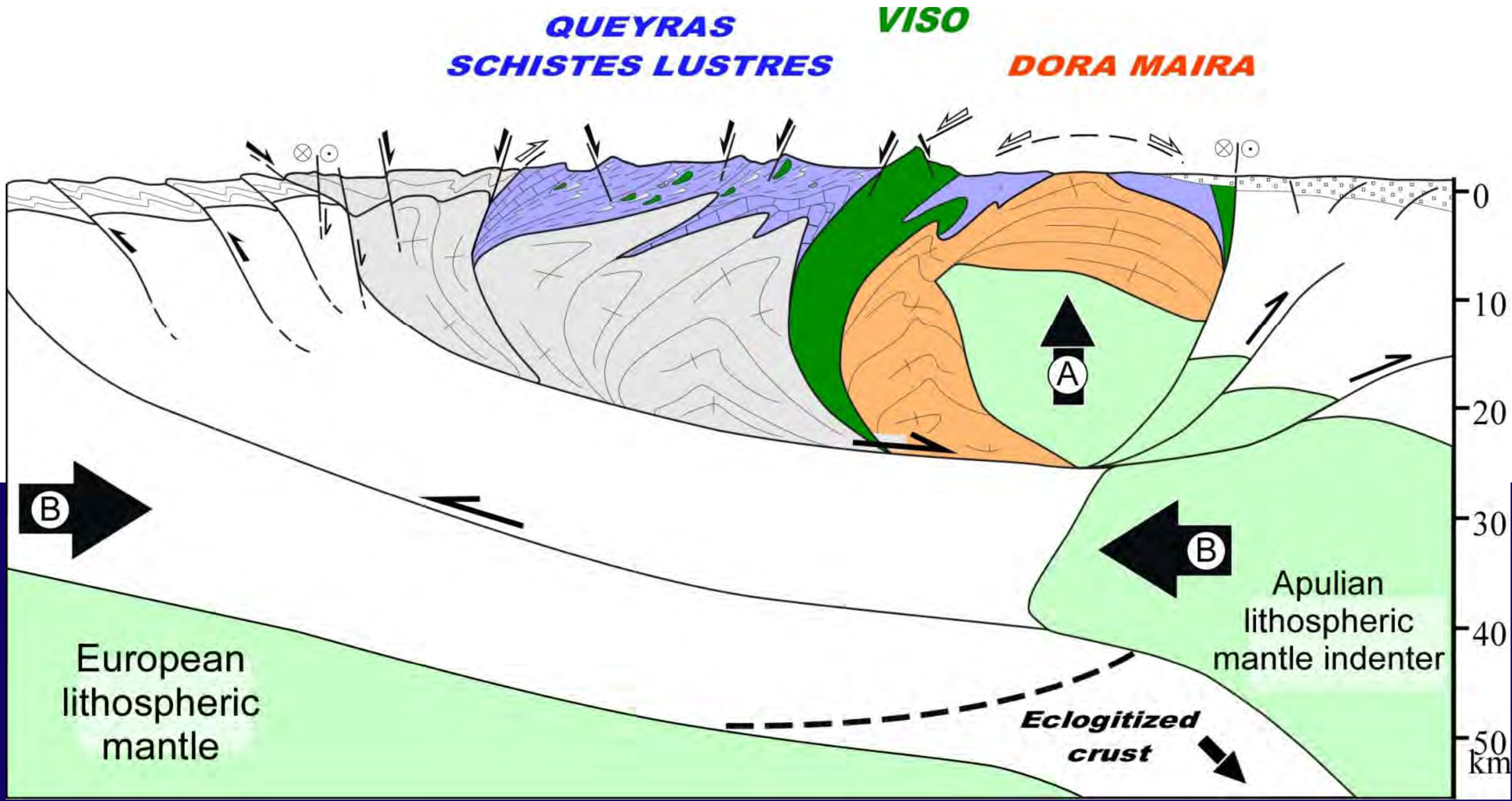
The viscosity of the subduction channel should be low !!

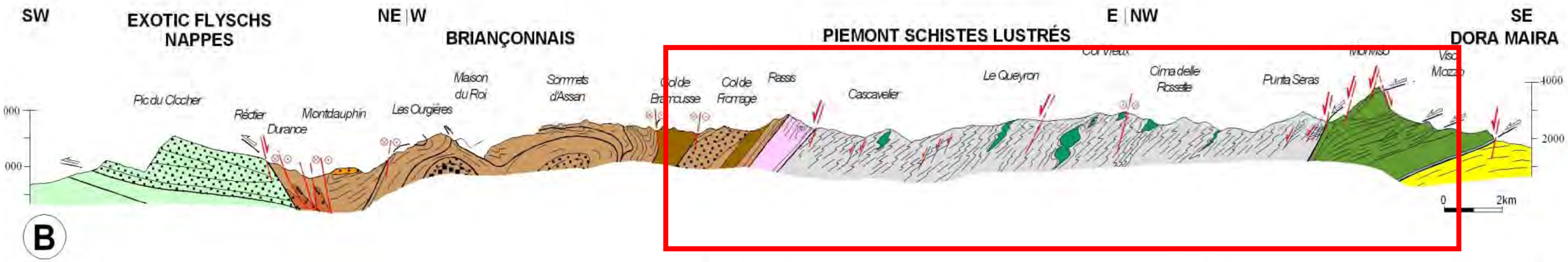

ITALY
N
AR
MB
External Crystalline Massifs
B
Grenoble
P
Briançonnais
DB
MR
SA
SE
GP
Ivrea
Insubric line
Zermatt Saas
DM
Torino
SL
Po Basin
Subalpine domain
Cuneo
AM
Penninic frontal thrust
Flysch nappe
Thrusts
Normal faults
Strike-slip faults
0
25
km
Schwartz et al., 2007



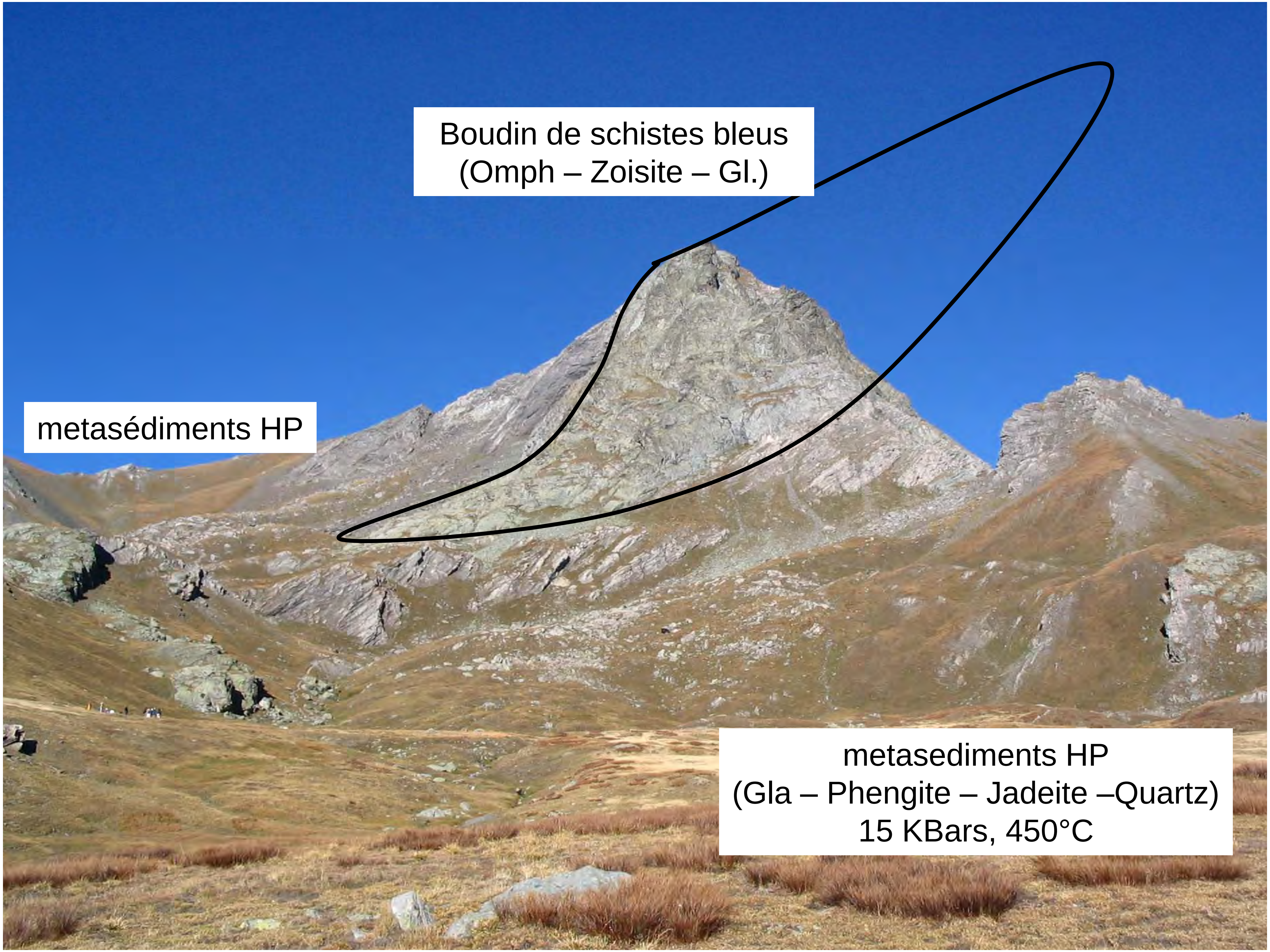



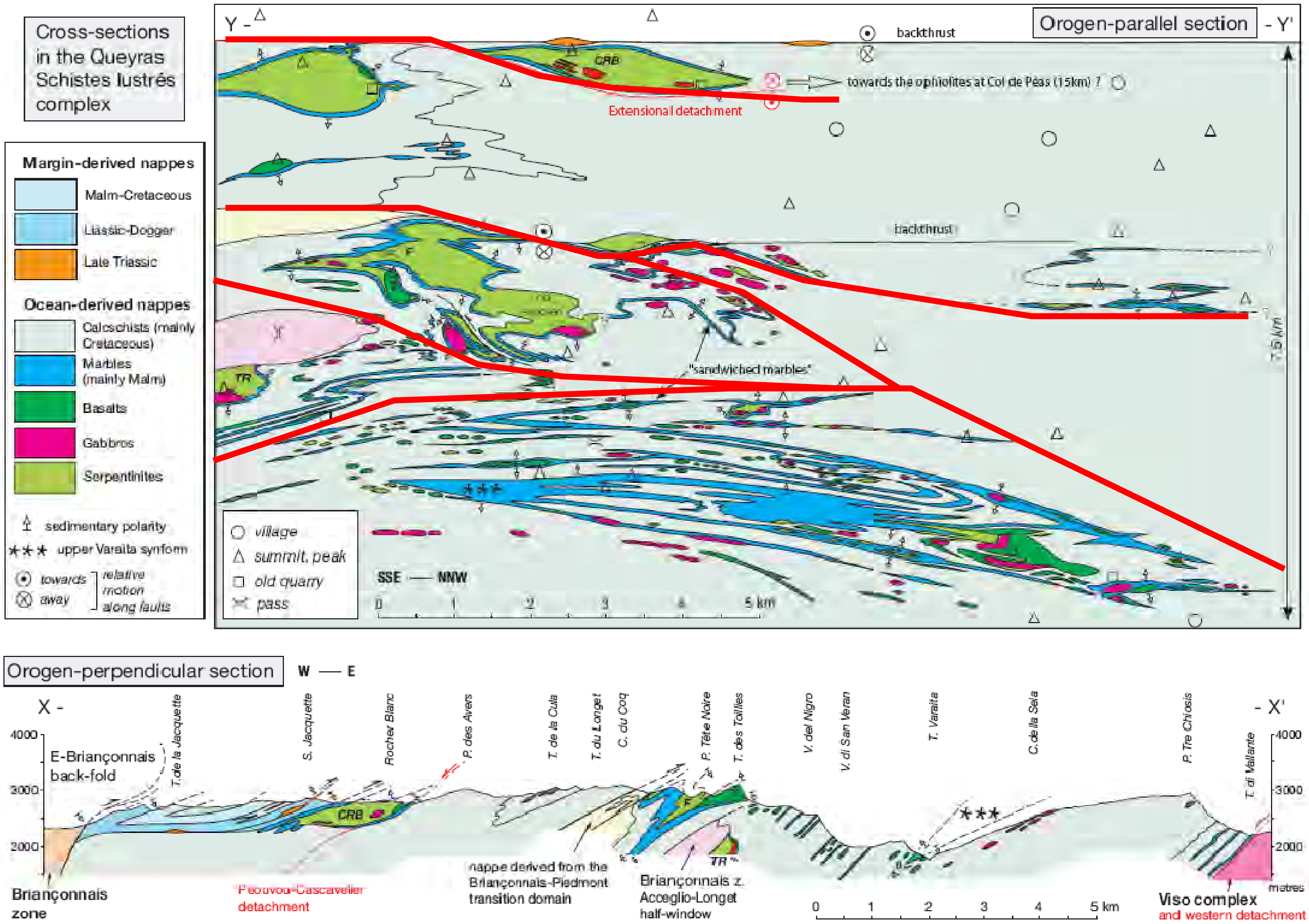

Schwartz et al., 2007



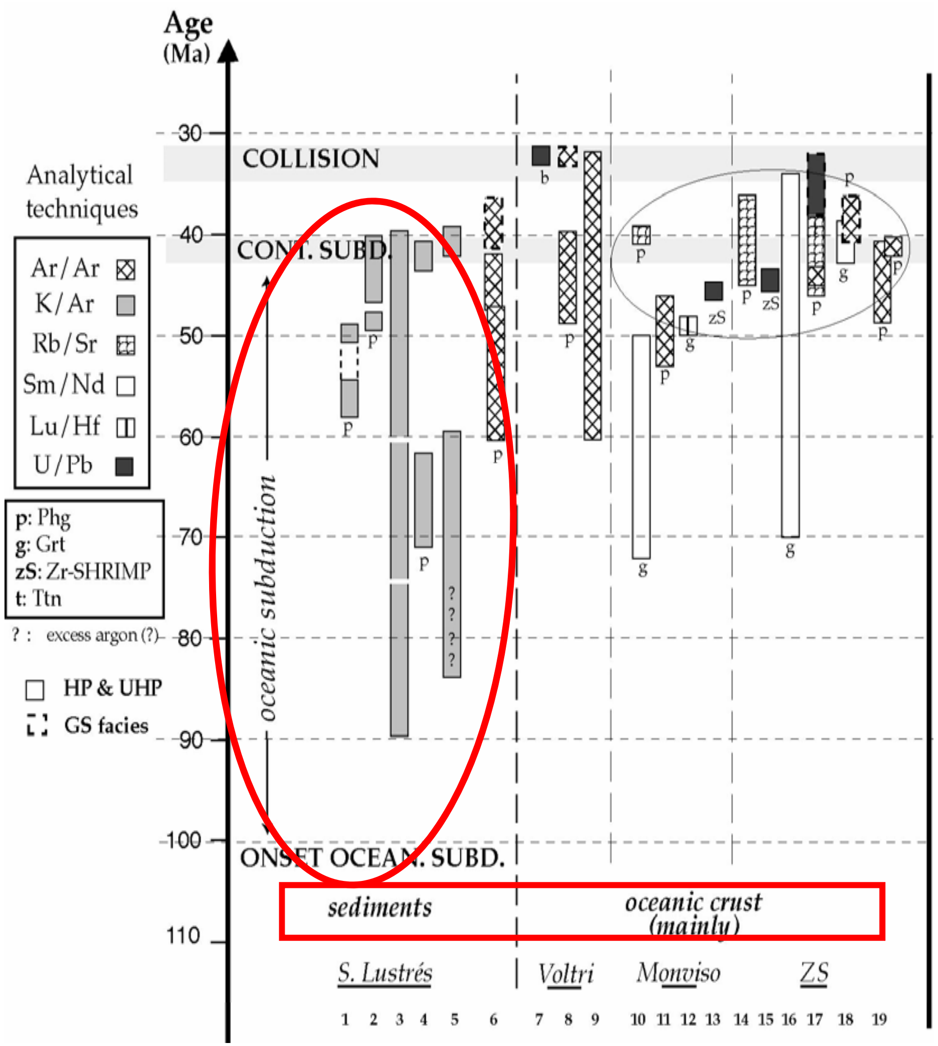




Lardeaux et al., 2007


Boudin de schistes bleus
(Omph – Zoisite – Gl.)
metasédiments HP
metasediments HP
(Gla – Phengite – Jadeite –Quartz)
15 KBars, 450°C

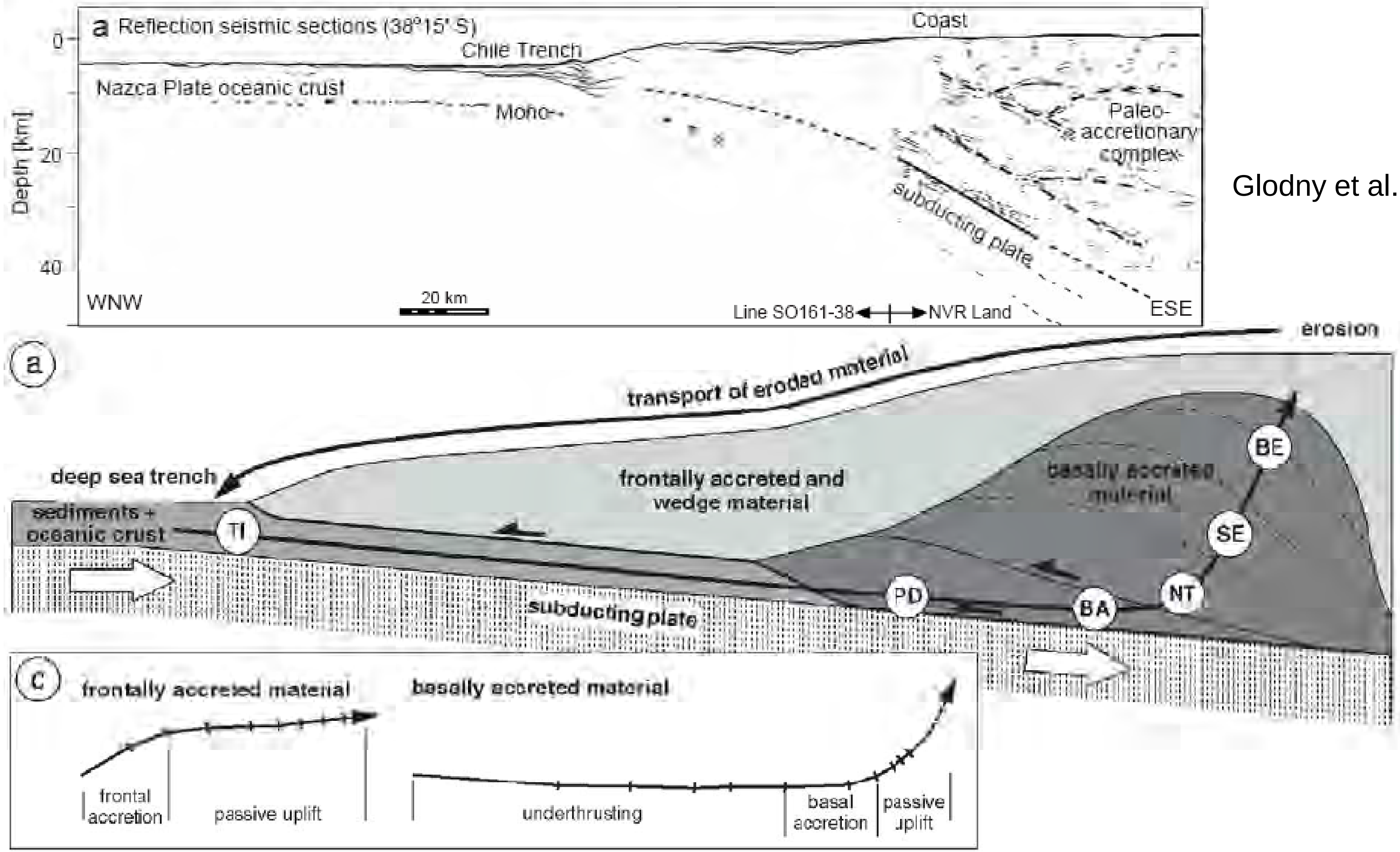



Tricart and Schwartz, 2007




Agard et al.,2002

Continuous subduction/exhumation processes from 90 to 40 Ma

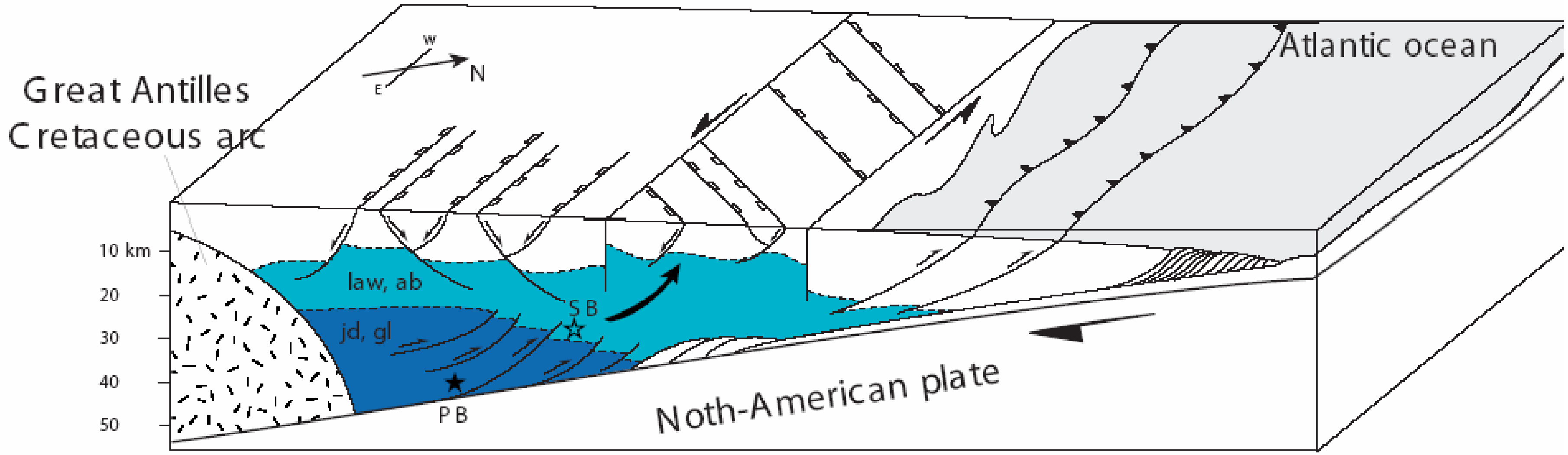



Glodny et al., 2005

**Exhumation in an accretionary wedge : e.g. Platt, 1986**

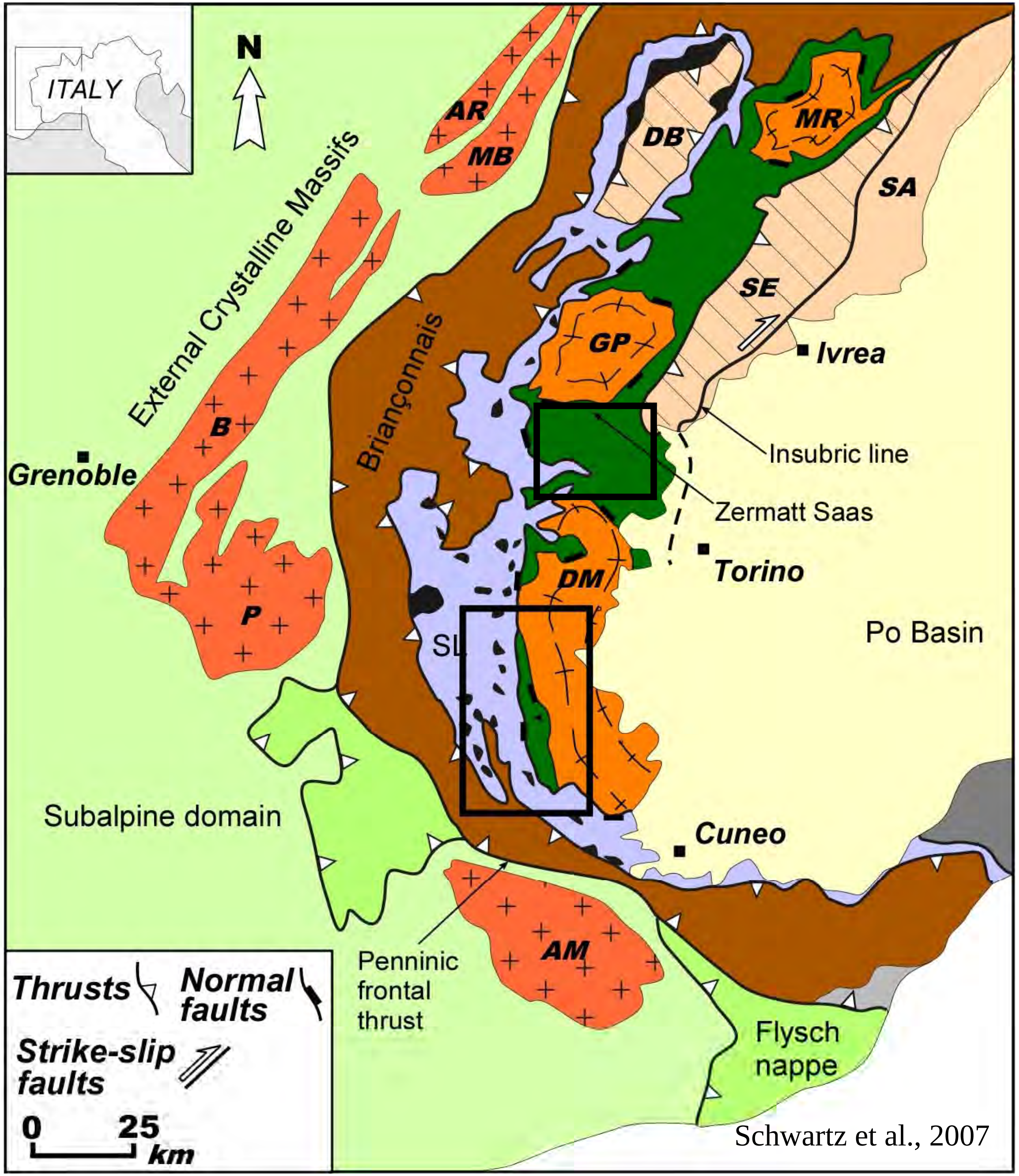
**Low viscosity clastic sediments more abundant than rigid oceanic rocks**

**Basal accretion and extension + erosion at the surface**

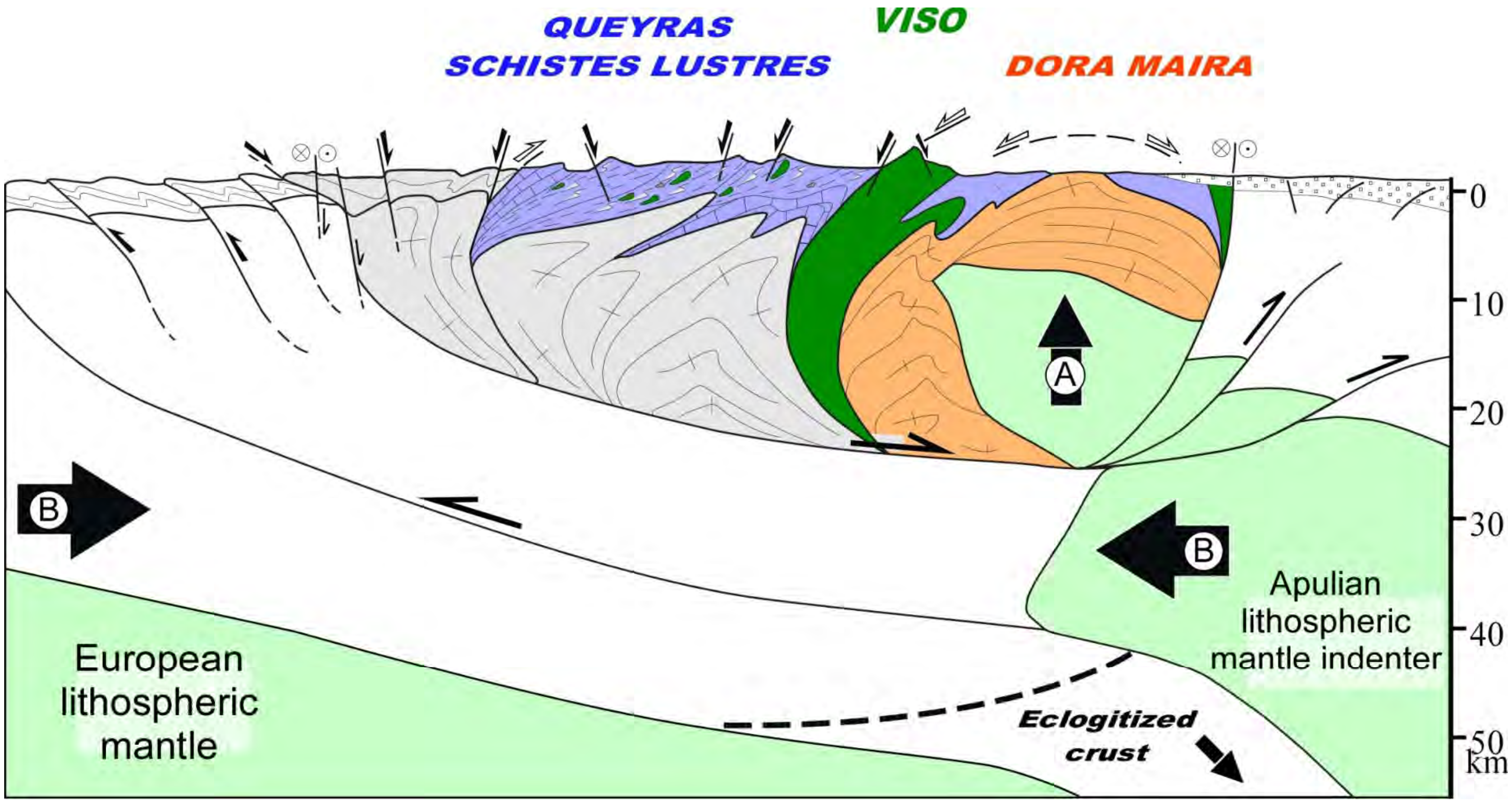



Model of tectonic exhumation of HP rocks by underplating processes in an accretionary wedge

*Goncalvez et al., 2000*



Schwartz et al., 2007

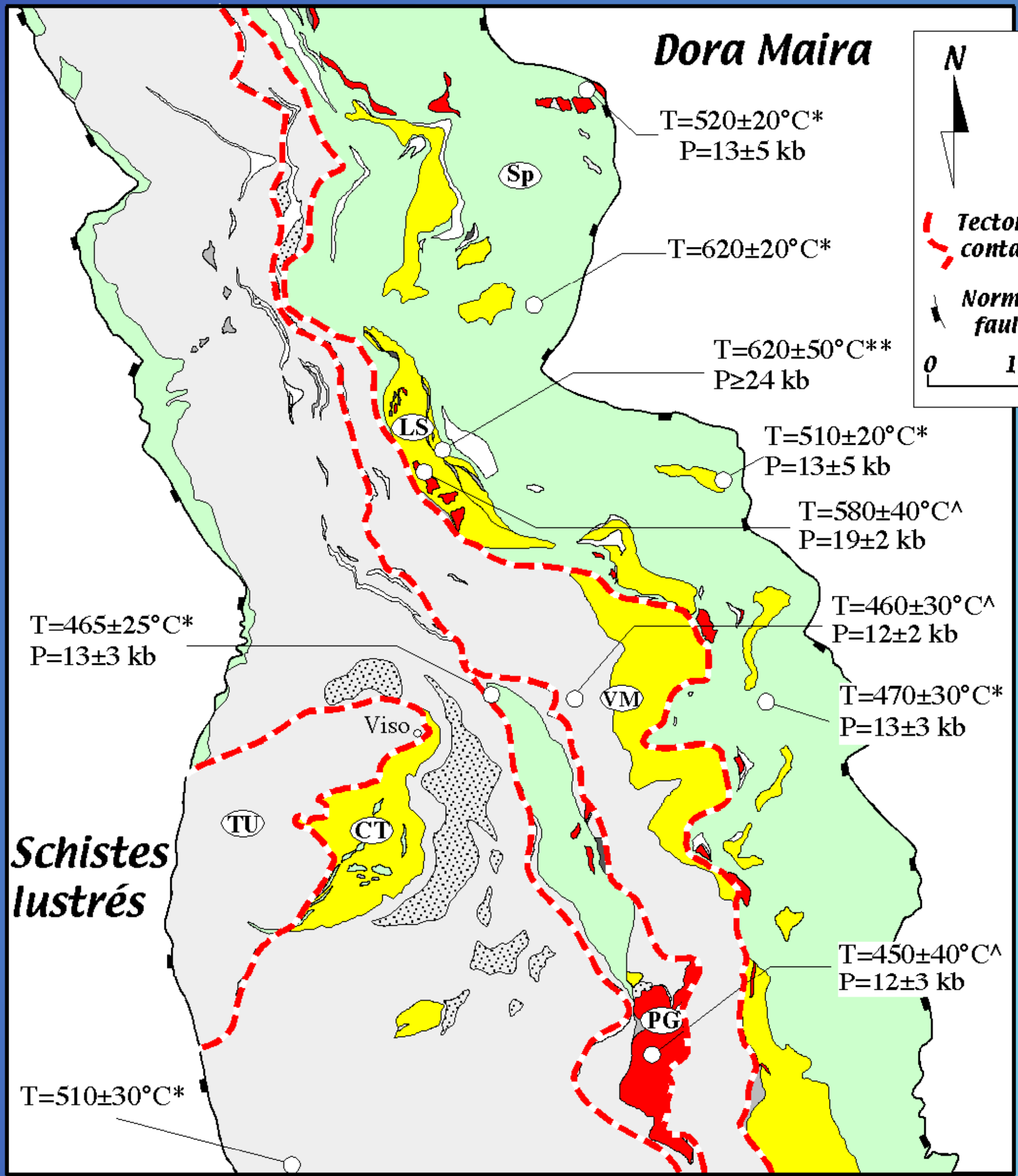



Lardeaux et al., 2007

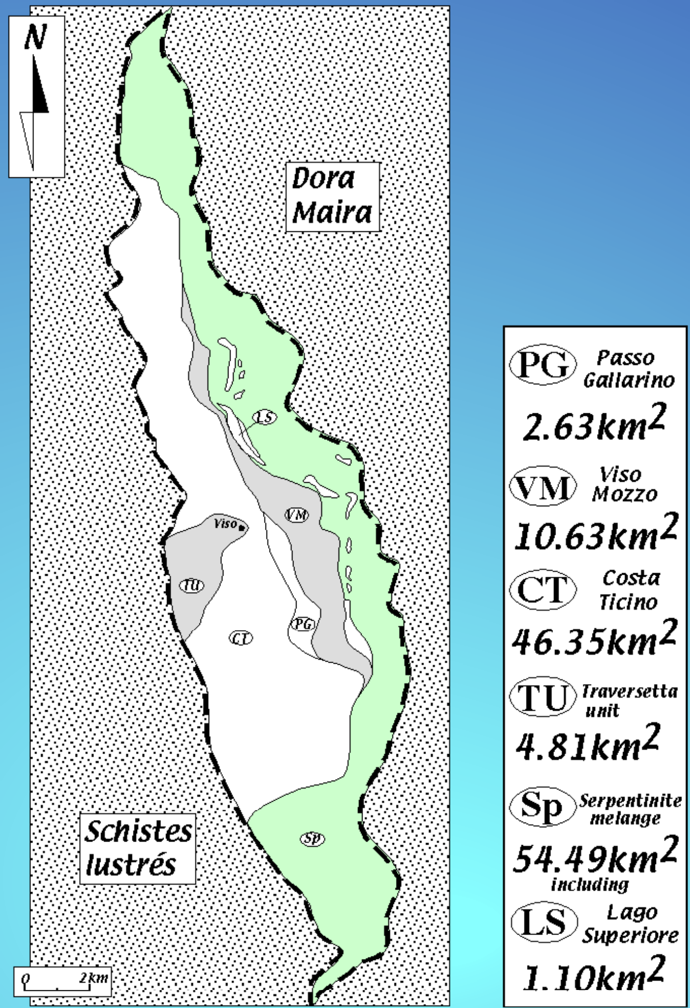

East
West


West
East

# LA PARTIE CENTRALE DU MONVISO

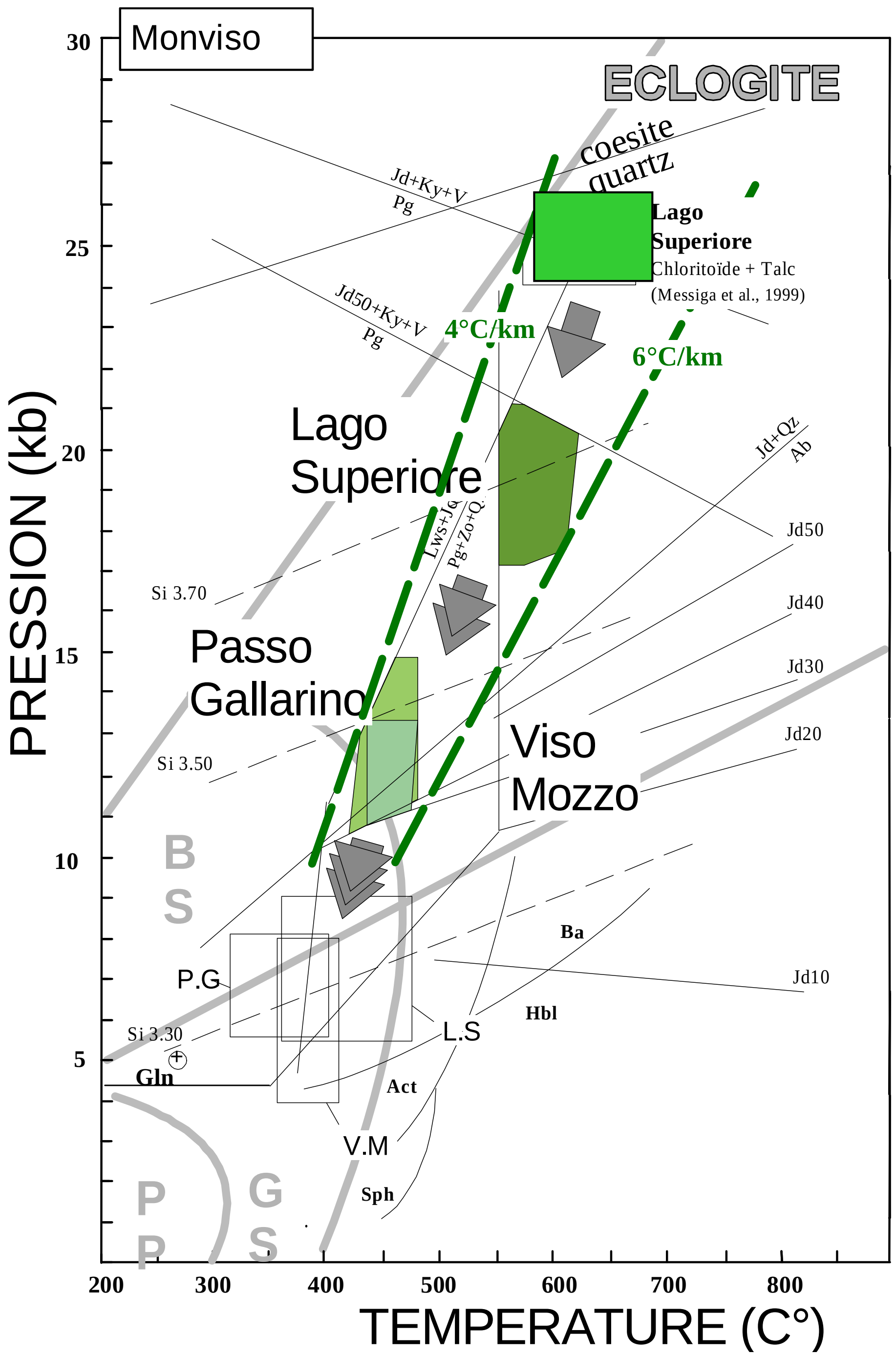



(*) Blake *et al.*, 1995
(**) Messiga *et al.*, 1999
(^) Schwartz *et al.*, 2000



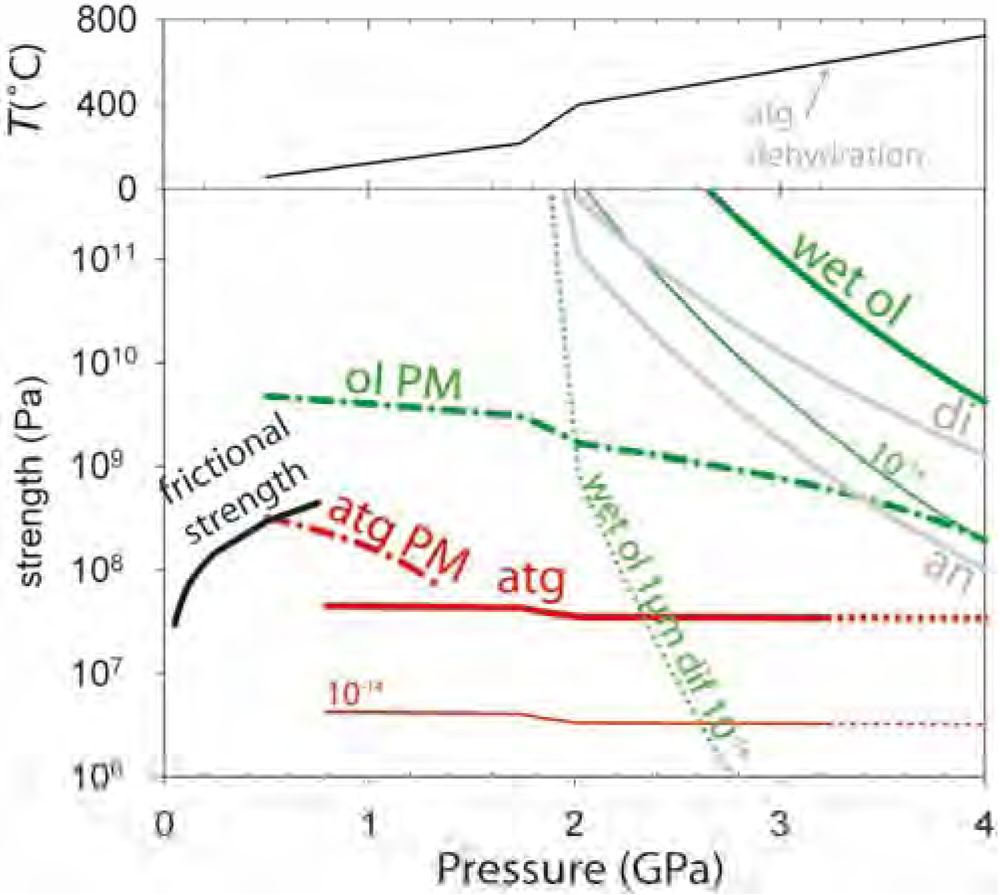

**Le volume des différentes unités est inférieur à 50km³**

Schwartz et al., 2001




Each eclogitic block records different P-T conditions but aligned along the same geotherm =>

