

Géologie Structurale

Les déformations fragiles



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2025-2026



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Cours 4 : Fractures, diaclases et failles (les bases)

Cours 4 : Fractures, diaclases et failles (les bases)

4a - La notion de fracture

Quelques définitions :

Fracture :

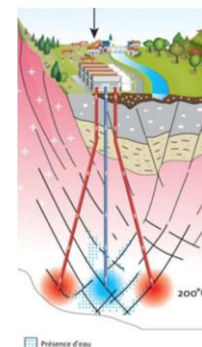
Faïlle :

Diaclase (joint) :

Veine (filon, fente) :

Stylolithe :

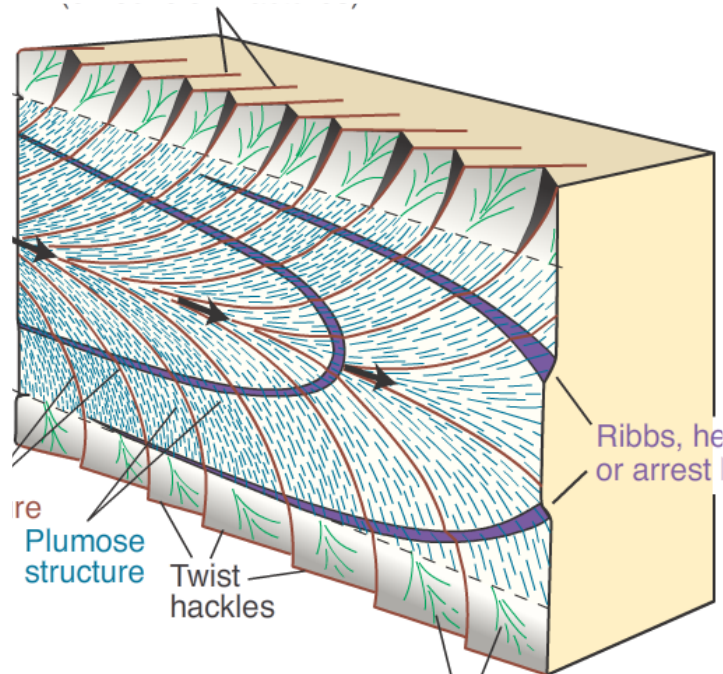
Intérêts et applications potentielles en ingénierie :



Prise de notes :

4b – Diaclases, fentes et veines

I – Anatomie d'une diaclase



(Haakon Fosen)

II – Les grands types de diaclases/joints

Dans les sédiments

Quelques définitions

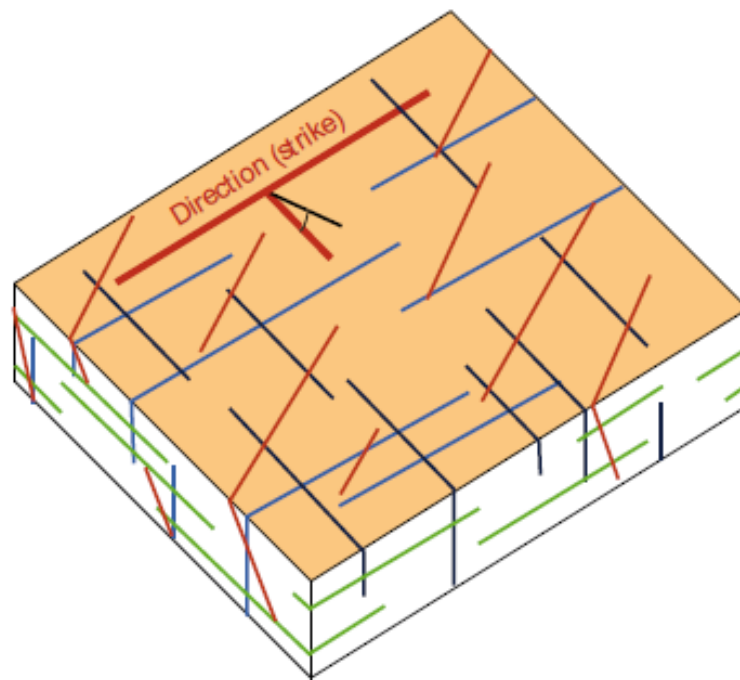
Ensemble de diaclases :

Ensemble de diaclases systématiques :

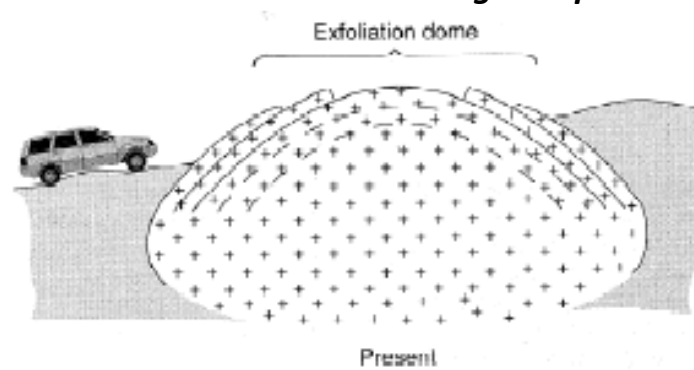
Ensemble de diaclases systématiques :

Prise de notes :

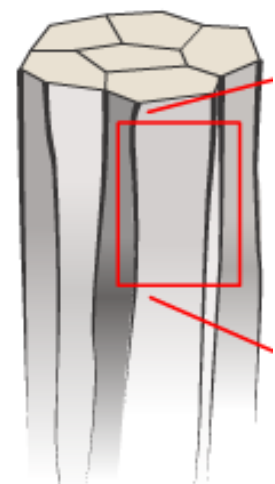
Définition par rapport au litage



Dans les roches magmatiques



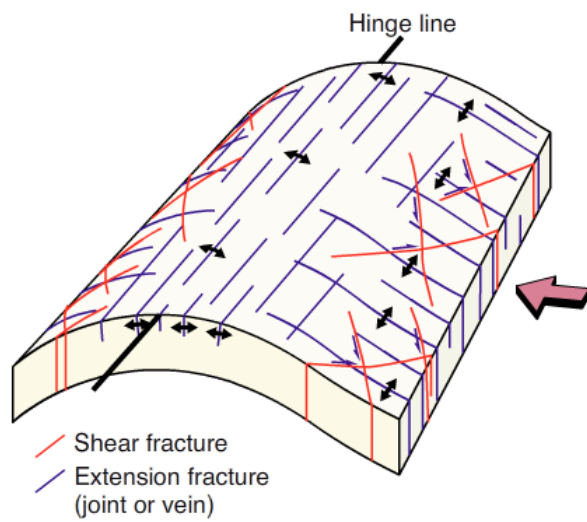
Les joints de colonne :



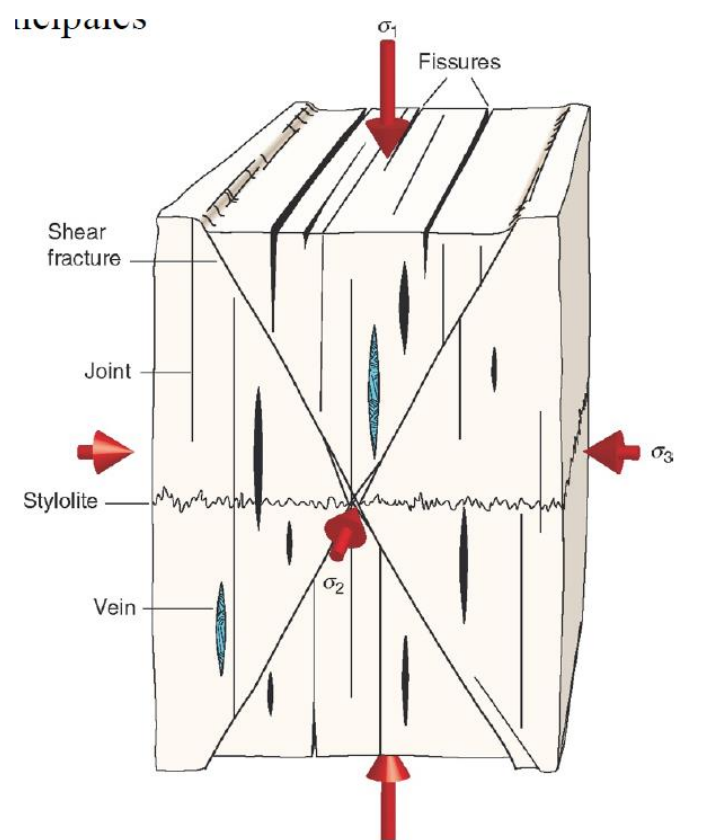
(Haakon Fosen)

Prise de notes :

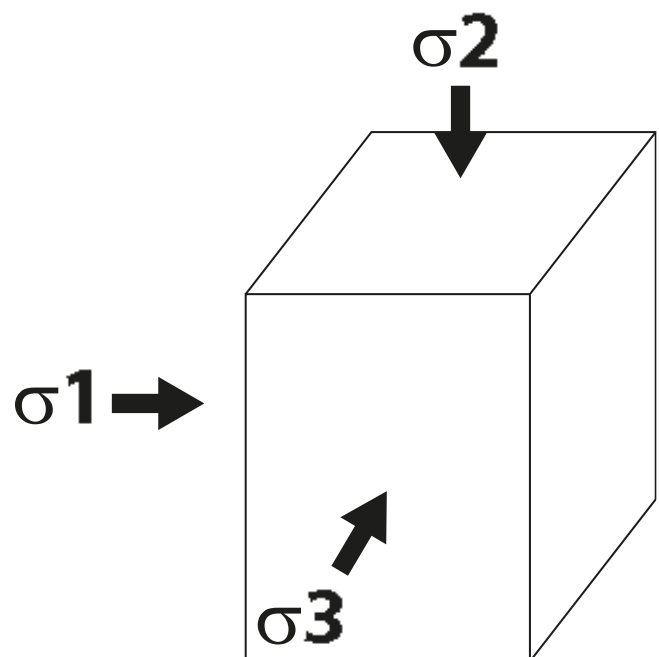
III – Origine et formation des diaclases



(Haakon Fossen)

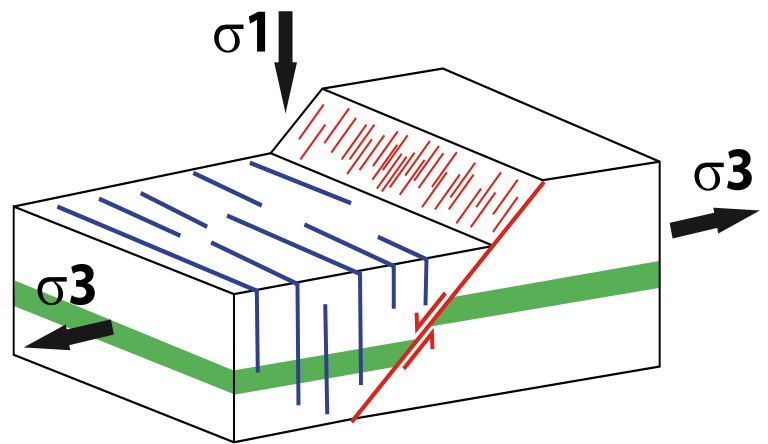


Exercice : dessiner les fentes de tension avec l'état de contraintes ci-dessous.



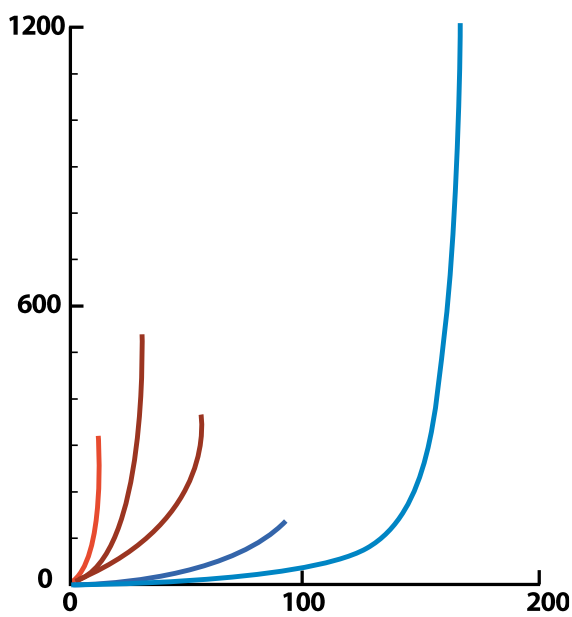
Prise de notes :

Pinnate fracture/joints feather :

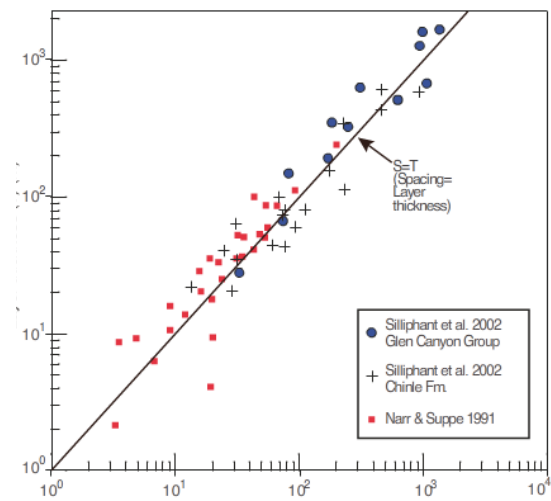


IV – Distribution

Cas des roches sédimentaires



D'après Ladeira et Price (1981)

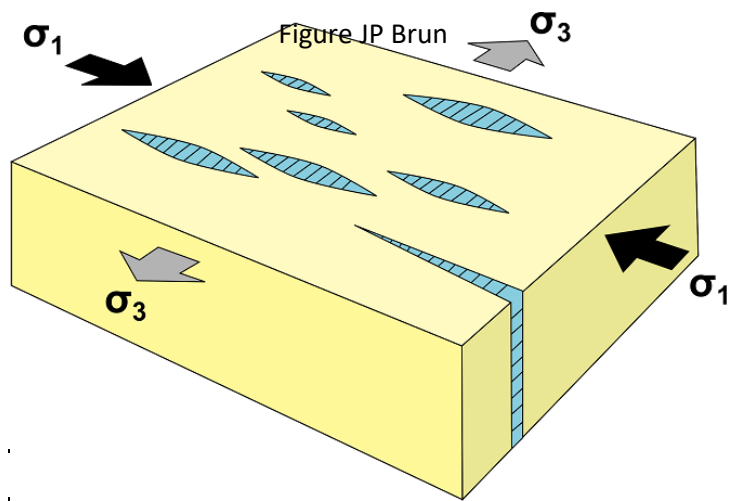


(Haaken Fossen)

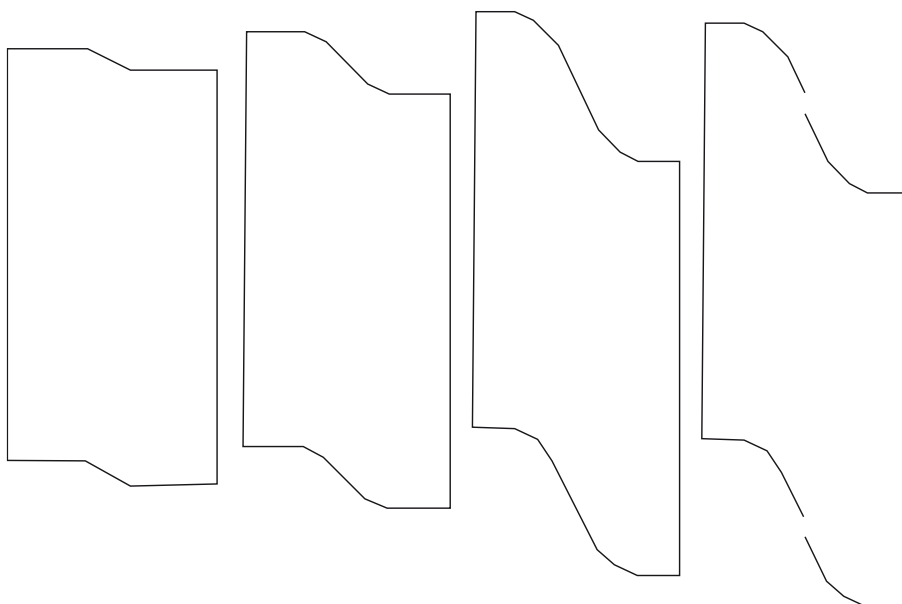
Prise de notes :

V – Fentes et veines

Fente de tension :

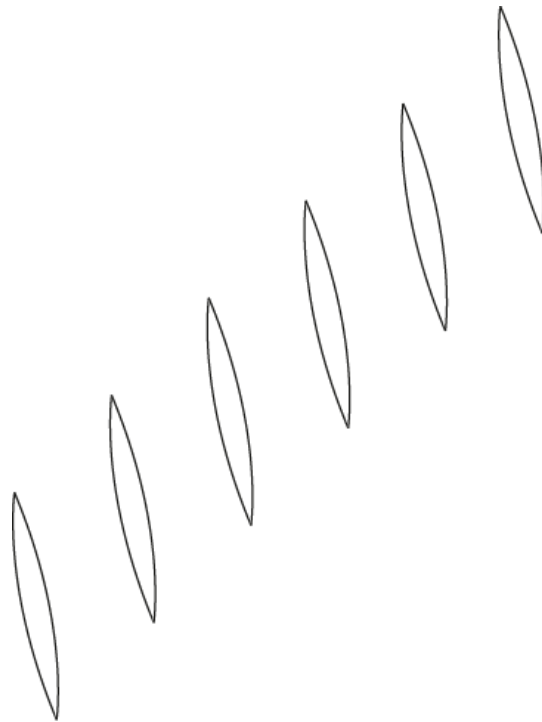


Fentes de tension en échelon :

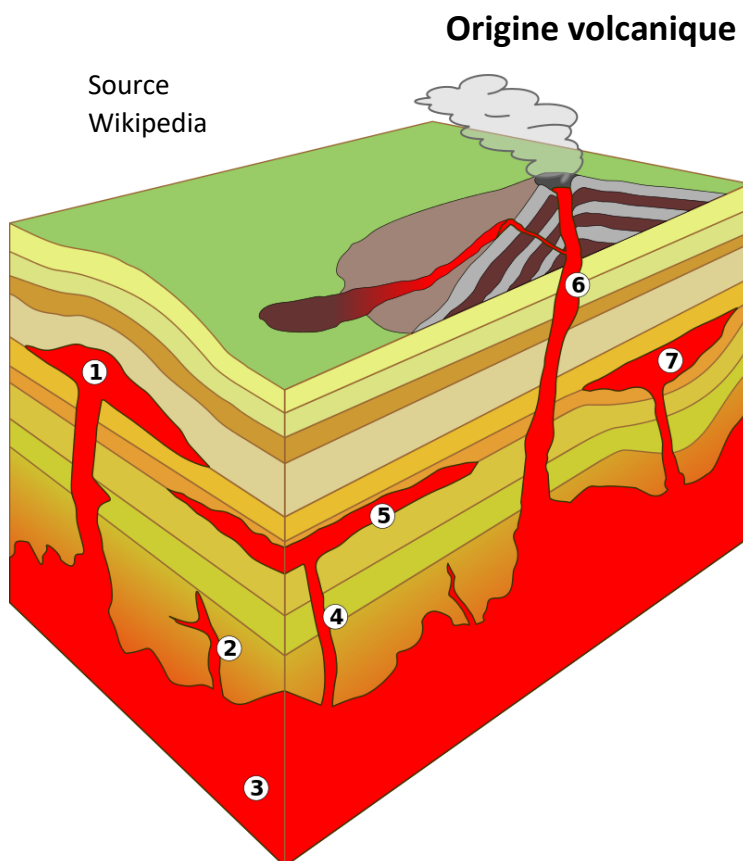


Prise de notes :

Exercice : localiser la zone de cisaillement, donner son sens et indiquer les contraintes.



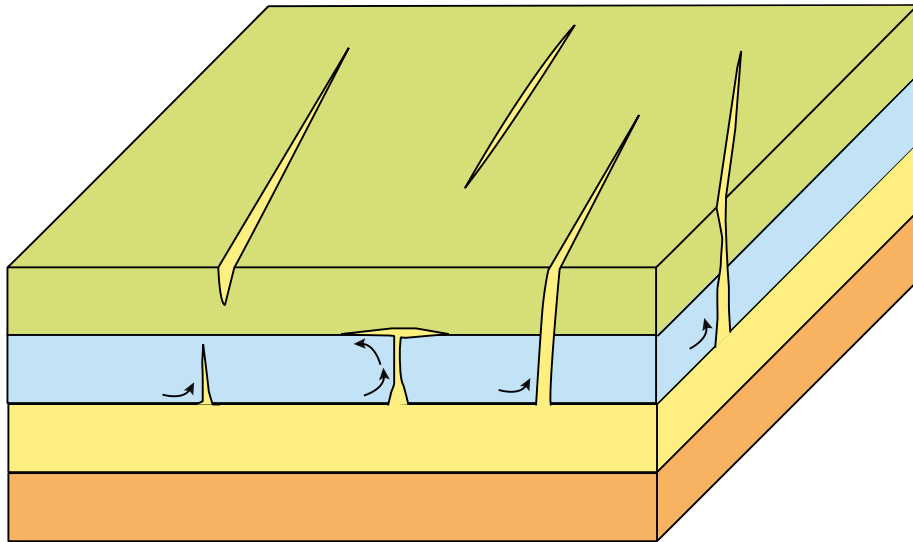
VI – Dykes volcaniques et sédimentaires



Dyke :

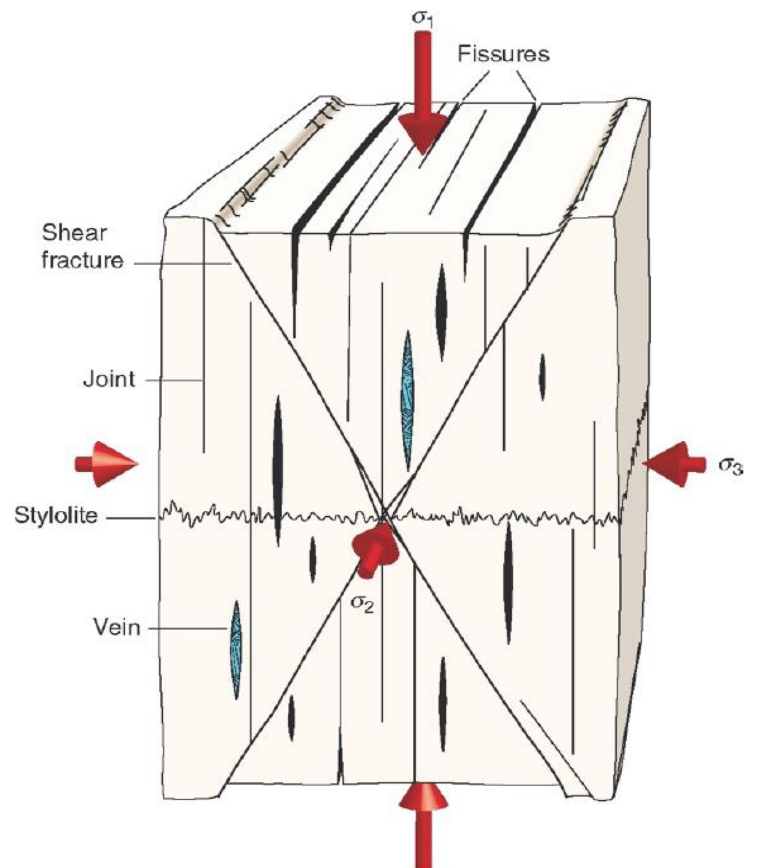
Prise de notes :

Origine sédimentaire

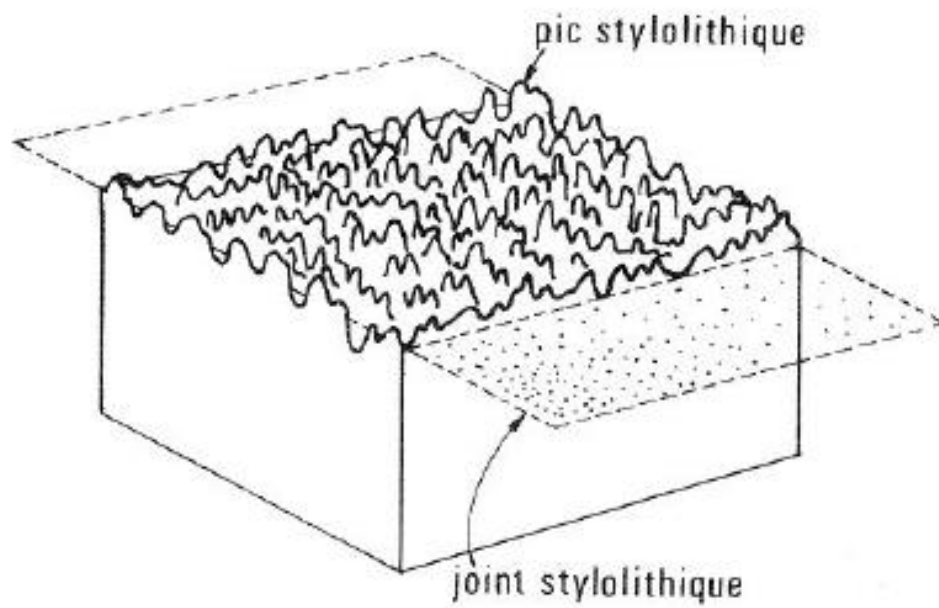


VII – Les stylolithes

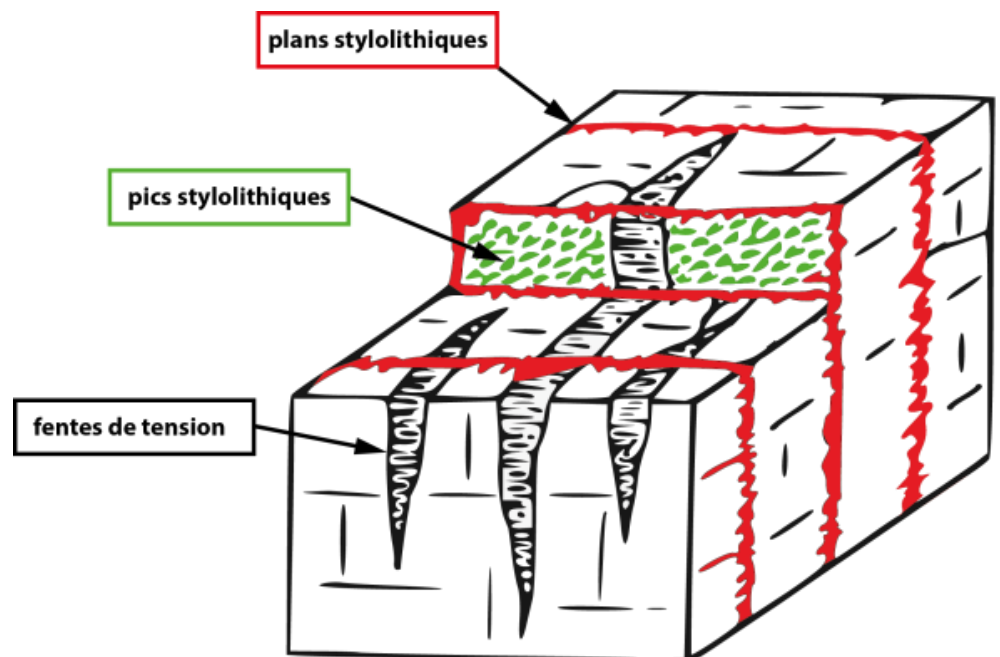
Les stylolithes (ou stylolites) :



Prise de notes :



Exercice : replacer les contraintes principales sur le schéma suivant
 (Source: Olivier Belcourt et David Salze, Mines d'Alès)

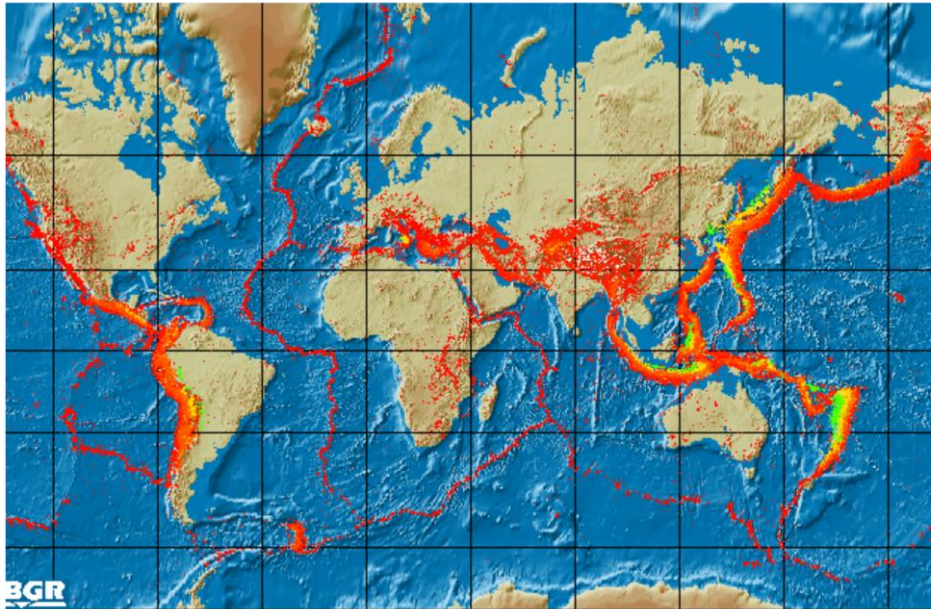


Prise de notes :

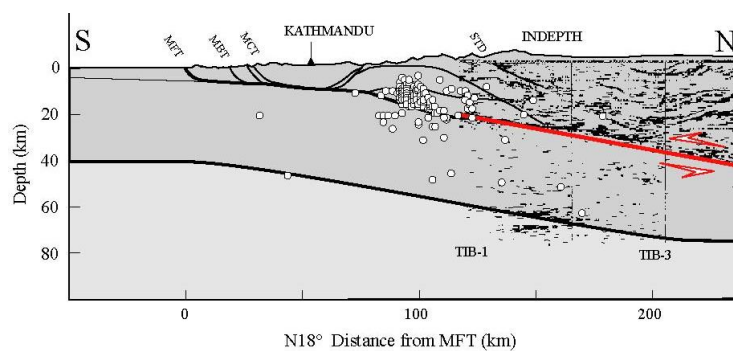
4a – Les failles, les bases

I – La notion de faille : rappel du début de cours

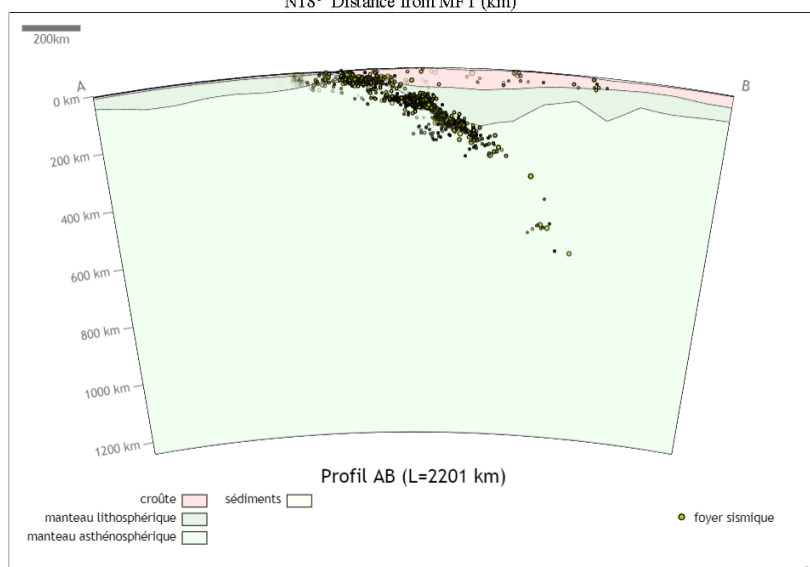
II – Localisation des failles



Source : USGS/BGR...