Schwartz et al., 2000



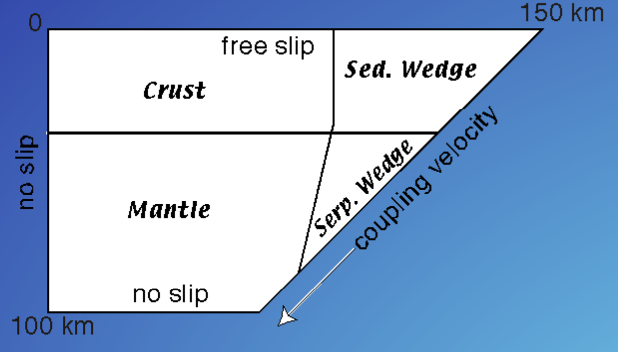

Low strengh of antigorite for a creep law at
$10^{-10}$ $s^{-1}$ (300 thick layer) and $10^{-14} s^{-1}$ (10 km thick layer)

Hilairet et al., Science, 2007

Effective viscosity :$10^{18}$ Pas to $4.10^{-19} s^{-1}$

# MODELISATION NUMERIQUE

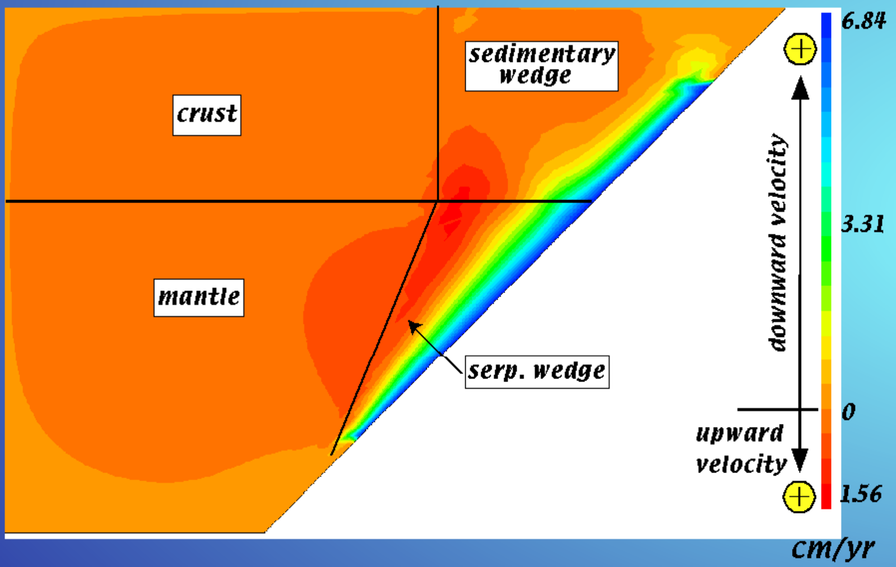
## GEOMETRIE

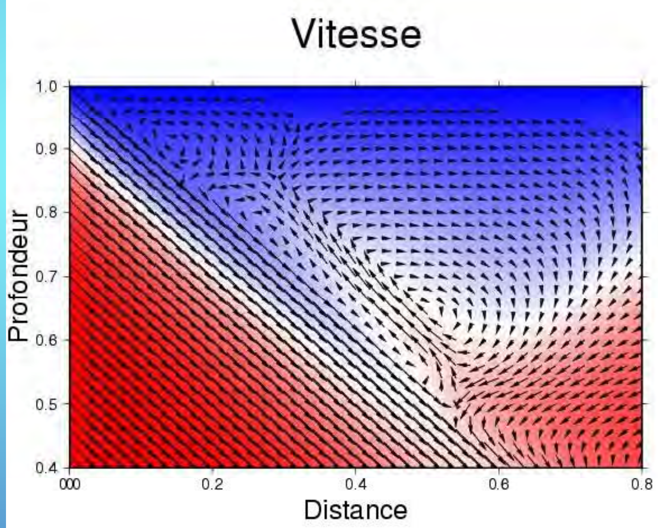



## PARAMETRES

| | density kg/m³ | viscosity Pas |
|---|---|---|
| ***Crust*** | 2700 | $10^{23}$ |
| ***Sed. Wedge*** | 2600 | $10^{18}$ |
| ***Mantle*** | 3300 | $10^{23}$ |
| ***Serp. Wedge 50%*** | 2975 | $10^{20}$ |

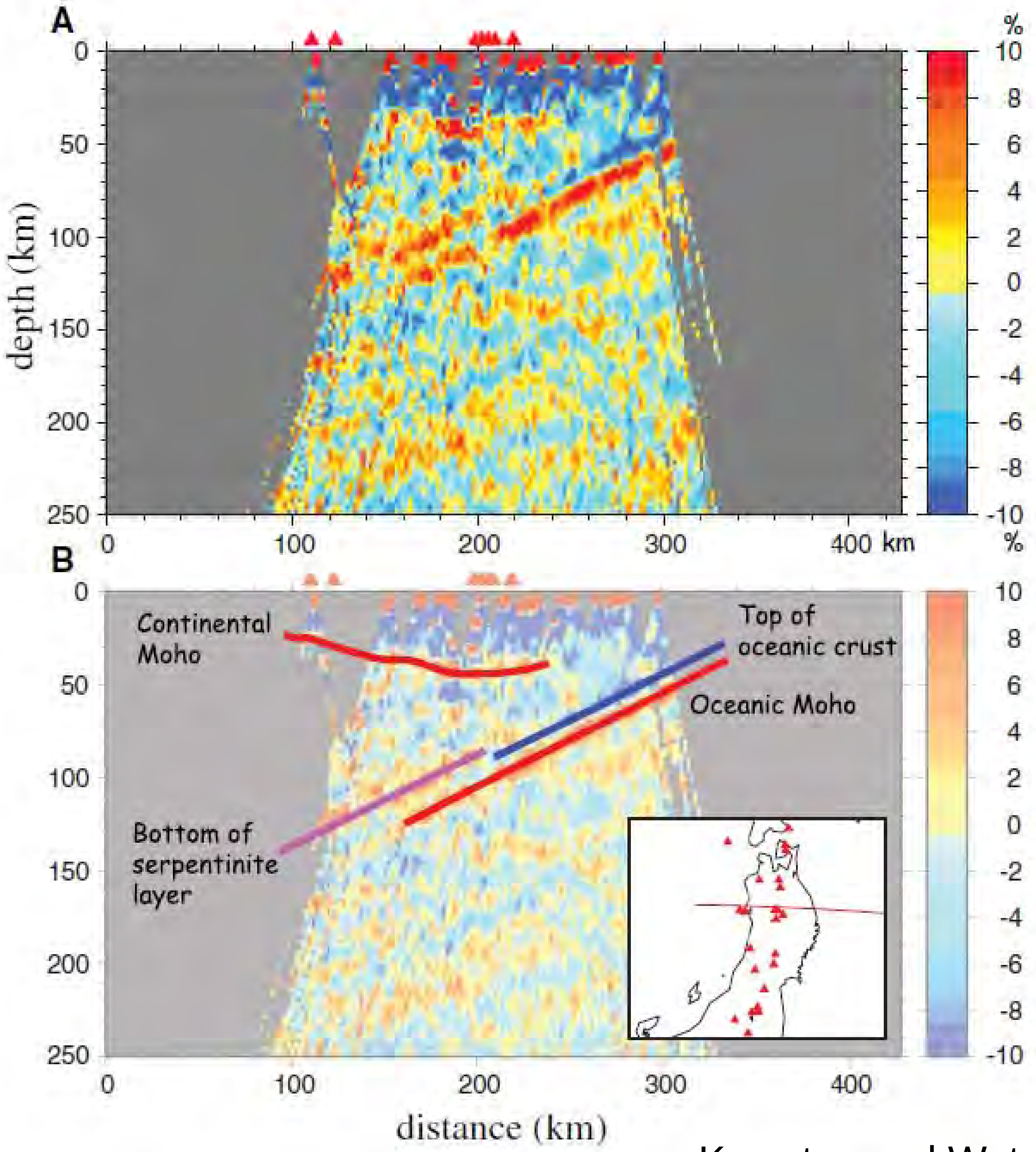
## RESULTATS



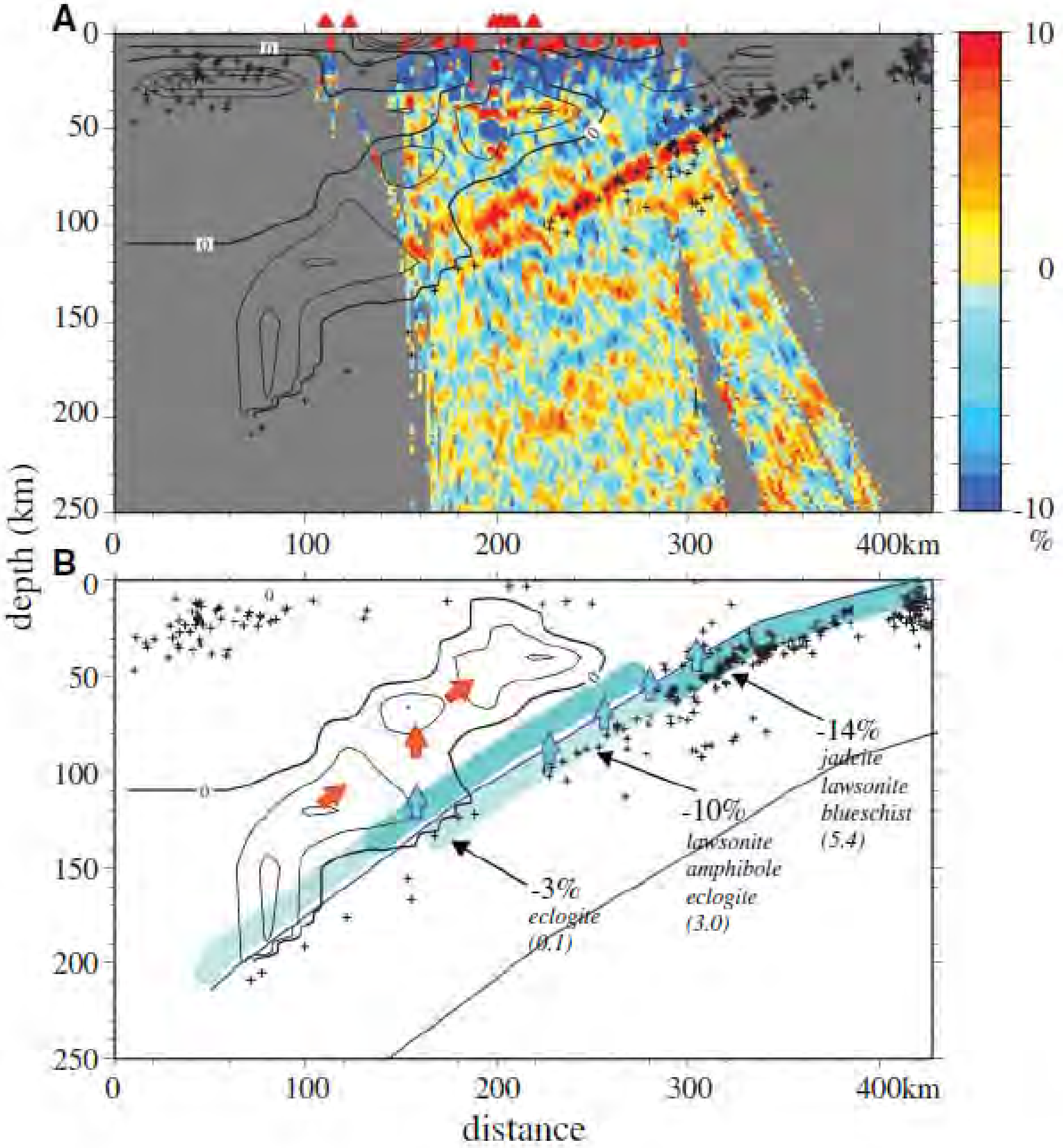




Schwartz et al., 2001

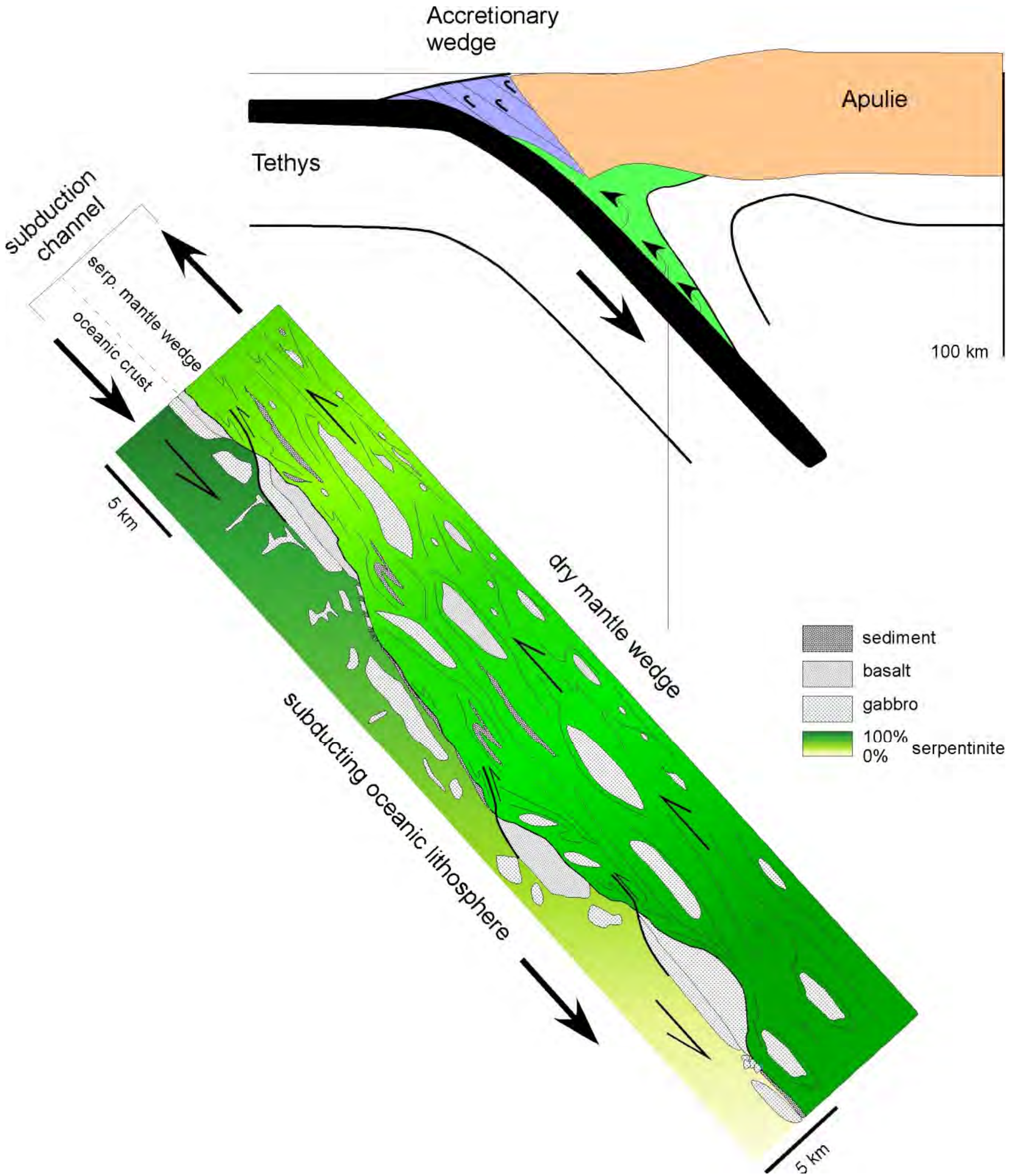
Receiver Function



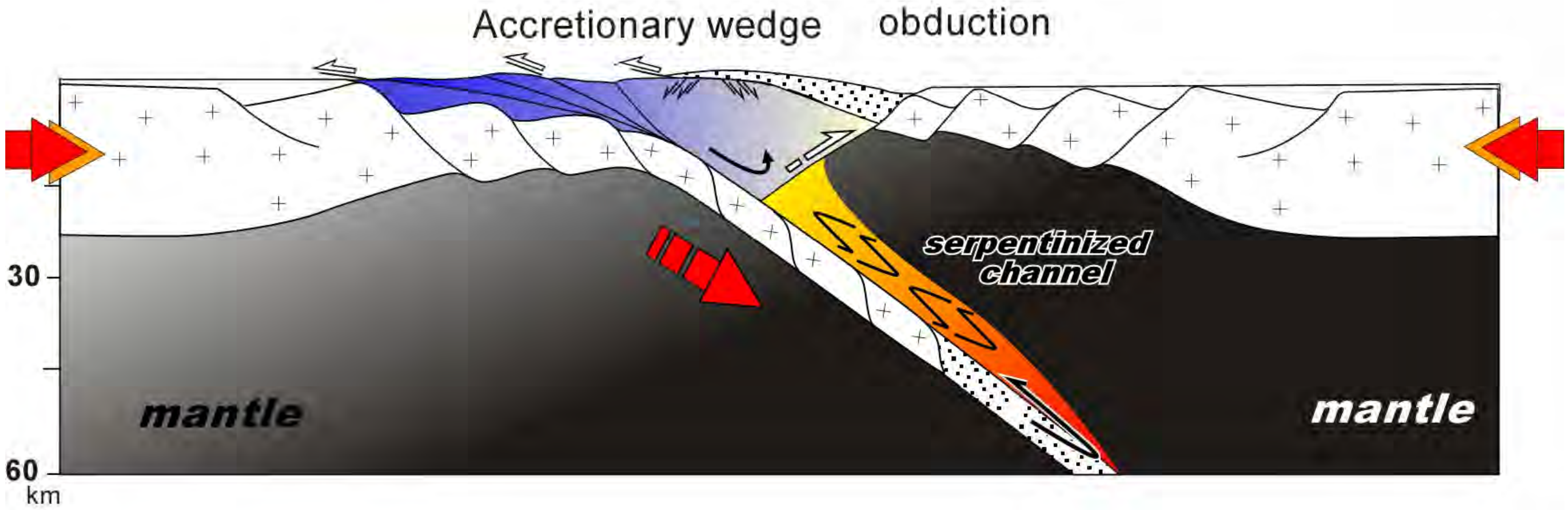

Kawatsu and Watada, Science, 200




Kawatsu and Watada, Science, 200




Guillot et al., 2008

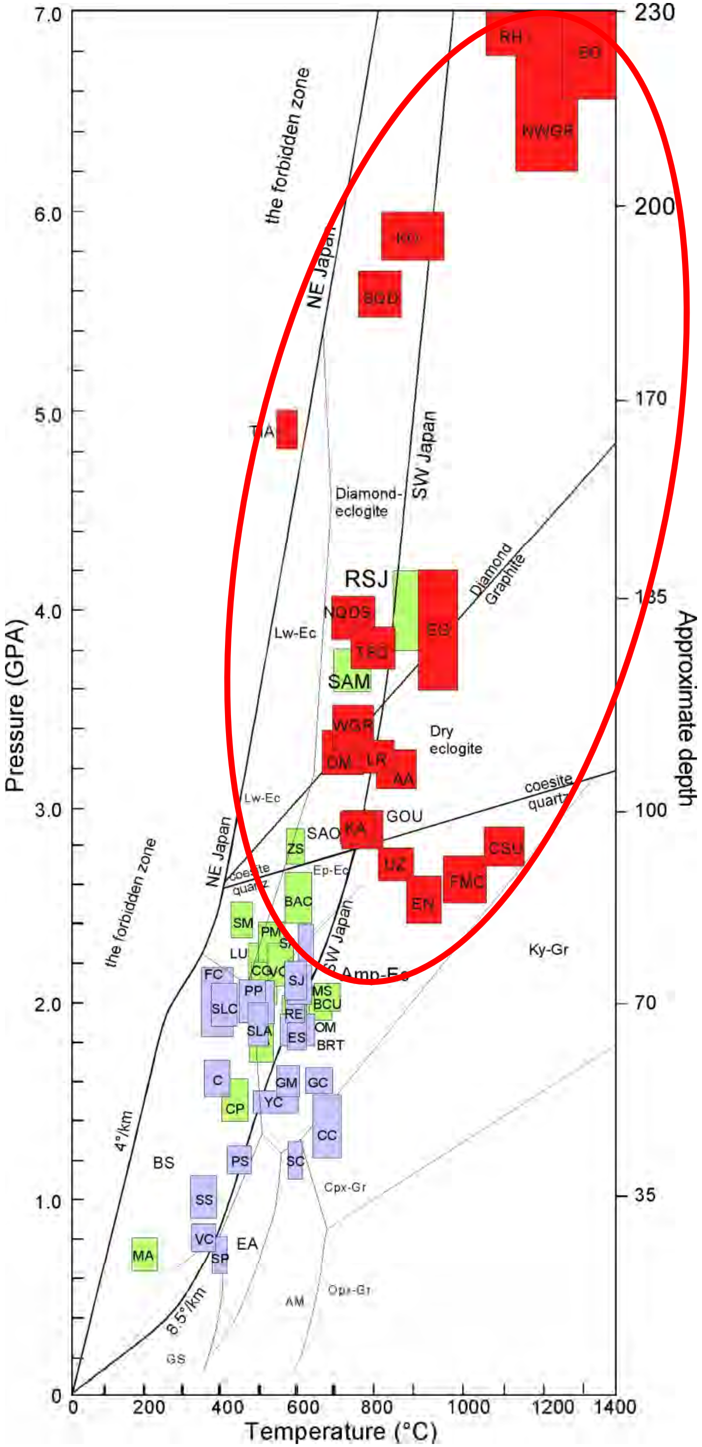



BS Schistes Lustrés : exhumed in an accretionary wedge

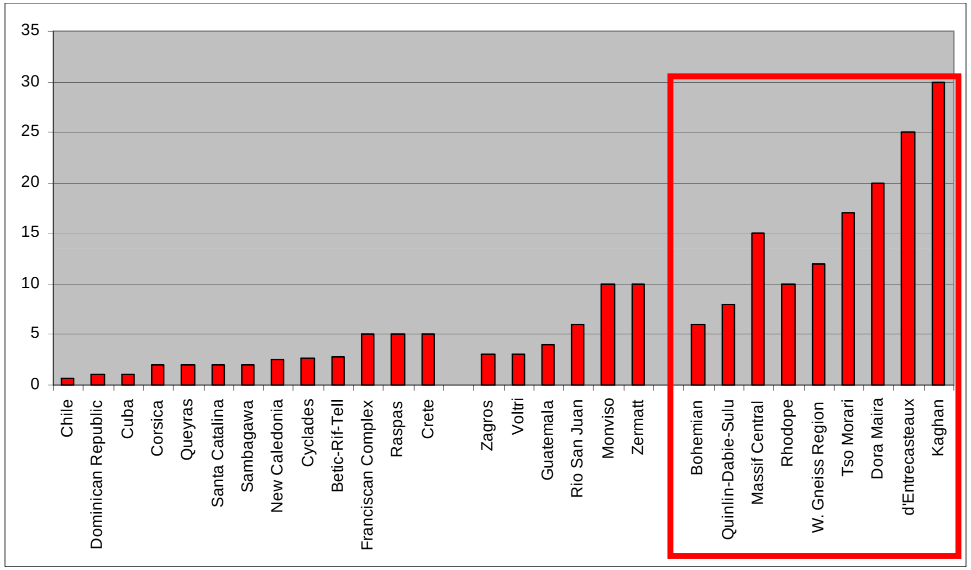
Monviso eclogites :
sampled and exhumed at different depths within a serpentinites subduction channel

Guillot et al., 2005
Schwartz et al. 2007

Exemple : warren serpentine 1



# Vitesse d'exhumation cm/yr




**Prisme D'accrétion**

**Chenal de serpentines**

**Subduction continentale**

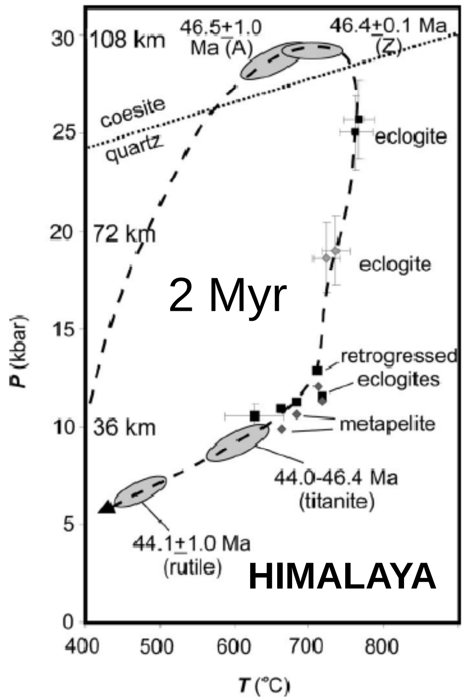
**forte $V_{exhum}$ (0.7-3 cm/yr)**

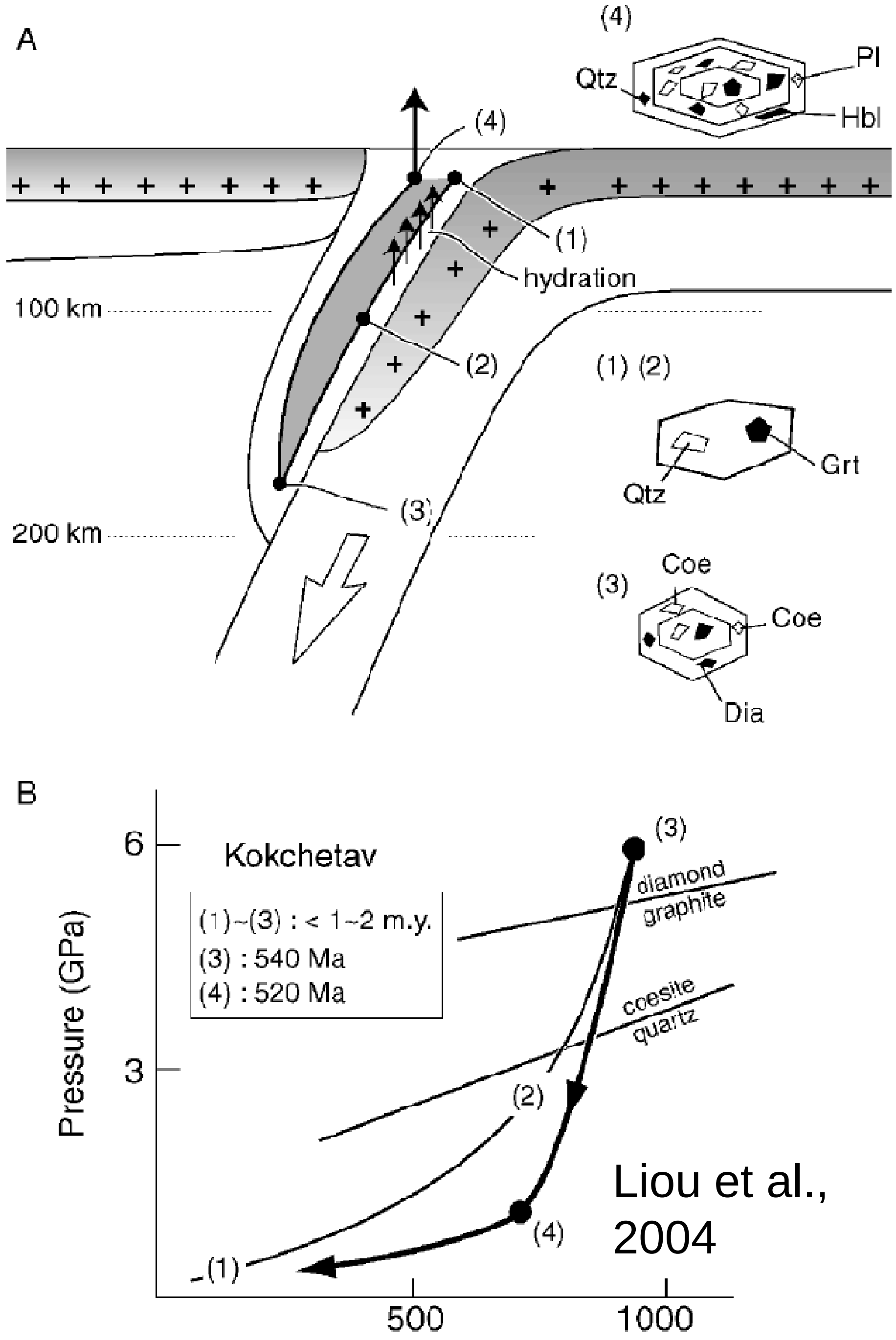
Croûte continentale

Guillot et al. 2008

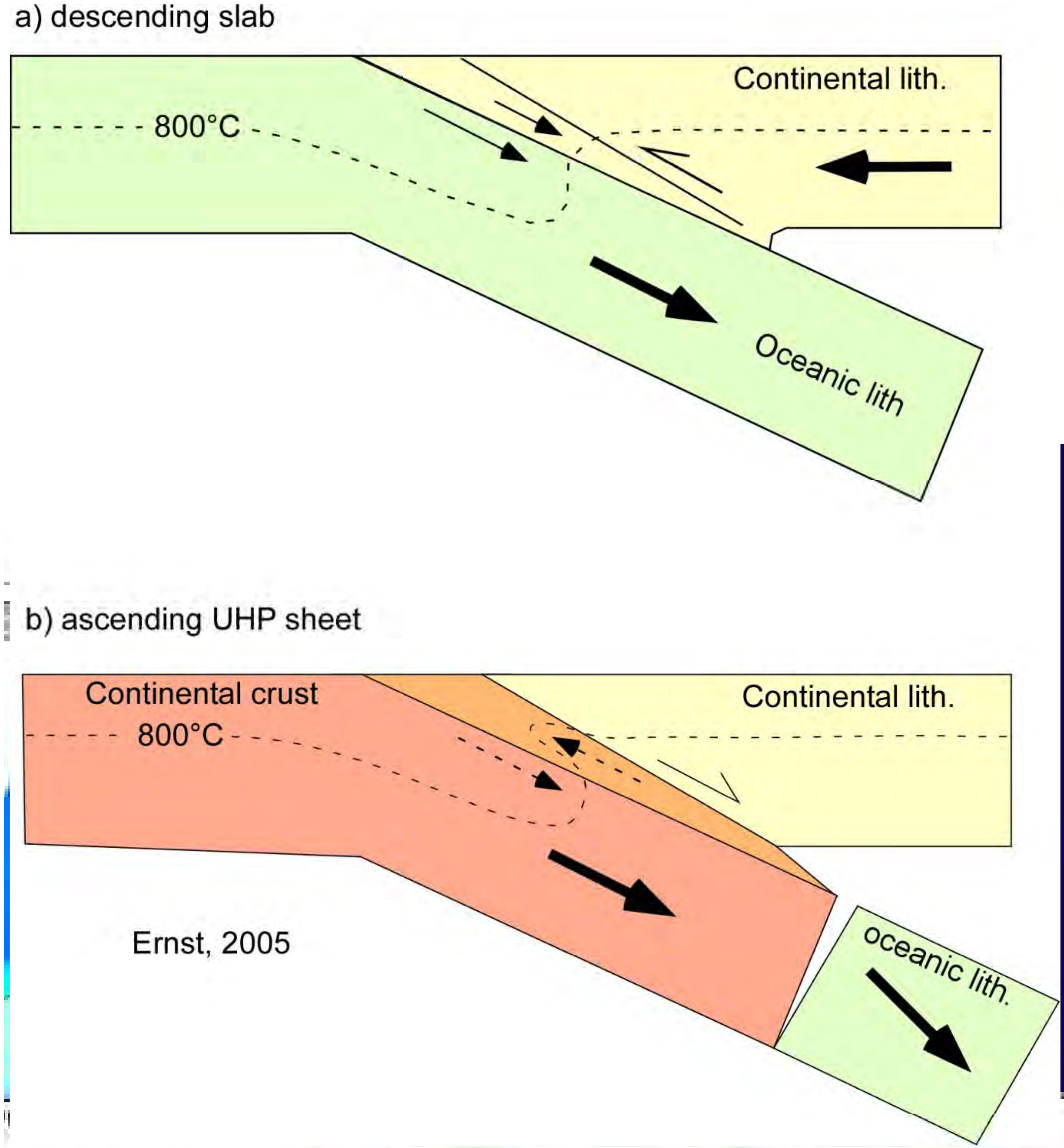
# Continental Subduction

Koktetav
Norway
Sulu
Dabie
Tienshan
New Guinea
Dora Maira
Erzgebirge
Himalaya



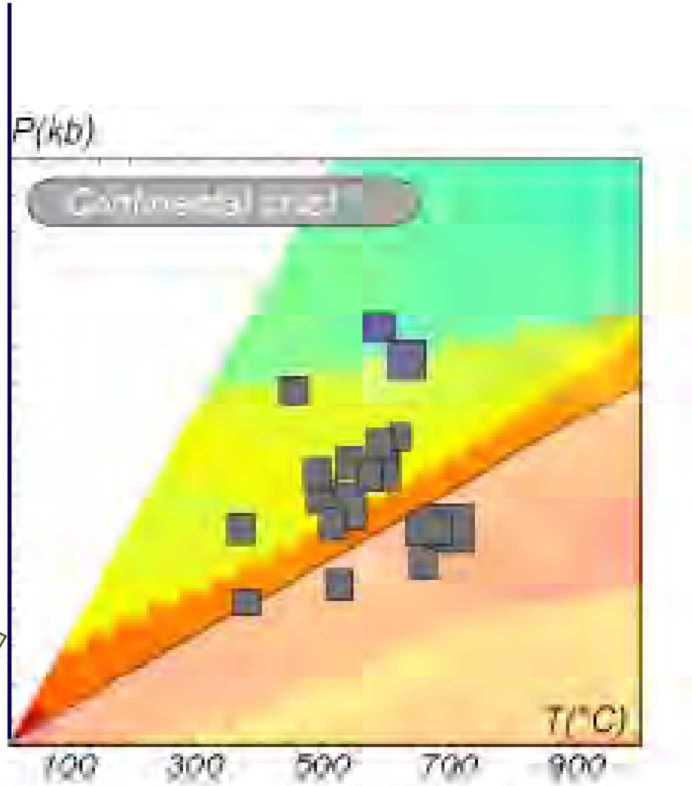
What controls exhumation of UHP continental units ?