Avouac et al. (2003)

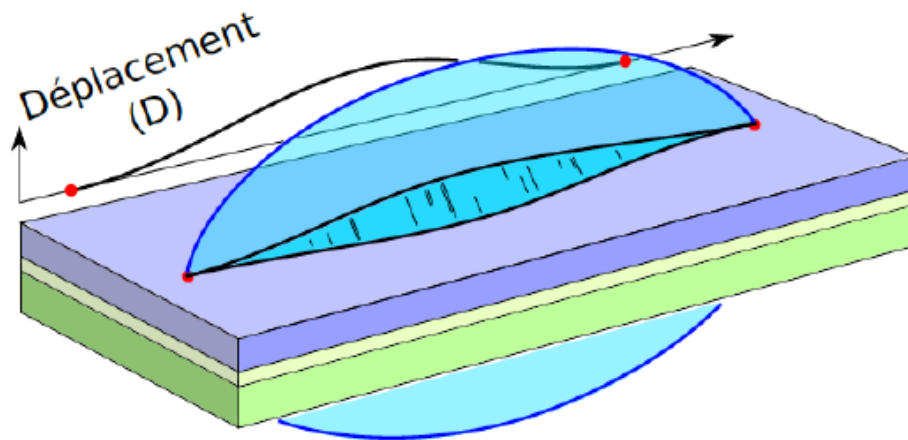


Tectoglobe 3D

Prise de notes :

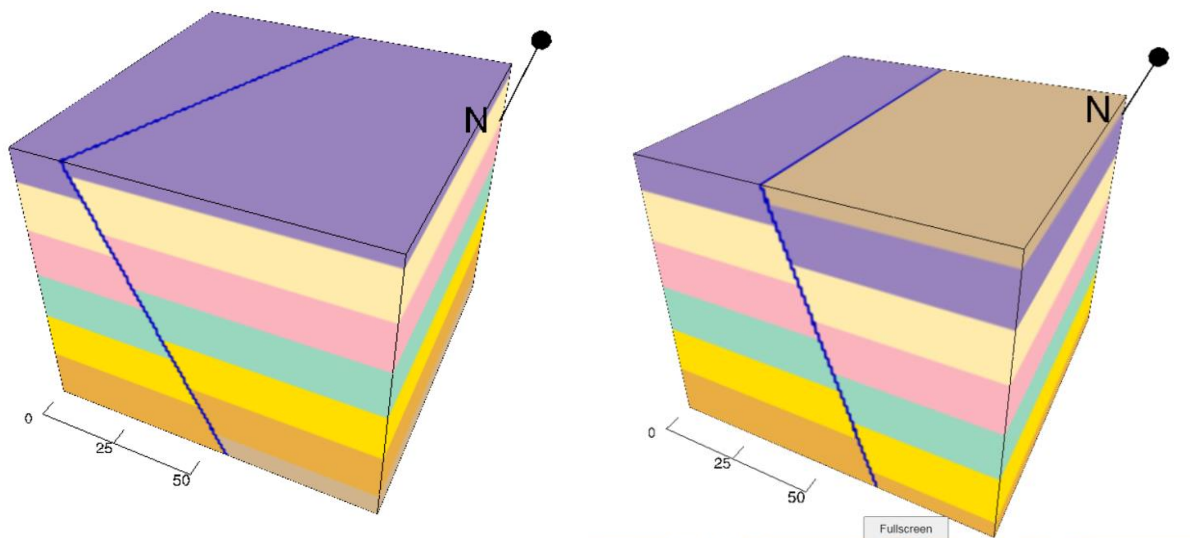
III- Anatomie d'une faille

Forme théorique d'une faille



(a) Vue 3D d'une faille théorique isolée

La notion de toit, de mur, d'éponte et de lèvre



Toit =

Mur =

Epontes :

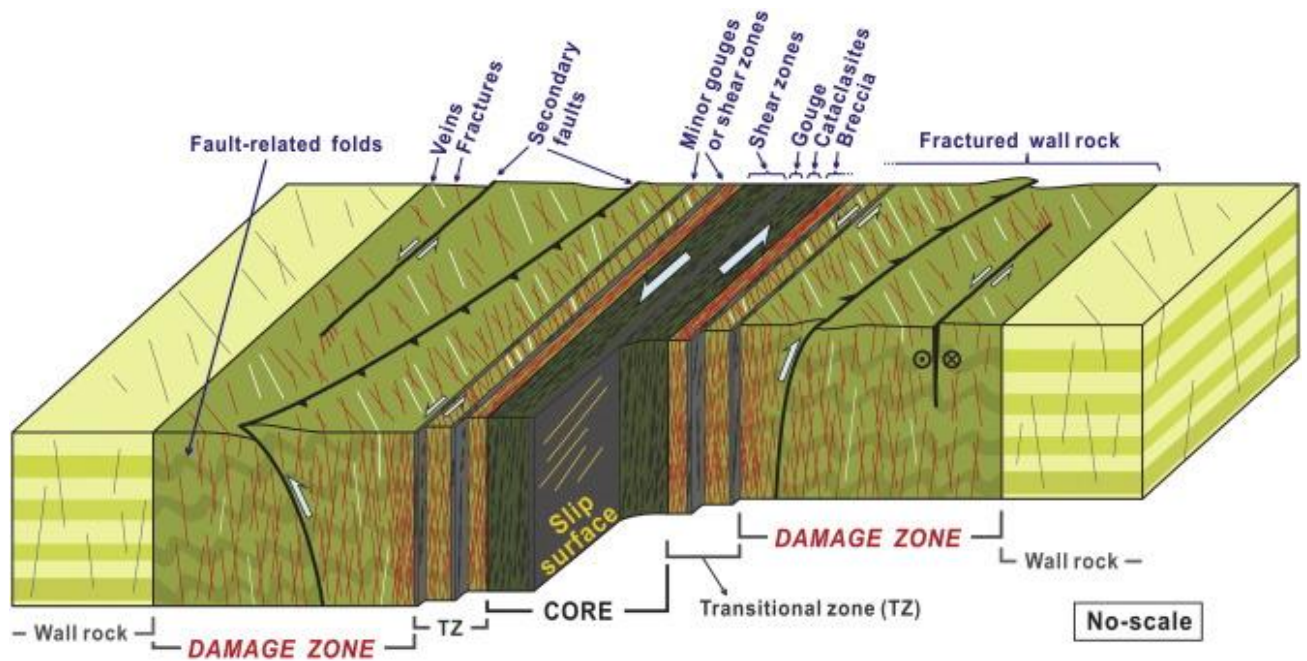
Lèvre de la faille :

Prise de notes :

La notion de miroir de faille

Un miroir de faille :

La notion d'endommagement et de cœur de faille



IV – Les roches de failles : les tectonites

Les tectonites :

Prise de notes :



Mylonite :



Prise de notes :

Implications en ingénierie

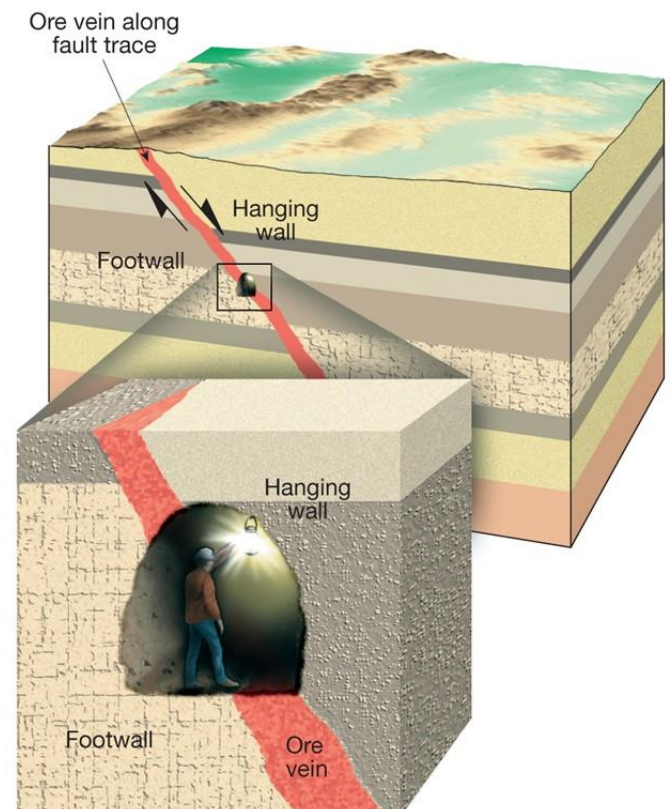


Photo : J. Tuduri (BRGM), mine d'Imiter (Maroc)

Un peu d'histoire

Hanging wall =

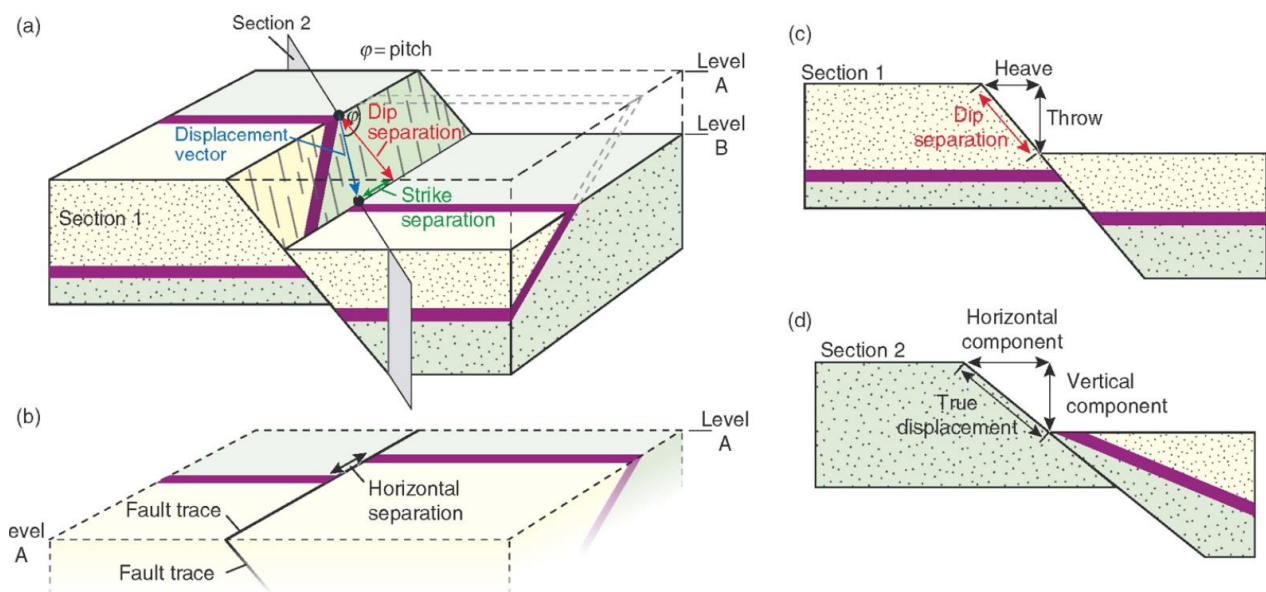
Footwall=



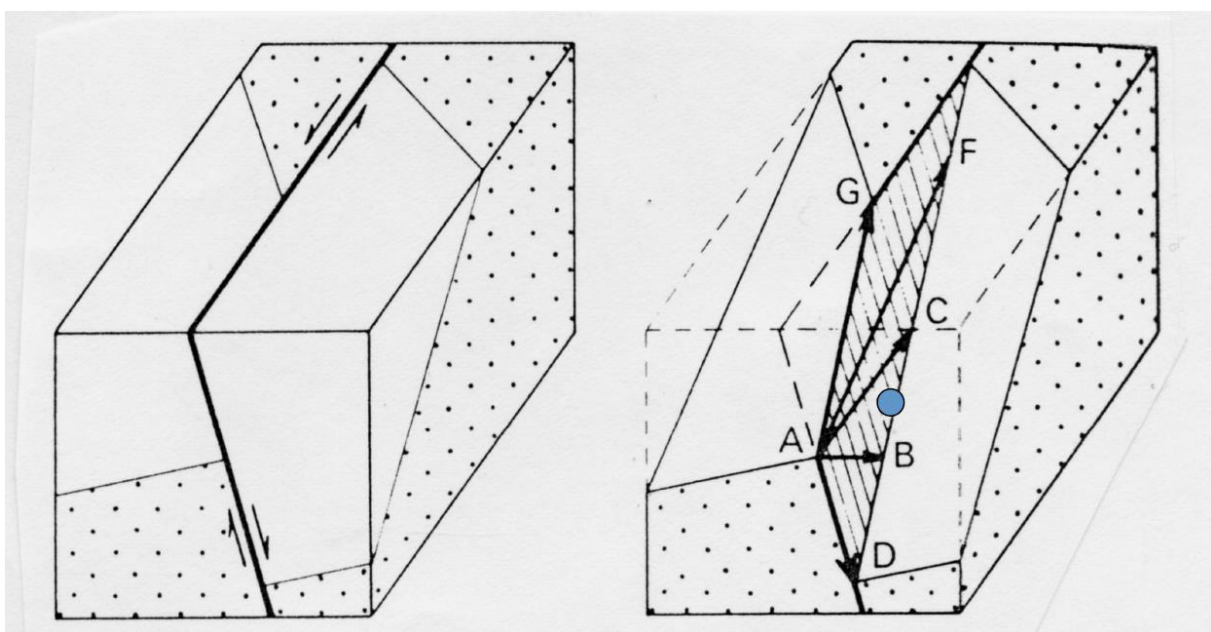
Prise de notes :

V- La notion de rejet

Rejet :

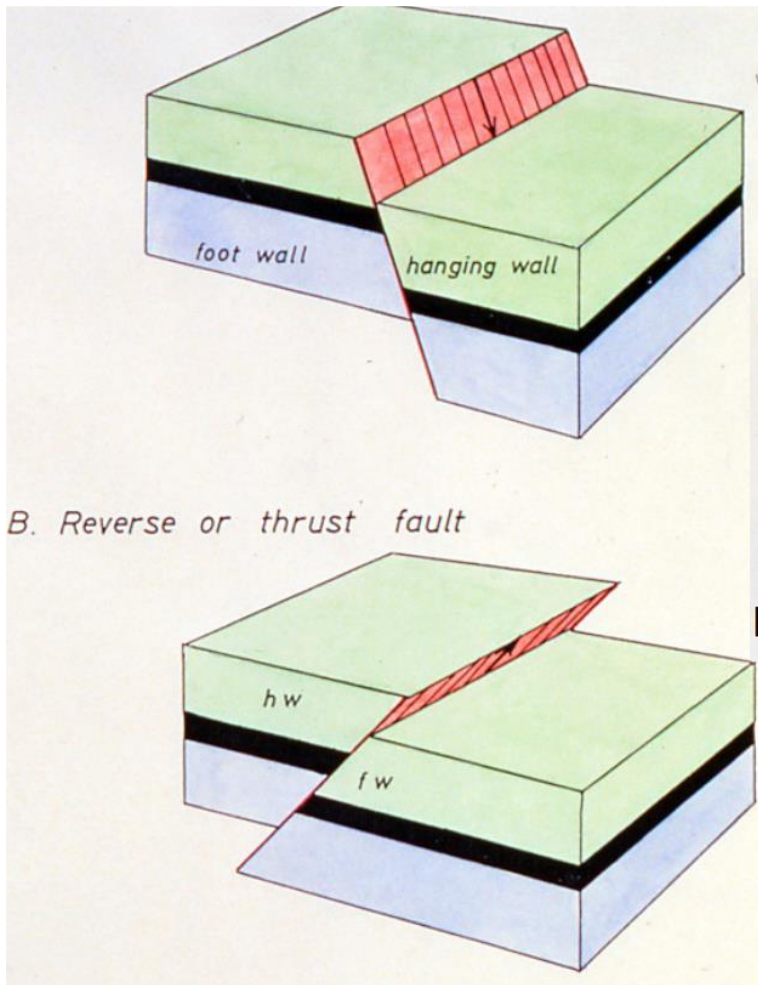


Rejet vrai vs. apparent

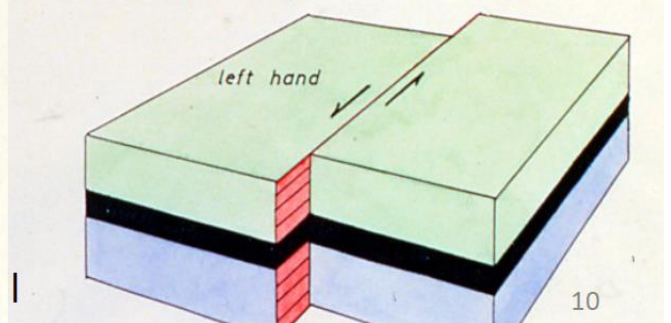


Prise de notes :