Ernst, 2005

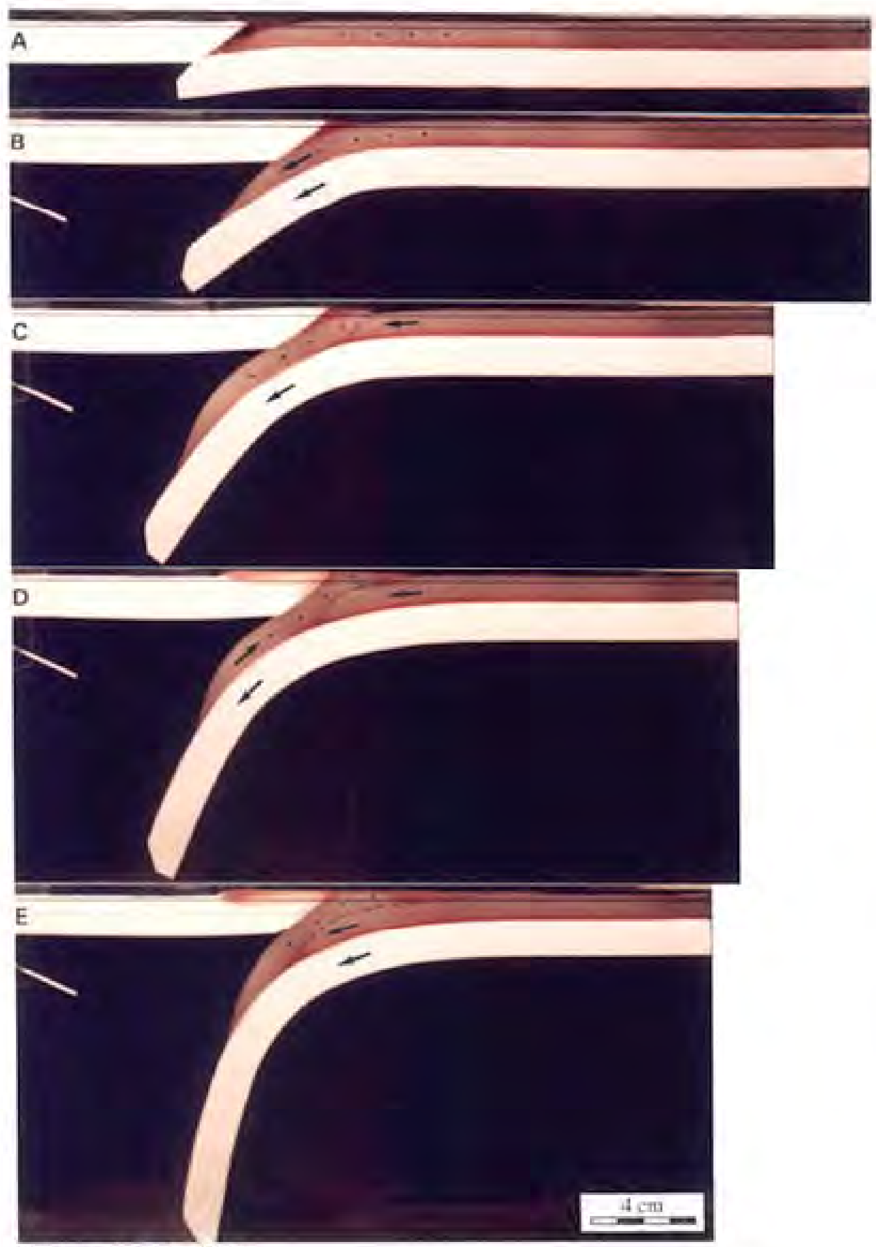
Motor of exhumation :

buoyancy of the continental crust



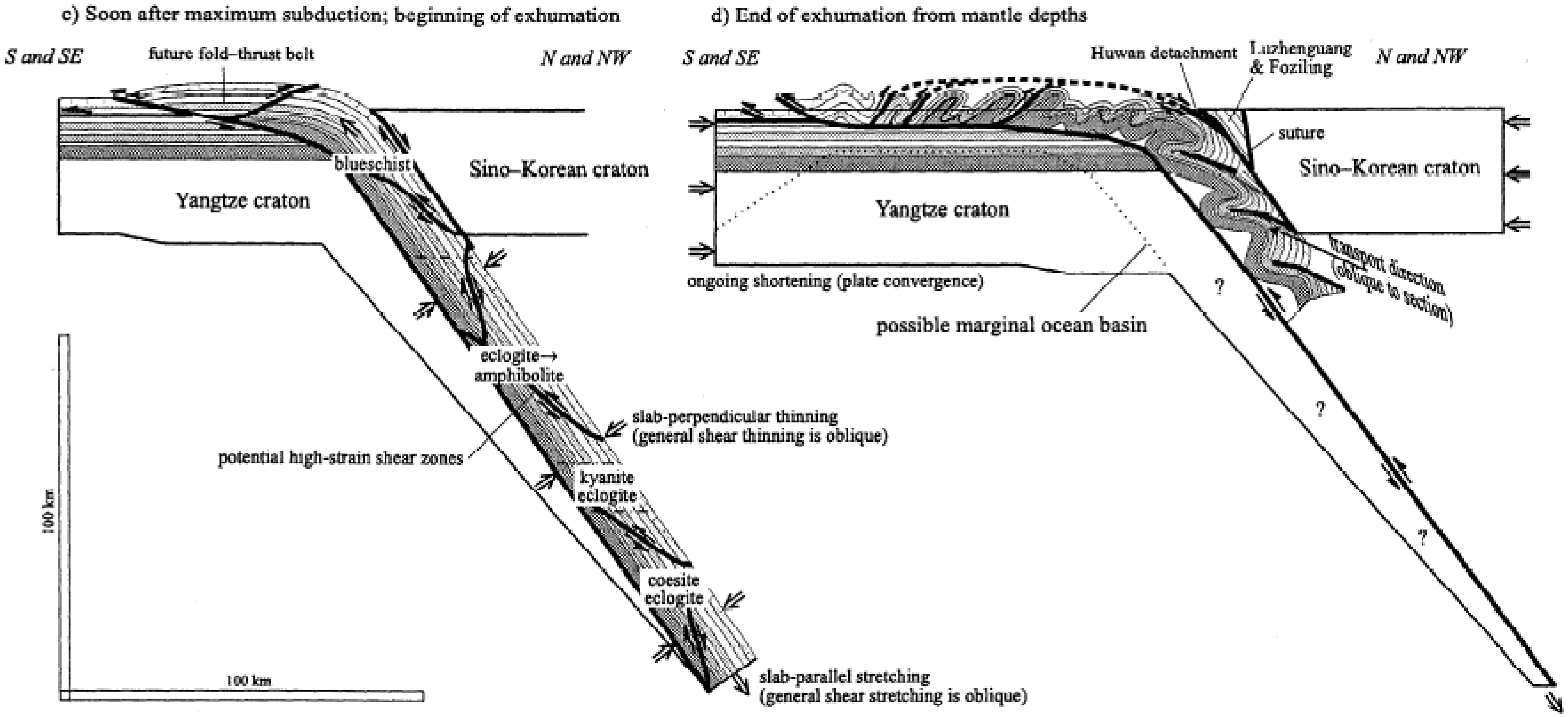

Agard et al., A.J.S.

# Buoyancy driven exhumation : exhumation of whole crust



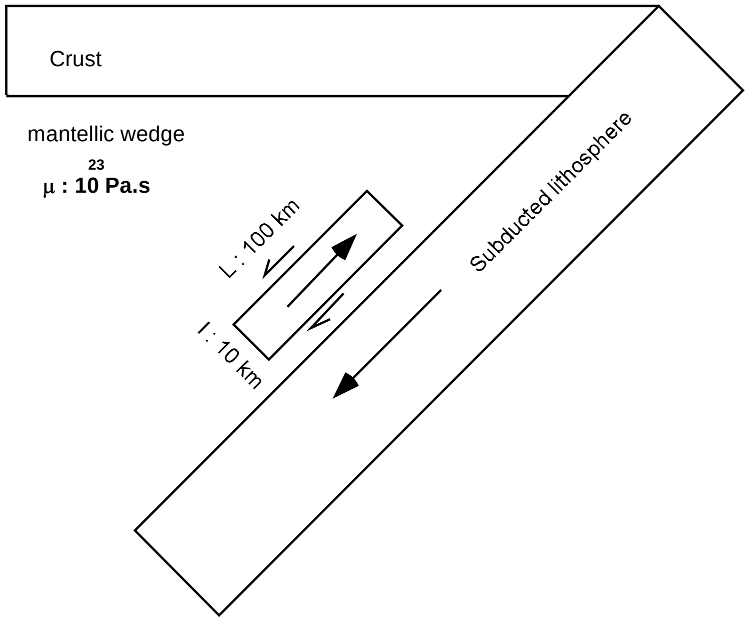

(Chemenda et al., 1995)

# Shortening and squeezing of the upper crust facilitate exhumation of UHP units




Hacker et al., 2000

# Peut on exhumer la CC dans le manteau? ?




Guillot et al, 2008

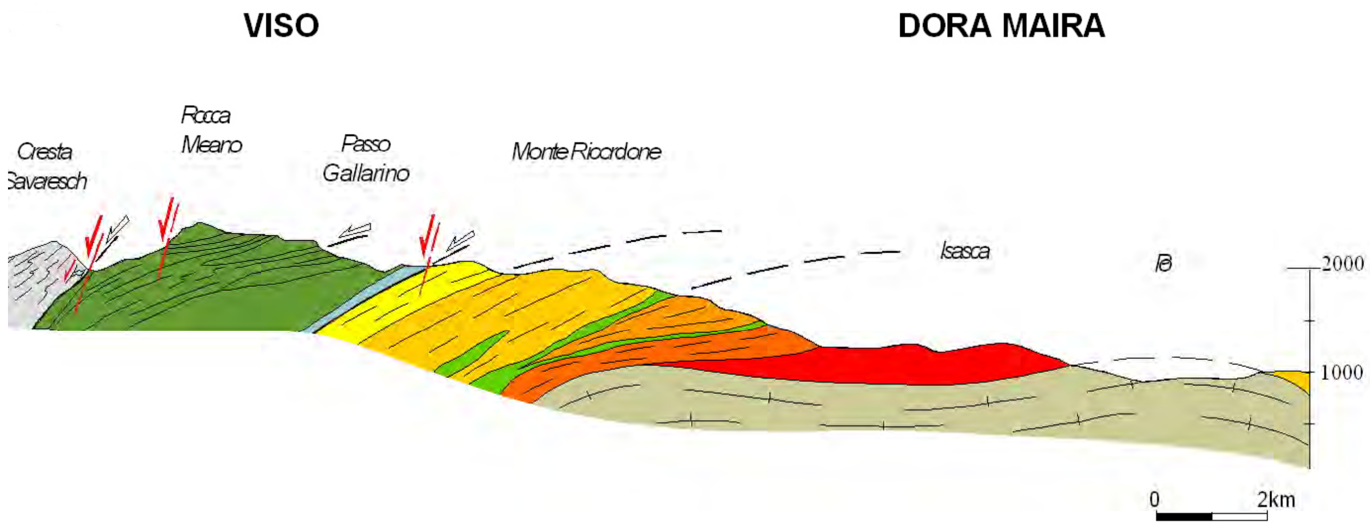
La force de flotabilité produit par une unité éclogitique (d1)
Exhumée aus ein du manteau (d2) est :

$$\boxed{Fa = \Delta(d2\text{-}d1).g.v = 3.10^{18}\ N}$$

La force de résistance du manteau anhydre à l'exhumation d'une unité éclogitique à 1 cm/an est

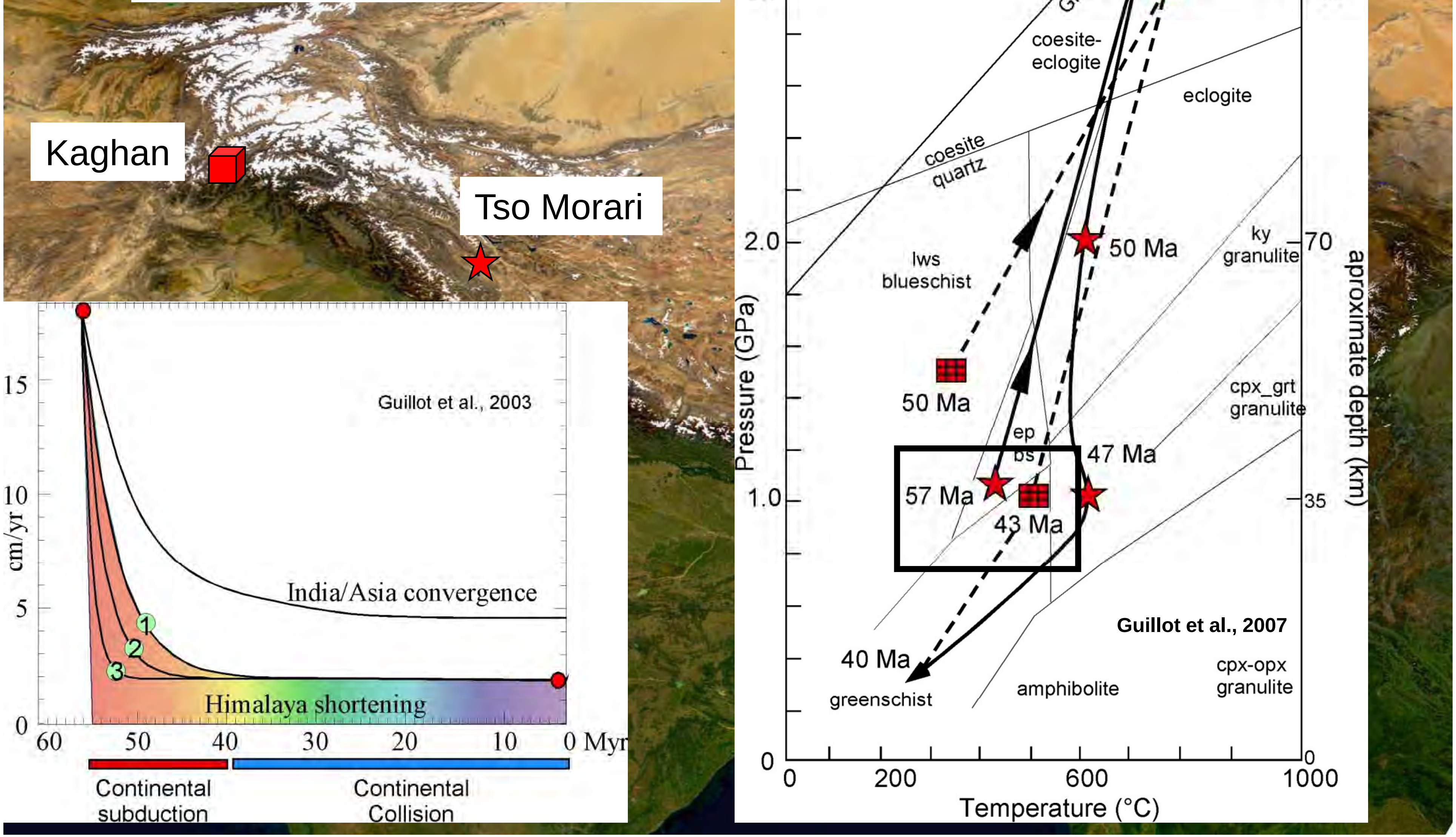
$$\boxed{Fr = 2.L.\mu.\delta u/\delta z\ = 5.10^{13}\ N}$$

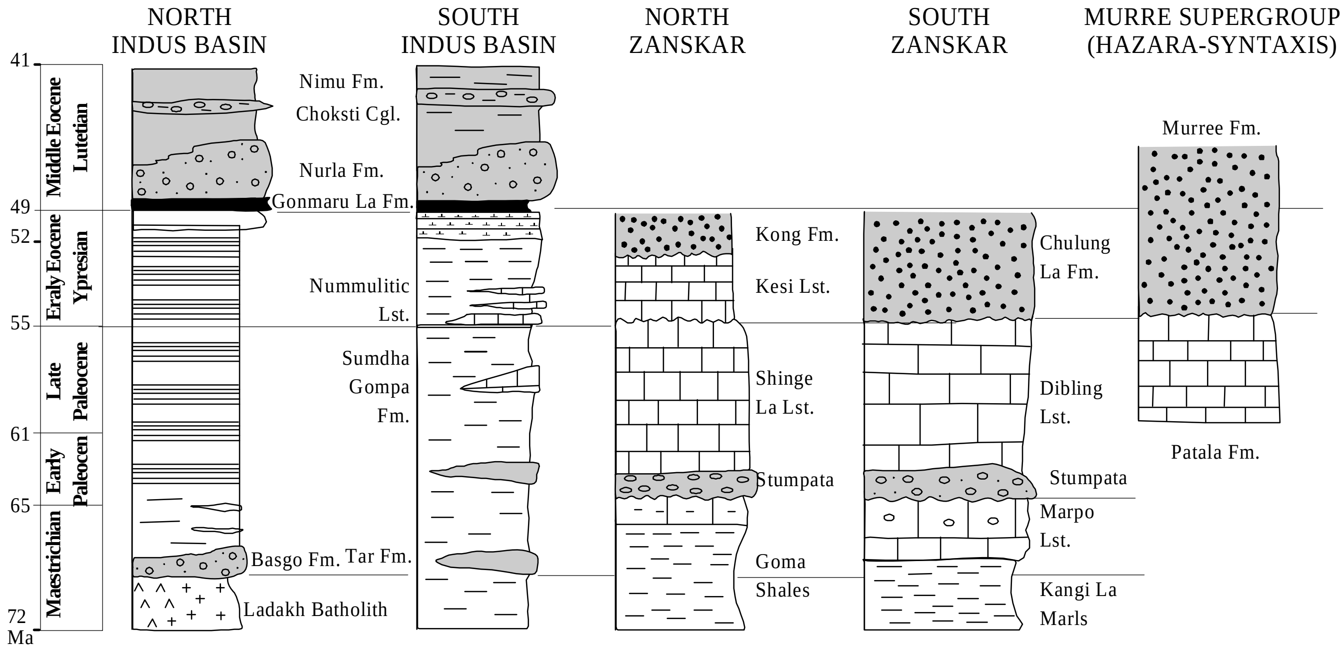
**=> flotabilité >> force de résistance**



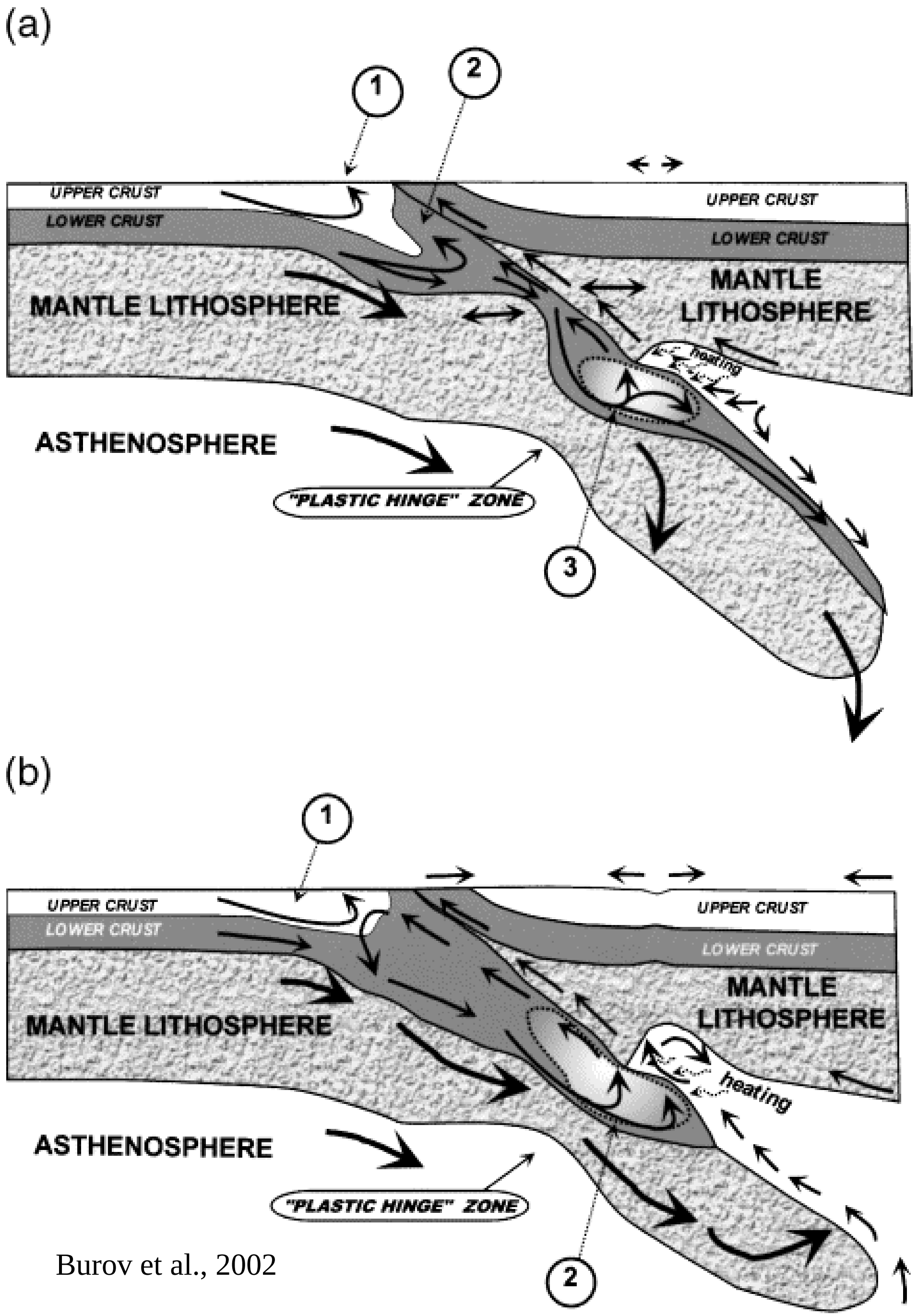

Thickness of UHP units: 1 to 7 km max (e.g. Alps, Himalaya, Dabie Shan)
=> Decoupling inside the upper crust

La formation et l'exhumation des roches de UHP se produit pendant la subduction continentale

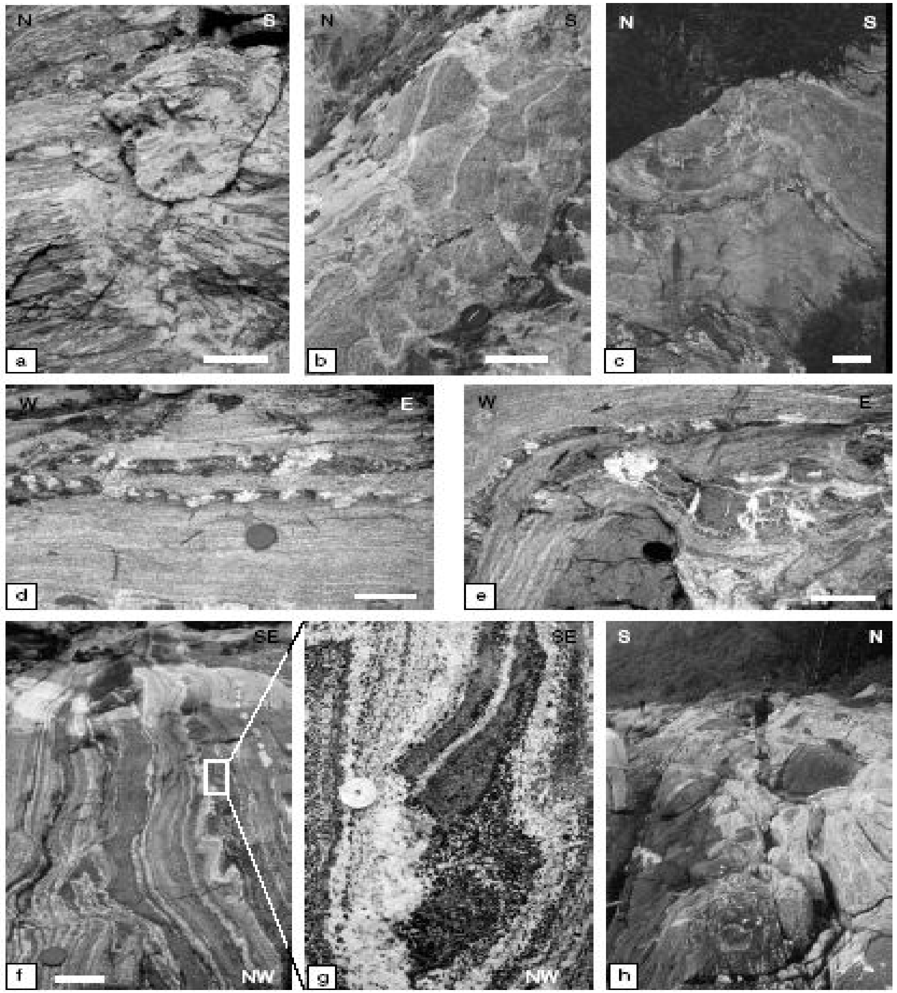





Guillot et al., 2003

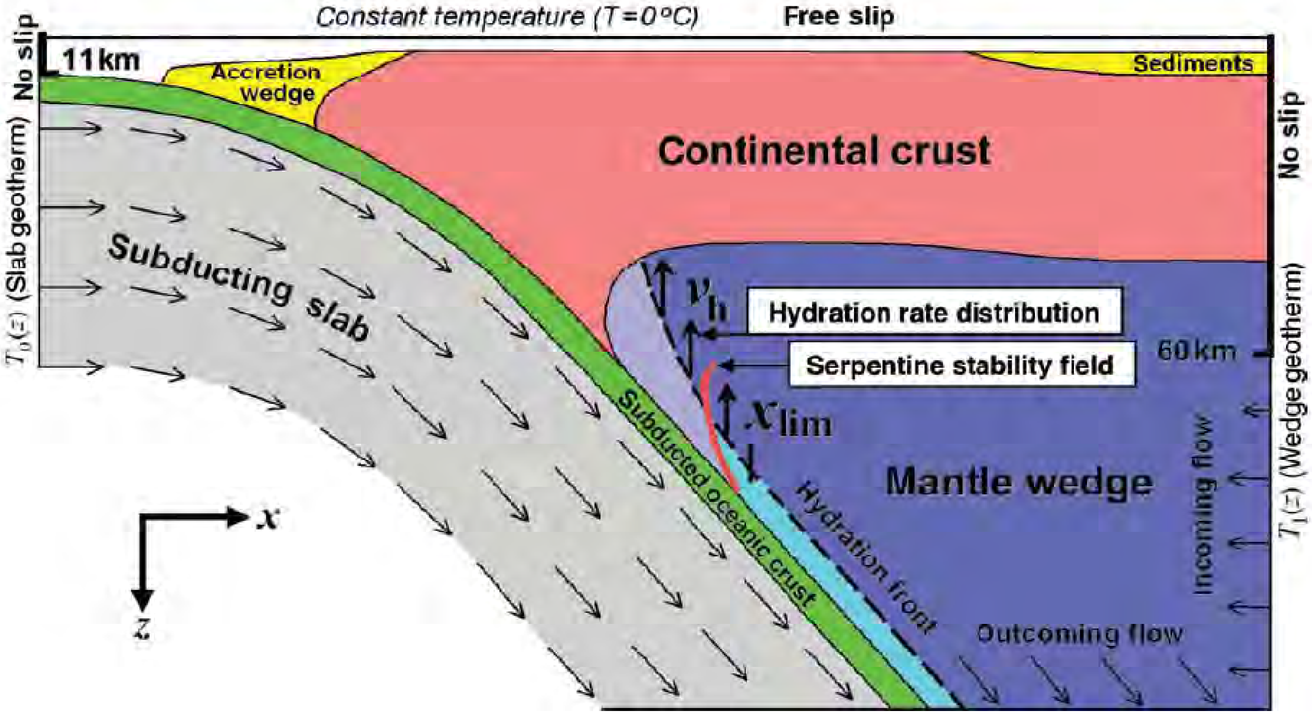



Burov et al., 2002



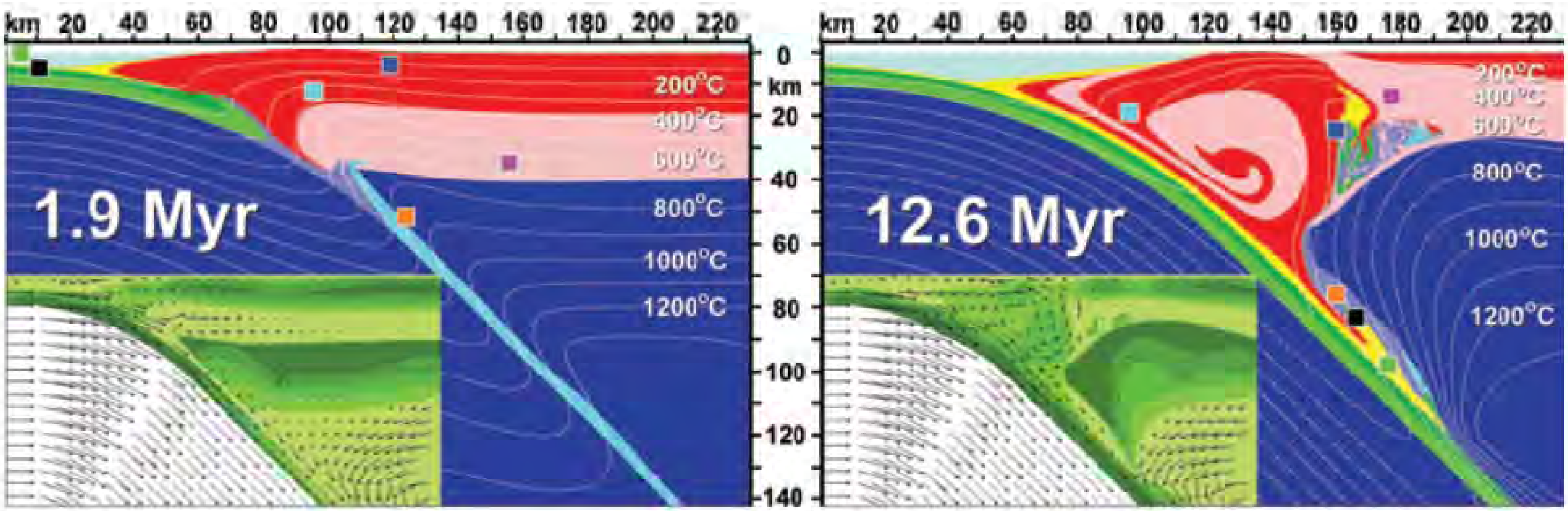

Labrousse et al., 2001

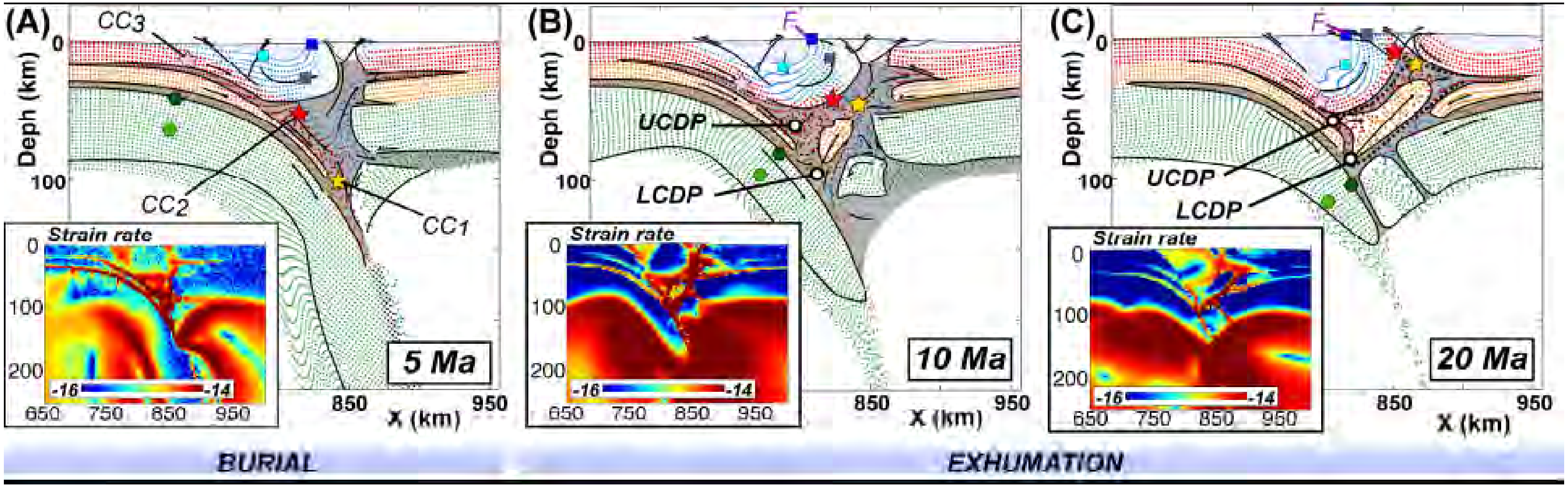
# Exhumation of eclogites in HT context : slab melting




**UHP unit derives from the upper plate ?**

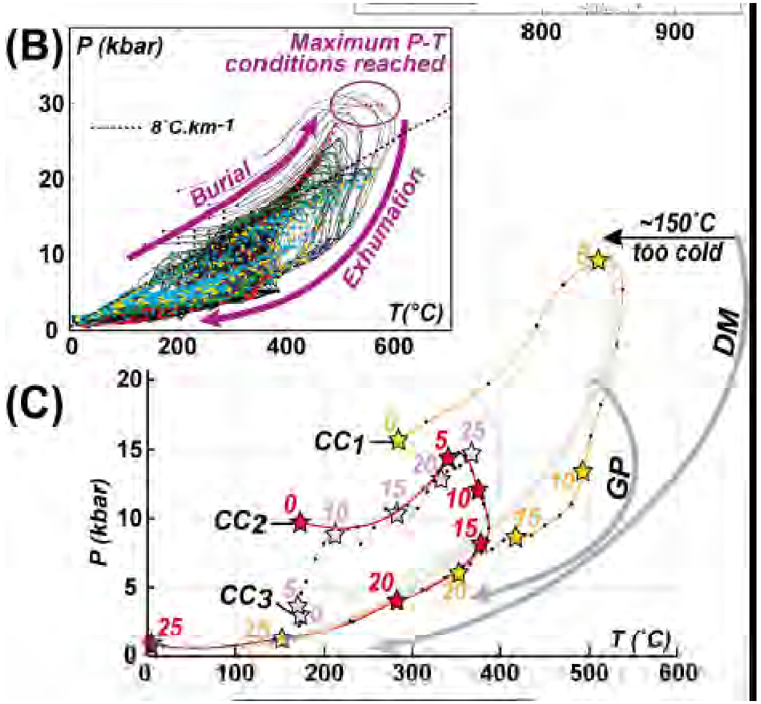
*Gerya et al., 2002*
*Stockhert and Gerya, 2005*