VI- Les catégories de faille

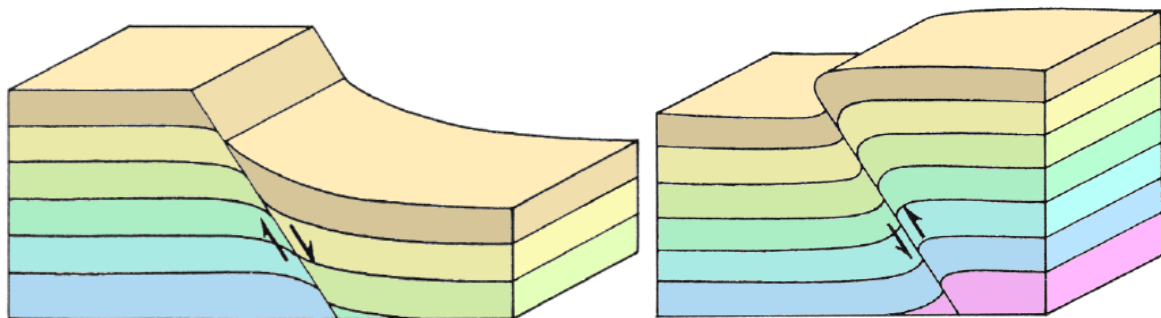


C. Strike-slip fault



VII- Les marqueurs de mouvements : stratigraphie et tectoglyphes

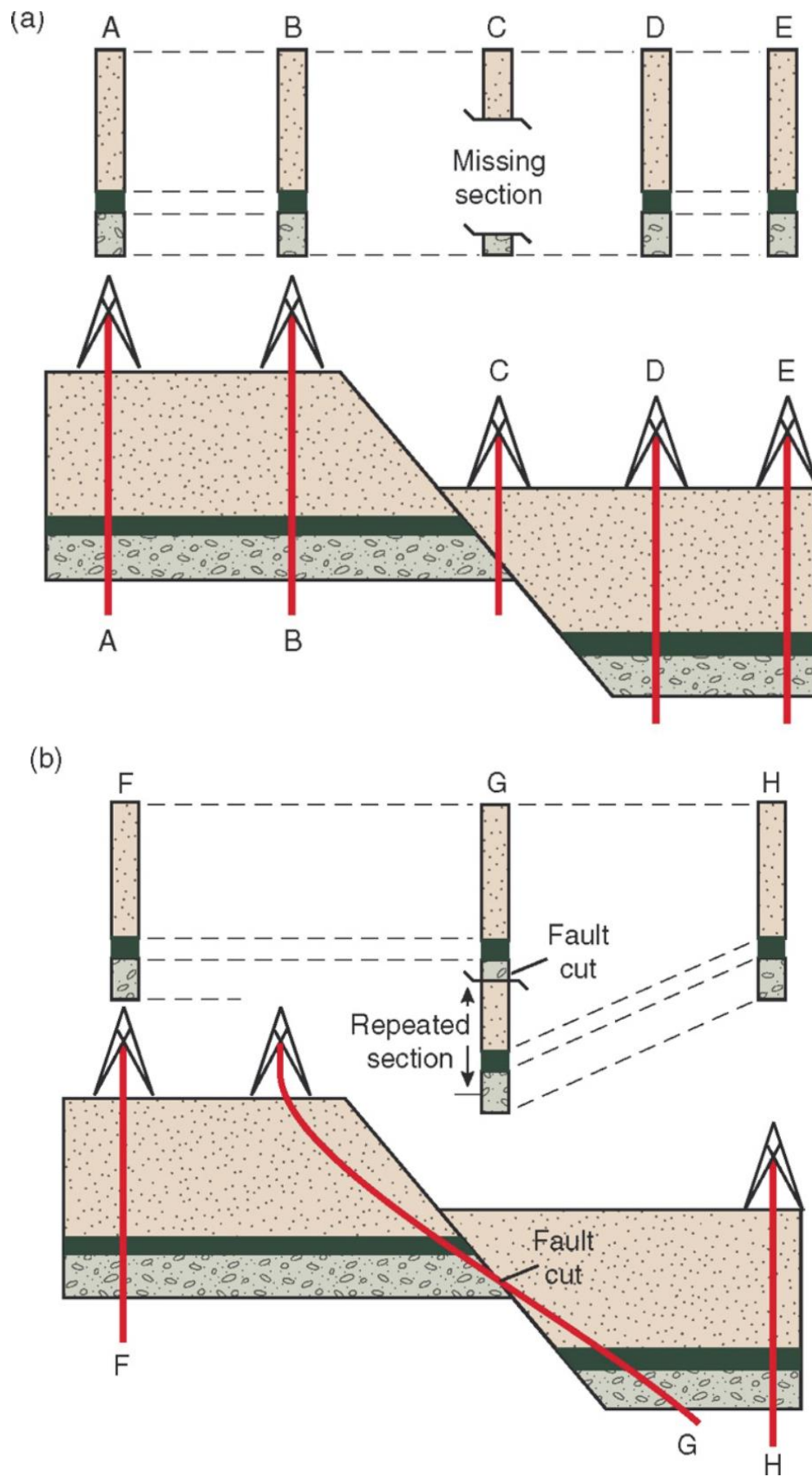
Les crochons de failles



Mattauer, M. Les déformations de l'écorce terrestre
Eds Herman

Prise de notes :

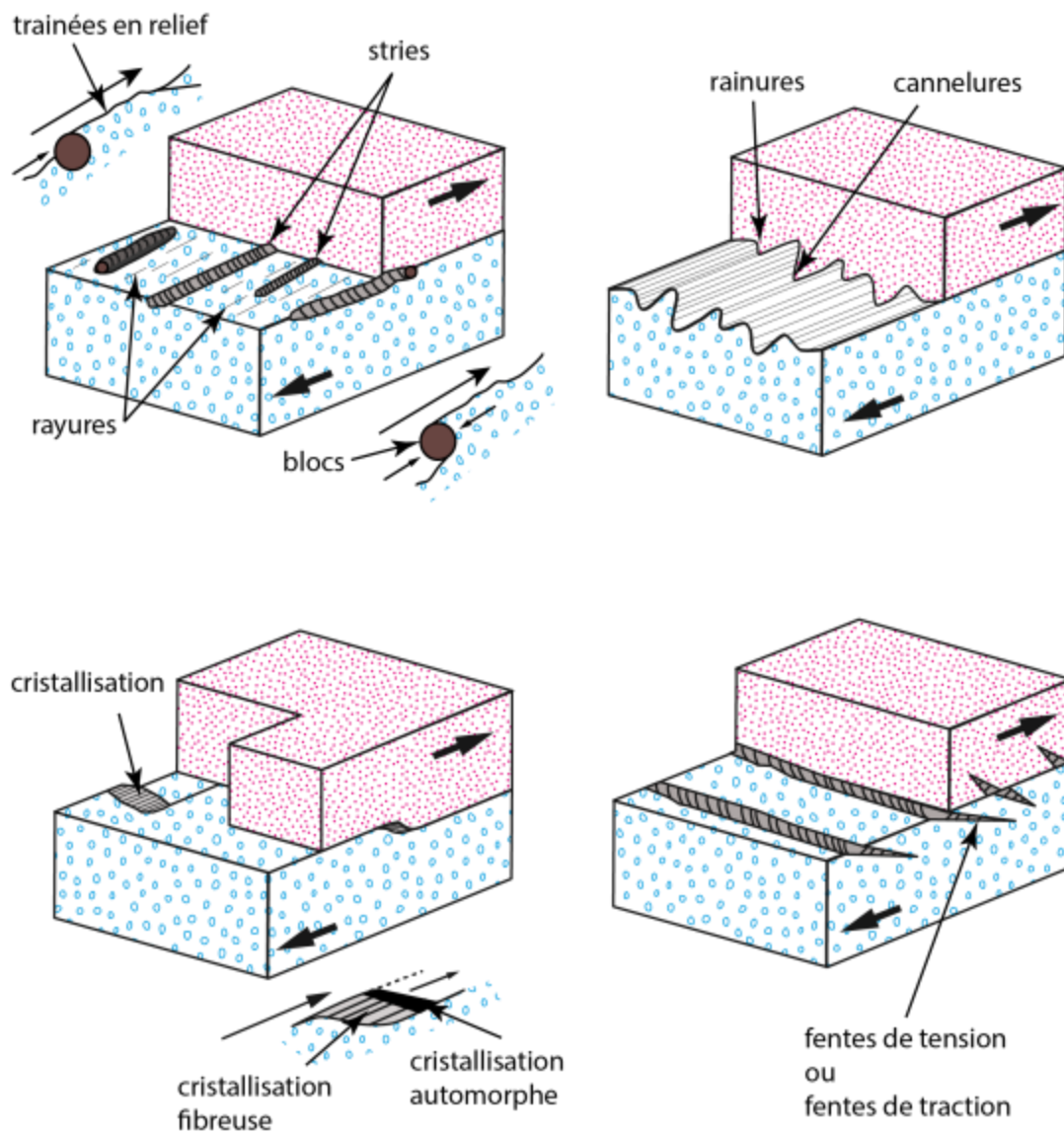
Répétitions stratigraphiques



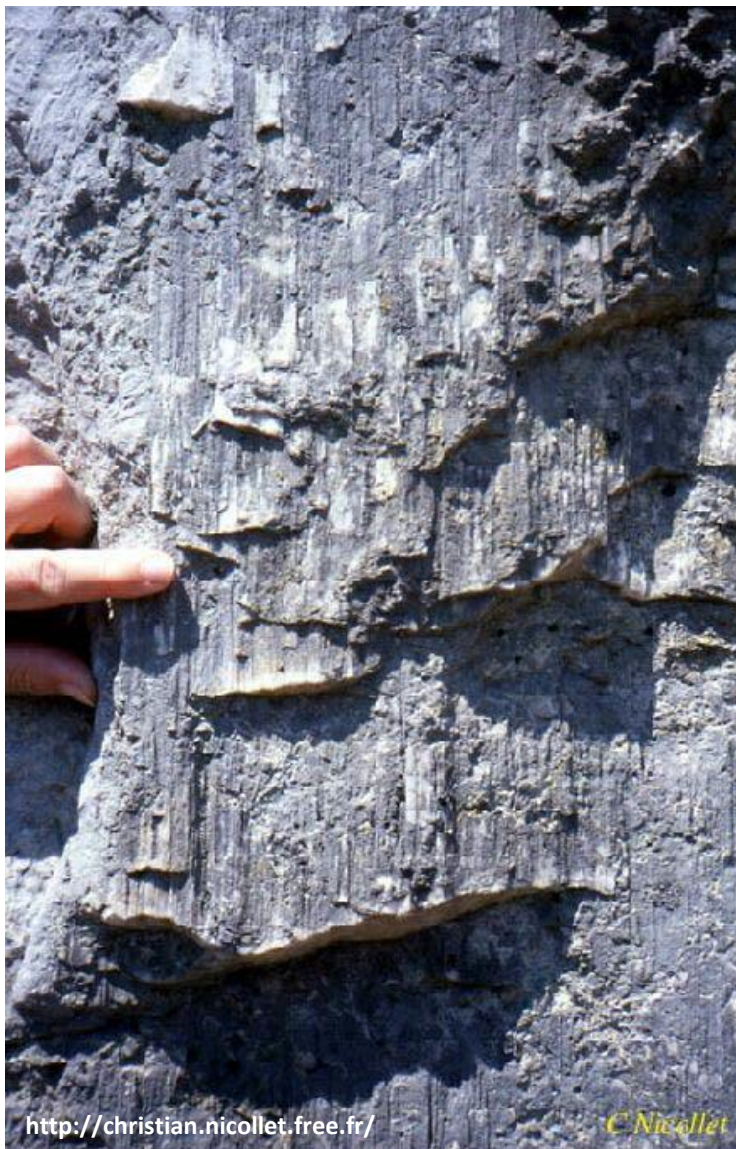
Prise de notes :

Les tectoglyphes

Les tectoglyphes :



Prise de notes :



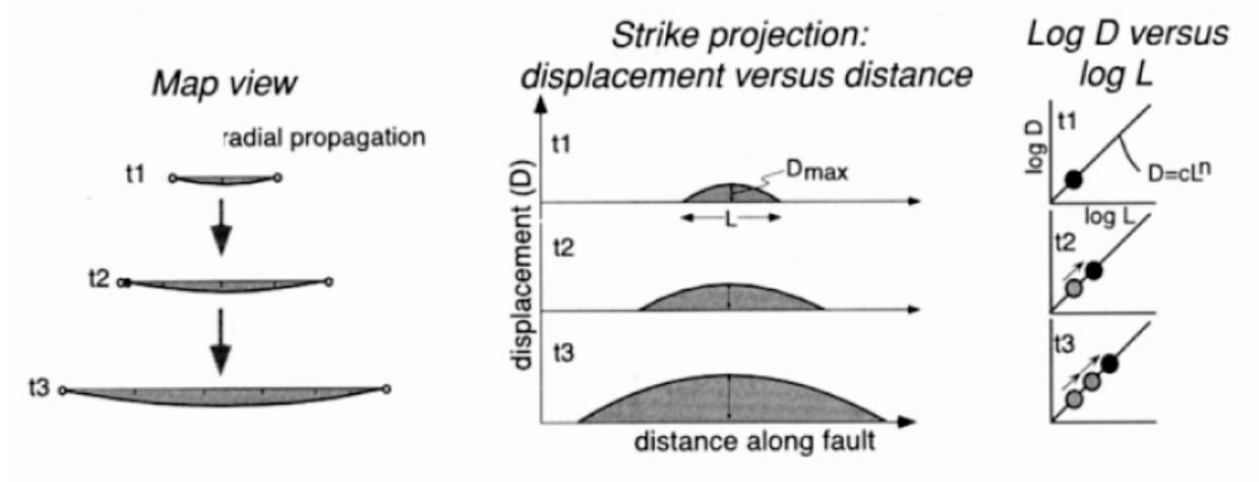
Exercice – interpréter les photos et donner le sens de mouvement, le type de faille. On supposera le plan de faille verticale en haut et fortement penté vers le photographe à gauche.

Prise de notes :

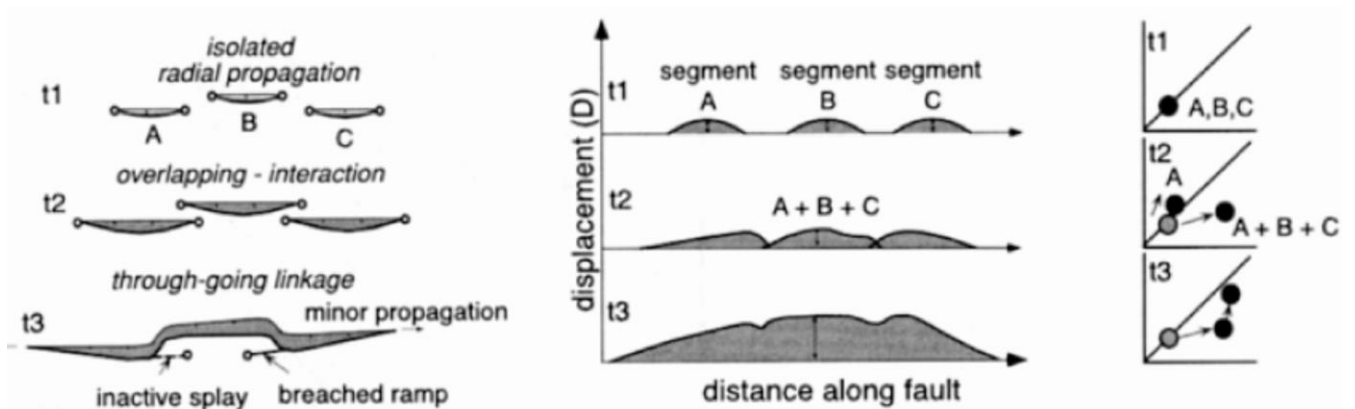
VIII – Croissance et évolution d'une faille

Les modèles de croissance

1- Propagation radiale

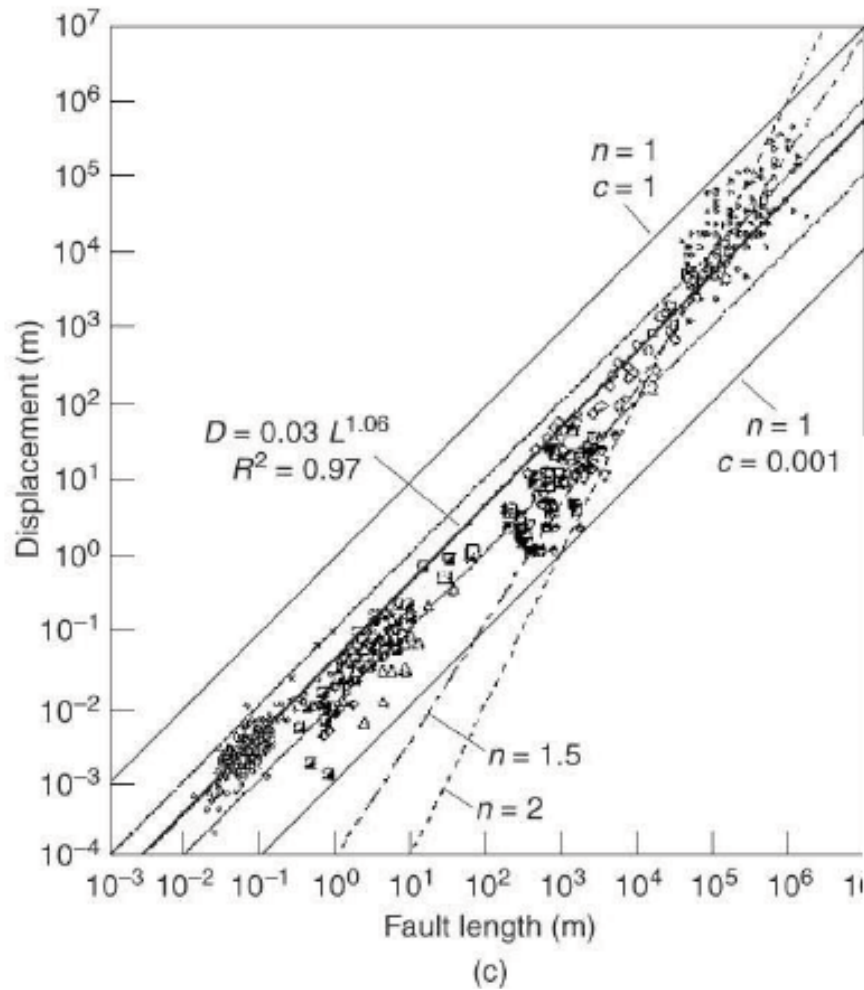


2- Connexion de plusieurs failles



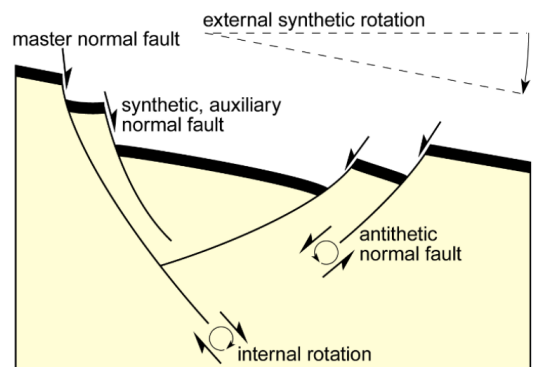
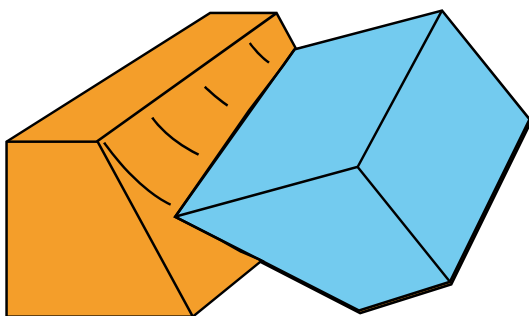
Modified from Cartright et al. (1995), in Burbank and Anderson (2001)