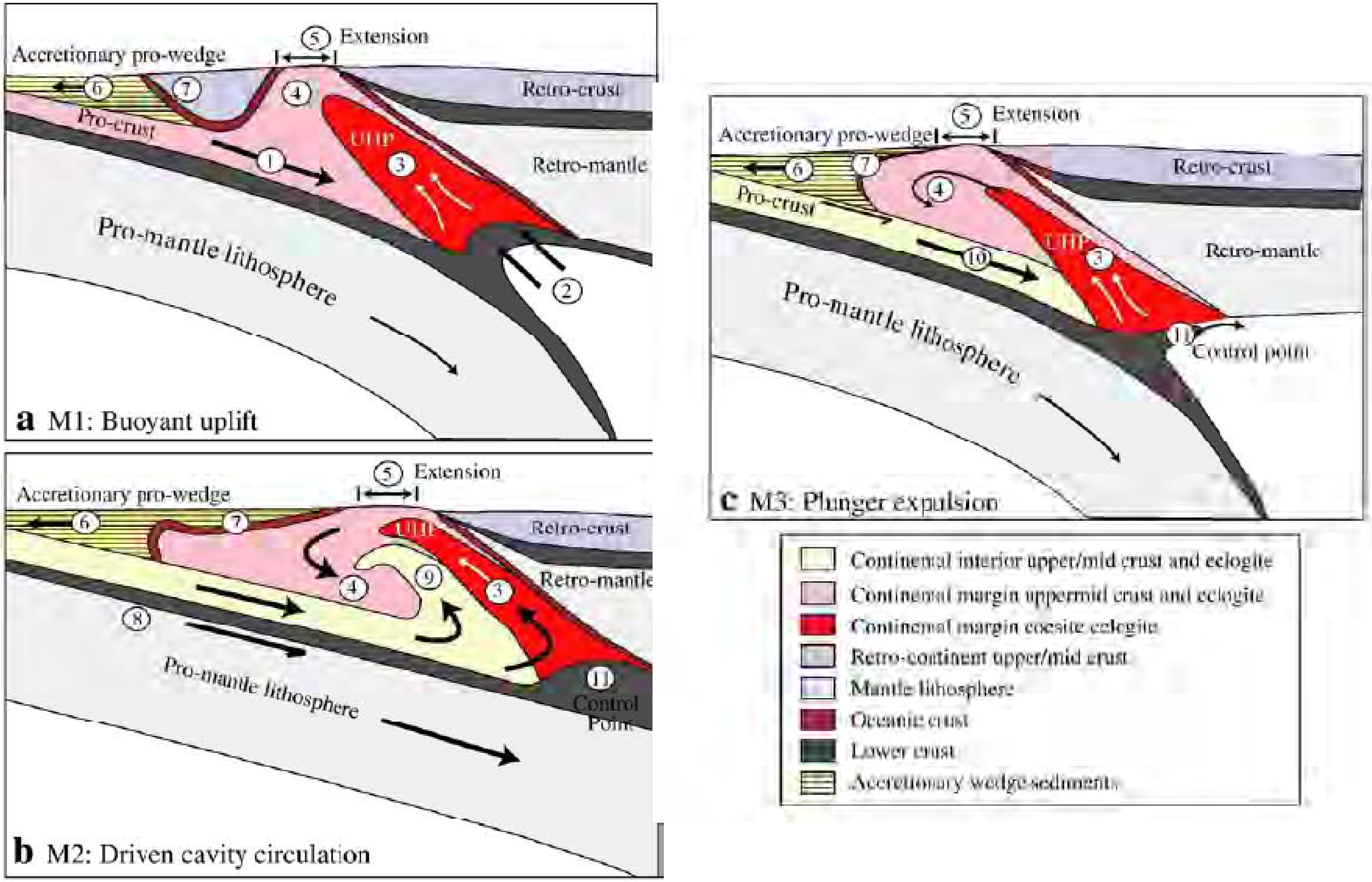

UHP rocks in the Alps

Decoupling between the upper crust
and the lower crust and exhumation within
the accretionary wedge

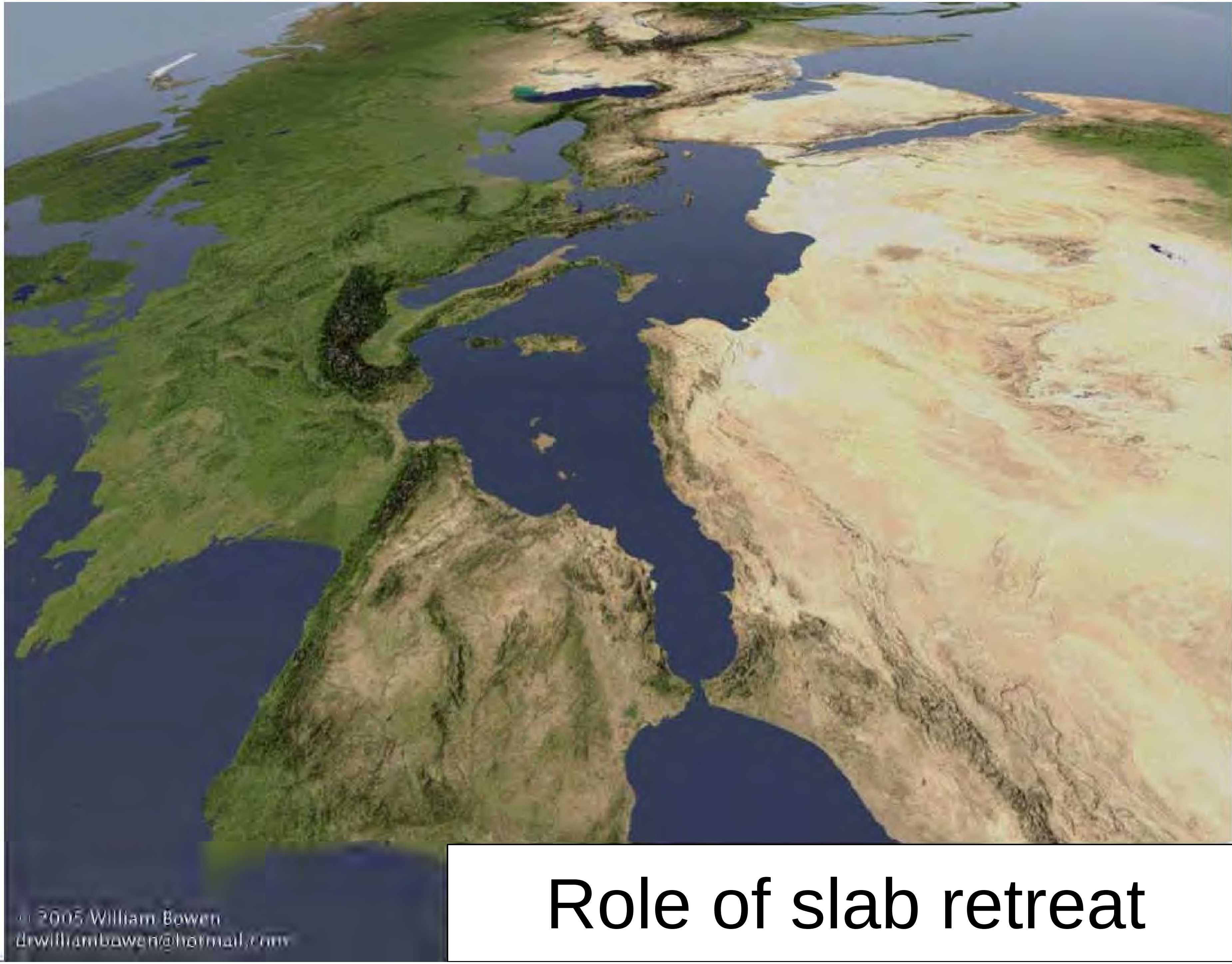



Yamato et al., submitted

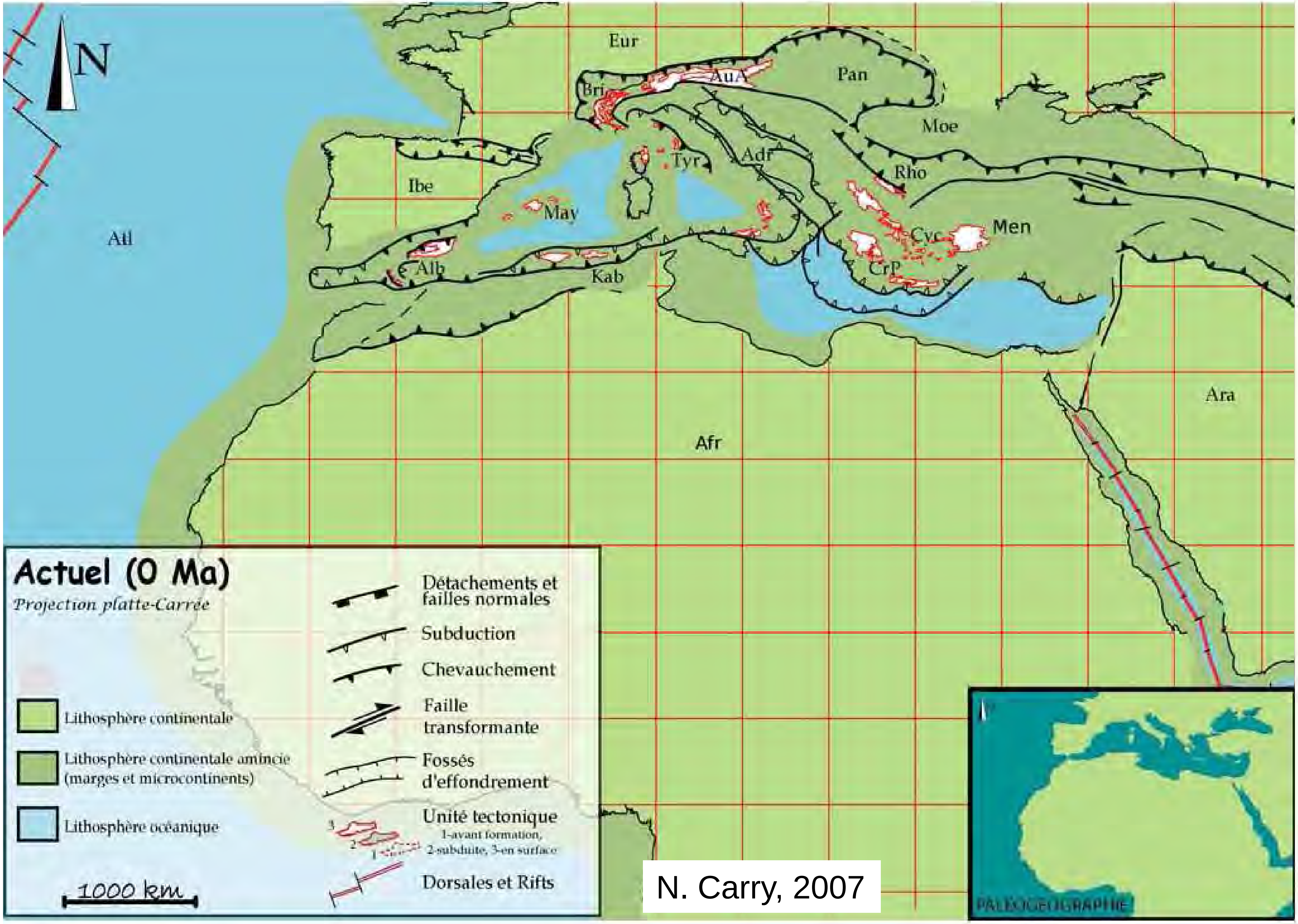
Animation exhumation en subduction continentale



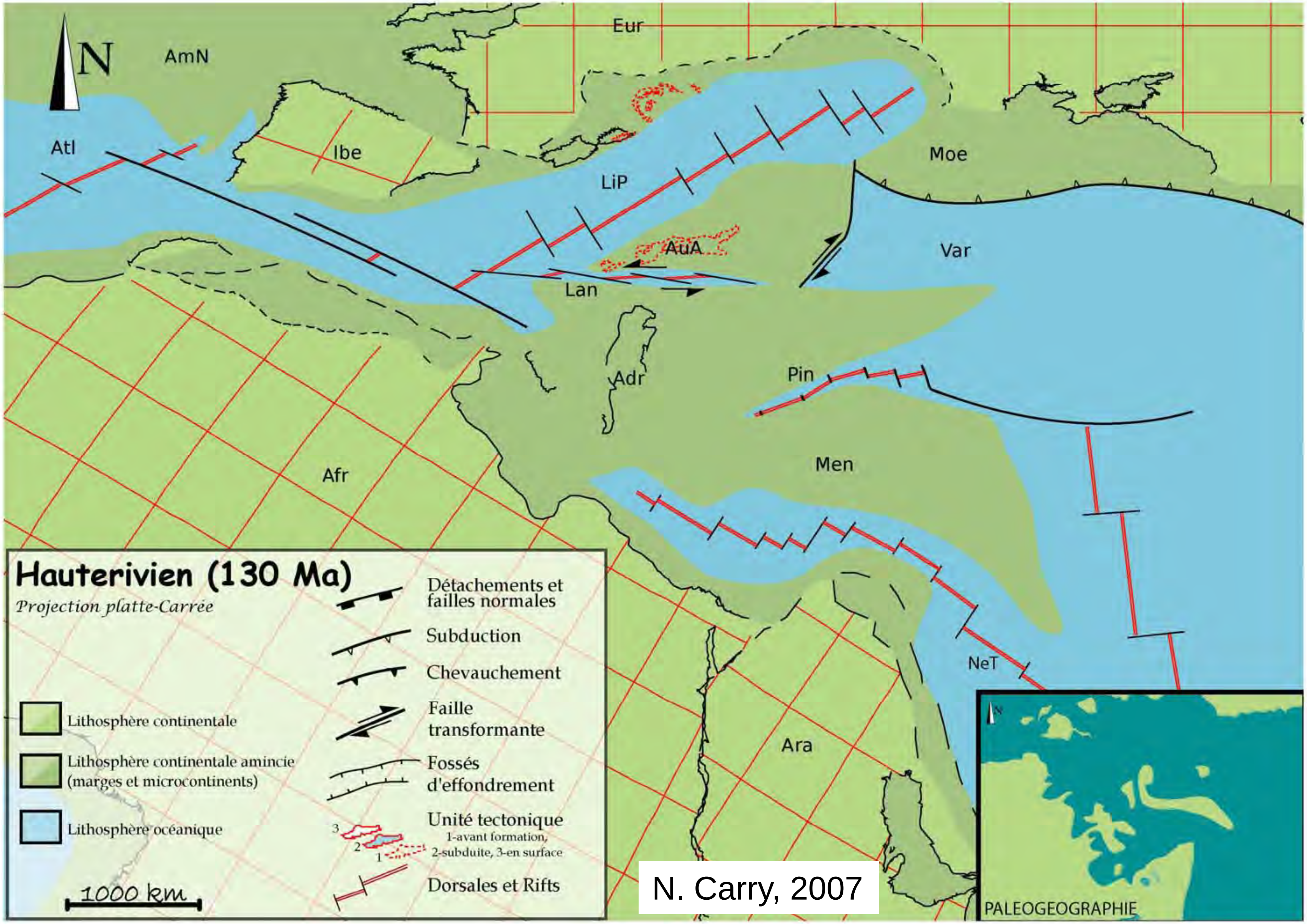

Warren et al., 2008




# Role of slab retreat


Eur
AuA
Bri
Pan
Moe
Tyr
Adr
Rho
Ibe
May
Men
Cyc
Atl
Alb
Kab
CrP
Ara
Afr
Actuel (0 Ma)
Projection platte-Carrée
Détachements et failles normales
Subduction
Chevauchement
Faille transformante
Fossés d'effondrement
Unité tectonique
1-avant formation, 2-subduite, 3-en surface
Dorsales et Rifts
Lithosphère continentale
Lithosphère continentale amincie (marges et microcontinents)
Lithosphère océanique
1000 km
PALEOGEOGRAPHIE

N. Carry, 2007



Hauterivien (130 Ma)
Projection platte-Carrée
N
AmN
Eur
Atl
Ibe
LiP
Moe
AuA
Var
Lan
Adr
Pin
Afr
Men
NeT
Ara
Détachements et failles normales
Subduction
Chevauchement
Faille transformante
Fossés d'effondrement
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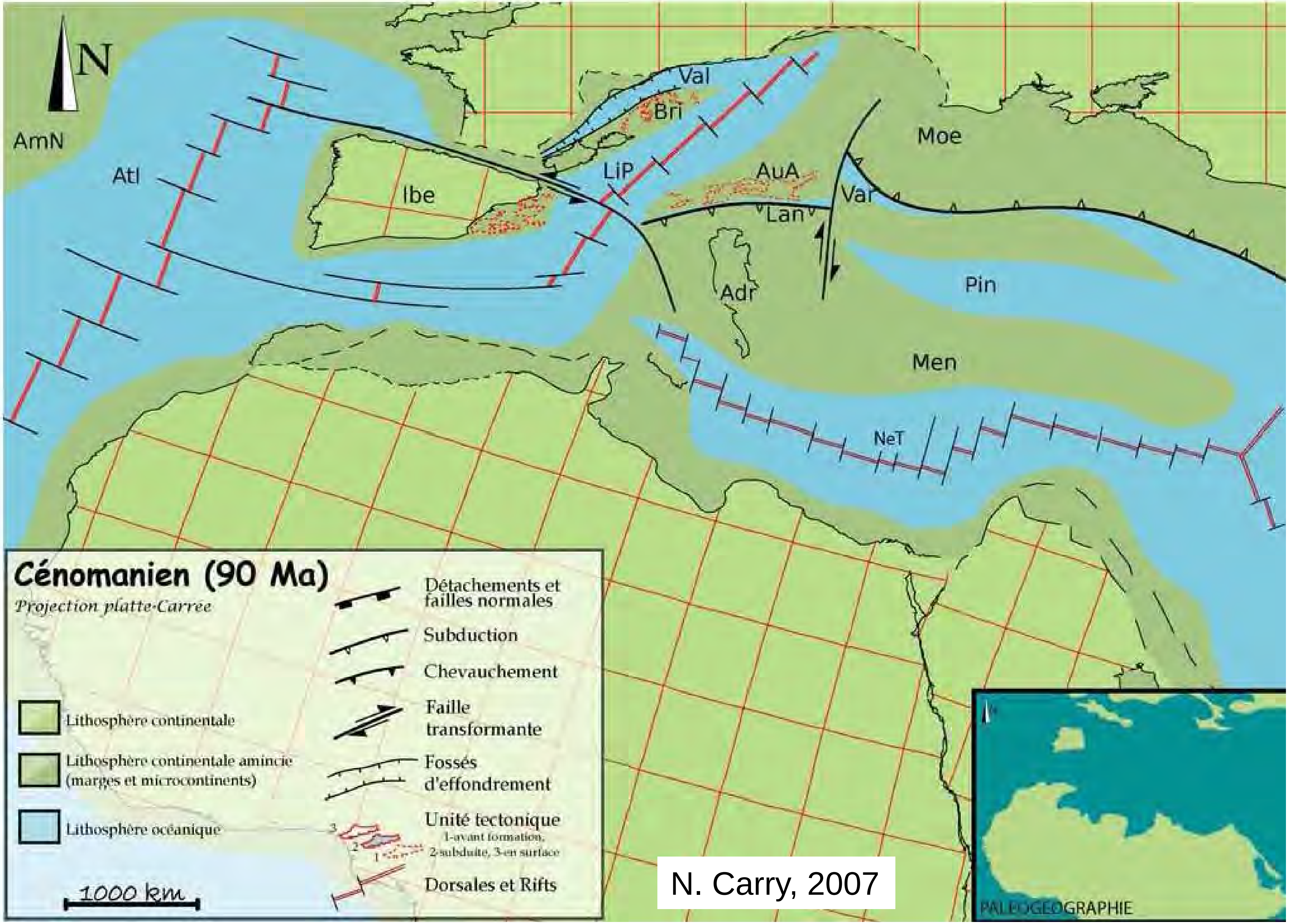
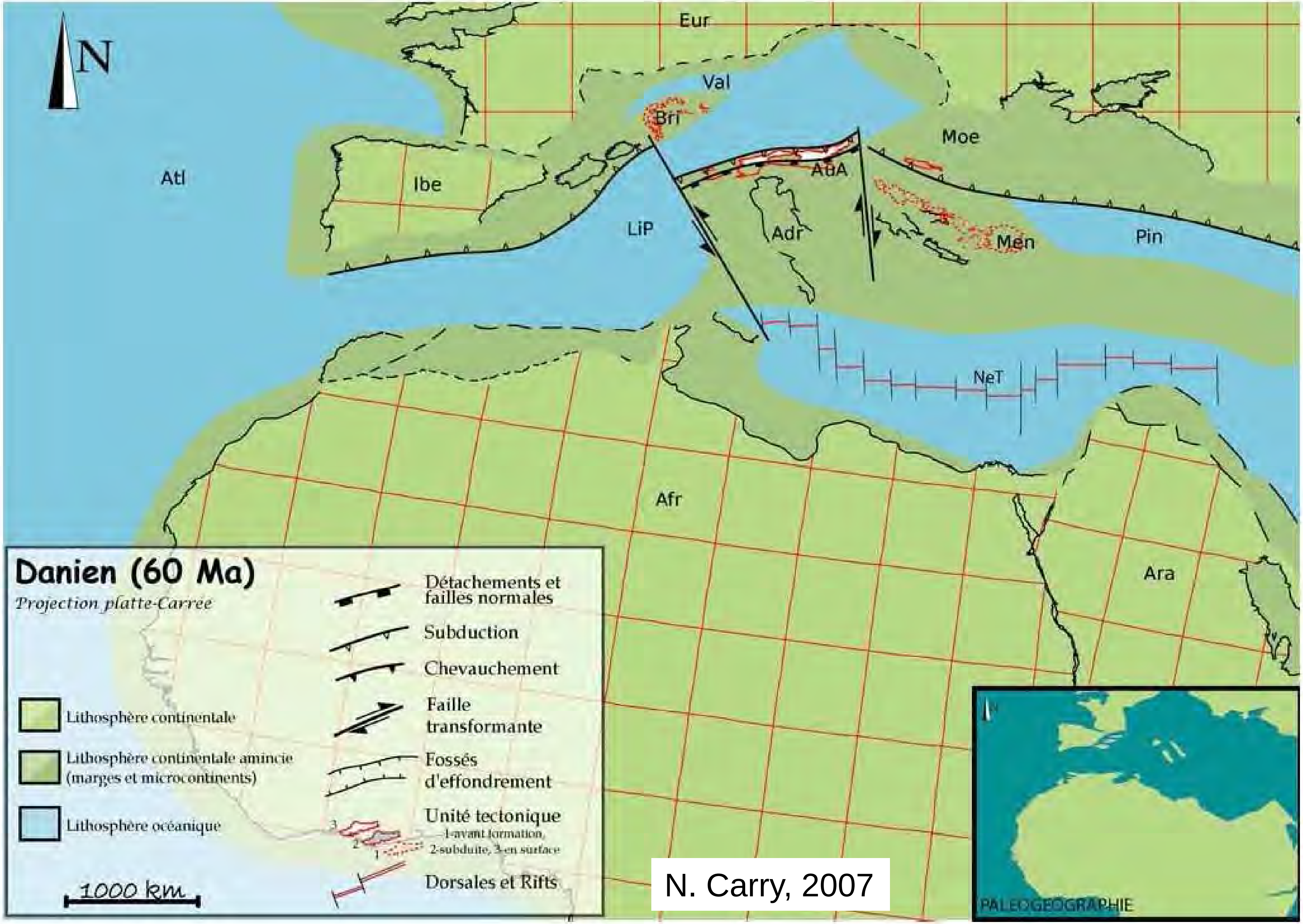
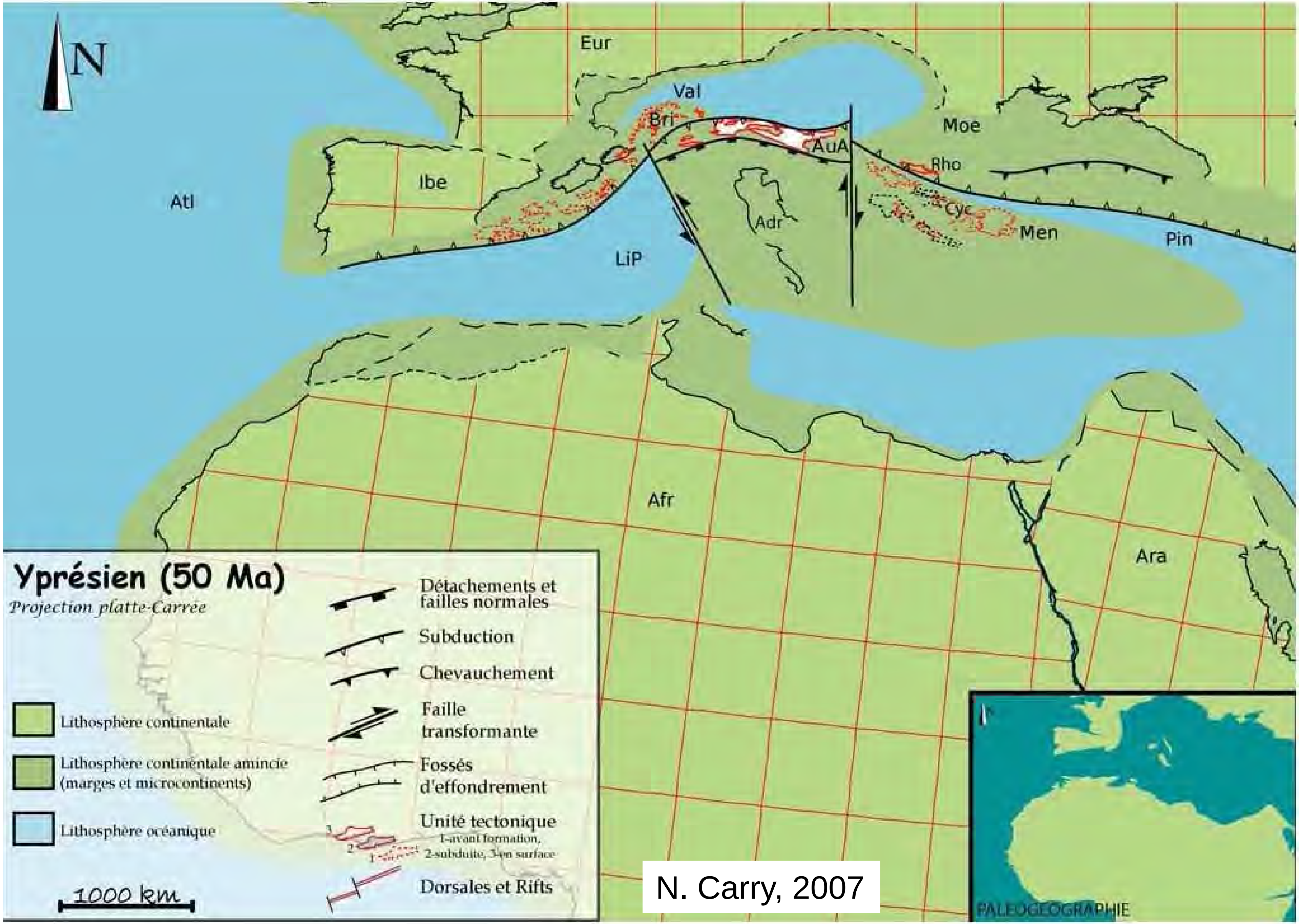
Lithosphère océanique
1000 km
PALEOGEOGRAPHIE

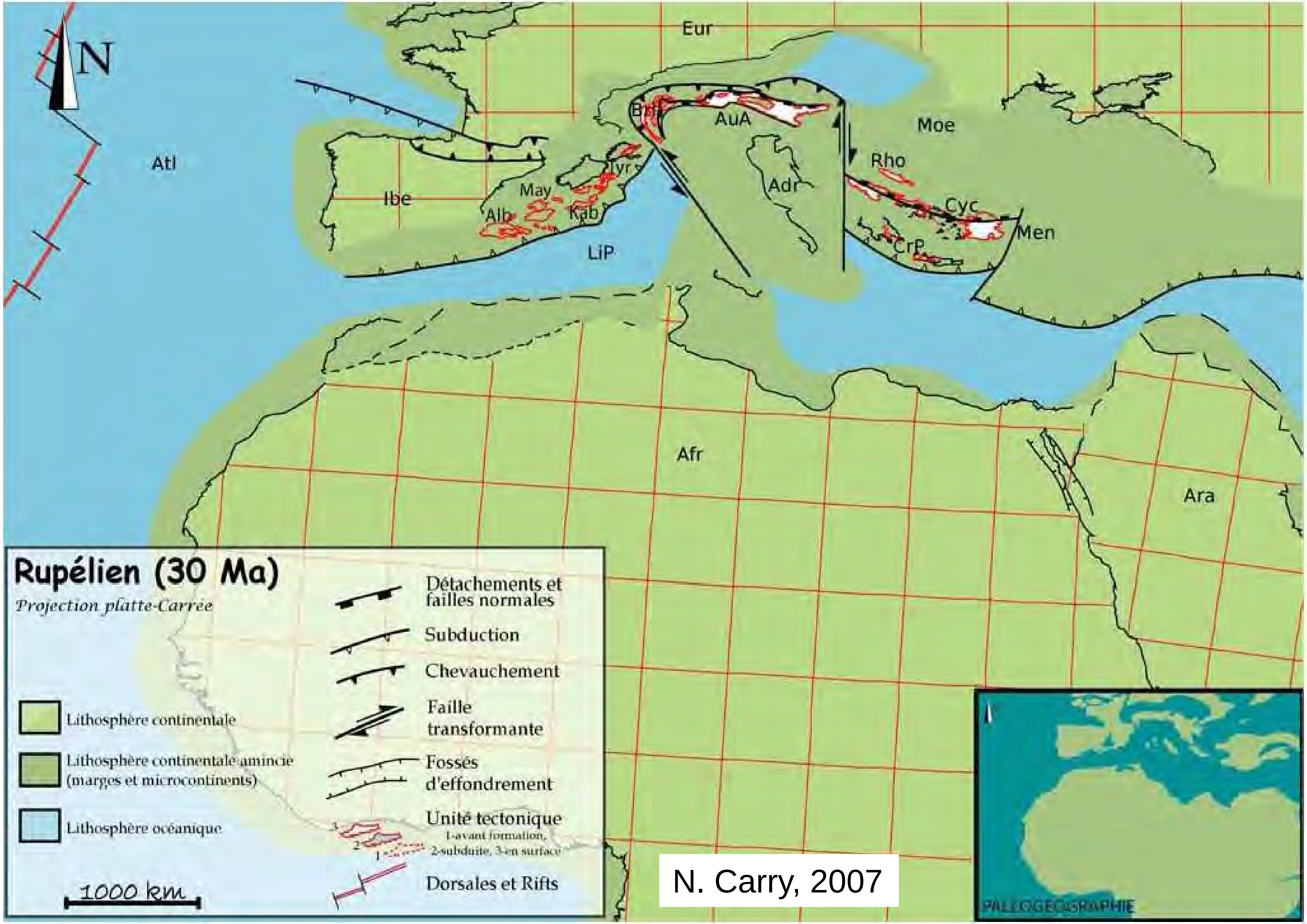

N. Carry, 2007


N
AmN
Atl
Ibe
Val
Bri
LiP
AuA
Lan
Moe
Var
Adr
Pin
Men
NeT
Cénomanien (90 Ma)
Projection platte-Carrée
Détachements et failles normales
Subduction
Chevauchement
Faille transformante
Fossés d'effondrement
Unité tectonique
1-avant formation, 2-subduite, 3-en surface
Dorsales et Rifts
Lithosphère continentale
Lithosphère continentale amincie (marges et microcontinents)
Lithosphère océanique
1000 km
N. Carry, 2007
PALEOGEOGRAPHIE

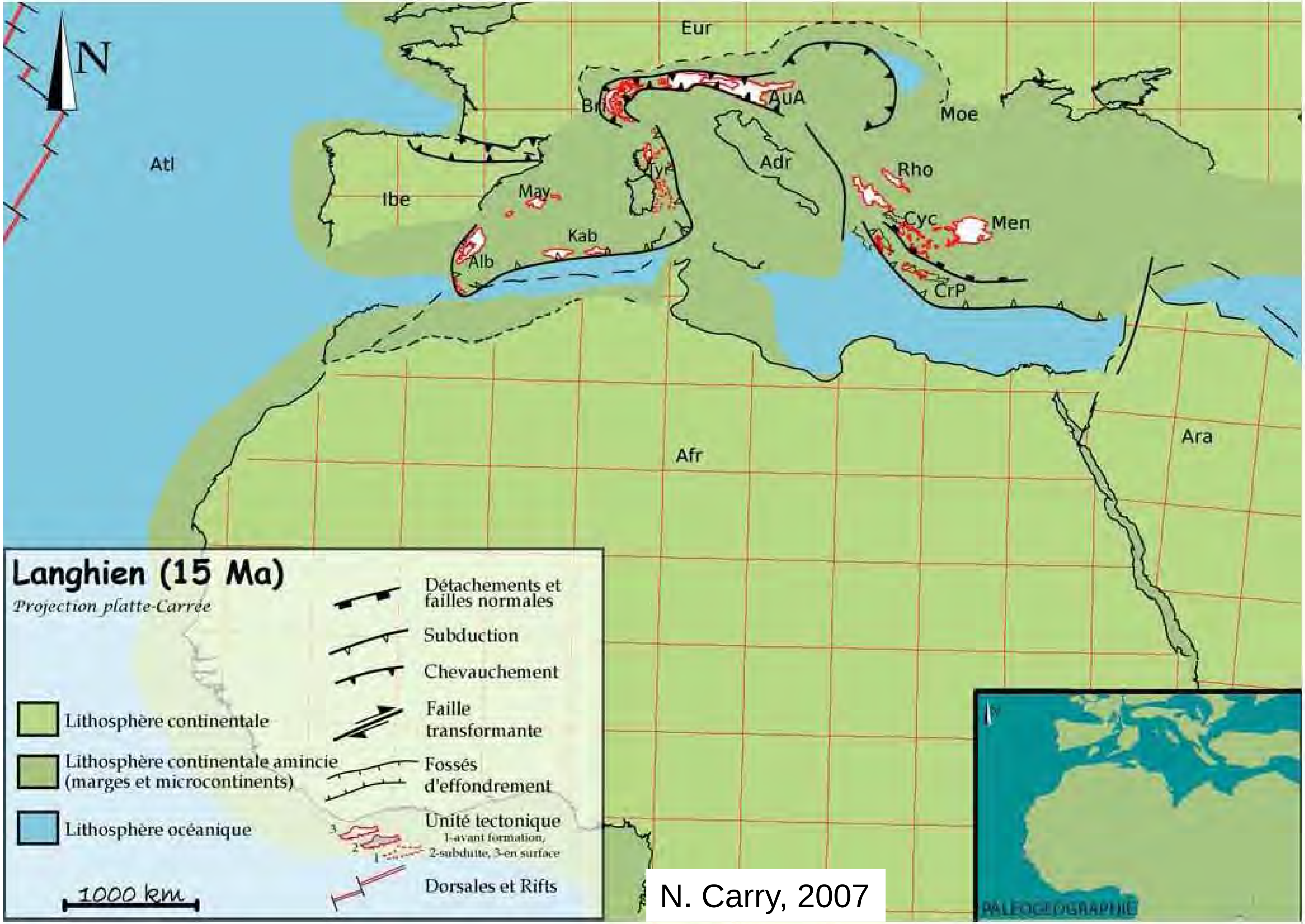

N
Eur
Val
Bri
Moe
AdA
Atl
Ibe
LiP
Adr
Men
Pin
NeT
Afr
Ara
Danien (60 Ma)
Projection platte-Carrée
Détachements et failles normales
Subduction
Chevauchement
Faille transformante
Fossés d'effondrement
Unité tectonique
1-avant formation, 2-subduite, 3-en surface
Dorsales et Rifts
Lithosphère continentale
Lithosphère continentale amincie (marges et microcontinents)
Lithosphère océanique
1000 km
N. Carry, 2007
PALEOGEOGRAPHIE


N
Eur
Val
Bri
AuA
Moe
Rho
Ibe
Atl
Adr
Cyc
Men
Pin
LiP
Afr
Ara
Yprésien (50 Ma)
Projection platte-Carrée
Détachements et failles normales
Subduction
Chevauchement
Faille transformante
Fossés d'effondrement
Unité tectonique
1-avant formation, 2-subduite, 3-en surface
Dorsales et Rifts
Lithosphère continentale
Lithosphère continentale amincie (marges et microcontinents)
Lithosphère océanique
1000 km
PALEOGEOGRAPHIE

N. Carry, 2007


Eur
Atl
Ibe
May
Alb
Kab
Tyr
Bri
AuA
Adr
Moe
Rho
Cyc
CrP
Men
LiP
Afr
Ara
Rupélien (30 Ma)
Projection platte-Carrée
Lithosphère continentale
Lithosphère continentale amincie (marges et microcontinents)
Lithosphère océanique
Détachements et failles normales
Subduction
Chevauchement
Faille transformante
Fossés d'effondrement
Unité tectonique
1-avant formation, 2-subduite, 3-en surface
Dorsales et Rifts
1000 km
N
PALEOGEOGRAPHIE

N. Carry, 2007


N
Eur
AuA
Br
Moe
Atl
Ibe
May
Tyr
Adr
Rho
Cyc
Men
Kab
Alb
CrP
Afr
Ara
Langhien (15 Ma)
Projection platte-Carrée
Détachements et failles normales
Subduction
Chevauchement
Faille transformante
Fossés d'effondrement
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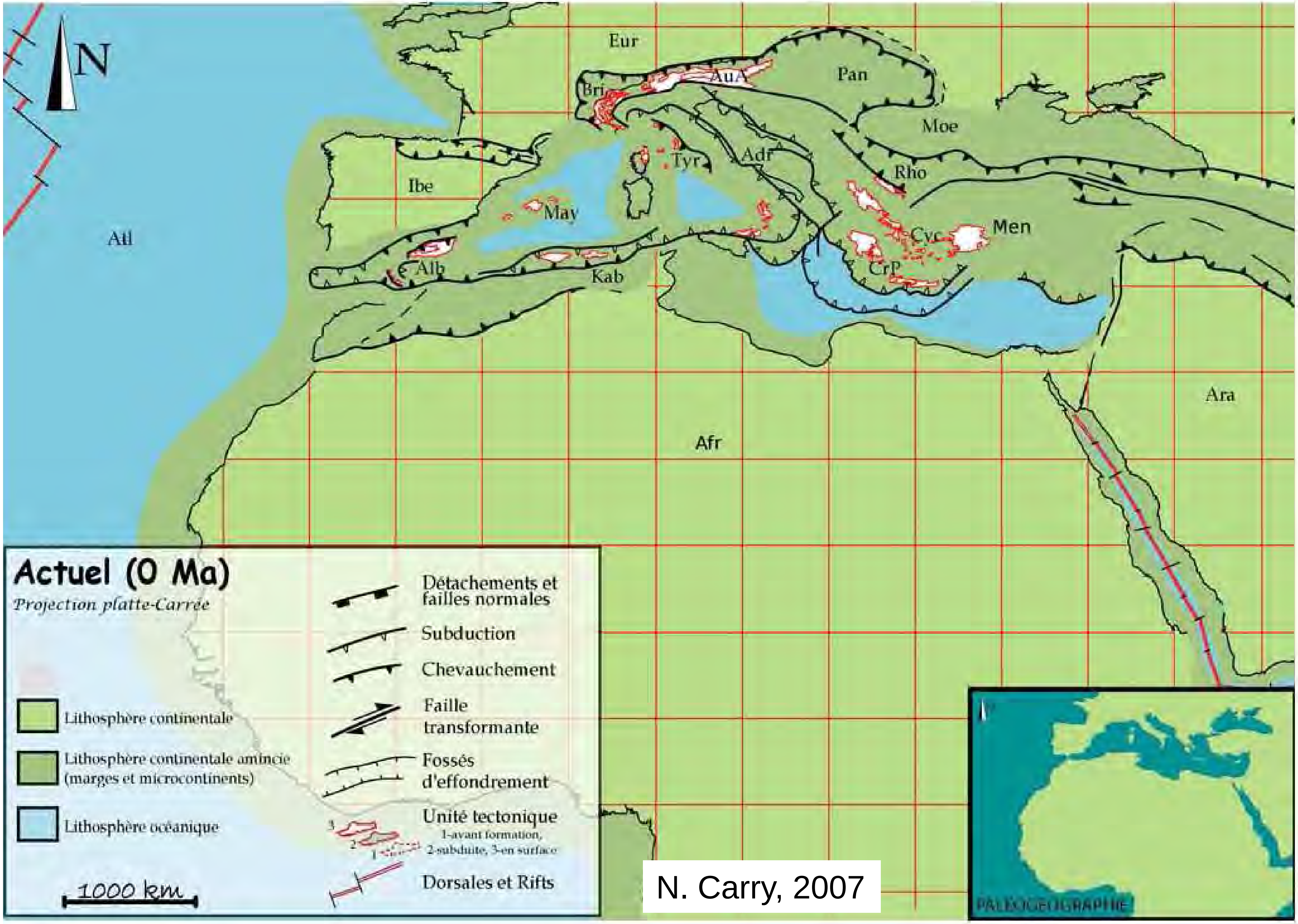
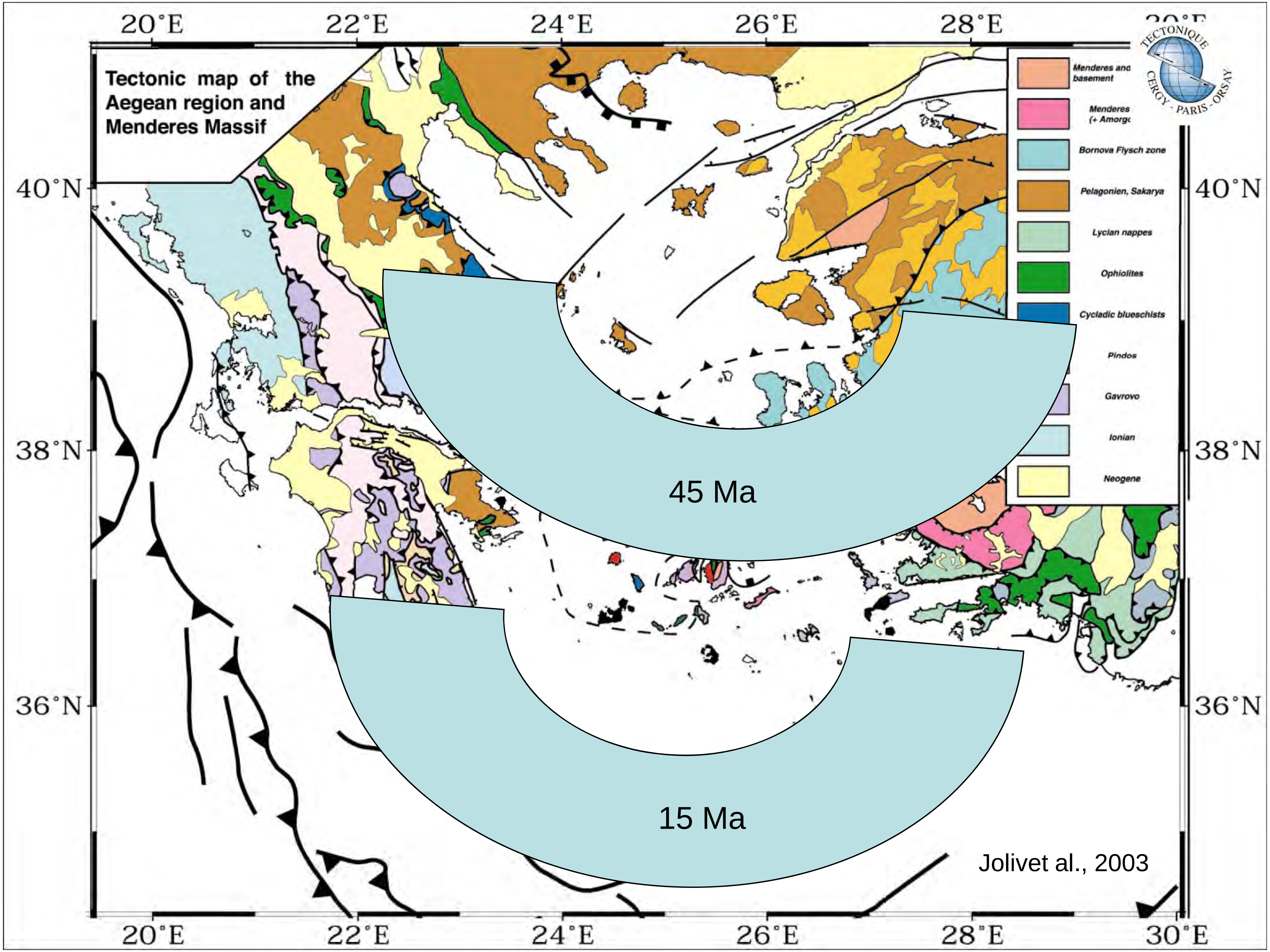
1-avant formation, 2-subduite, 3-en surface
Dorsales et Rifts
Lithosphère continentale
Lithosphère continentale amincie (marges et microcontinents)
Lithosphère océanique
1000 km
PALEOGEOGRAPHIE

N. Carry, 2007

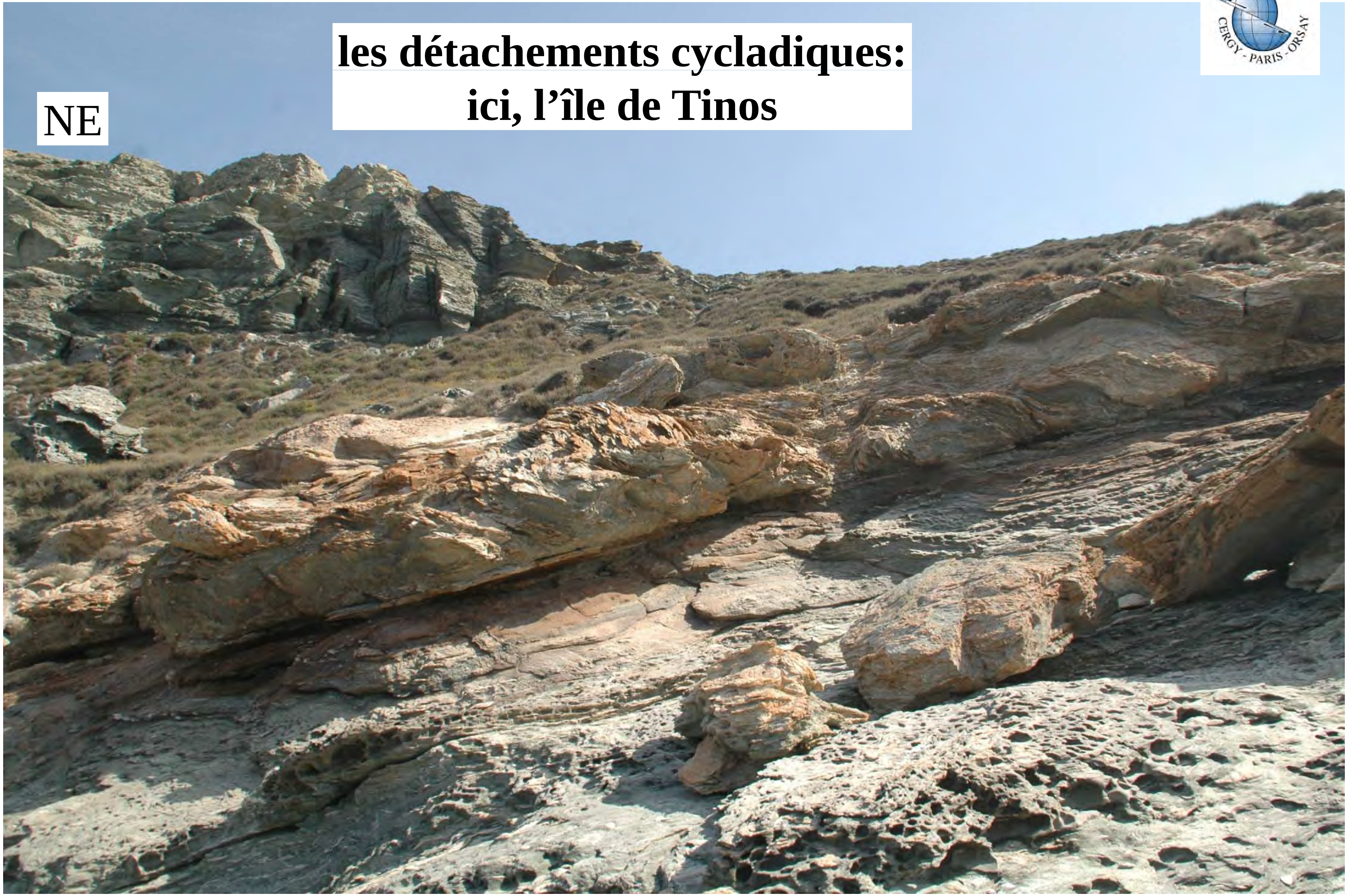

N
Eur
Pan
Moe
Bri
AuA
Tyr
Adr
Rho
Ibe
May
Men
Cyc
CrP
Atl
Alb
Kab
Ara
Afr
Actuel (0 Ma)
Projection platte-Carrée
Lithosphère continentale
Lithosphère continentale amincie (marges et microcontinents)
Lithosphère océanique
1000 km
Détachements et failles normales
Subduction
Chevauchement
Faille transformante
Fossés d'effondrement
Unité tectonique
1-avant formation, 2-subduite, 3-en surface
Dorsales et Rifts
PALÉOGÉOGRAPHIE
N. Carry, 2007


Tectonic map of the Aegean region and Menderes Massif
20°E
22°E
24°E
26°E
28°E
30°E
40°N
38°N
36°N
Menderes and basement
Menderes (+ Amorgo
Bornova Flysch zone
Pelagonien, Sakarya
Lycian nappes
Ophiolites
Cycladic blueschists
Pindos
Gavrovo
Ionian
Neogene
45 Ma
15 Ma
Jolivet al., 2003

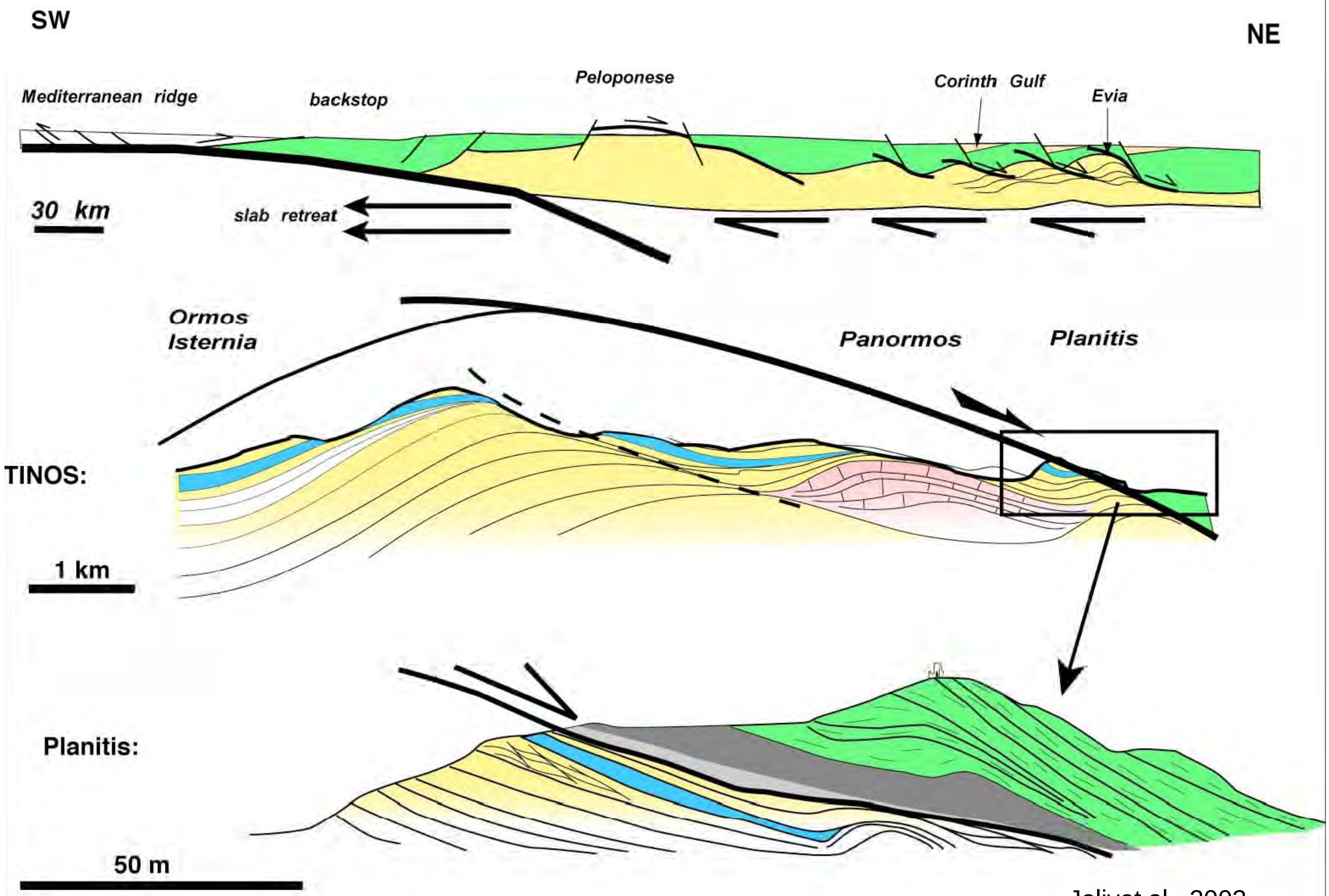
# les détachements cycladiques: ici, l'île de Tinos

TECTONIQUE CERGY - PARIS - ORSAY

# les détachements cycladiques:
# ici, l'île de Tinos

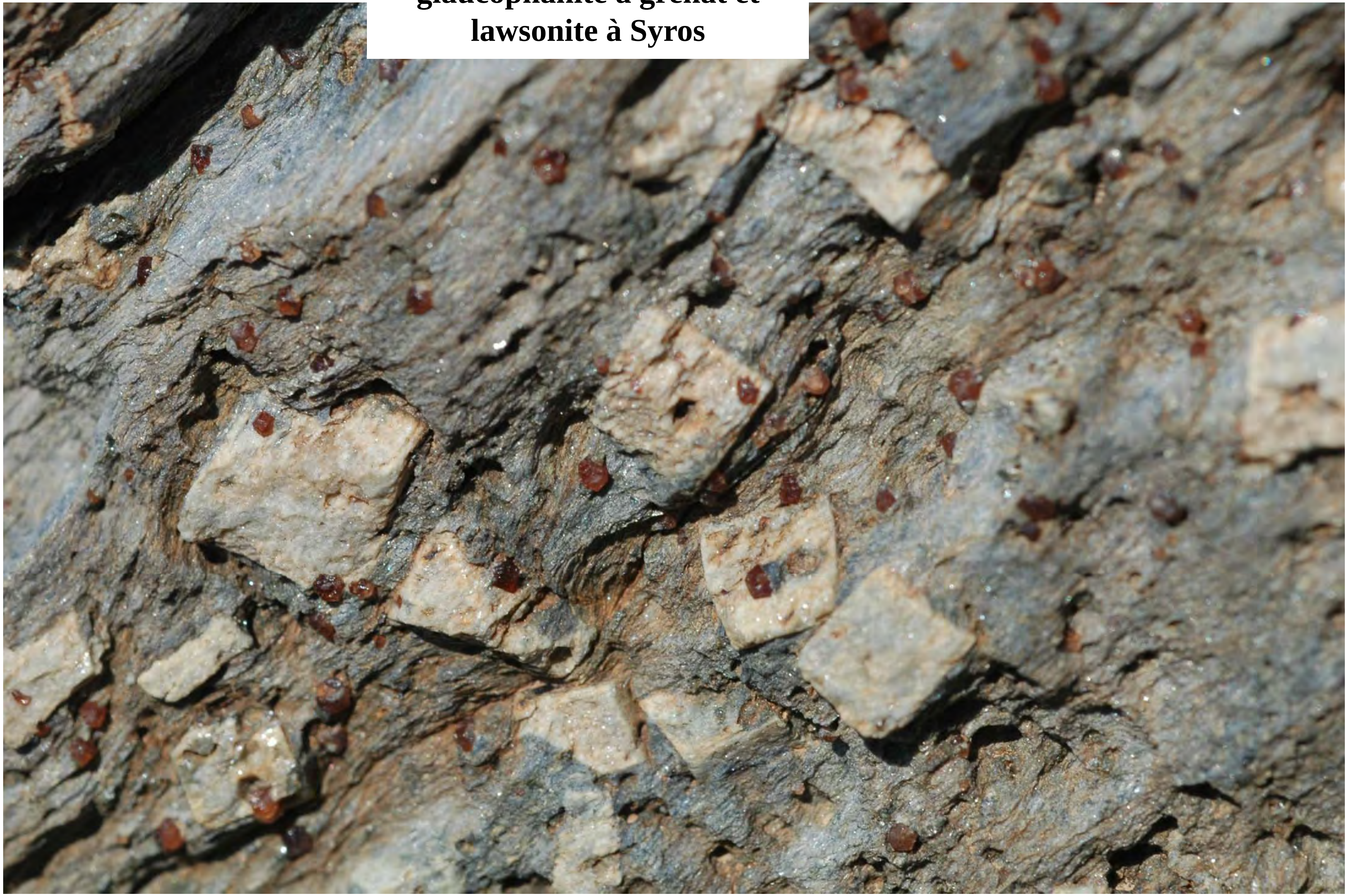


**les détachements cycladiques:**
**ici, l’île de Mykonos**

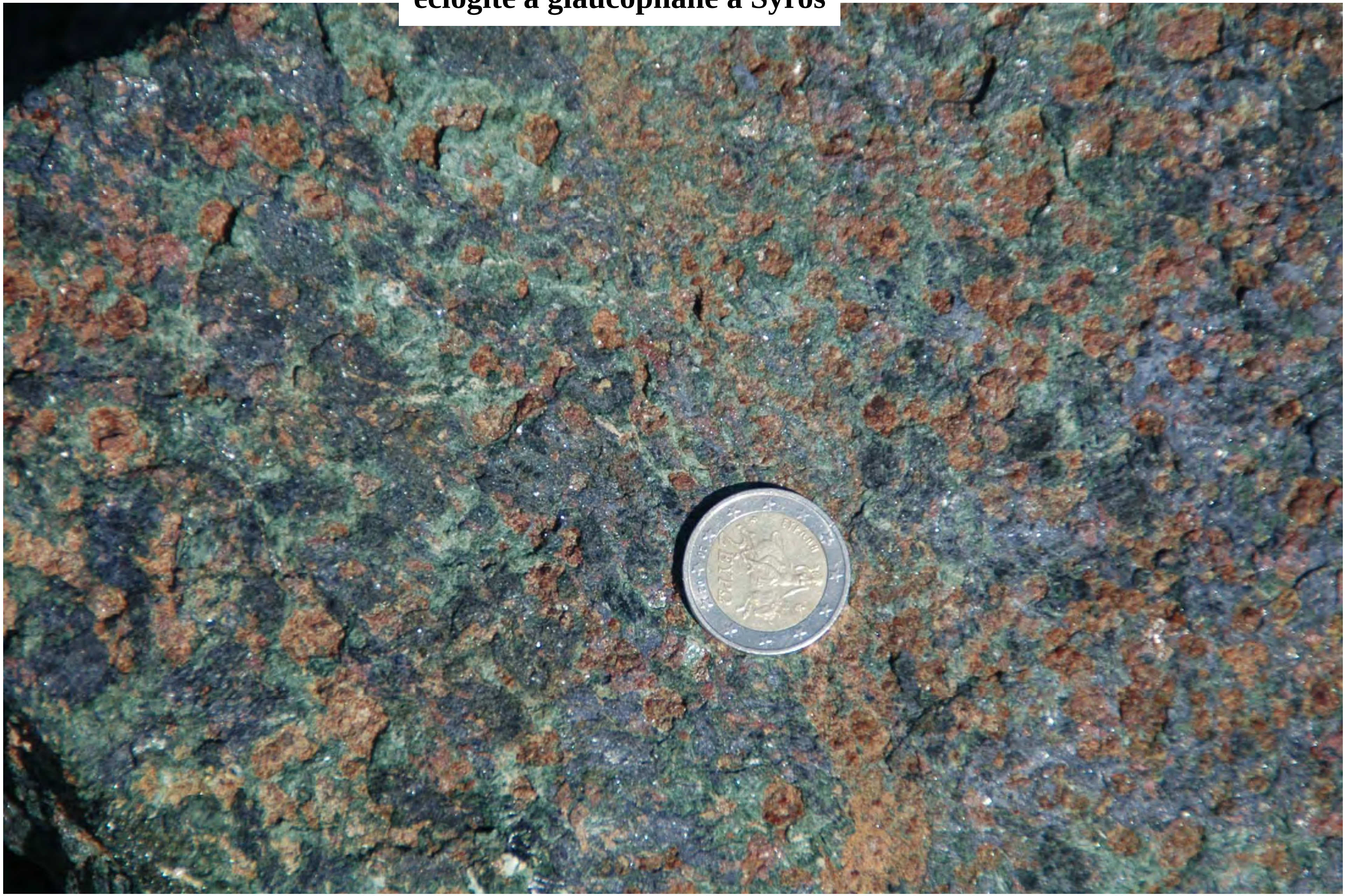


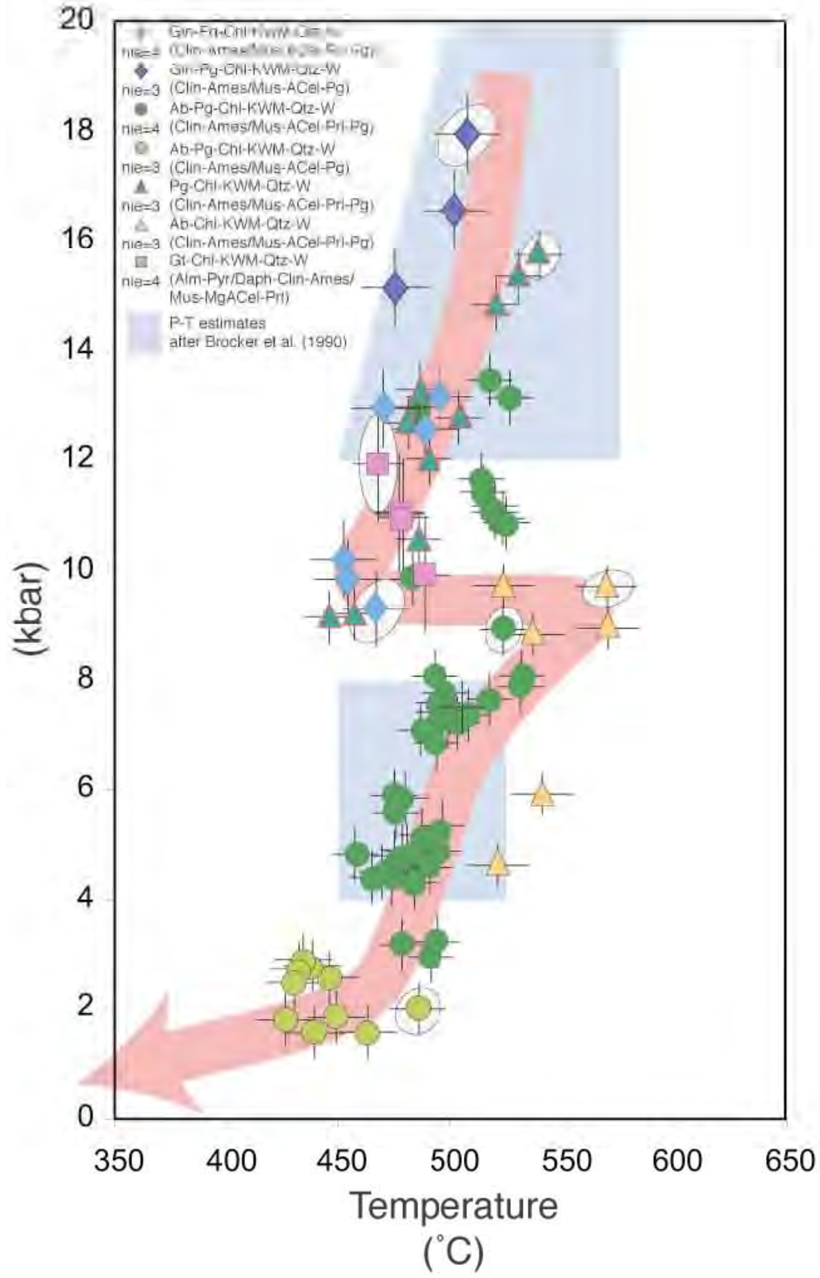

Jolivet al., 2003

**glaucophanite à grenat et lawsonite à Syros**

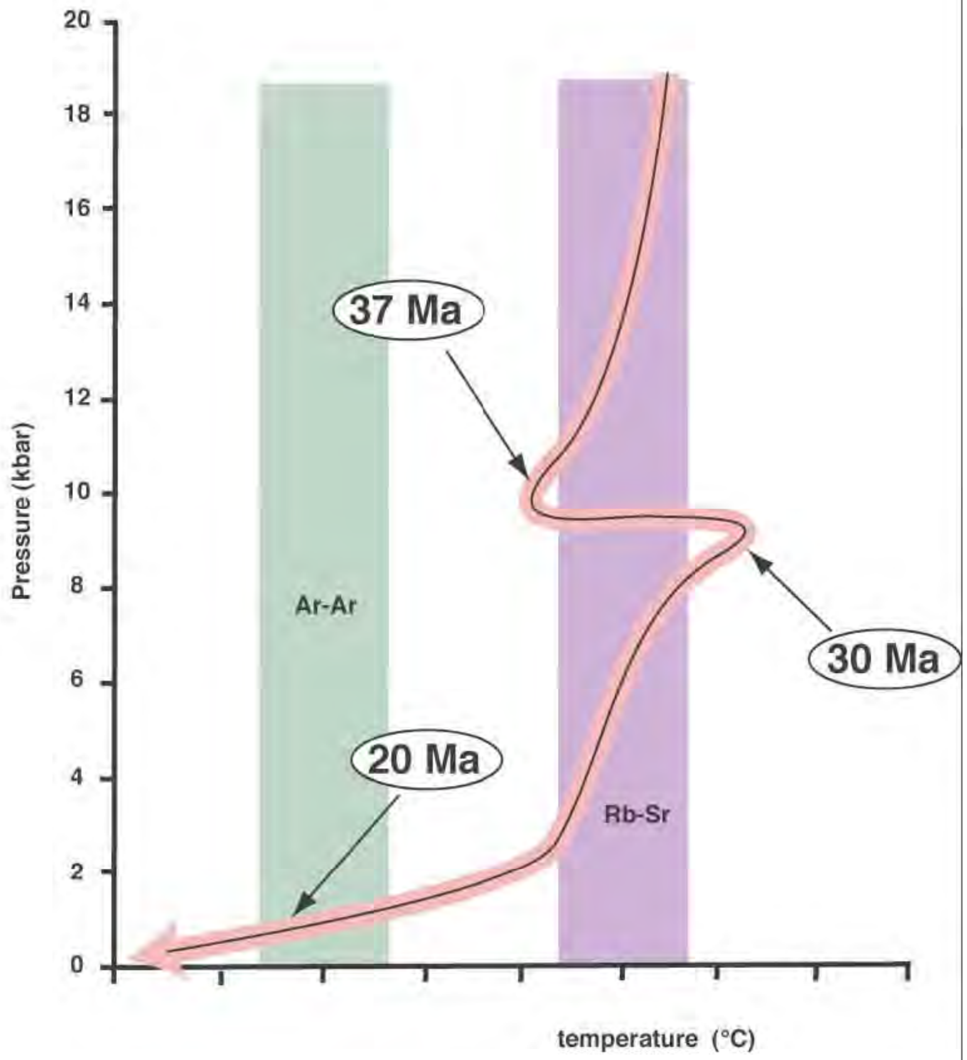


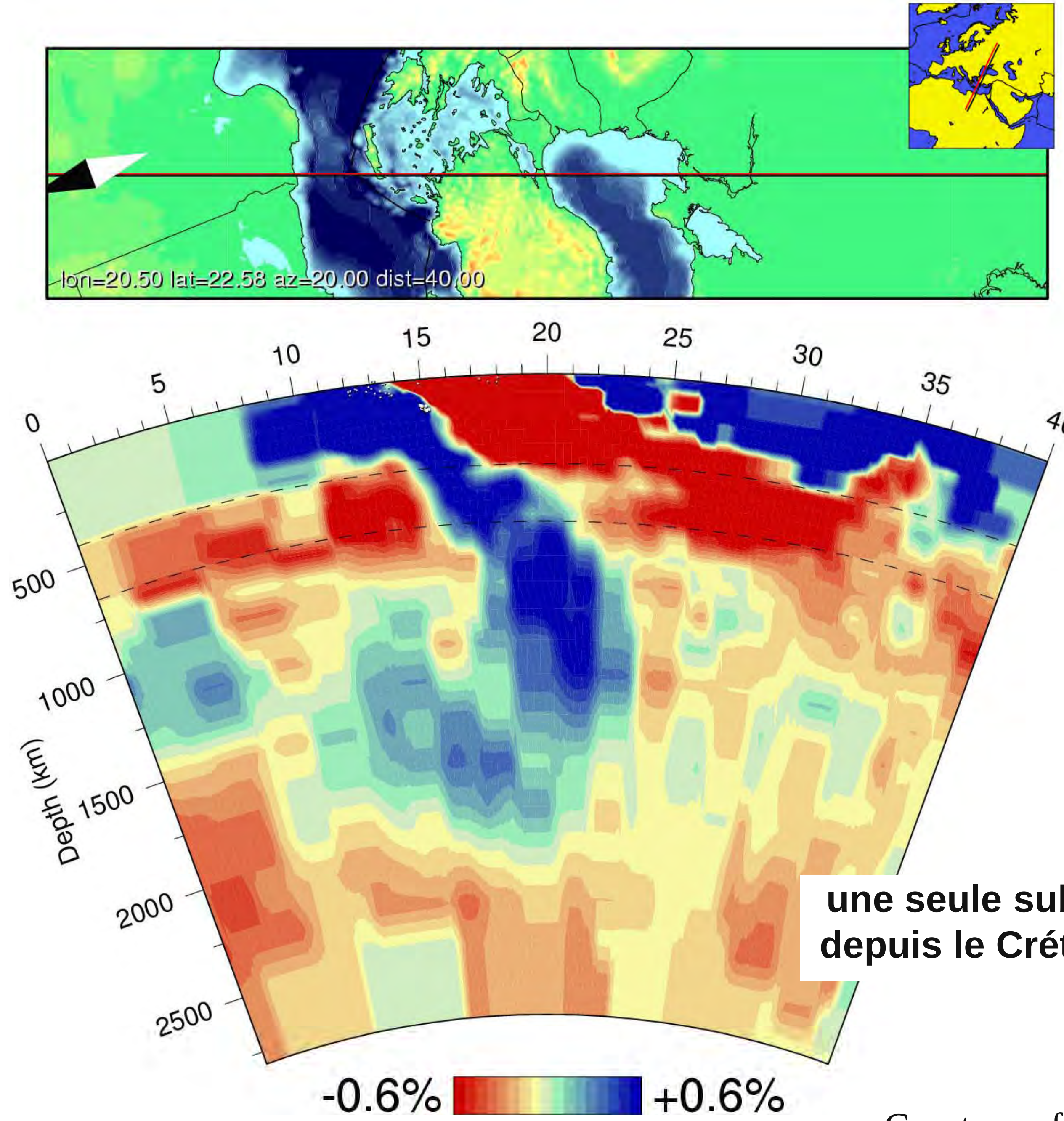
**éclogite à glaucophane à Syros**





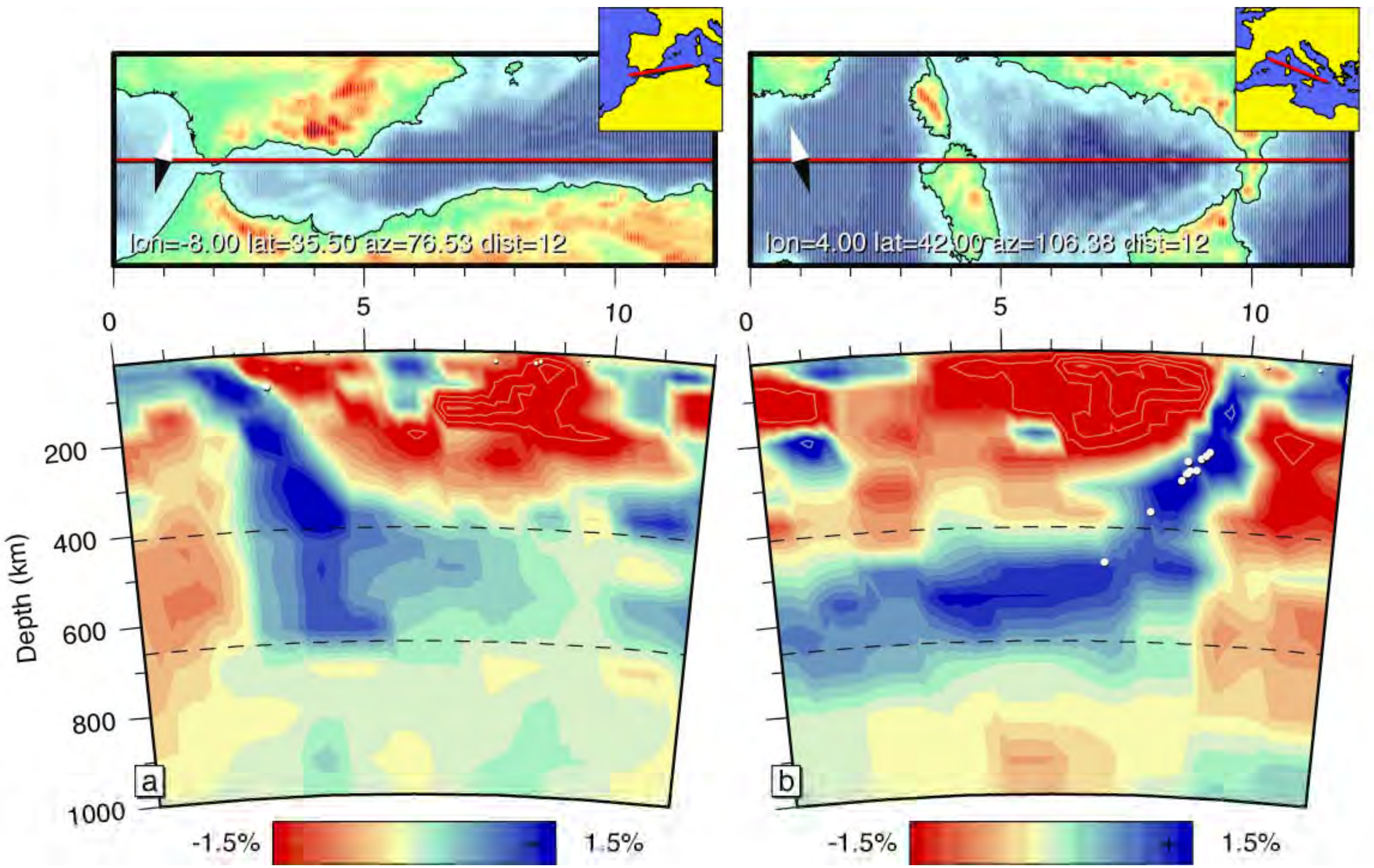

Tinos Island (Cyclades, Greece)
Parra, Vidal and Jolivet (2002)