Prise de notes :

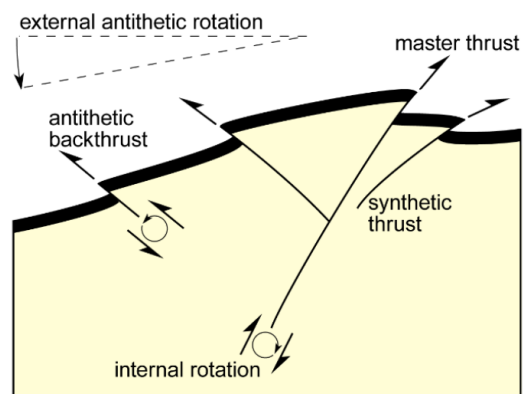
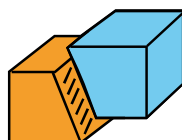
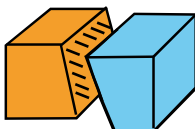


IX – Autres éléments de classification

Faillles Rotationnelles



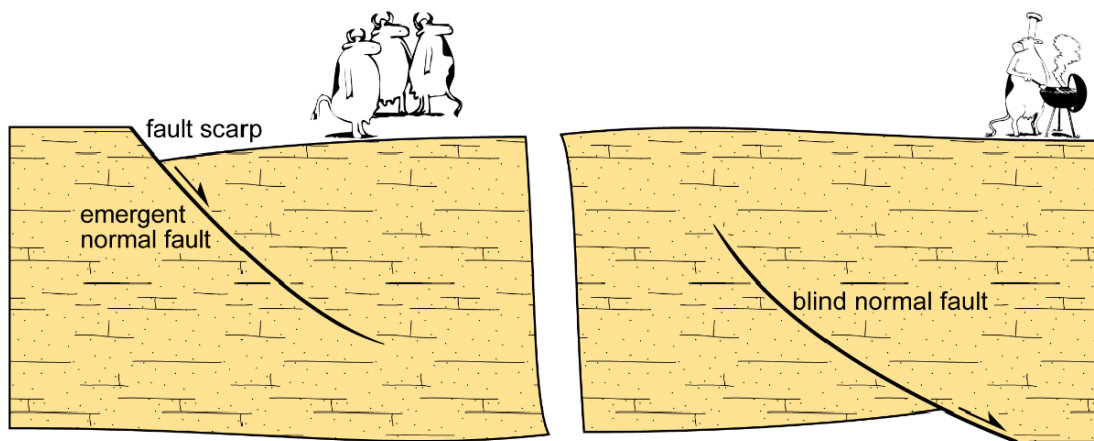
Normale/Senestre Inverse/Senestre



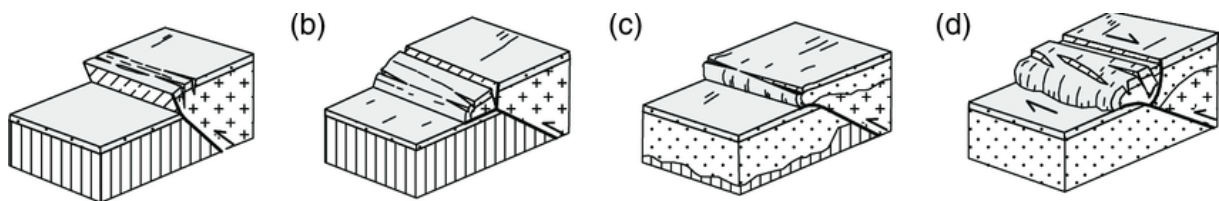
Figures: JP Brun (Rennes)

Prise de notes :

Failles conjuguées :



Figures: JP Brun (Rennes)

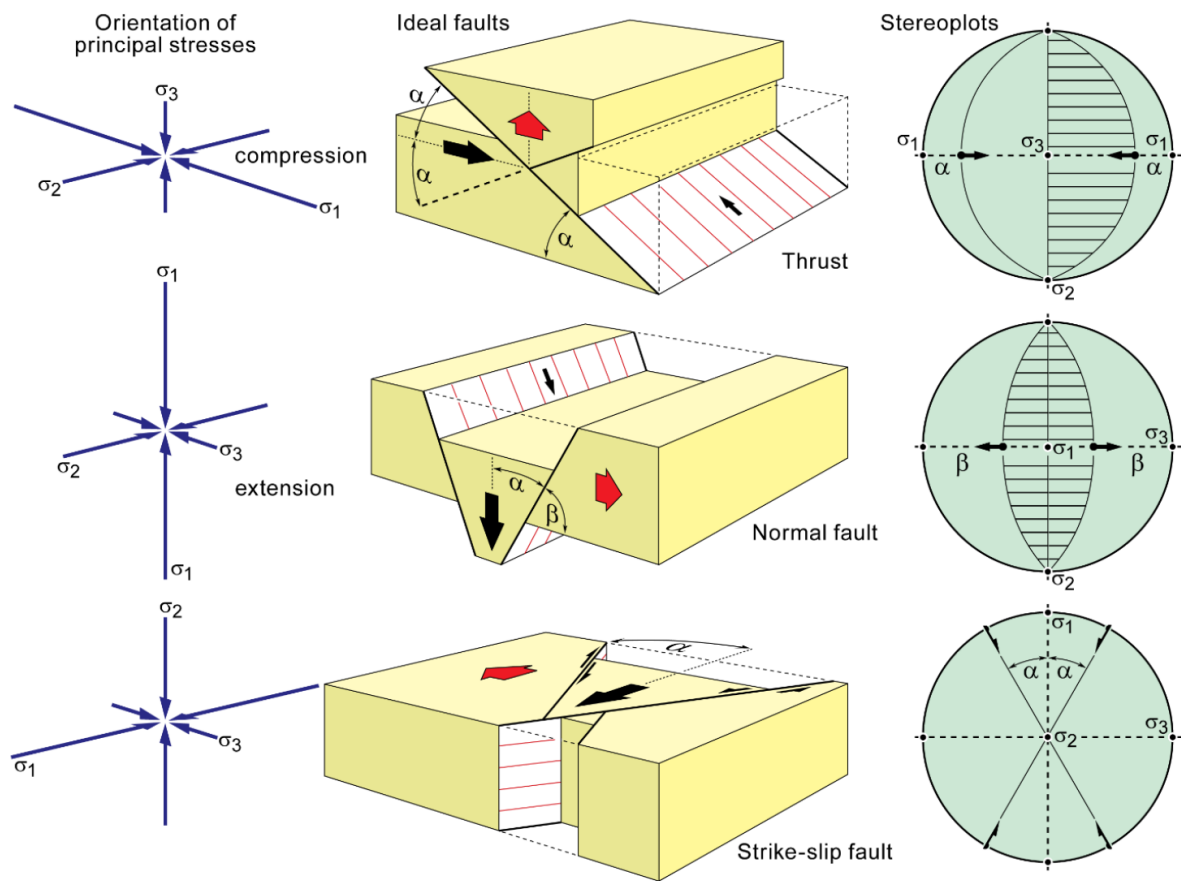


Yu et al. (2010)



Prise de notes :

X – Relations contraintes vs. Familles de failles



Figures: JP Brun (Univ Rennes)

Prise de notes :

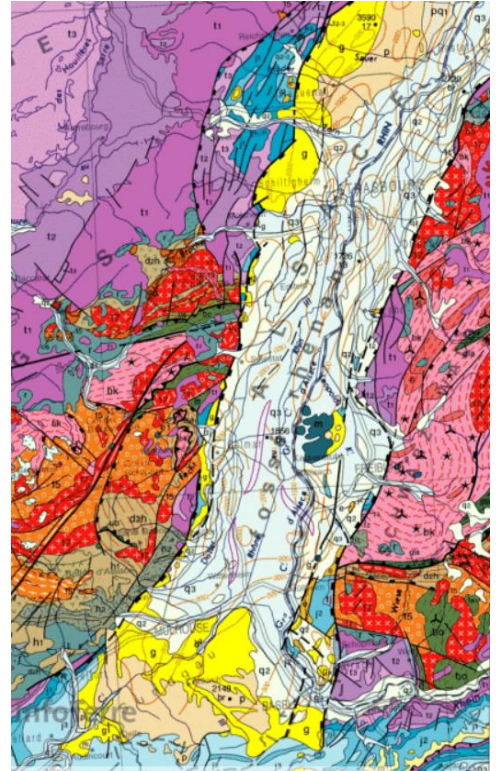
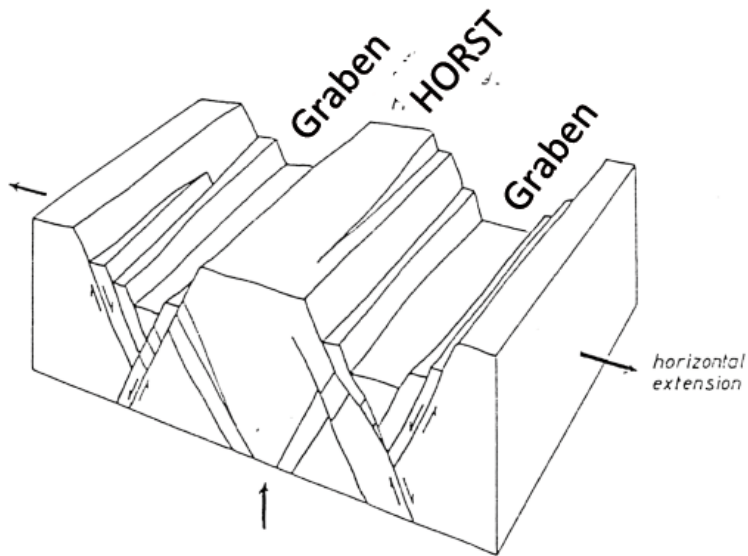
Cours 7 : Les systèmes distensifs

Cours 7 : Les systèmes distensifs

I – Rappels

II – Les grands types de failles normales

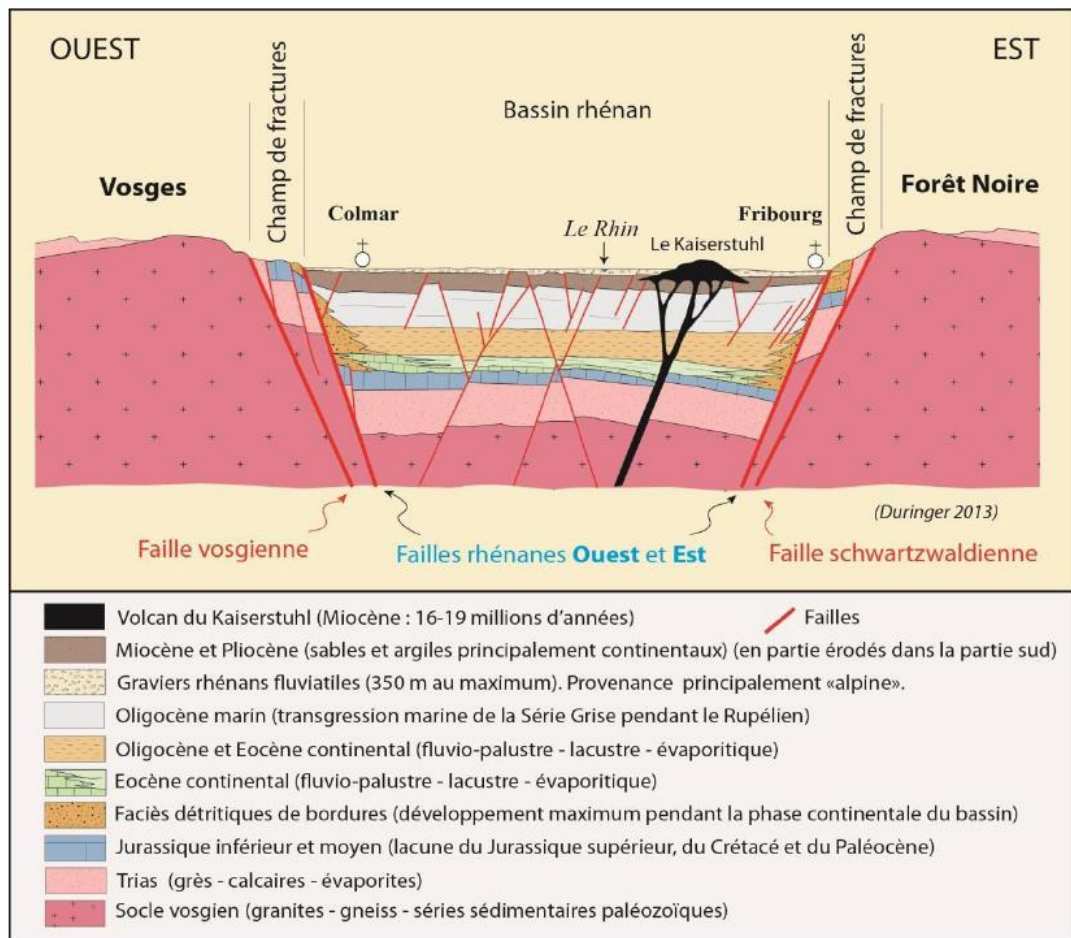
Failles normales plates



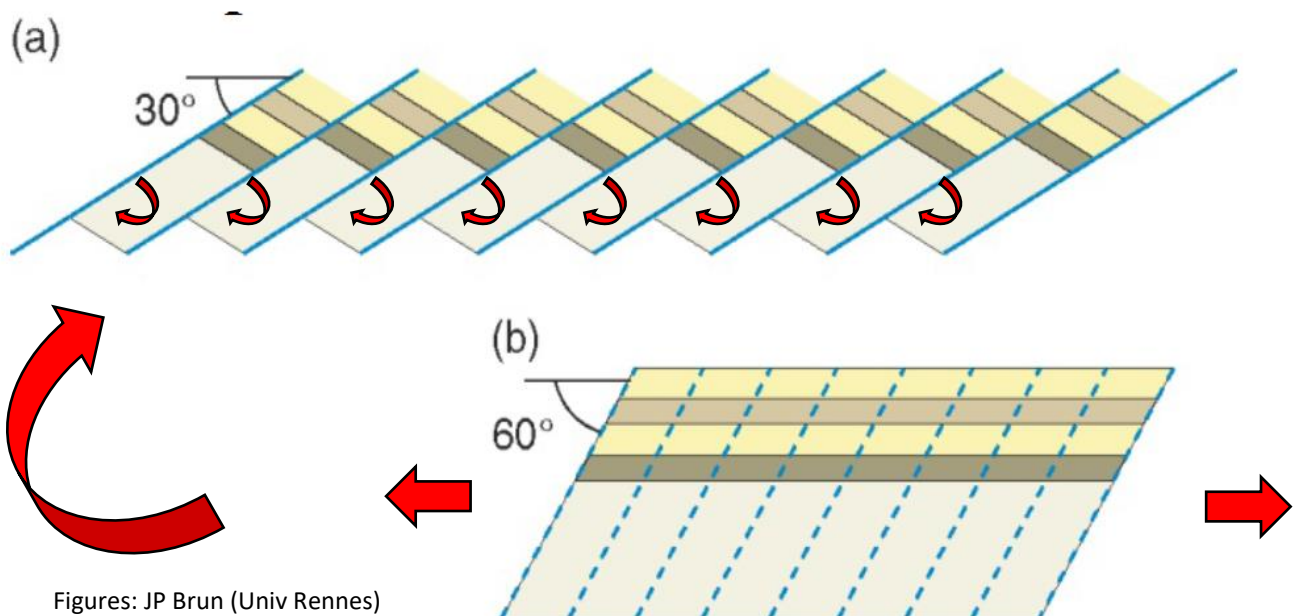
Graben:

Horst :

Prise de notes :

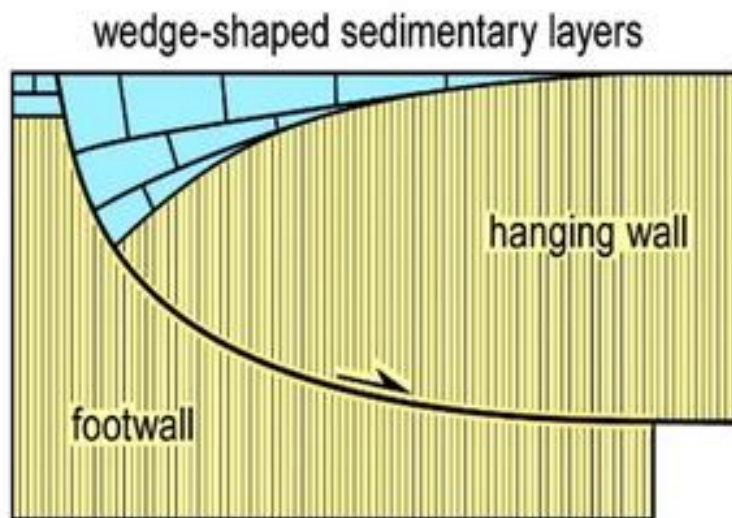


Les blocs basculés

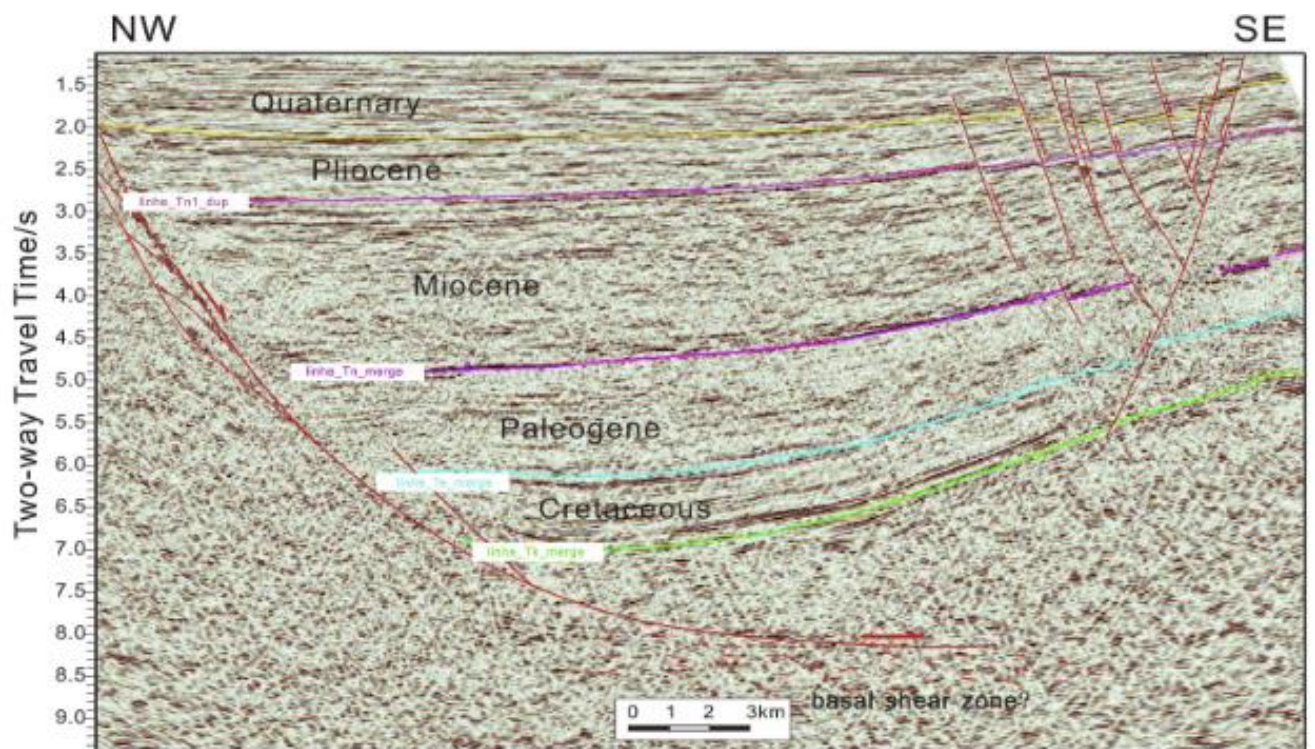


Prise de notes :

Les failles listriques



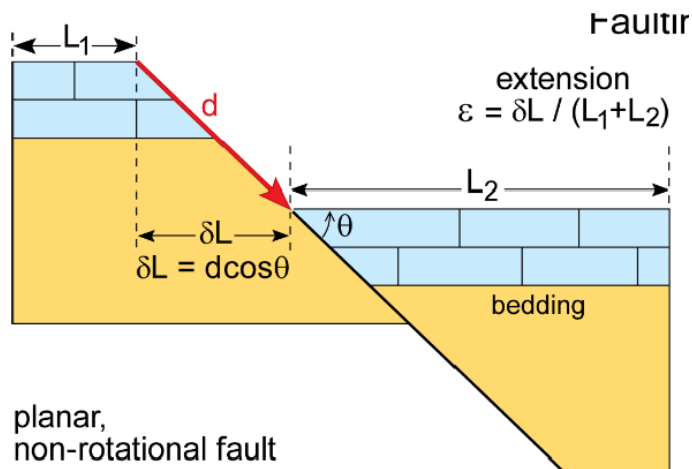
Figures: JP Brun (Univ Rennes)



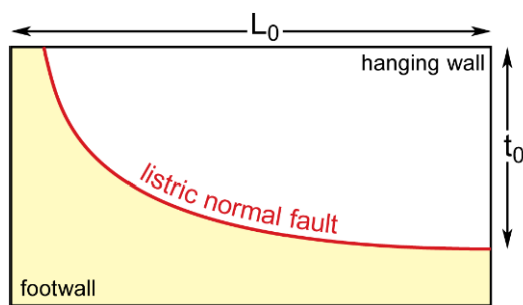
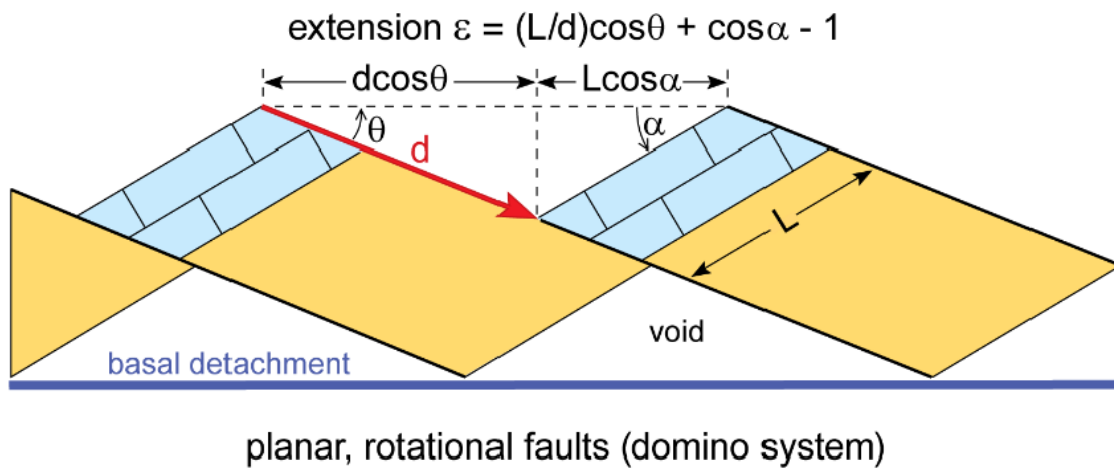
Zhao et al. (2020) – bassin de Langshan (Chine)

Prise de notes :

III – Quantification de l'extension

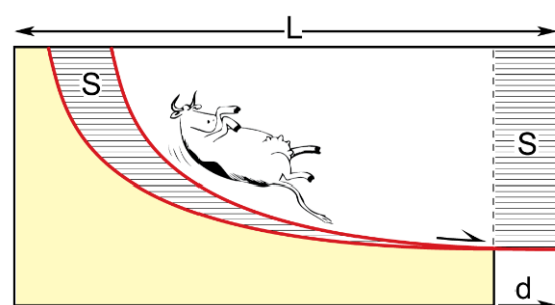


Figures: JP Brun (Univ Rennes)



$$S = (L - L_0) \times t_0 = \text{constant}$$

$$\text{stretching factor } \beta = L / L_0$$



$$\text{extension} = \text{displacement } d = L - L_0$$

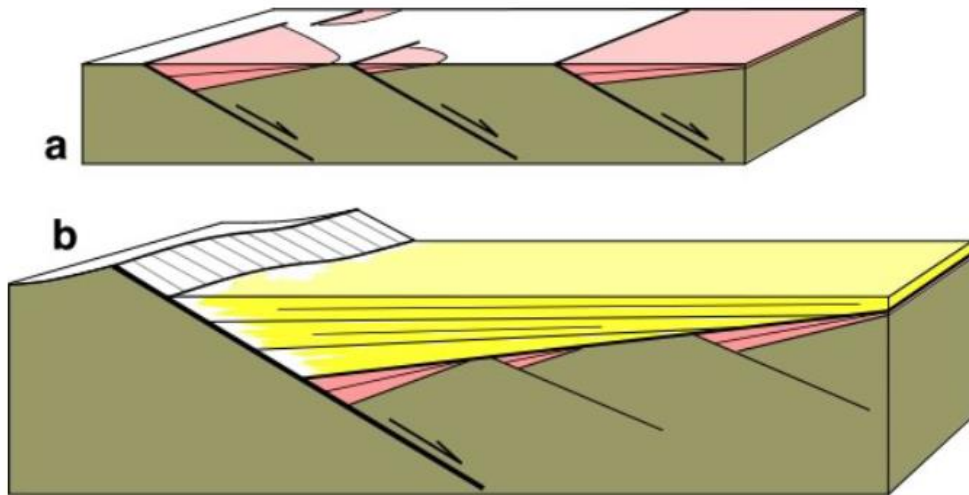
$$\text{relative extension} = d / L_0 \times 100\%$$

Prise de notes :

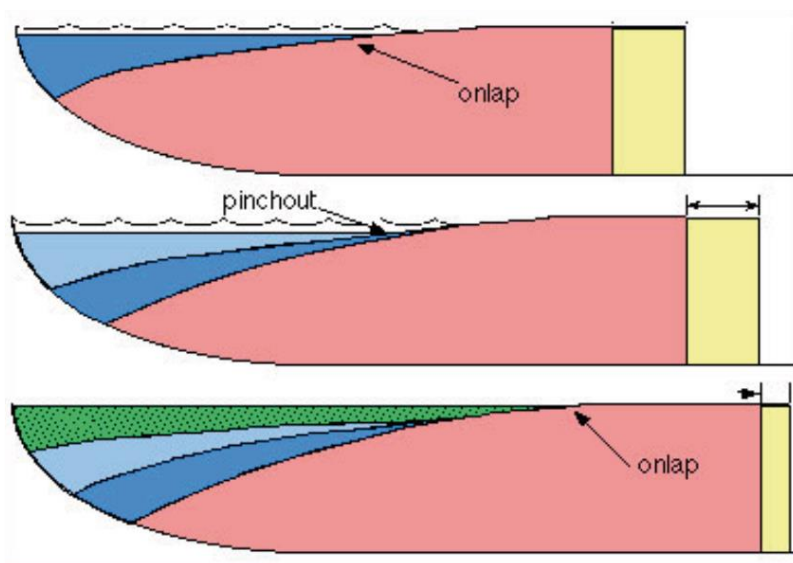
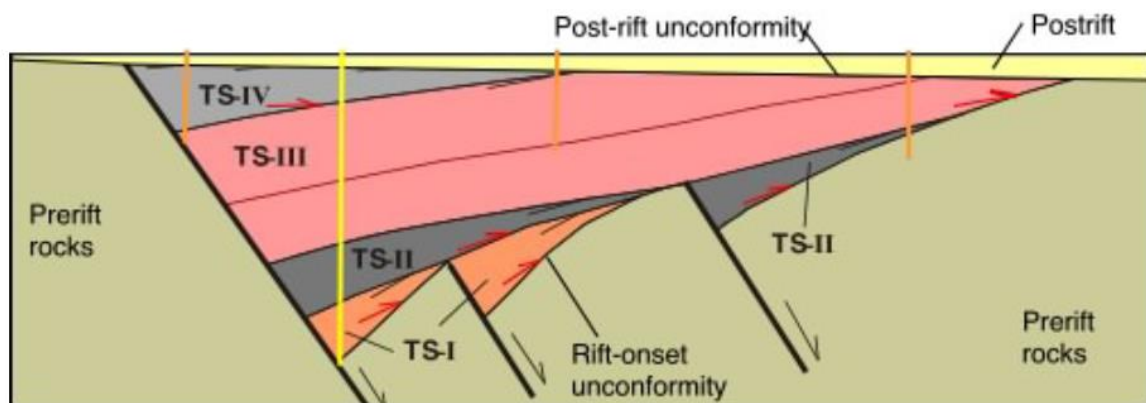
IV – La sédimentation associée

Les bassins symétriques

Les bassins asymétriques (demi-graben)

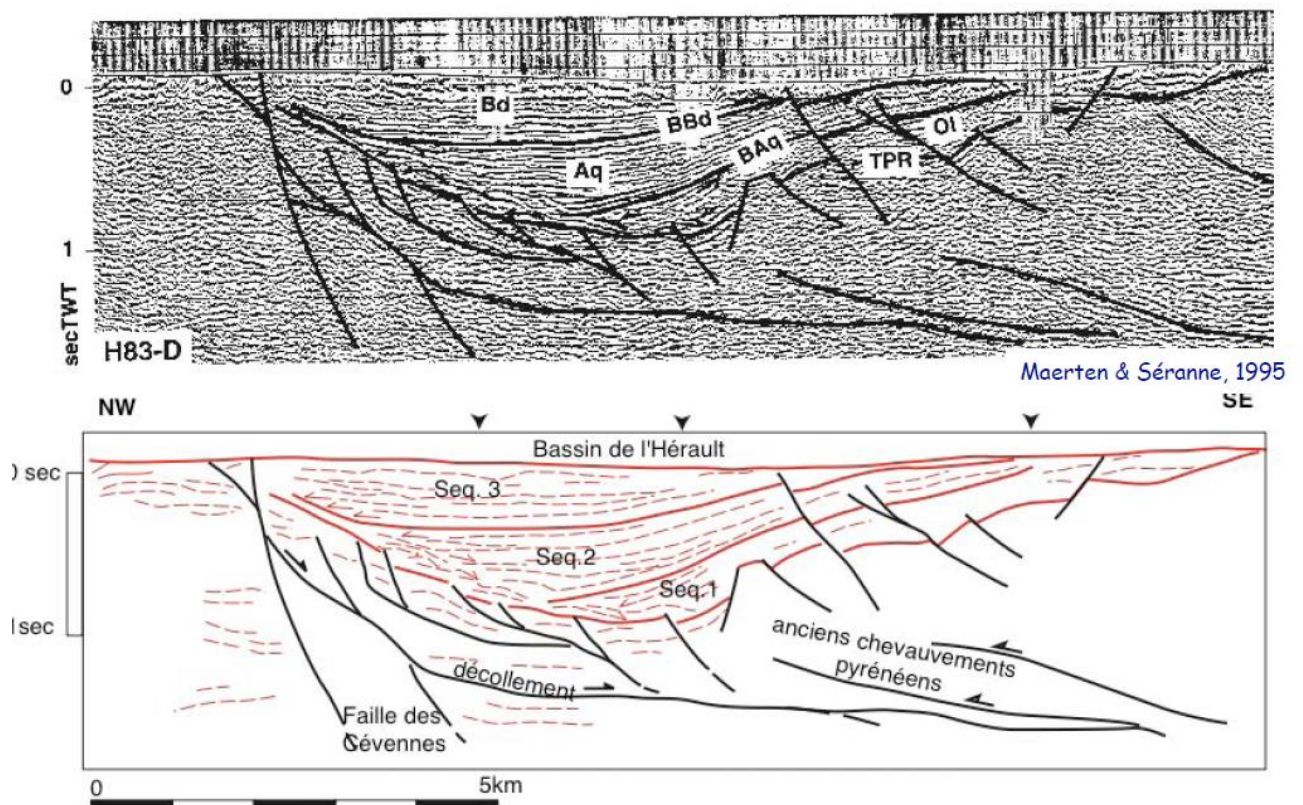
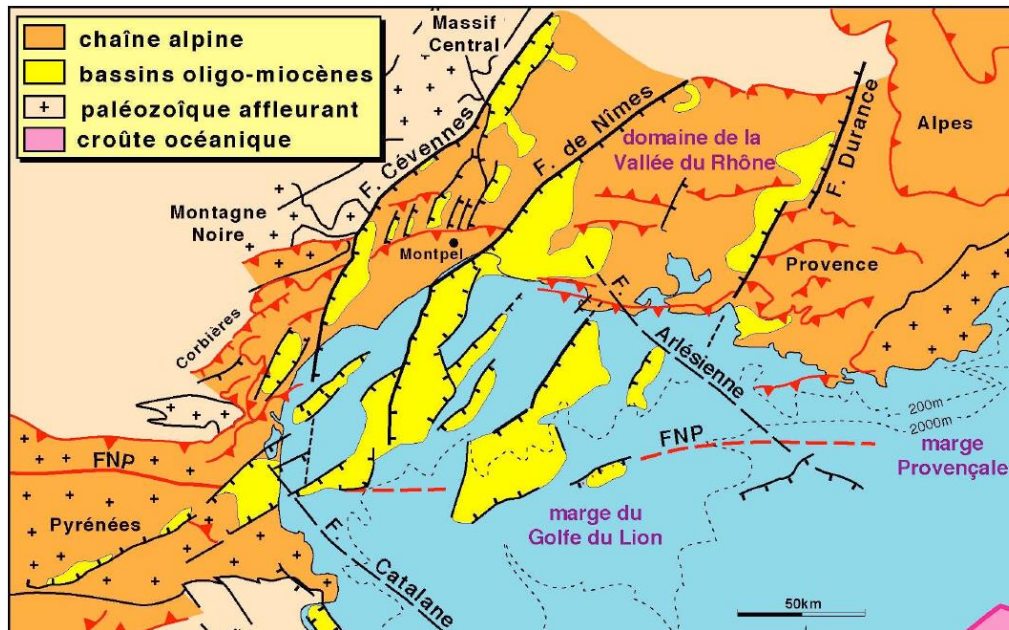