**une seule subduction depuis le Crétacé sup.**

Courtesy of Wim Spakman

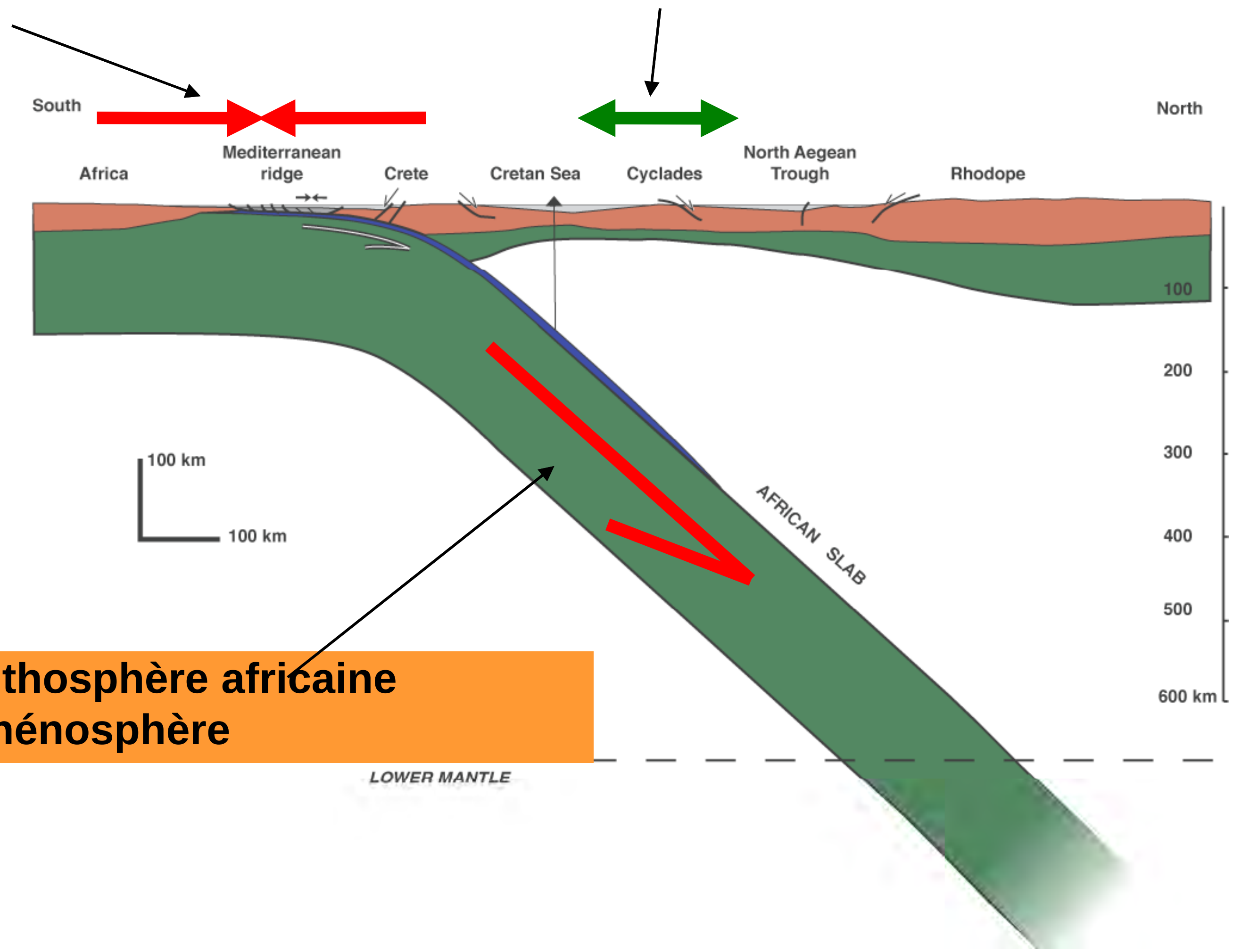



Spakman & Wortel, 2004

# SUBDUCTION

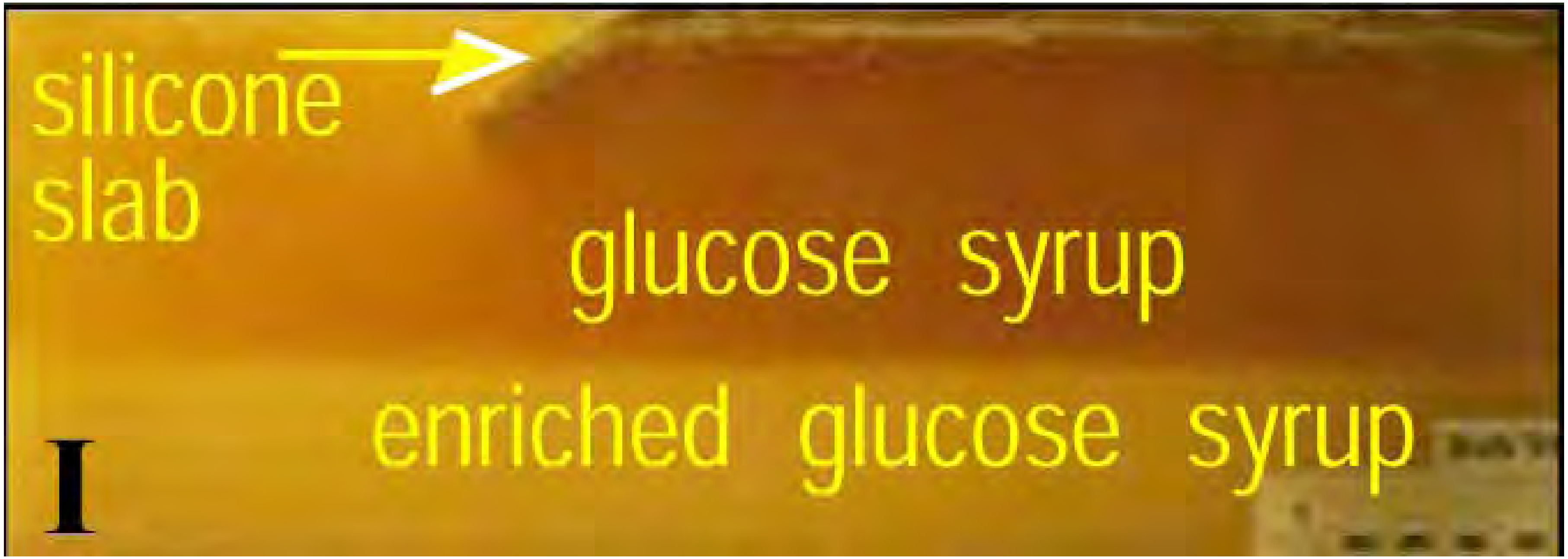
**compression et raccourcissement frontaux**

**extension ou compression arrière-arc**



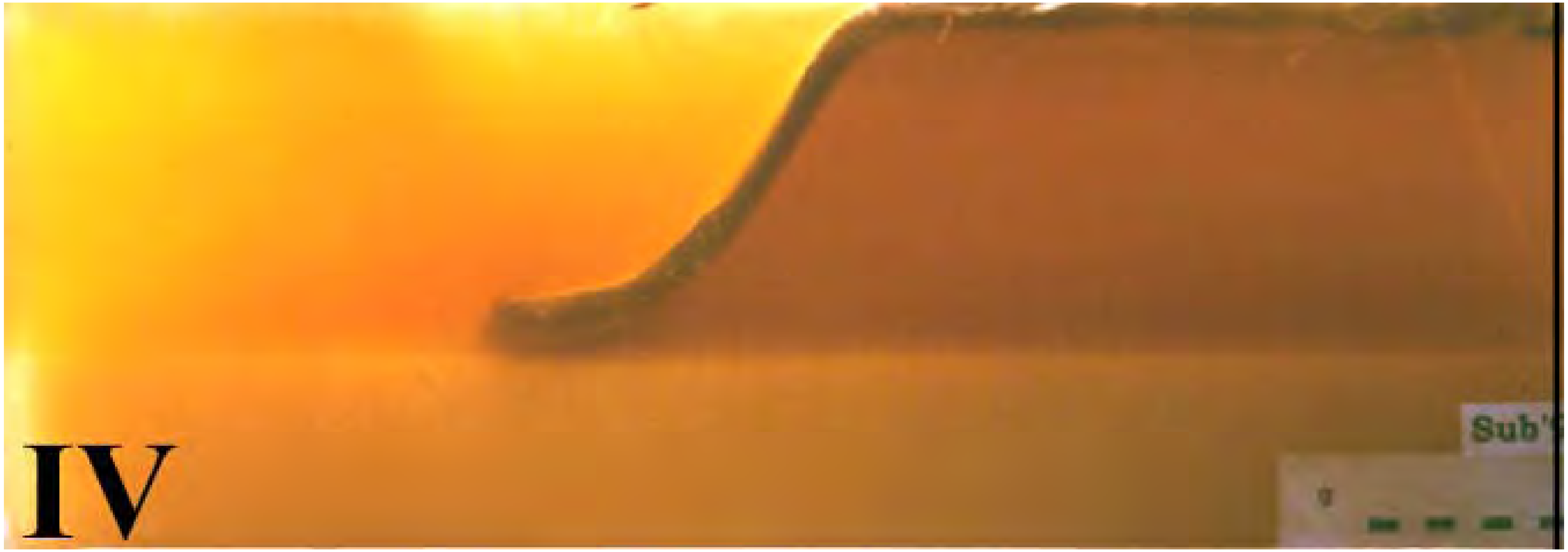

**Present**

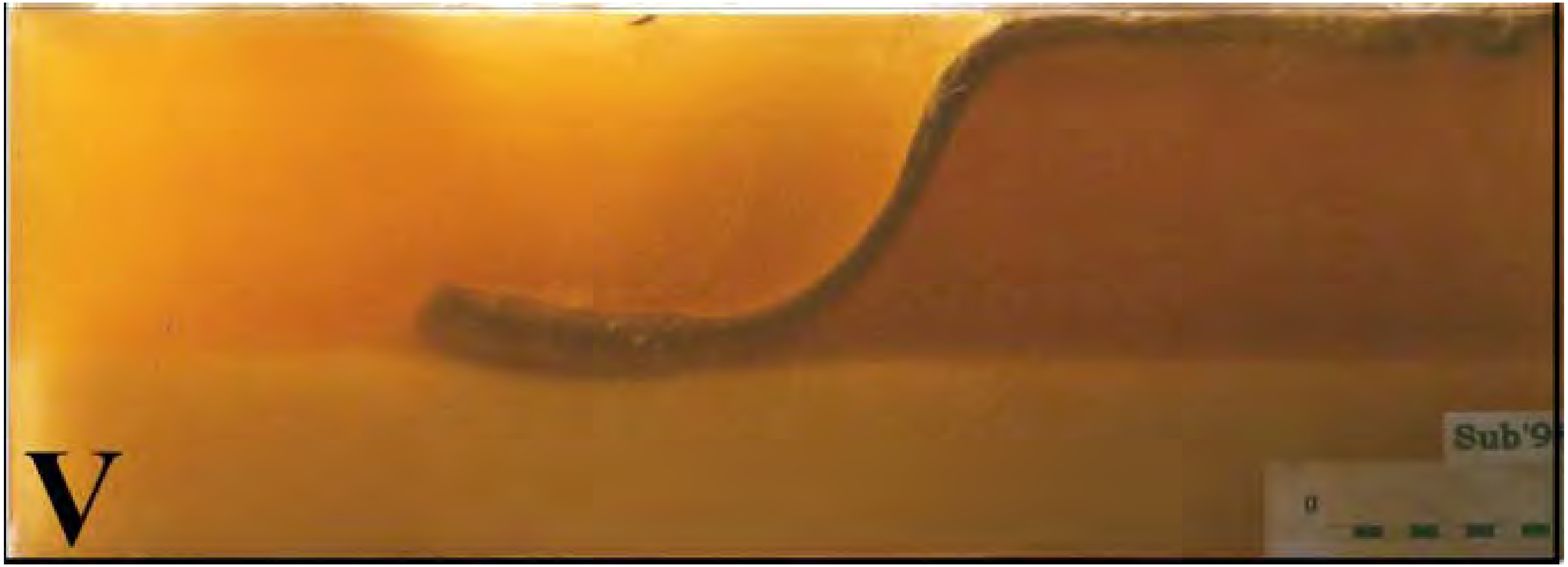
**plongement de la lithosphère africaine dans l' asthénosphère**

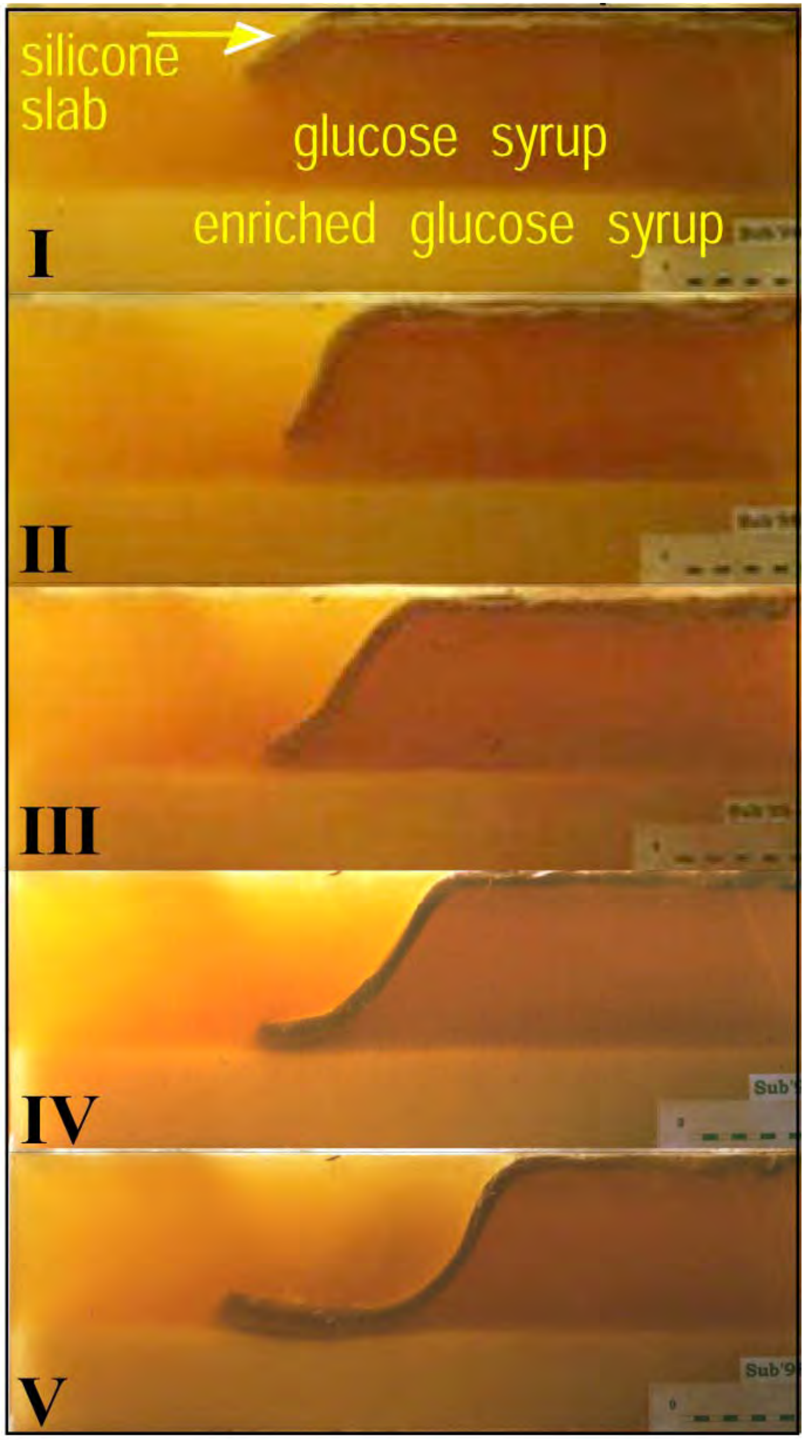



C. Faccenna

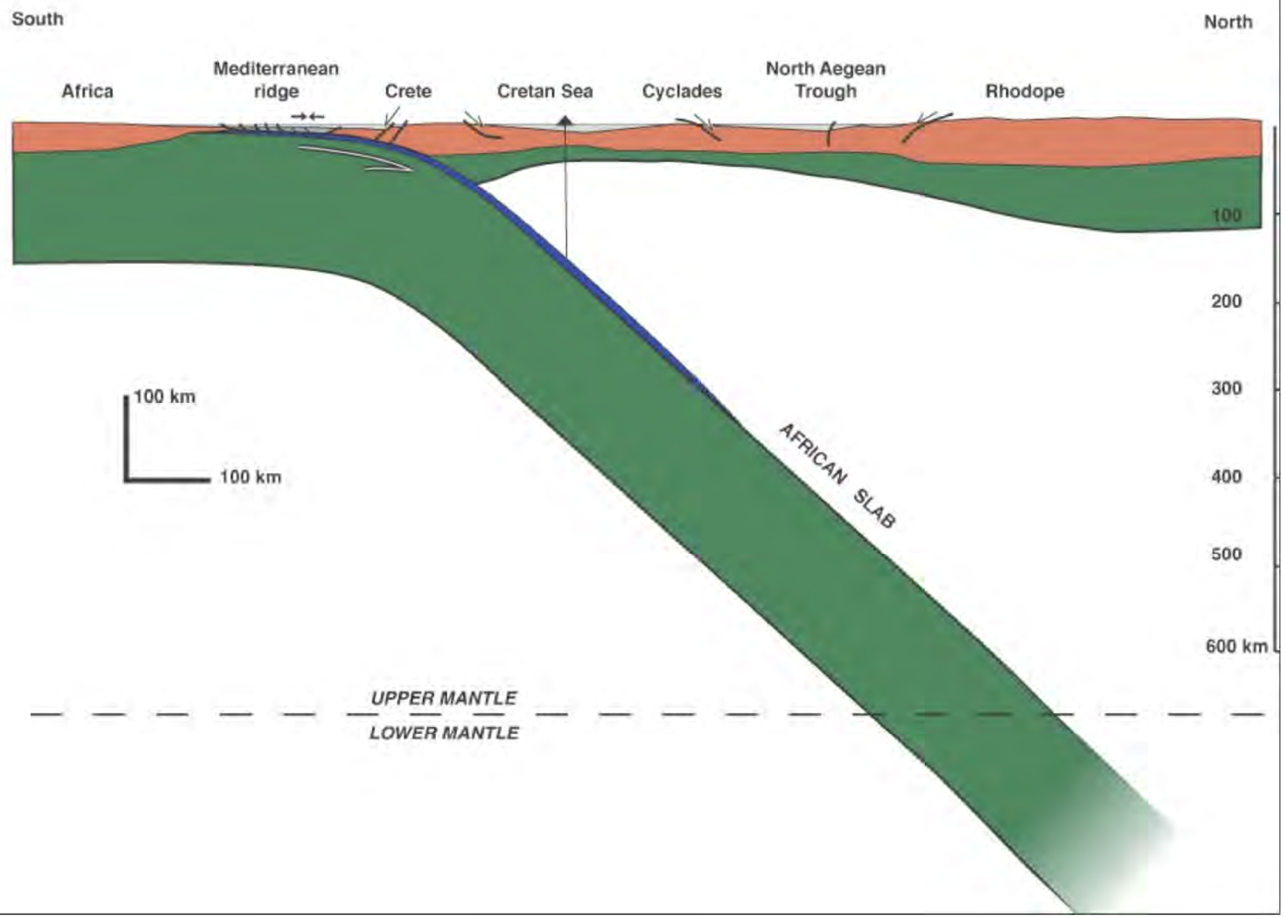

III

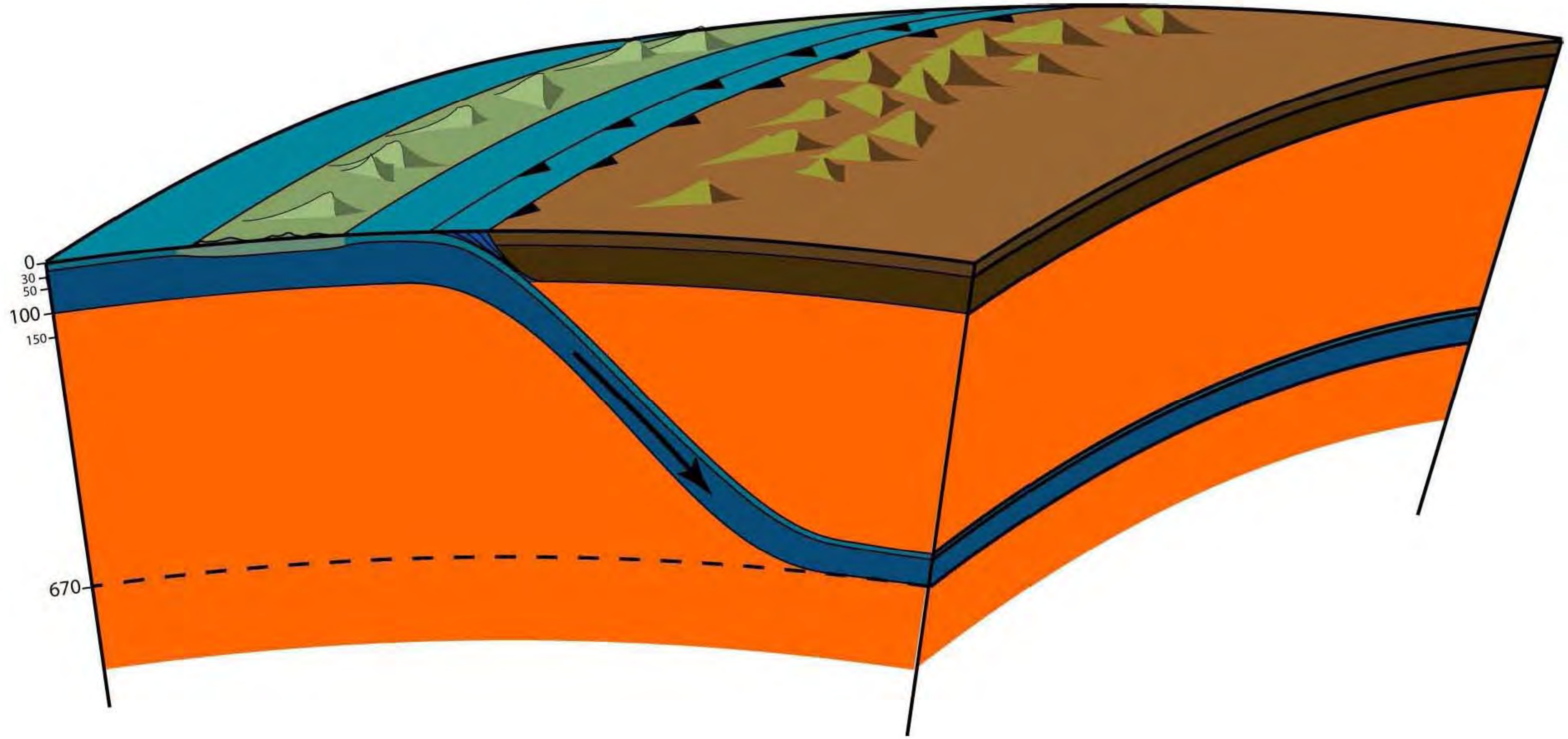

IV
Sub'


V
Sub'9
0

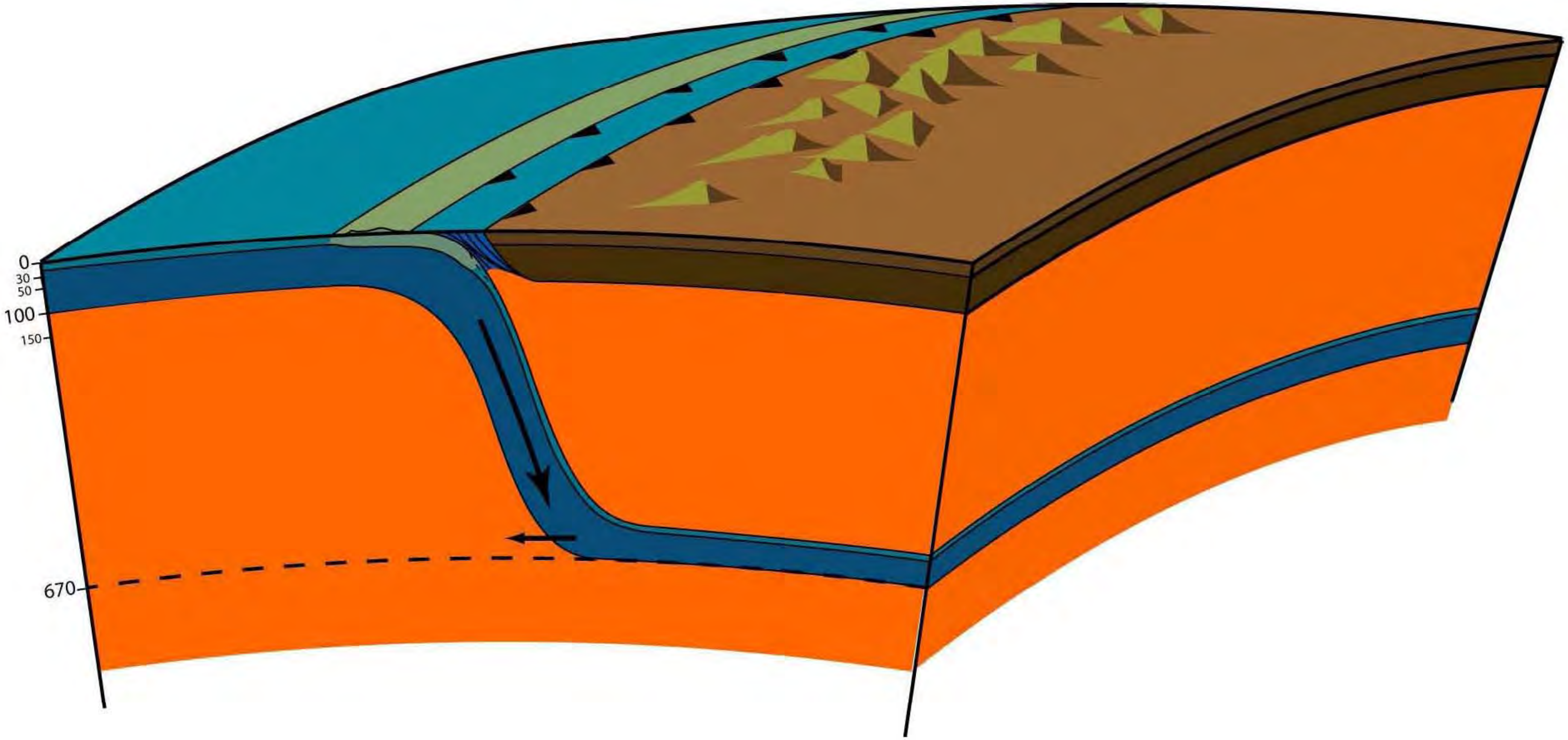

silicone
slab
glucose syrup
enriched glucose syrup
I
II
III
IV
V

# Present

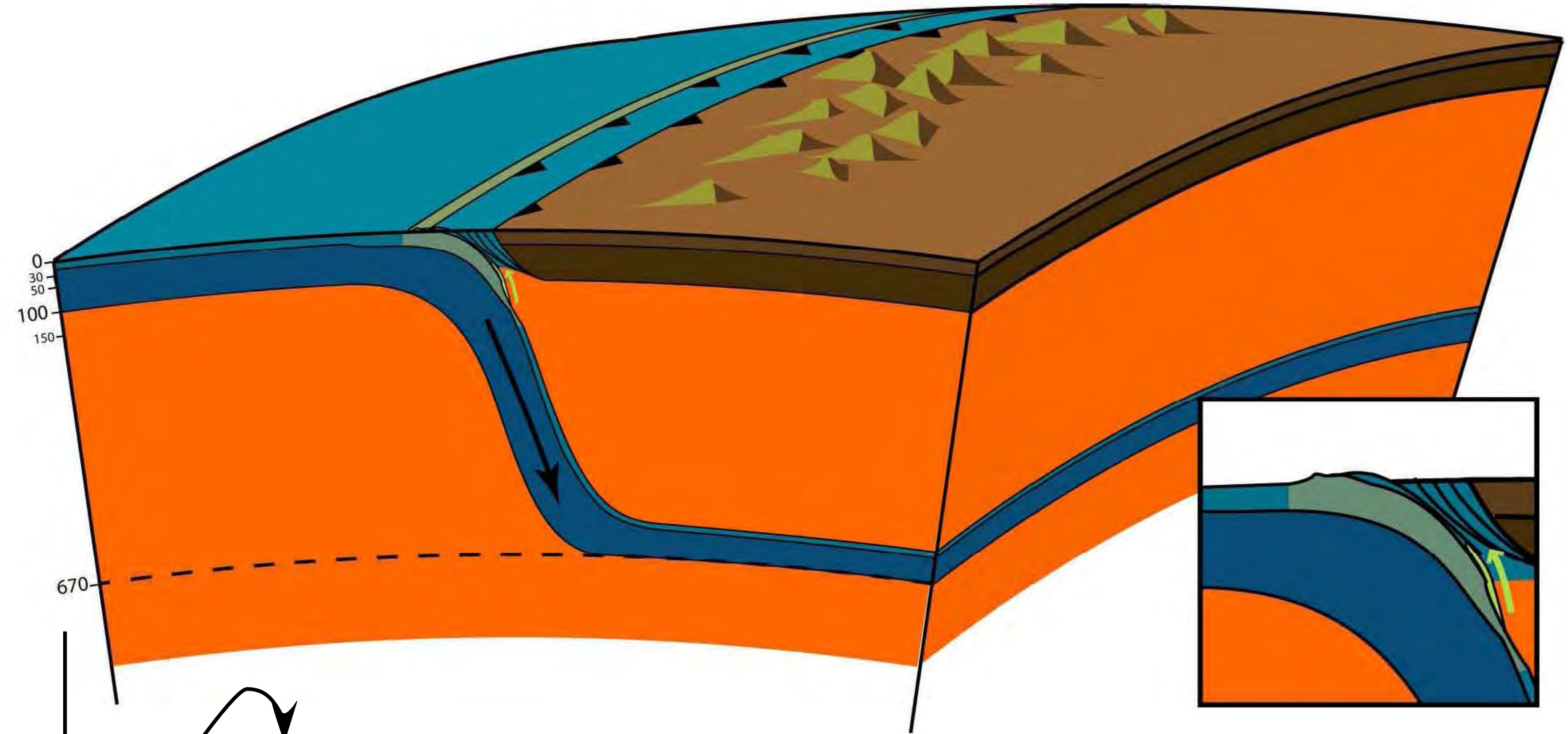

South
North
Africa
Mediterranean ridge
Crete
Cretan Sea
Cyclades
North Aegean Trough
Rhodope
100
200
300
400
500
600 km
100 km
100 km
AFRICAN SLAB
UPPER MANTLE
LOWER MANTLE

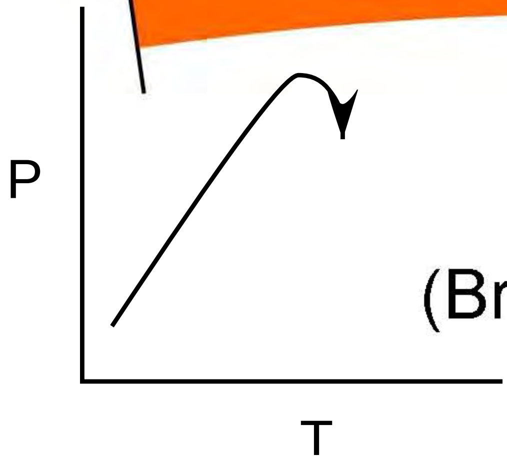



(Brun et Faccenna 2007 - soumis)

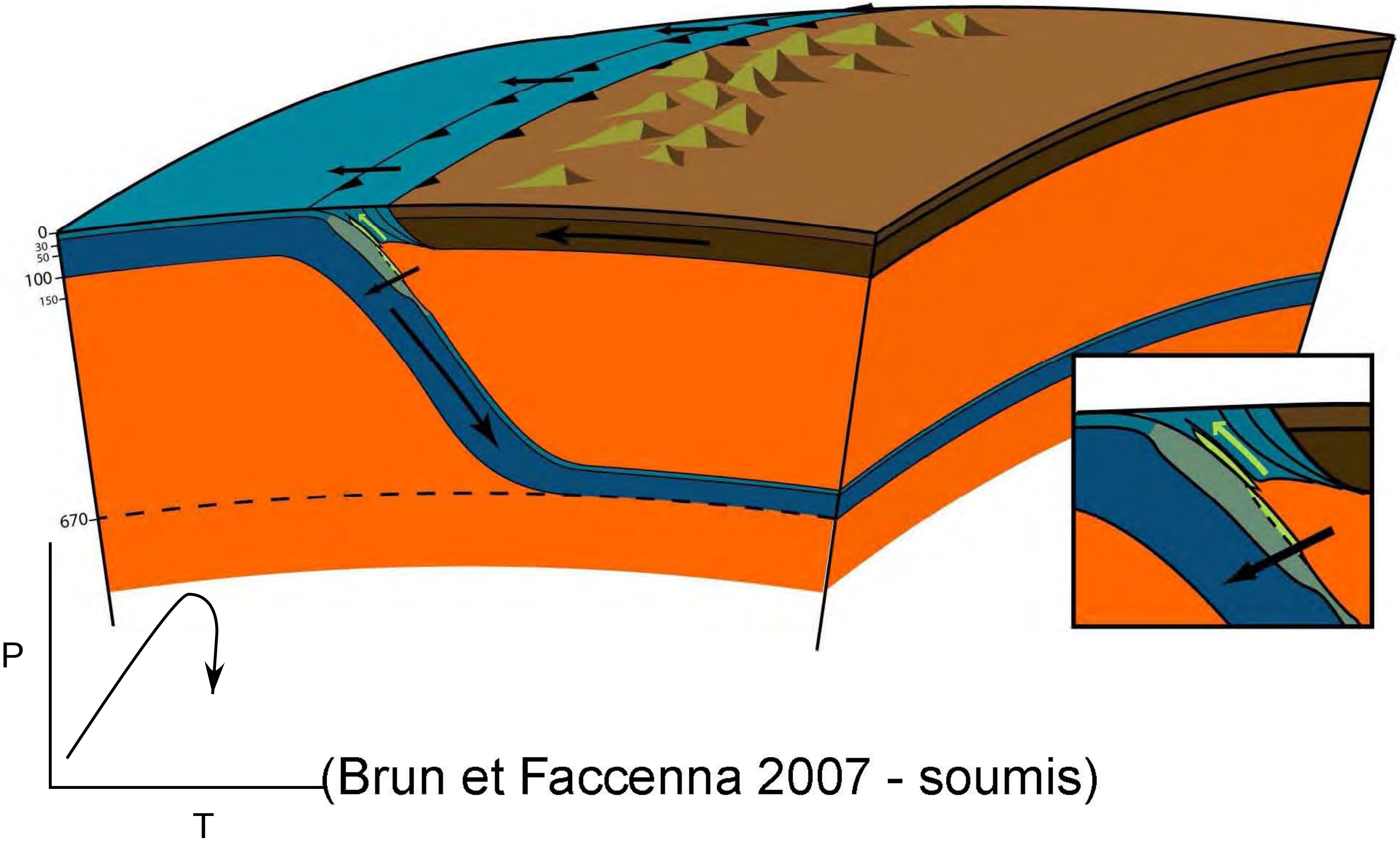



(Brun et Faccenna 2007 - soumis)

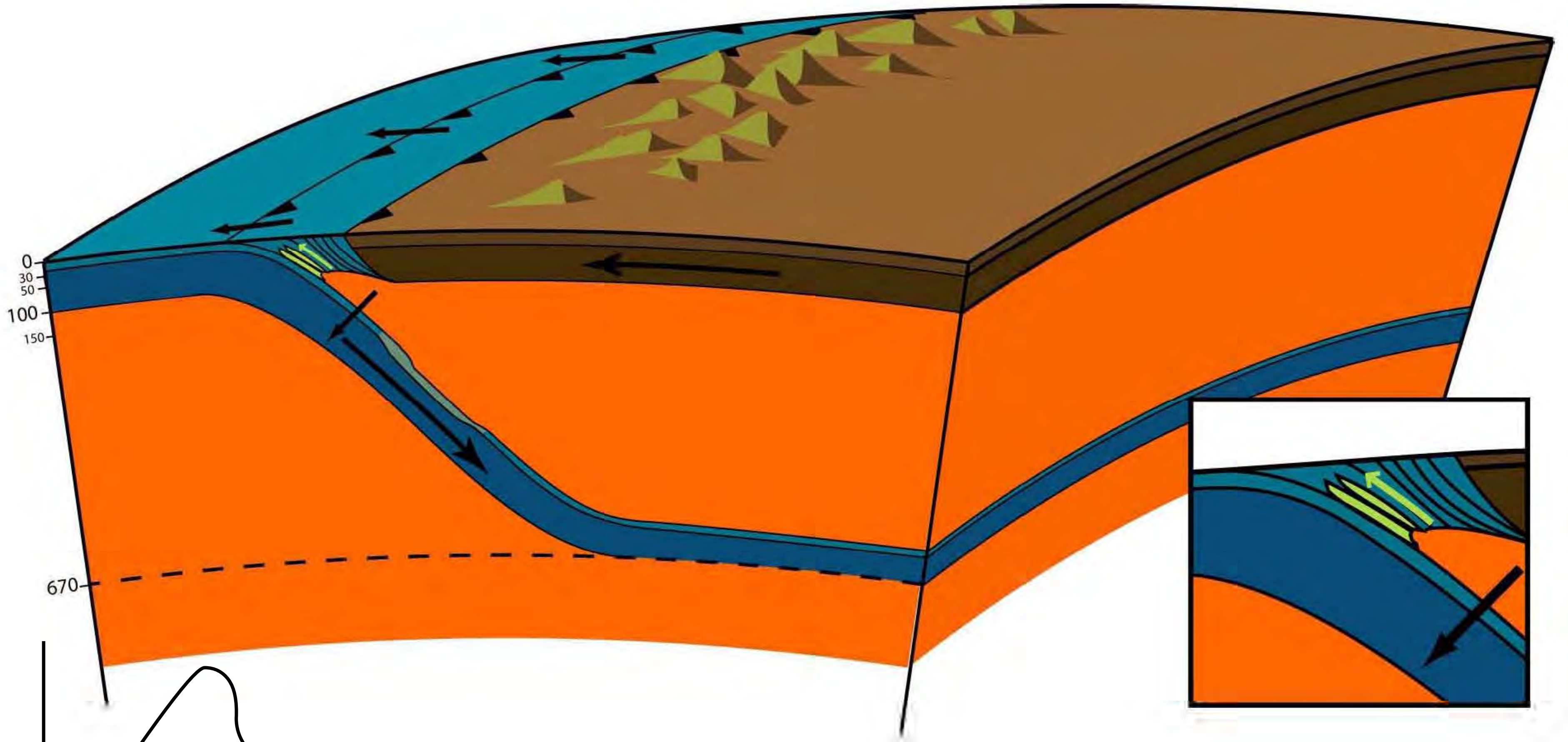


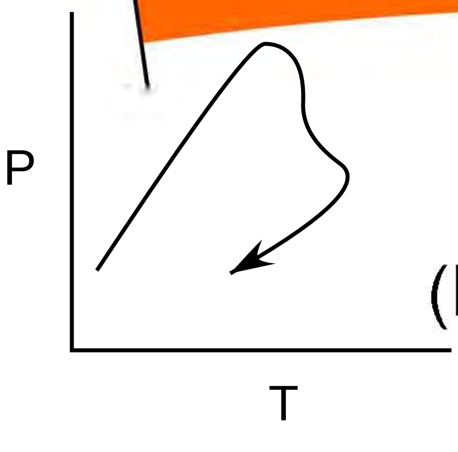




(Brun et Faccenna 2007 - soumis)

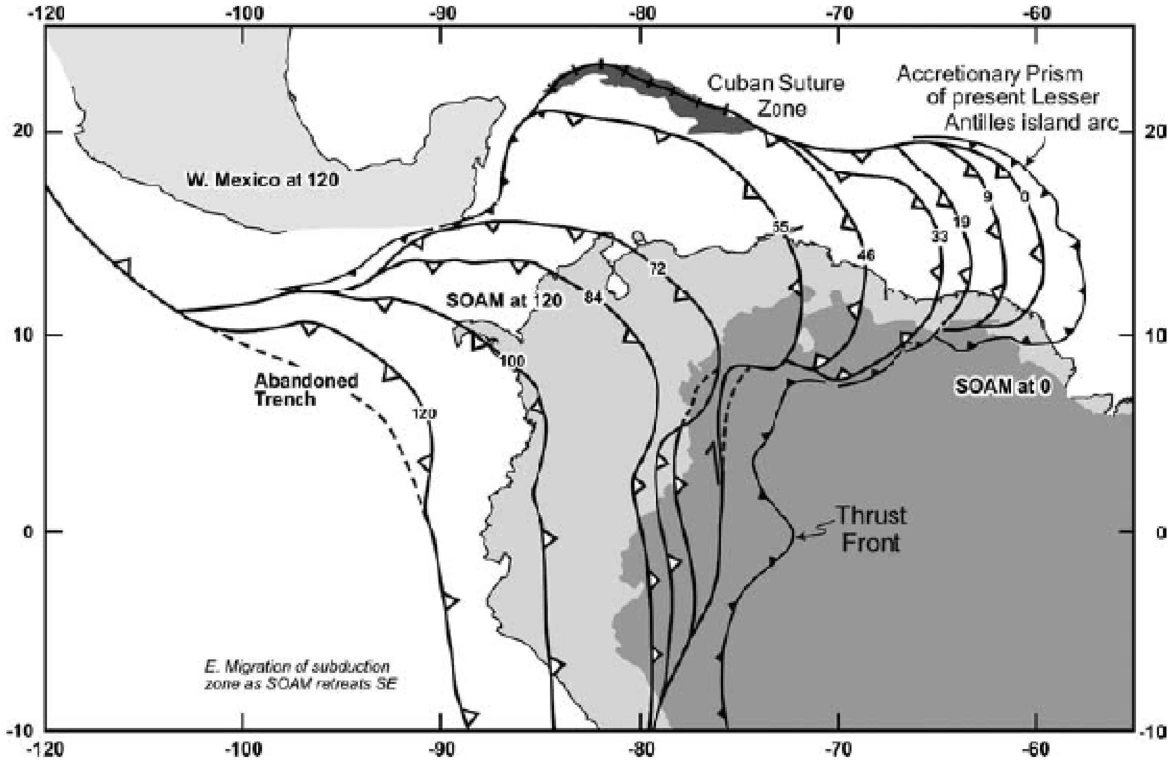



(Brun et Faccenna 2007 - soumis)

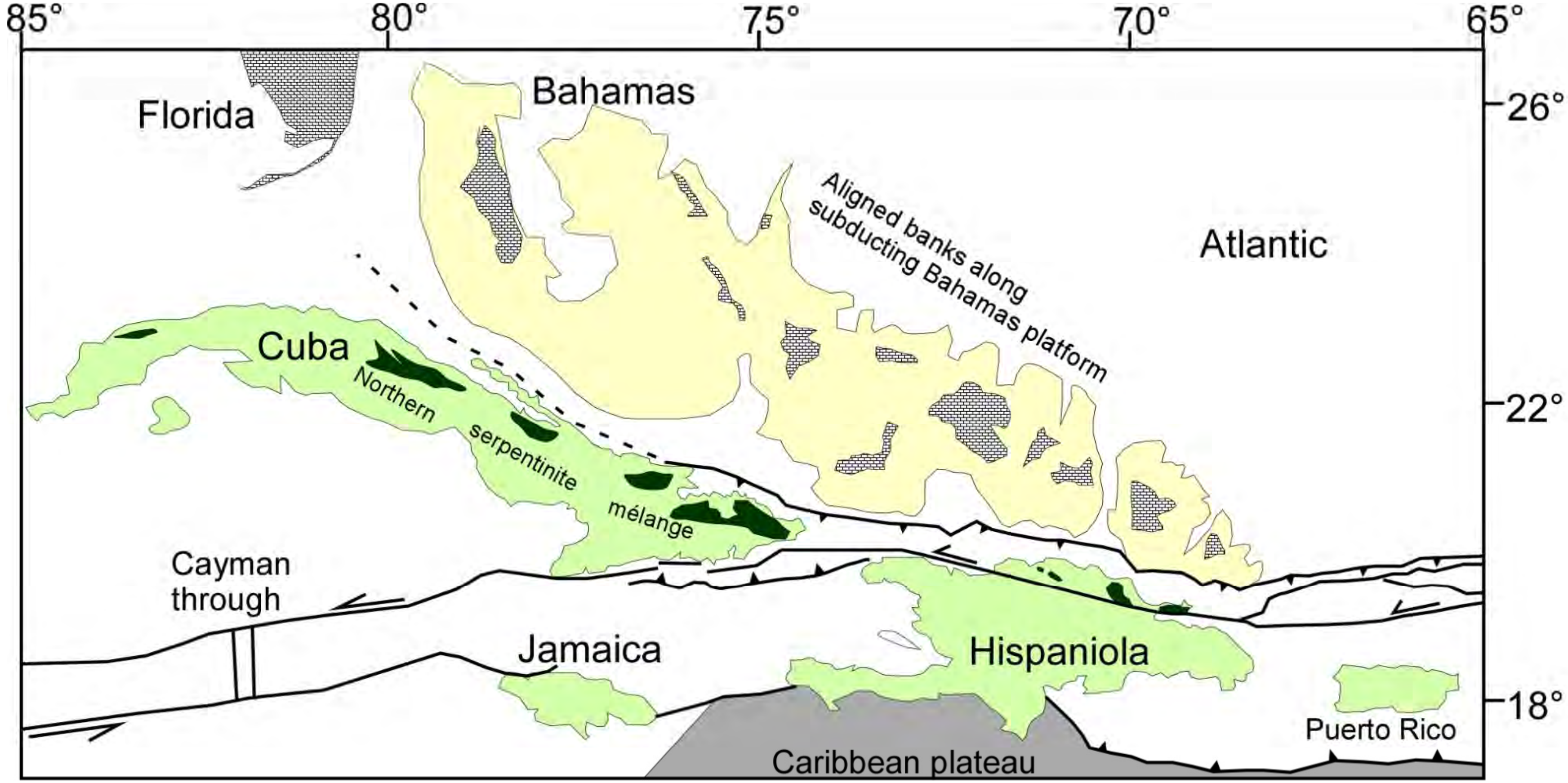


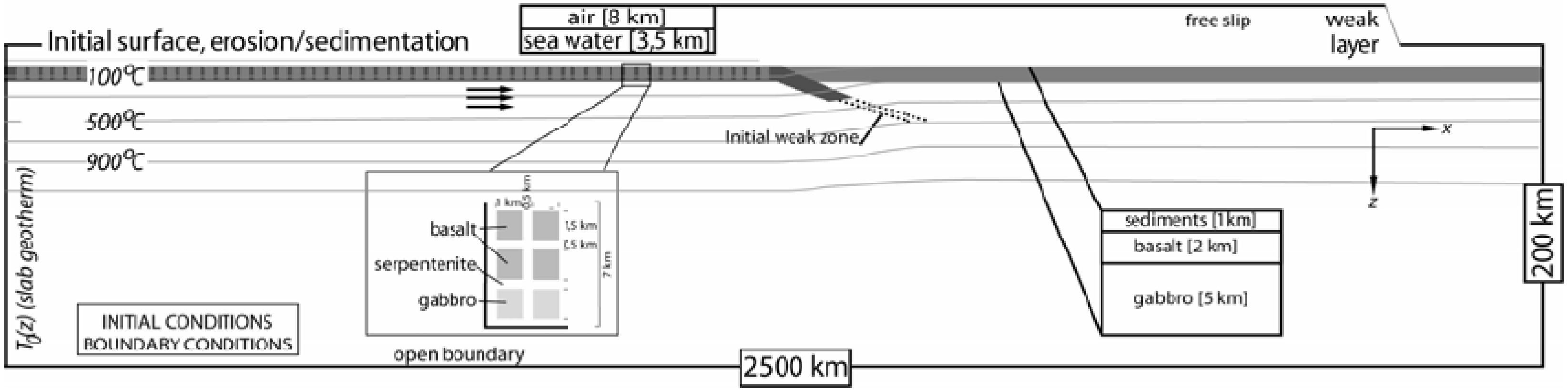

(Brun et Faccenna 2007 - soumis)

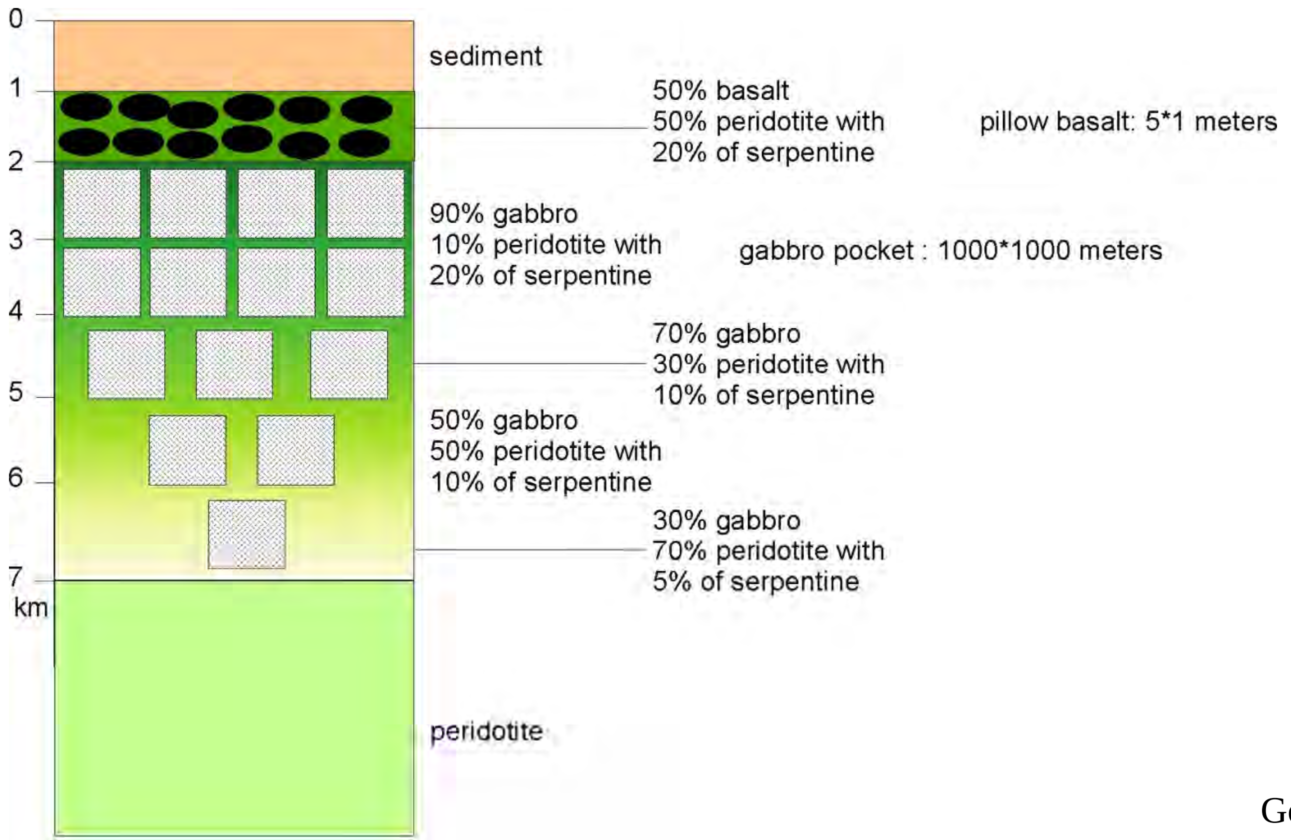



Pindell et al., 2005

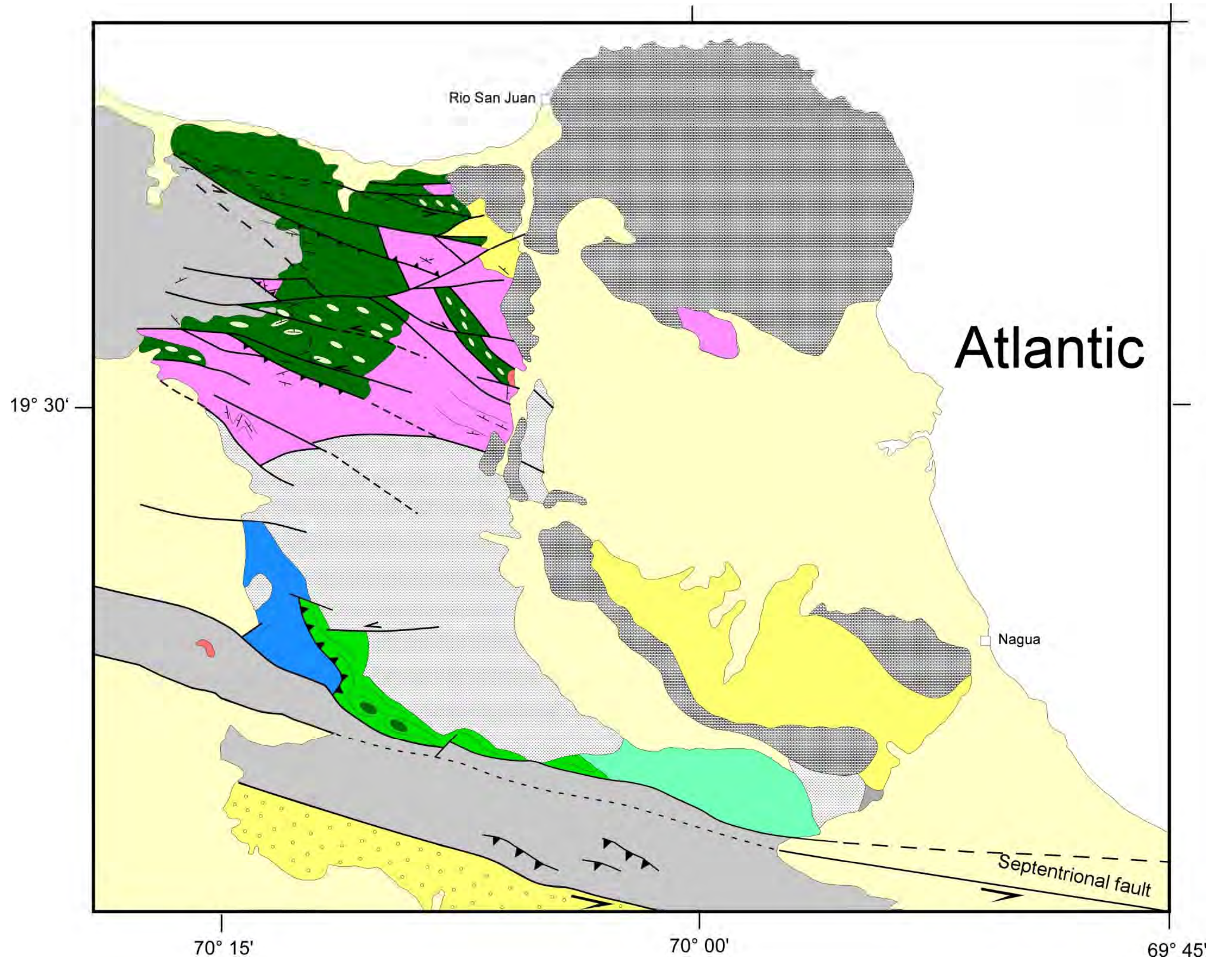



*Guillot et al., in prep.*

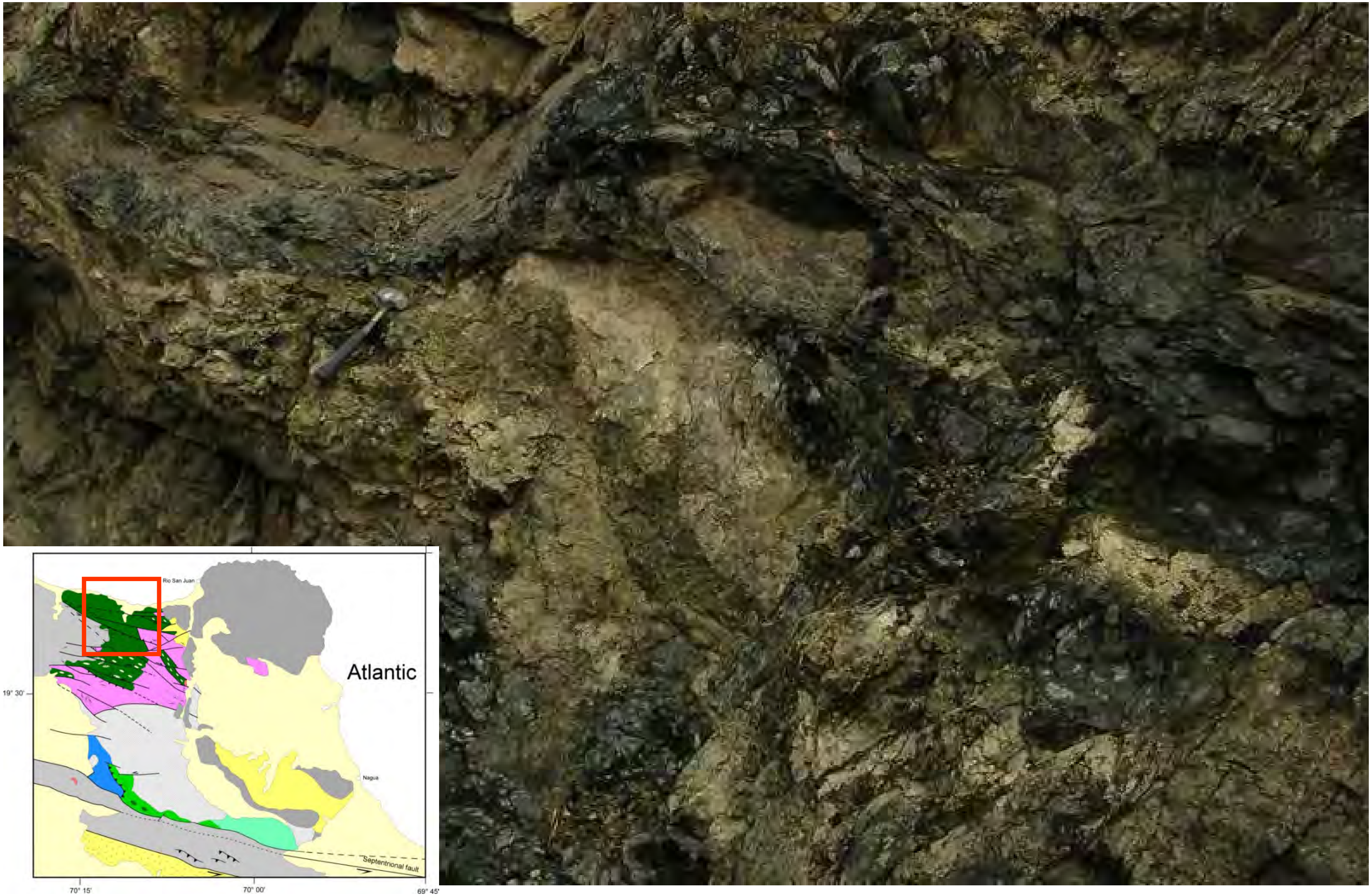


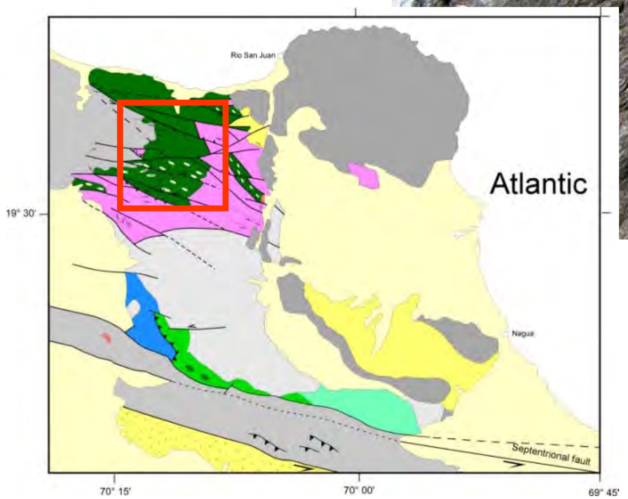

Gorczyk et al, 2007



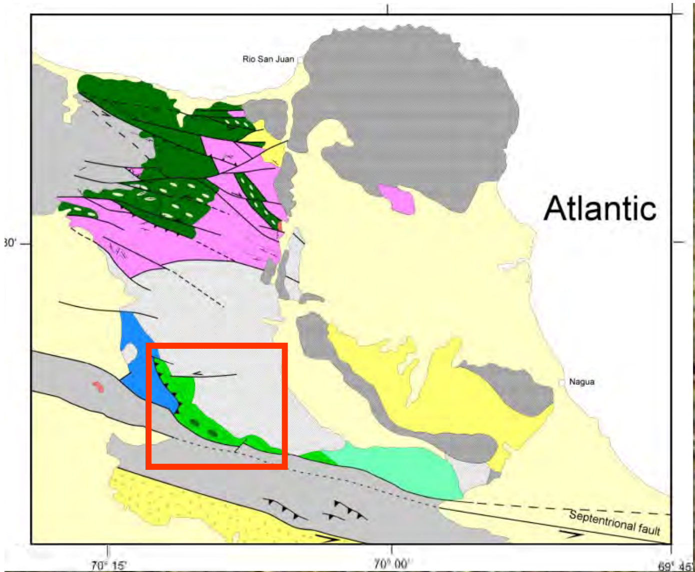
Rio San Juan
Atlantic
19° 30'
Nagua
Septentrional fault
70° 15'
70° 00'
69° 45'



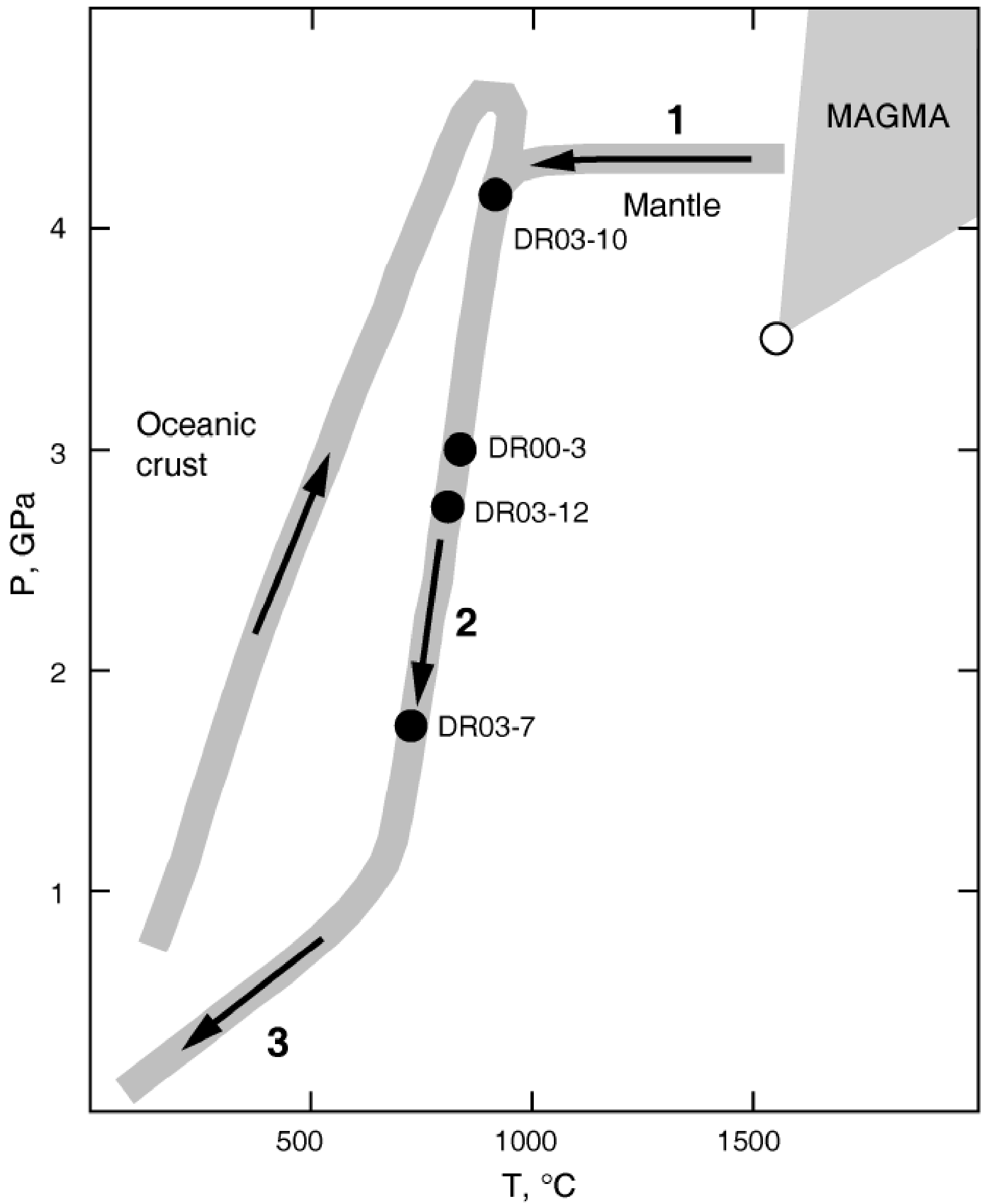

Avant arc externe : des sills de gabbros dans une matrice de serpentine




**Avant arc interne: Schistes bleus dans les serpentines**


Rio San Juan
Atlantic
Nagua
Septentrional fault
70° 15'
70° 00'

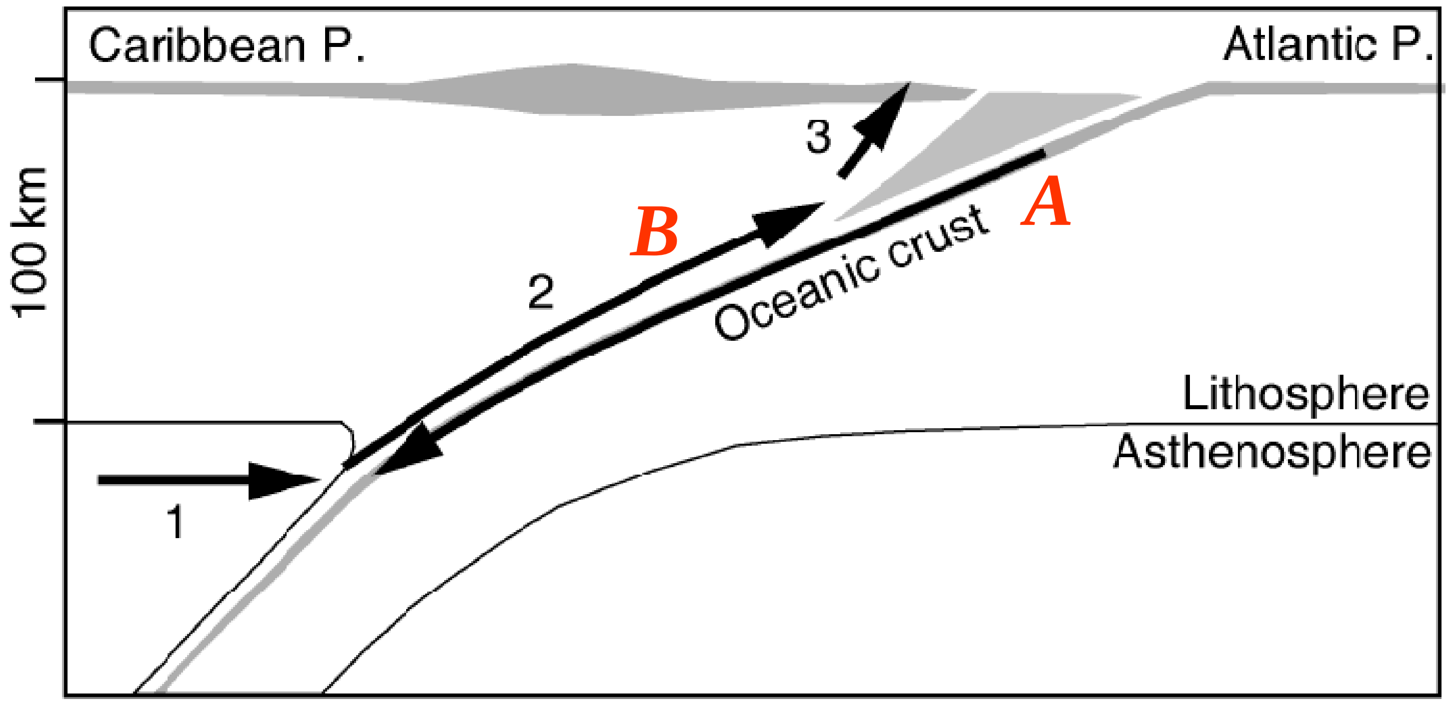

Garnet bearing peridotites as hectometric lenses in retrogressed eclogites




**Eclogites :**
**Subduction du pro-Atlantique**

**Péridotites à grenat:**
**Coin mantellique ?**

*Abott et al., 2006*

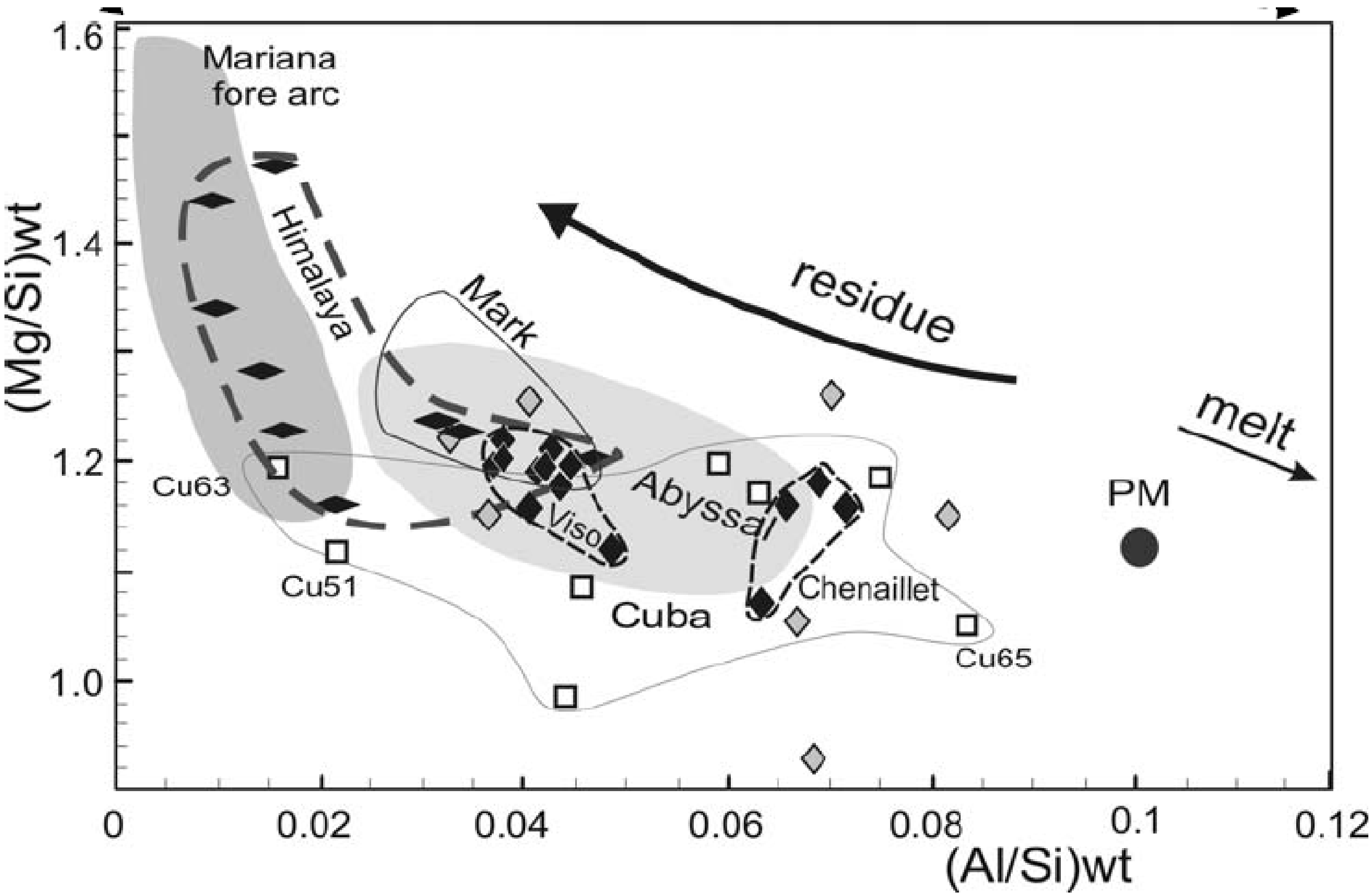



**D'où viennent les serpentinites**

**A: péridotites océaniques ayant subi l hydrothermalisme à la ride ?**

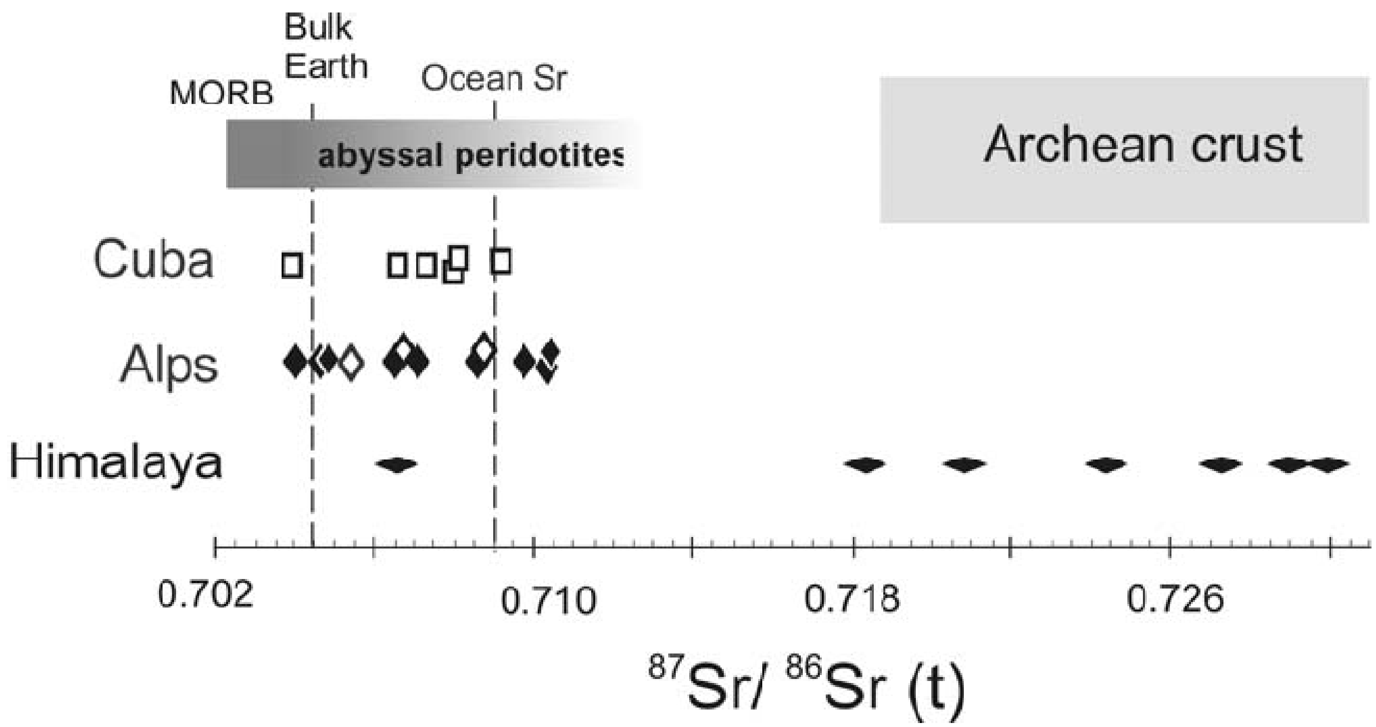
**or**

**B: hydratation du coin mantellique par les fluides relachées par la plaque subduite ?**




*Hattori et Guillot, 2007*

# Origine des fluides



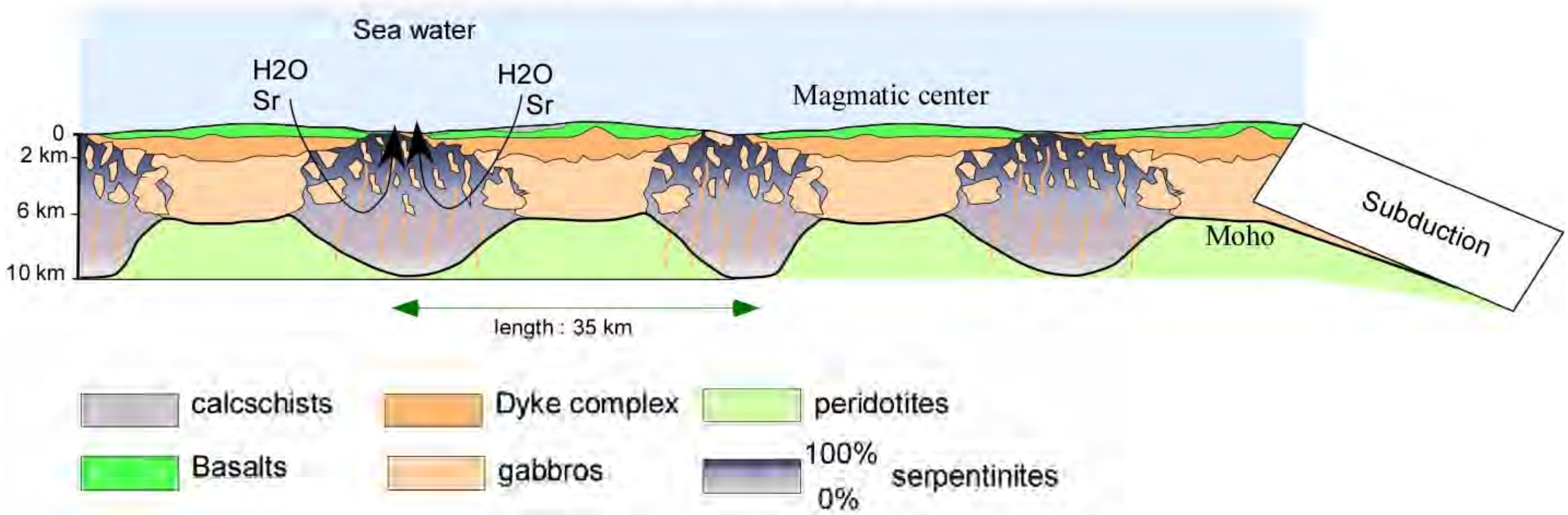

Cuba et Alpes : eau de mer

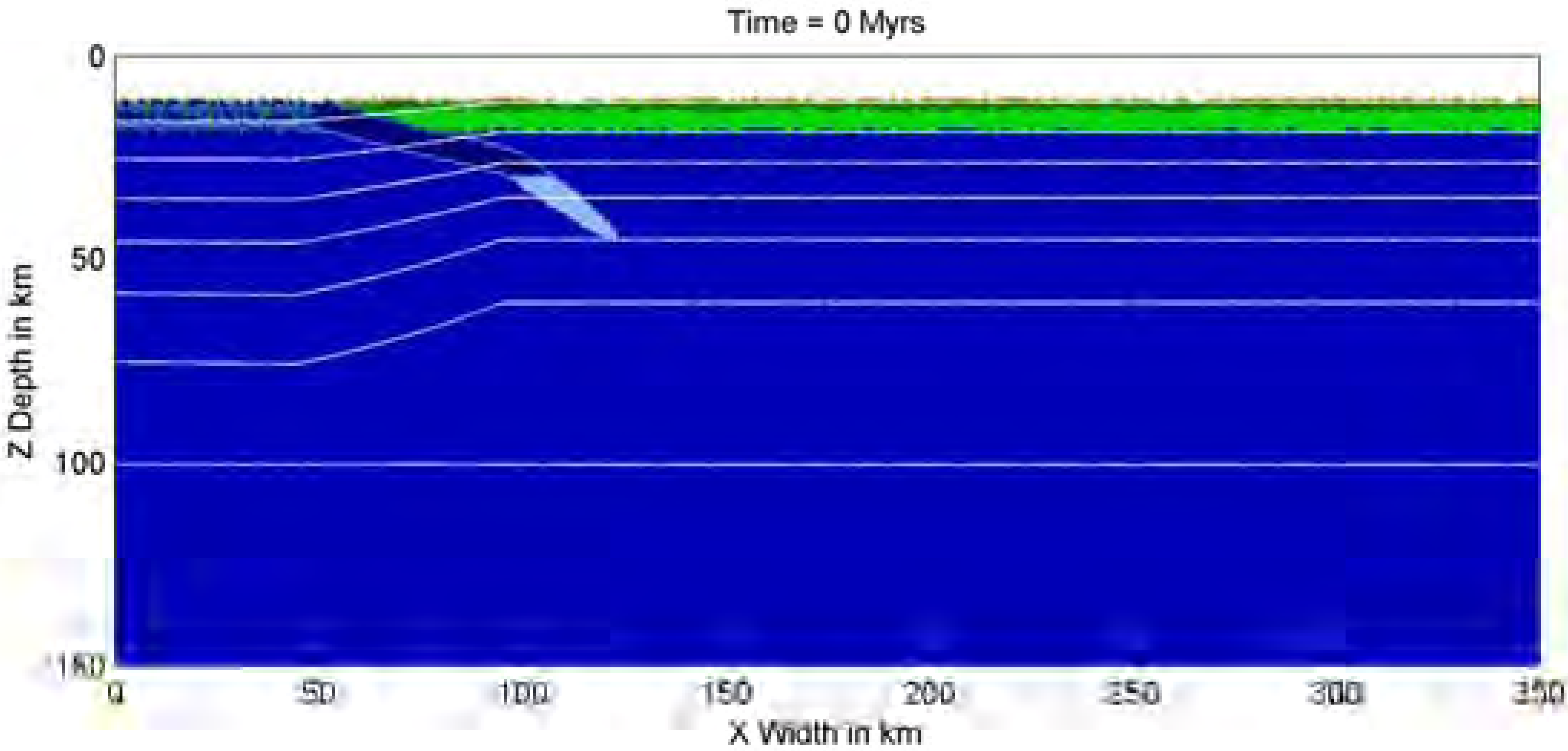
Himalaya: déshydratation des sédiments terrigènes
et/ou de la plaque continentale Indienne