<https://www.ldeo.columbia.edu/~polsen/nbcp/breakupintro.html>



<http://www.geosci.usyd.edu.au/>

Prise de notes :



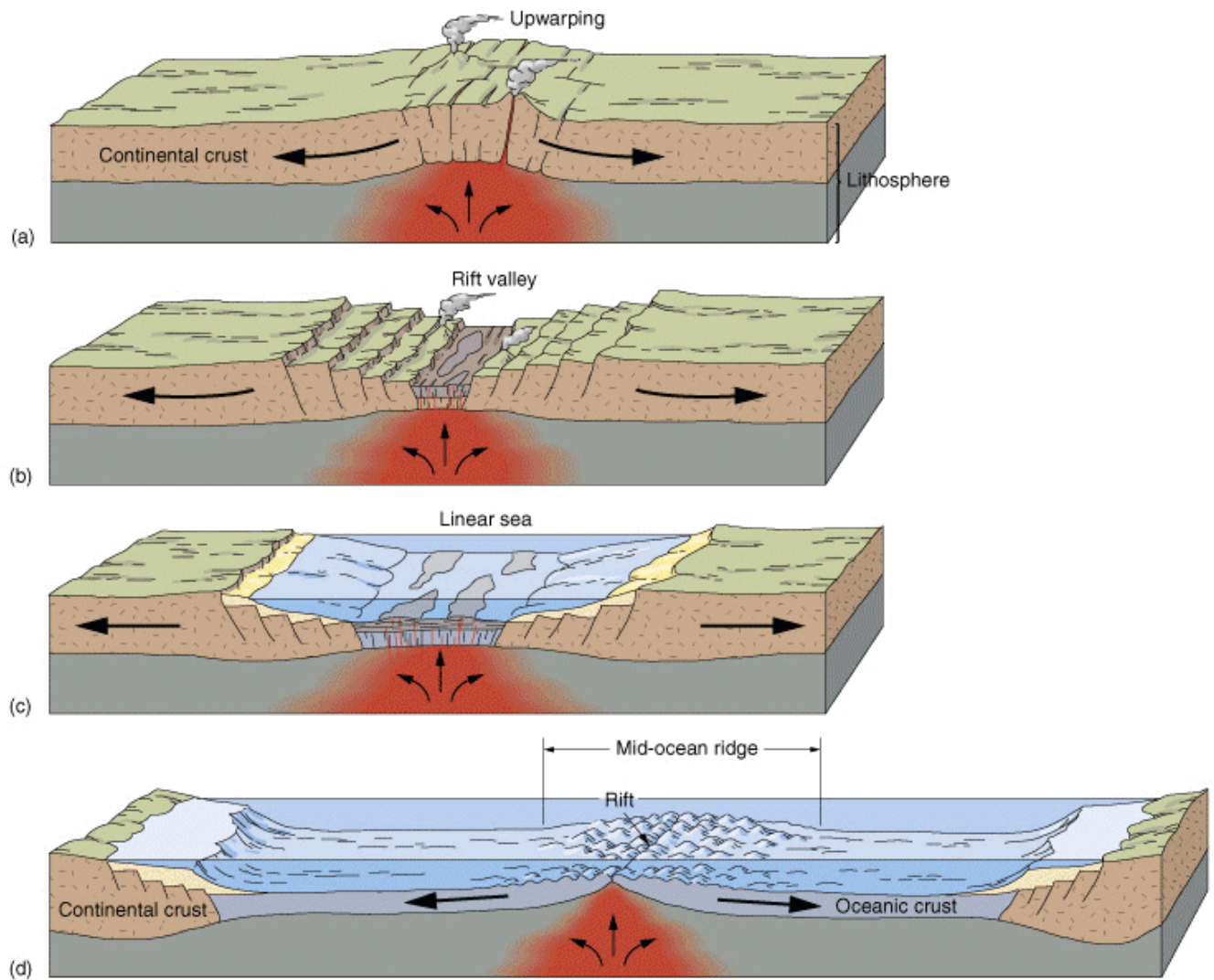
Carte et coupes : M. Seranne (Université de Montpellier)

Prise de notes :

V – Origine et distribution

Les zones rift

Rift :



<https://www.csus.edu/indiv/k/kusnickj/geology12/tectonicbasins.html>

Prise de notes :

Marge passive :

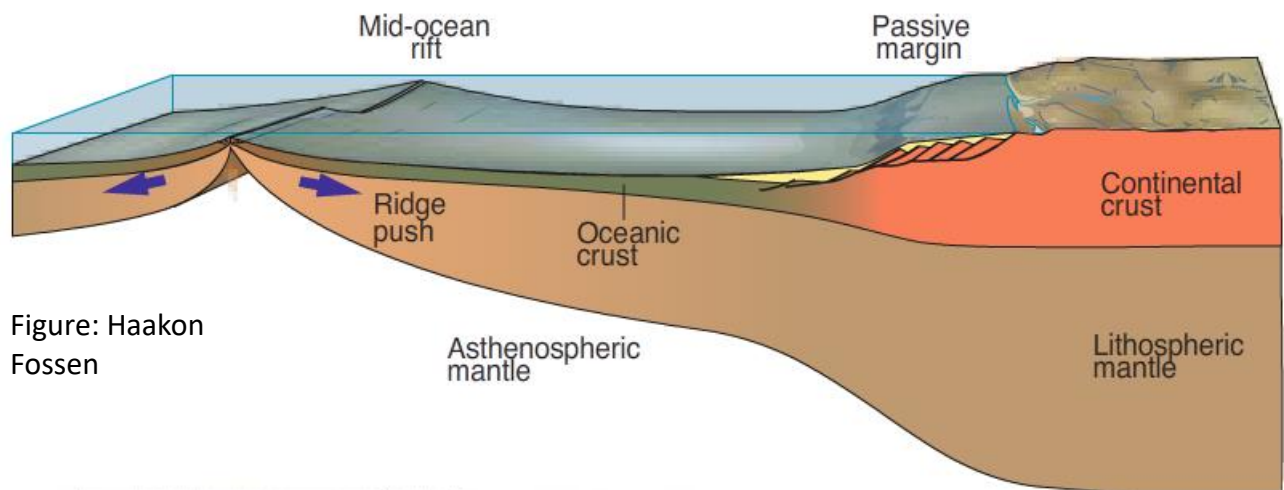
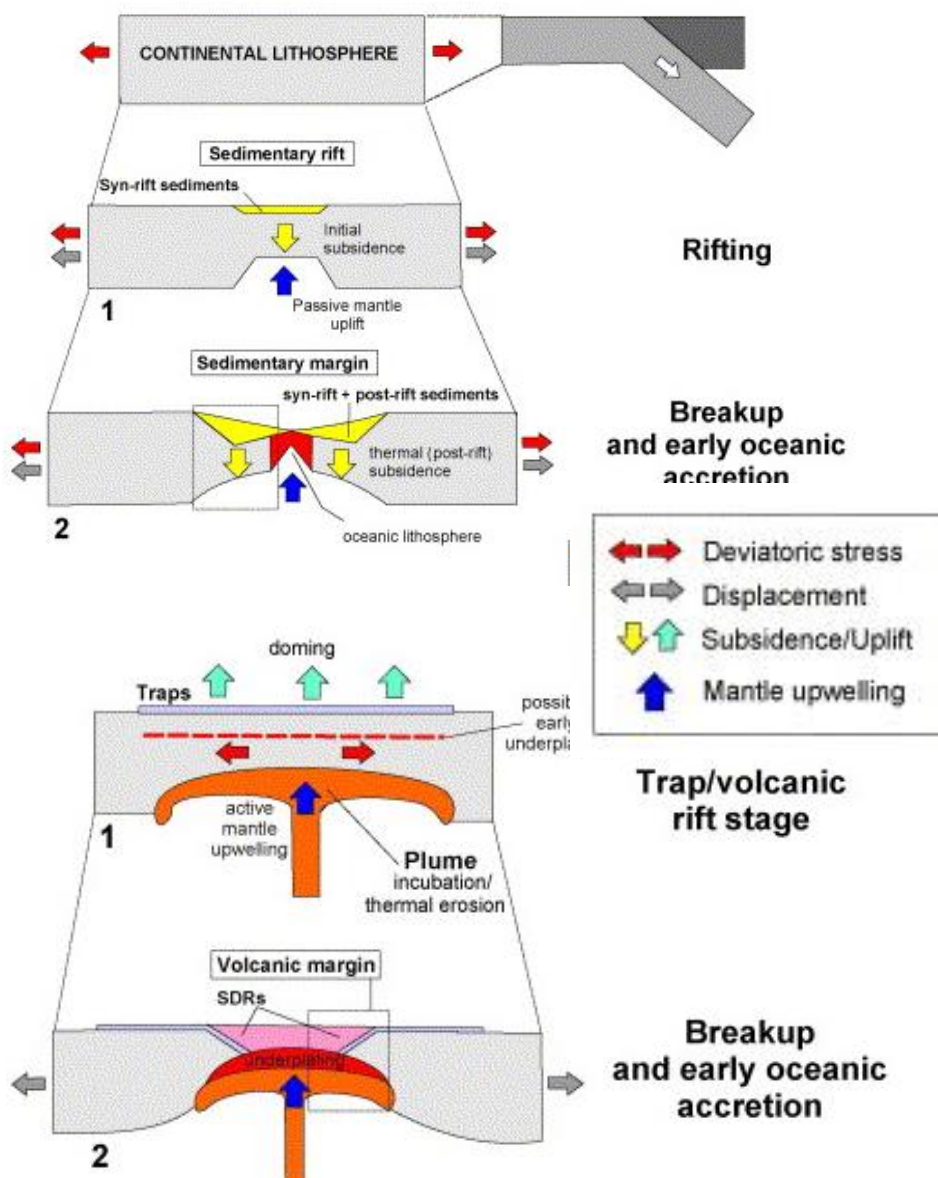


Figure: Haakon Fossen



Geoffroy (2005)

Prise de notes :

Extension d'arrière arc

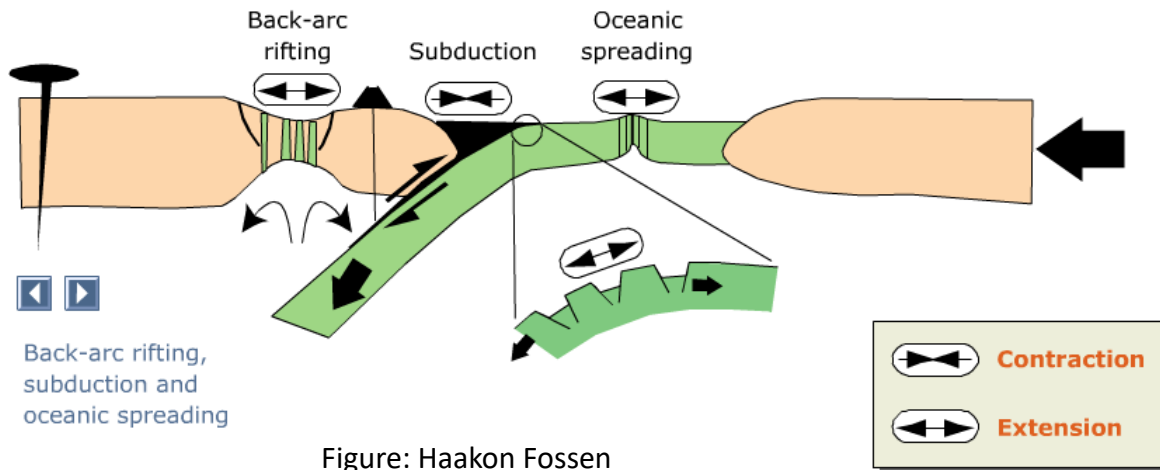
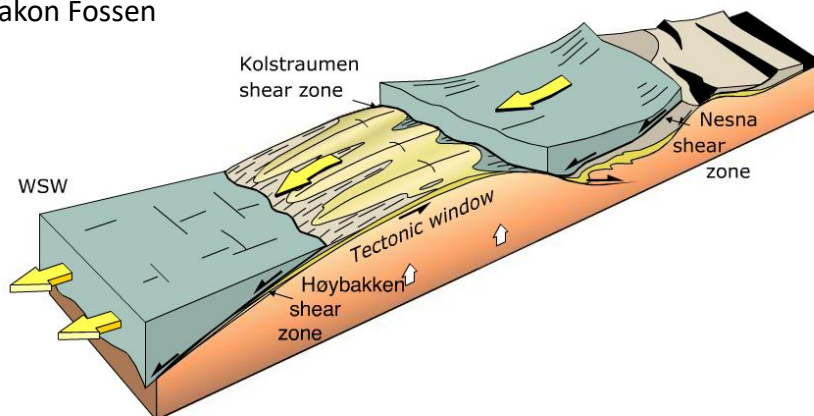


Figure: Haakon Fossen

Extension d'arrière arc

Figure: Haakon Fossen



Extension syn-orogénique

A major normal fault zone (NHNF) developed along the top.