Guillot et al., 2001; Hattori et Guillot, submited

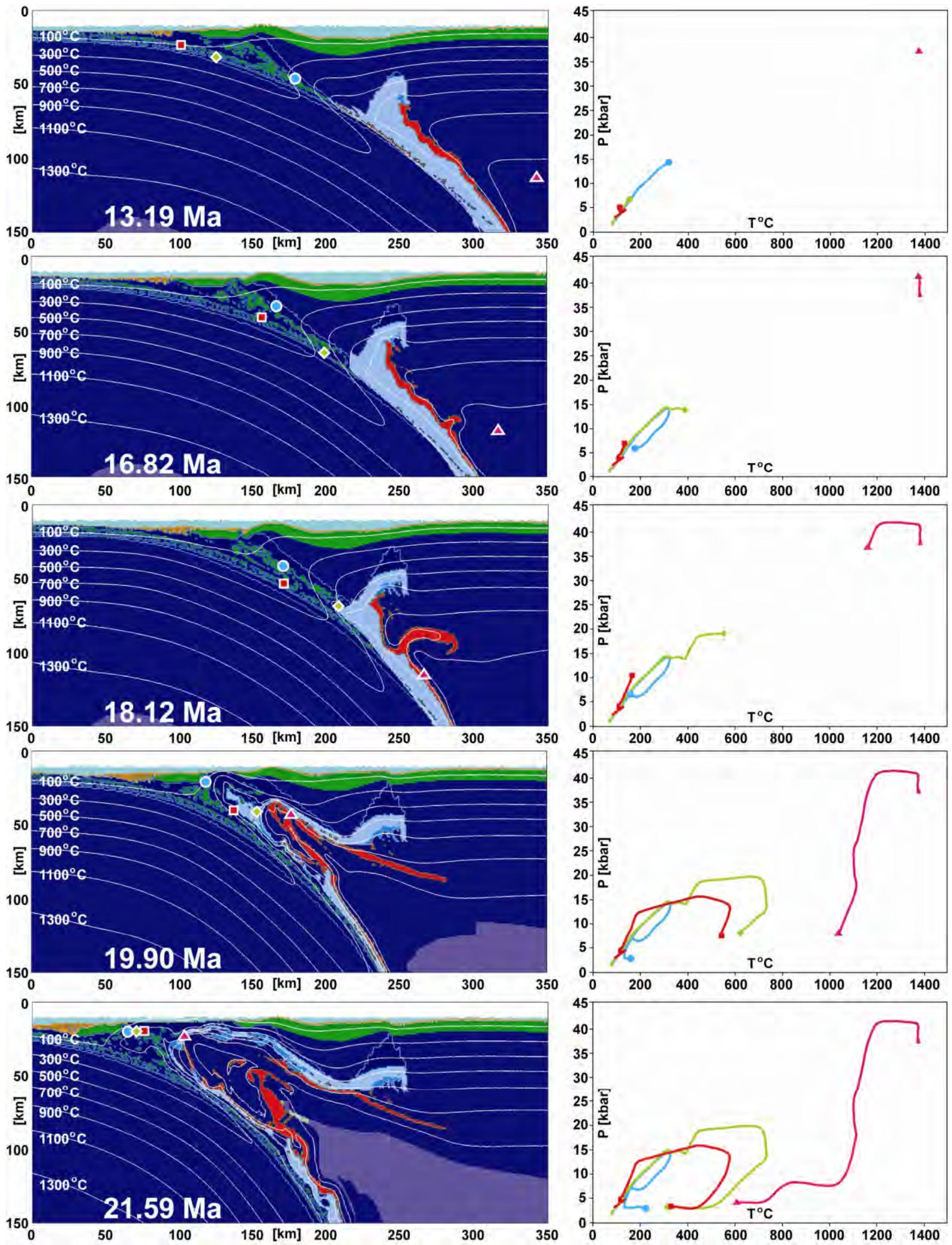
Carribean and Alpine cases
slow-spreading ridge with discontinuous magmatic activity
=> serpentinites at the sea-floor with strong hydrothermalism

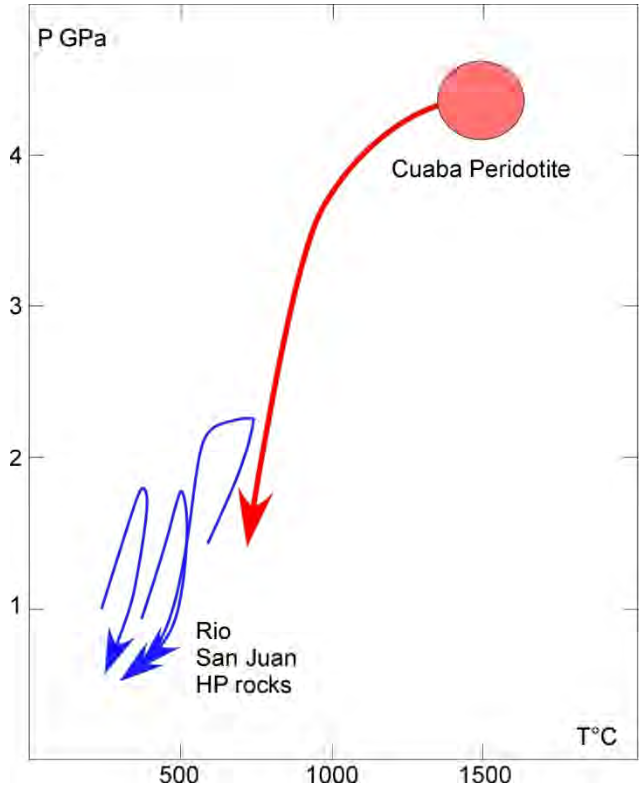
then subduction of oceanic serpentinites





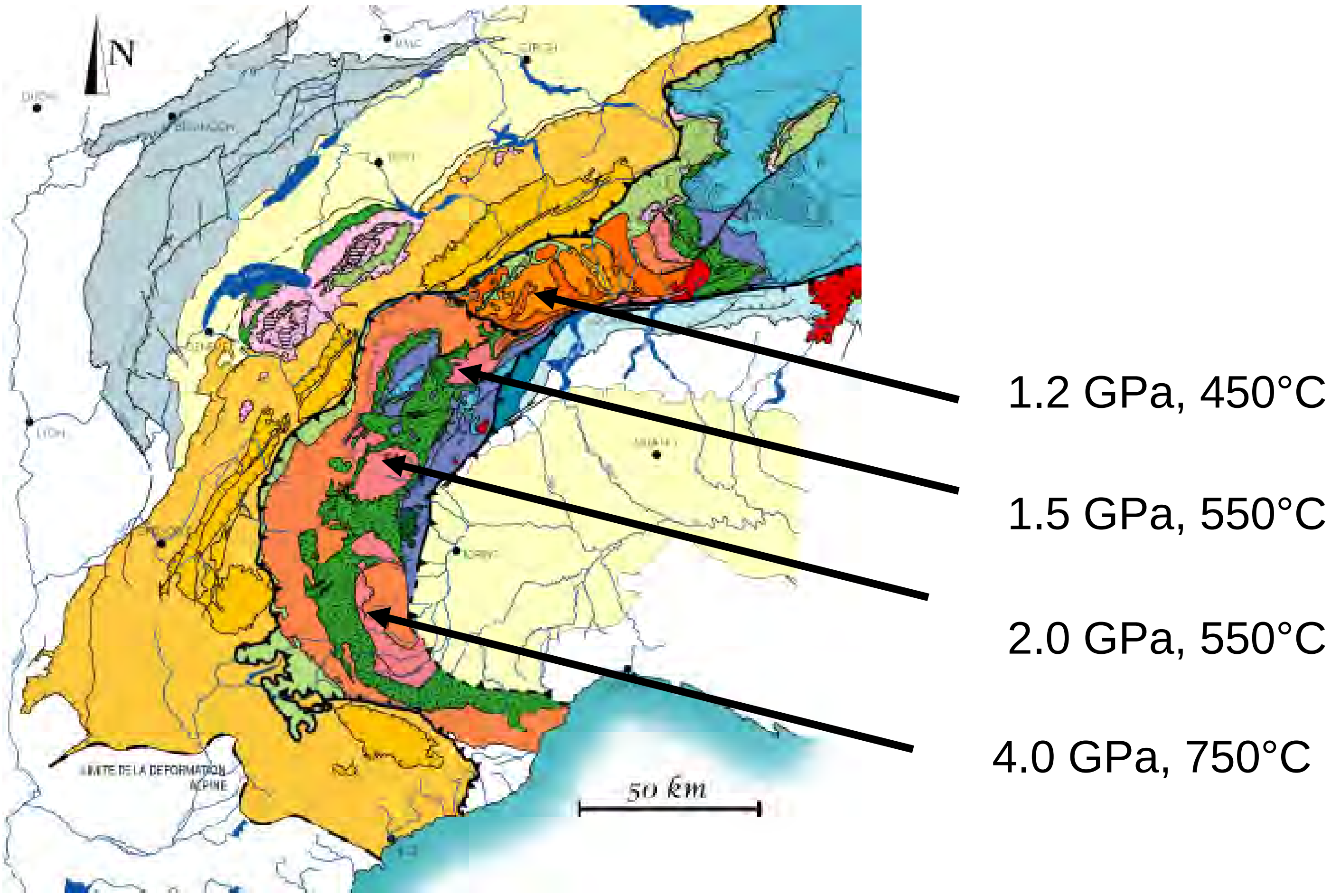

*Gorczyk et al, 2007.*



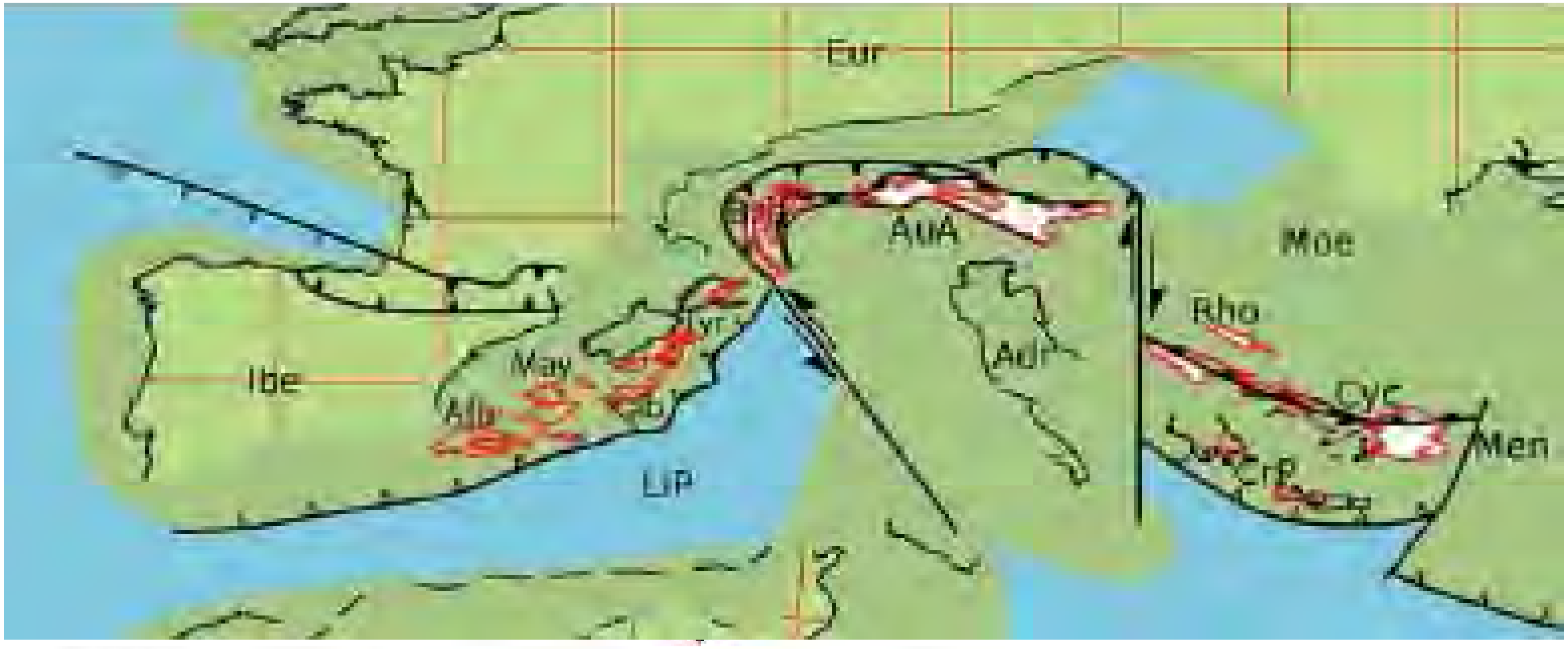



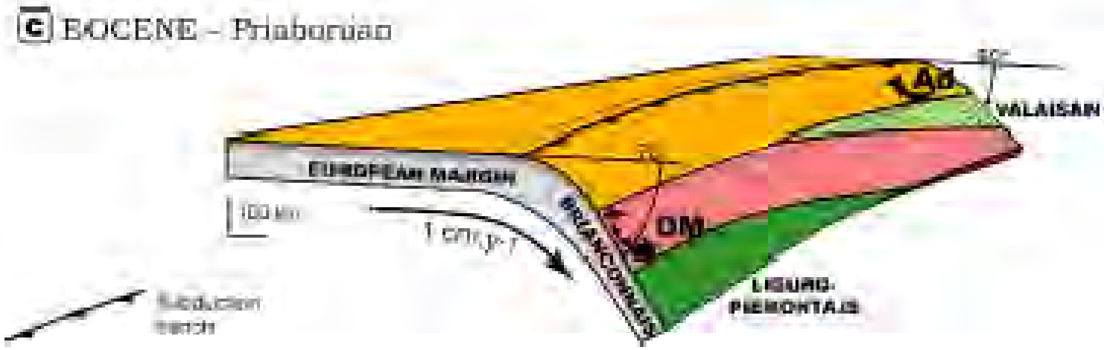

after Abbott et al., 2006,
Krebs et al. in press

# Why P-T conditions vary laterally ?

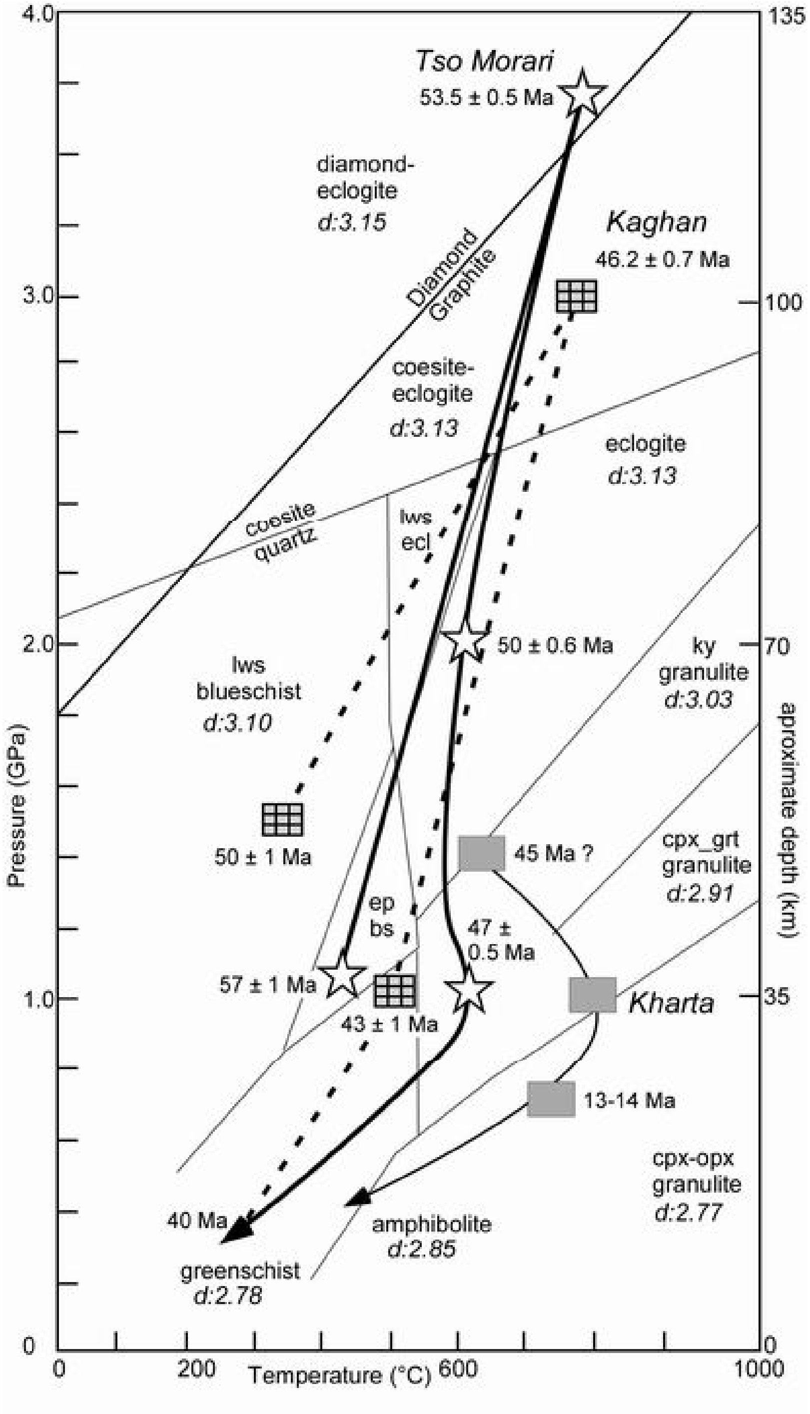


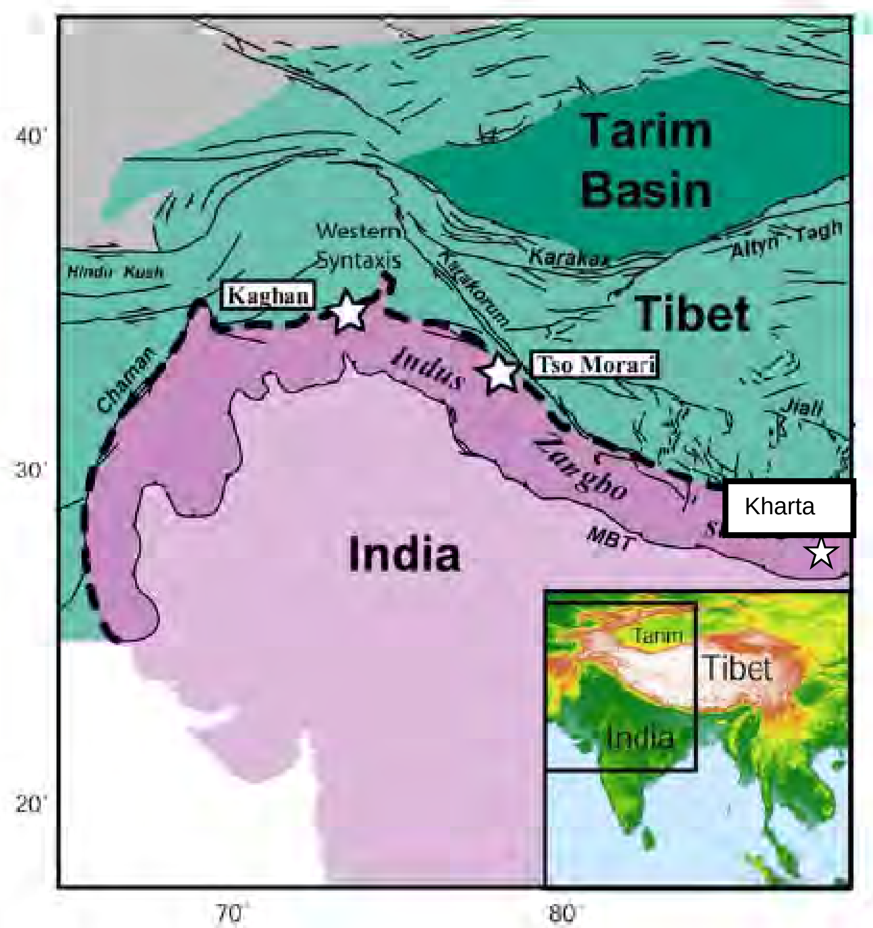

(After Carry, 2007)


Eur
AuA
Moe
Rho
Ibe
Adr
Cyc
LiP
Men

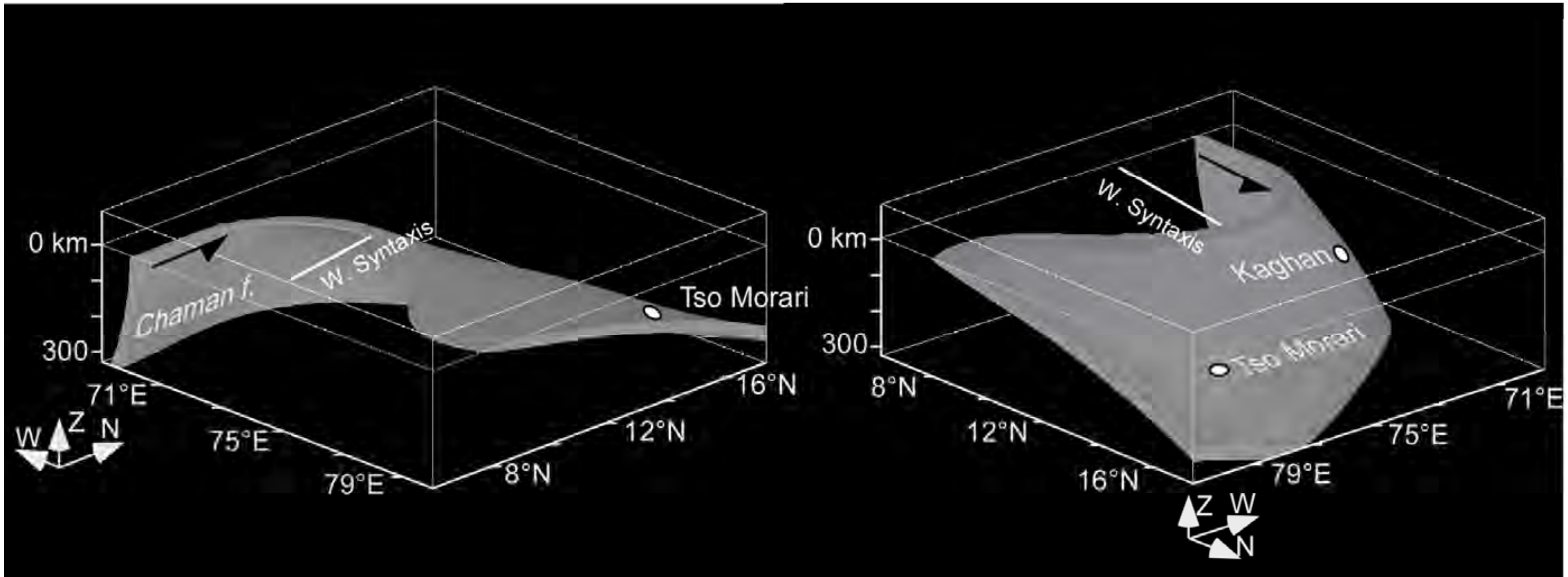

C EOCENE - Priaborian
Ad
VALAISAN
EUROPEAN MARGIN
BRIANCONNAIS
DM
LIGURO-
PIEMONTAIS

Carry, 2007

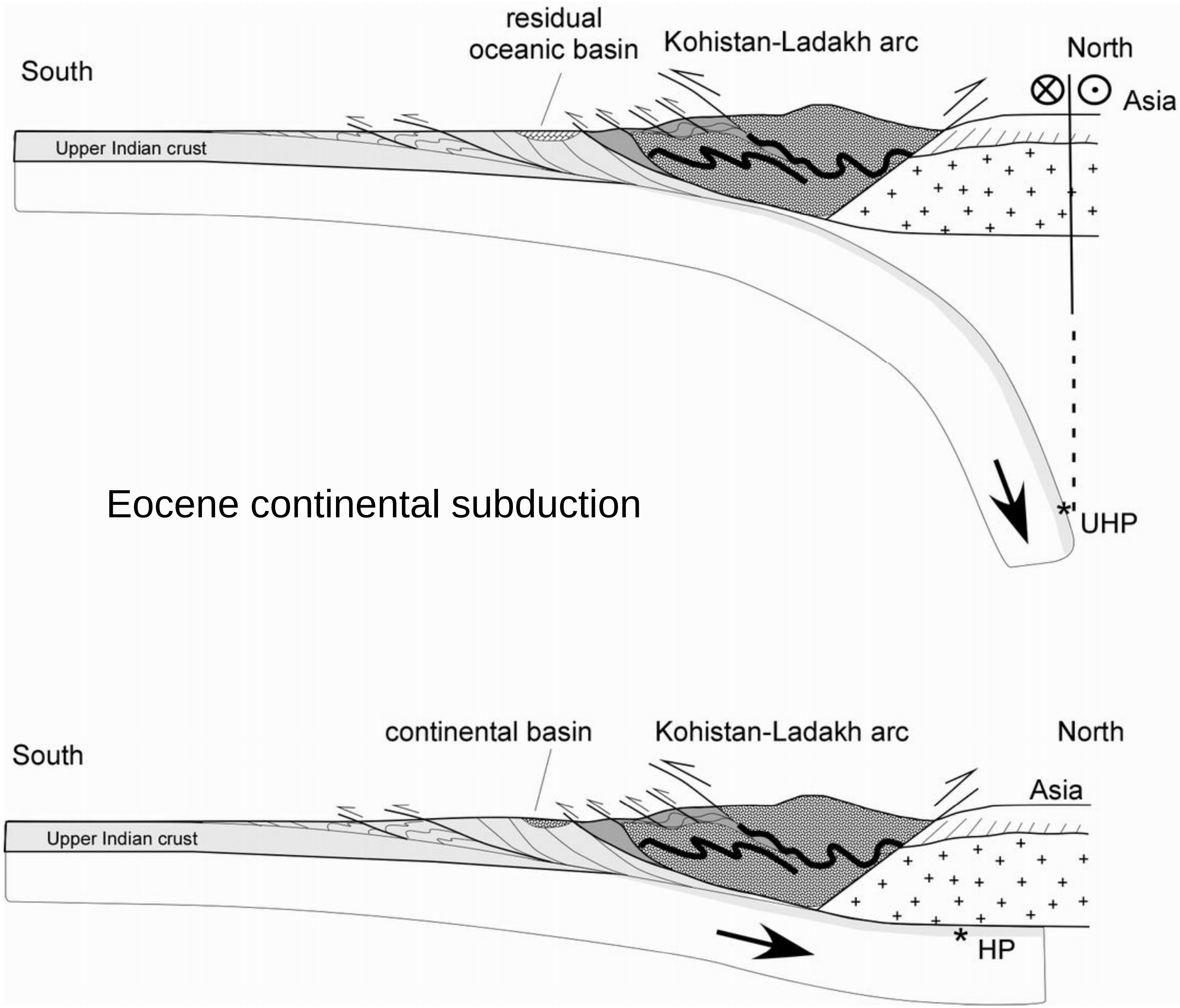


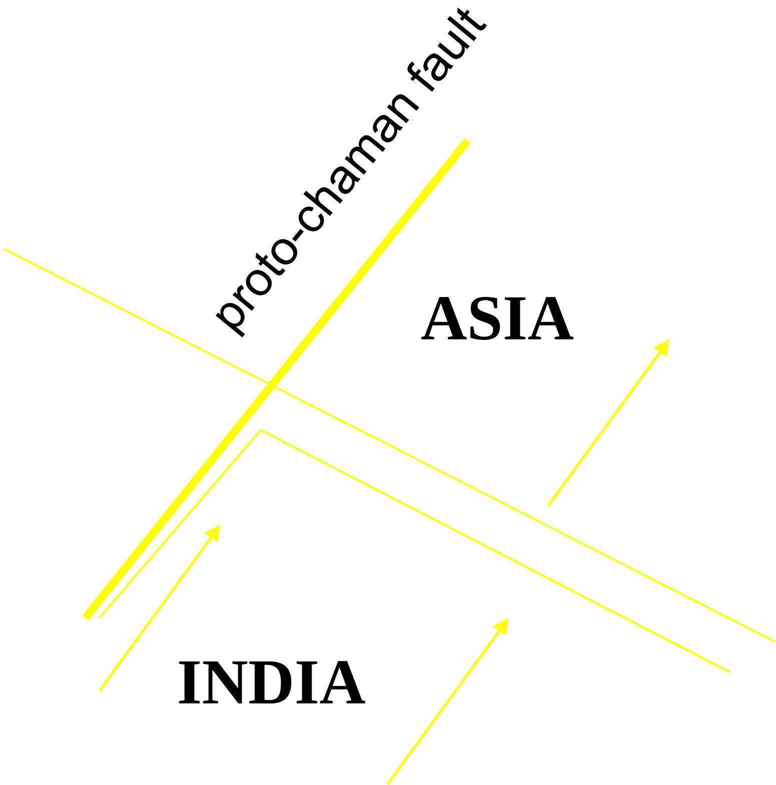

Guillot et al., 2007

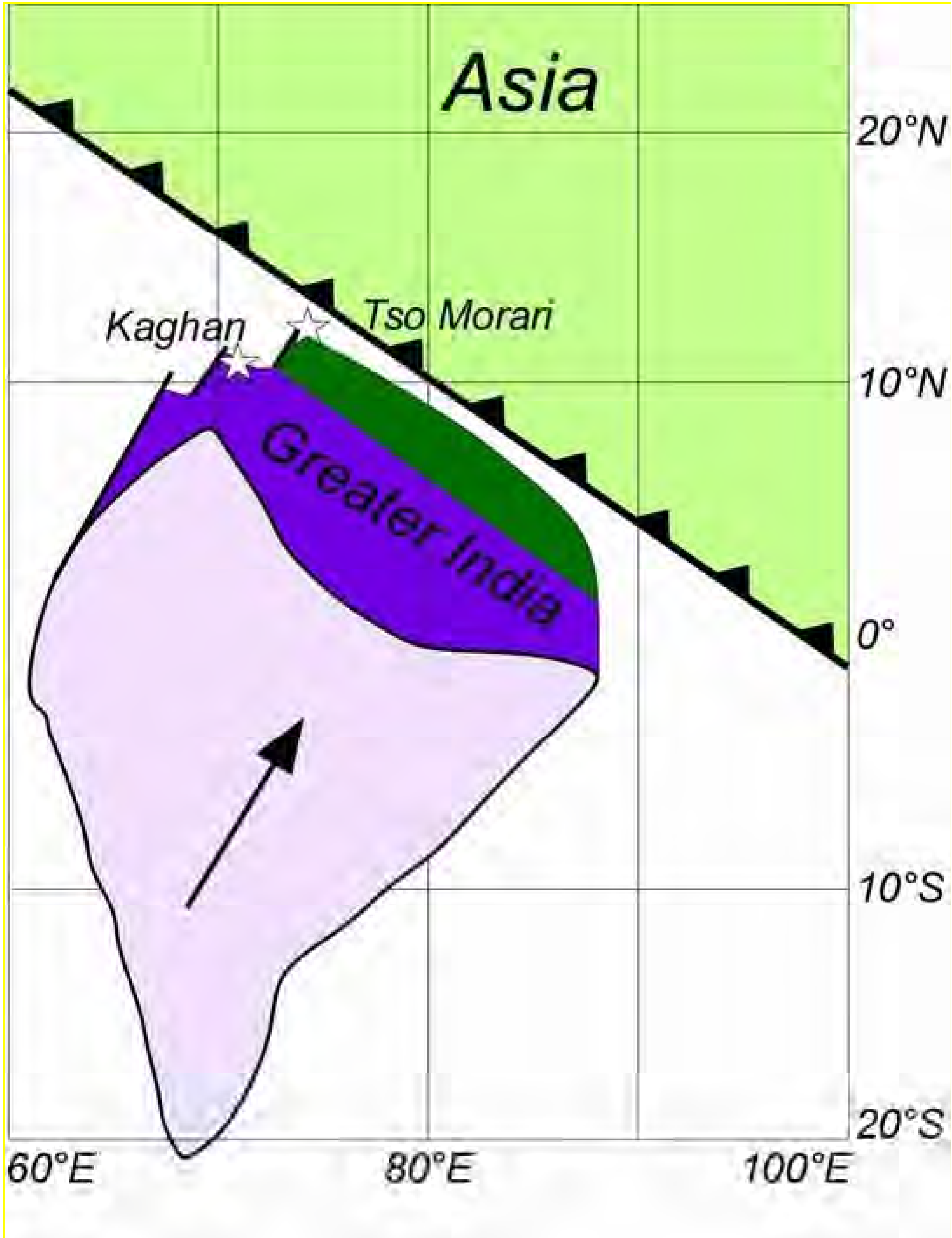



Guillot et al., 2007




Guillot et al., 2007




Guillot et al., 2007

# Conclusions

- Whatever their origin (continental or oceanic), the exhumation of HP to UHP rocks is related to subduction processes.

- Exhumation of solid rocks requires the weakening of the subduction channel by the occurrence of hydrated sediments, hydrated peridotites or local melting.

- The driving forces responsible for exhumation are a combination of buoyancy (dominant for exhumation of continental rocks) and channel flow coupled with underplating (dominant for exhumation of oceanic rocks)

- Exhumation velocities are independent of plate velocities and erosion processes

- Low velocity (< 5 mm/yr) exhumation of HP-LT metasediments is a long-lasting process, which occurs in an accretionary wedge environment;

- low to intermediate velocity (1 < v < 20 mm/yr) exhumation of HP to UHP oceanic rocks is a discontinuous process which occurs within a serpentinized subduction channel

- high velocity exhumation (up to 80 mm/yr) of UHP units is extremely short-lived (<10Myr) and occurs in the mantle wedge, combining both astenospheric return flow and buoyancy forces.

- Slab retreat, almost in modern cases, triggered exhumation of HP to UHP rocks

- Lateral P-T variations are related to variation of the dip of the subduction plane