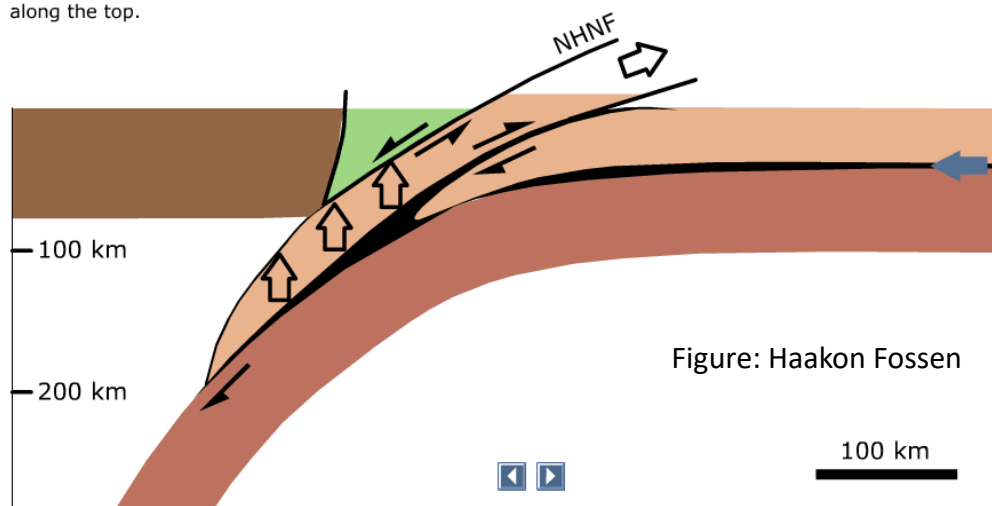
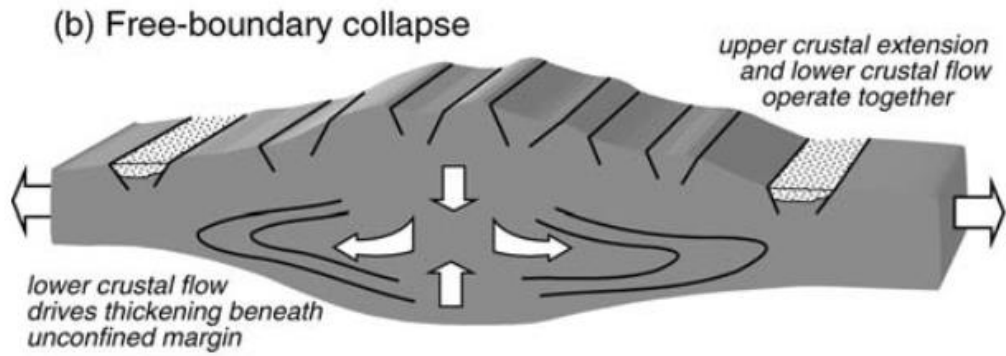
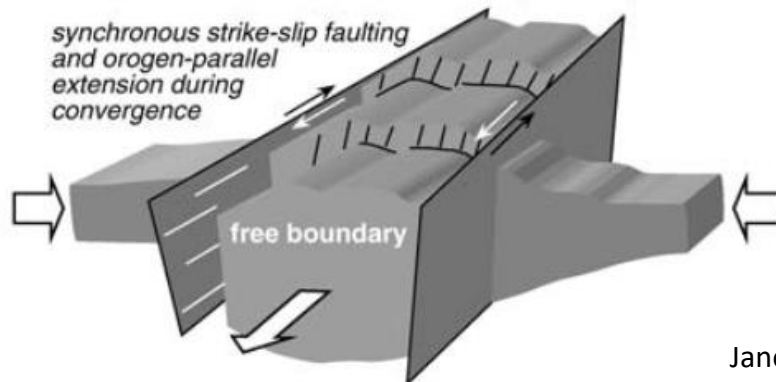


Figure: Haakon Fossen

Prise de notes :

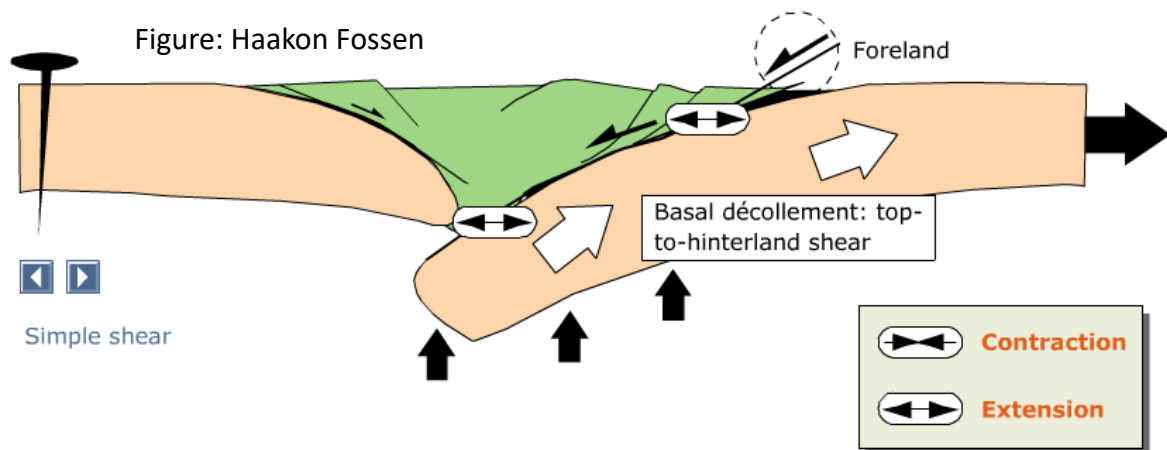


(c) Lateral extrusion with free-boundary "collapse"

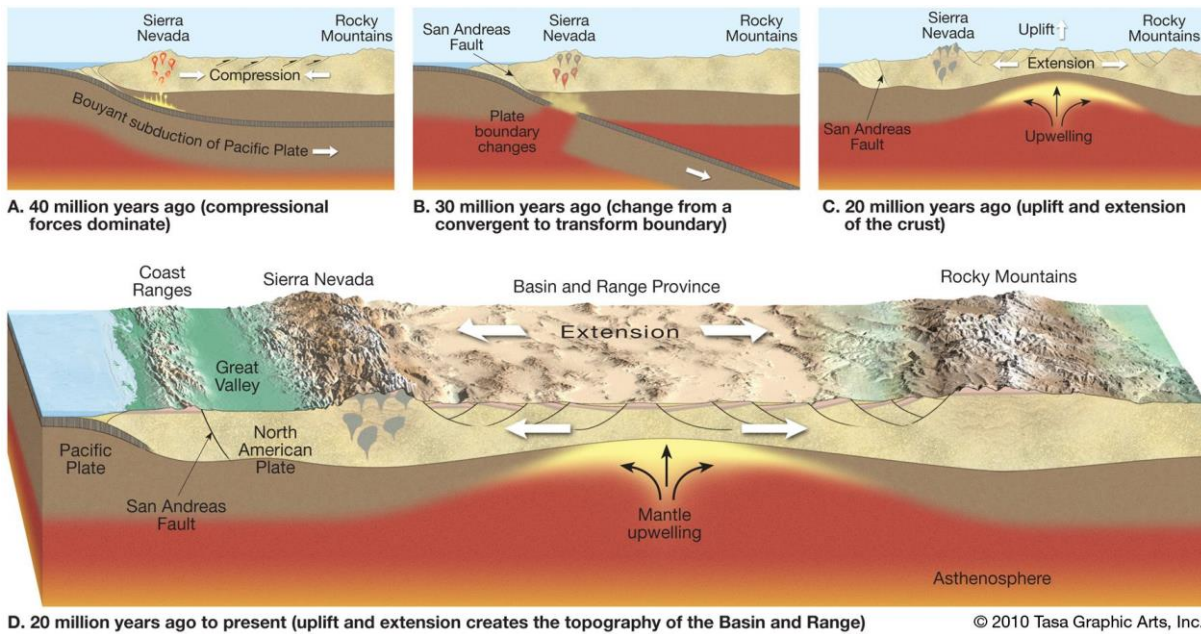


Jane Selverstone (2005)

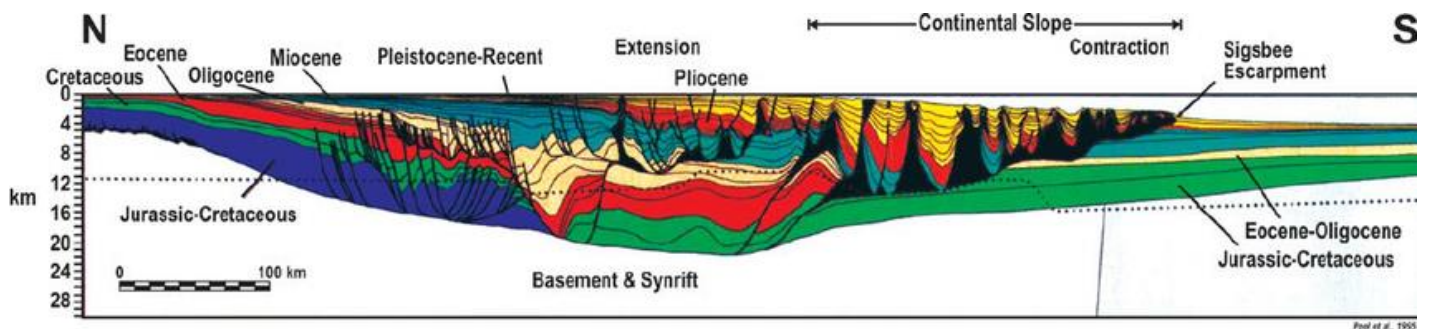
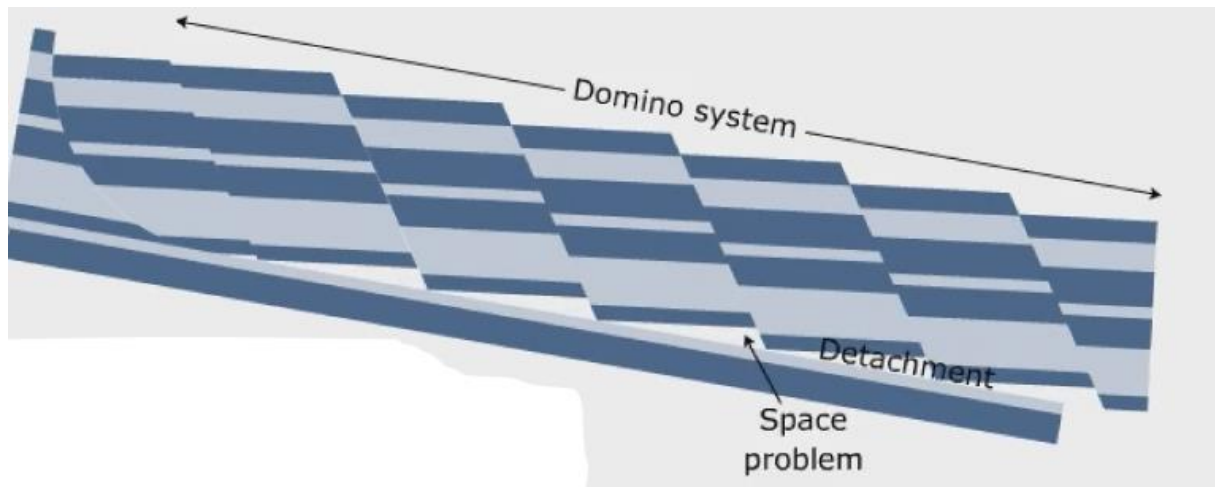
Extension post-orogénique



Prise de notes :

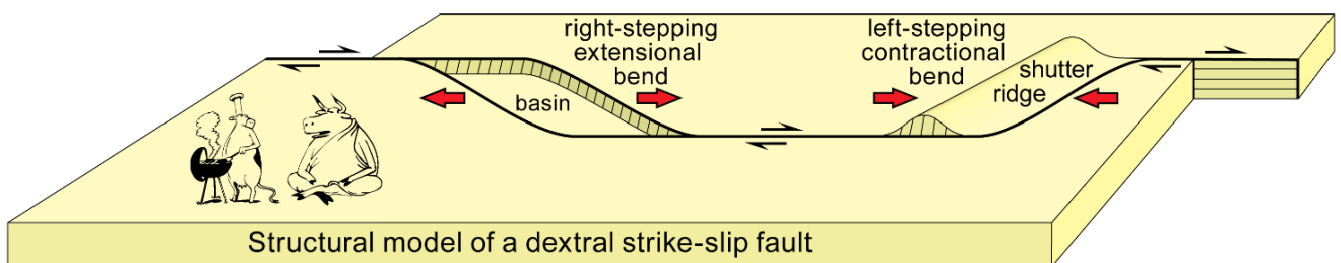
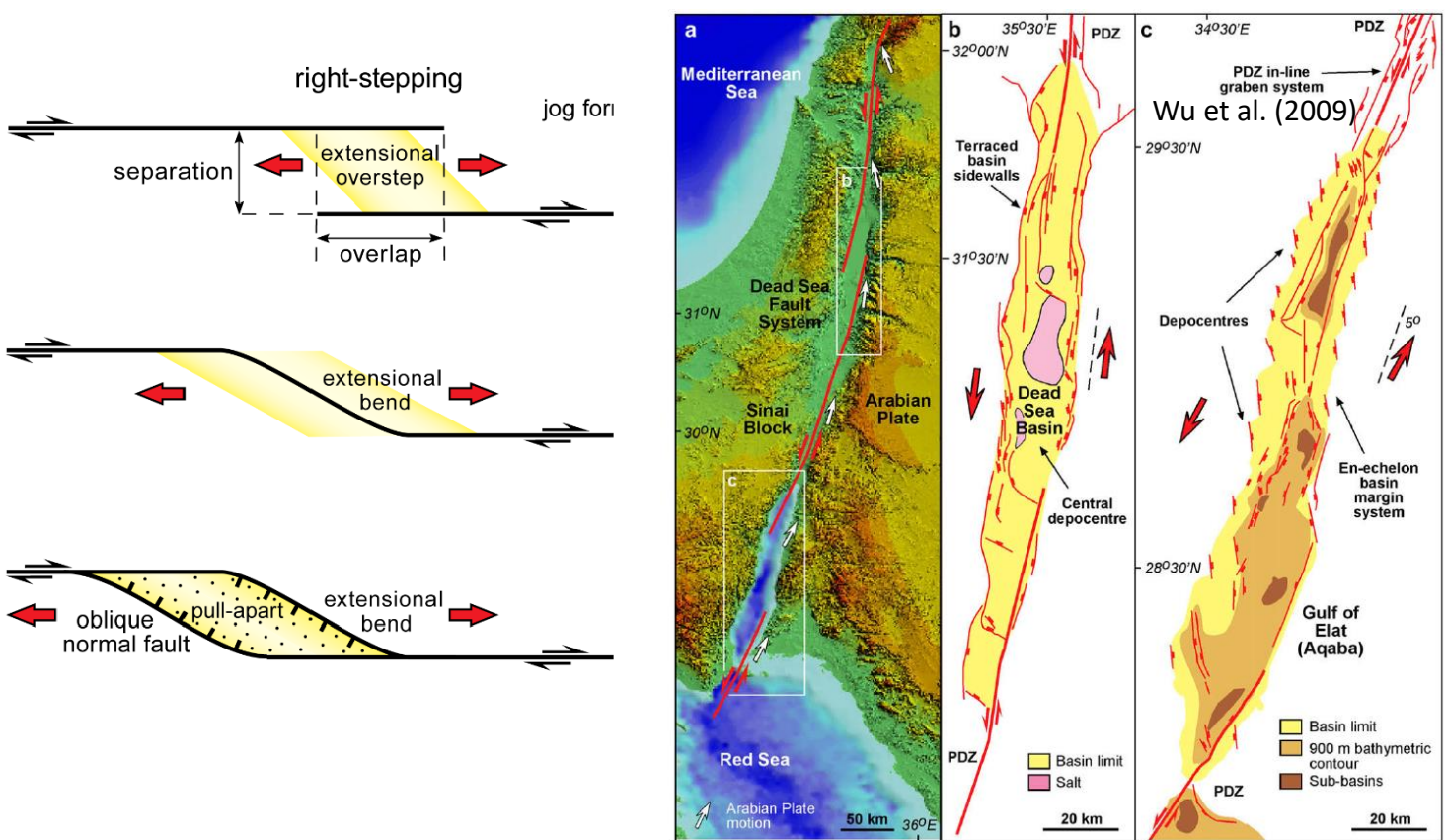


La tectonique gravitaire

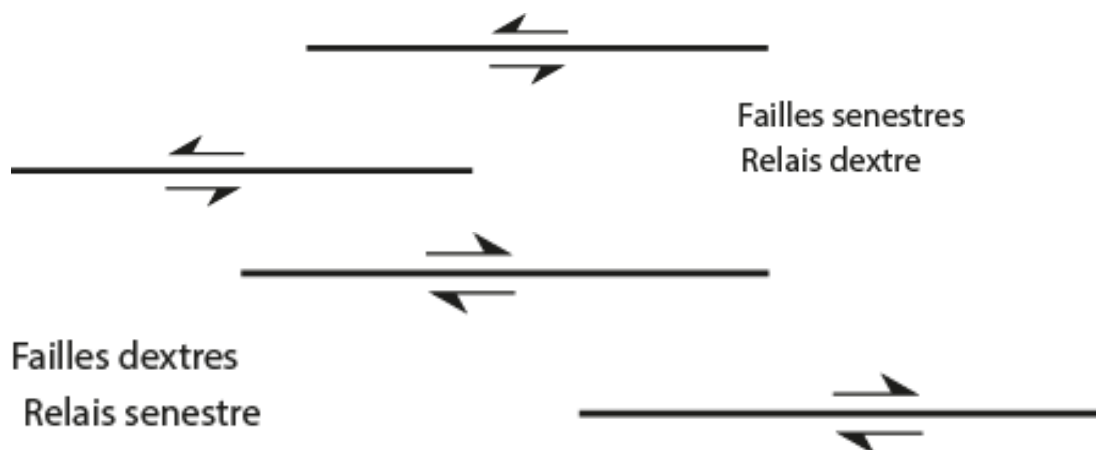


Prise de notes :

Zone de relais entre deux failles décrochantes : bassin pull-apart



Exercice : interpréter les zones de relais ci-dessous. Dessiner en rouge les failles de relais (avec légende) et hachurer les zones qui s'effondrent.



Prise de notes :

Cours 8 : Les systèmes compressifs

Cours 8 : Les systèmes compressifs

I – Rappels

II – Les grands types de failles inverses

Faillle inverse :

Chevauchement :

Décollement/détachement :

Un chevauchement n'est pas nécessairement une nappe de charriage (voir définition plus loin)



III – Les décollements

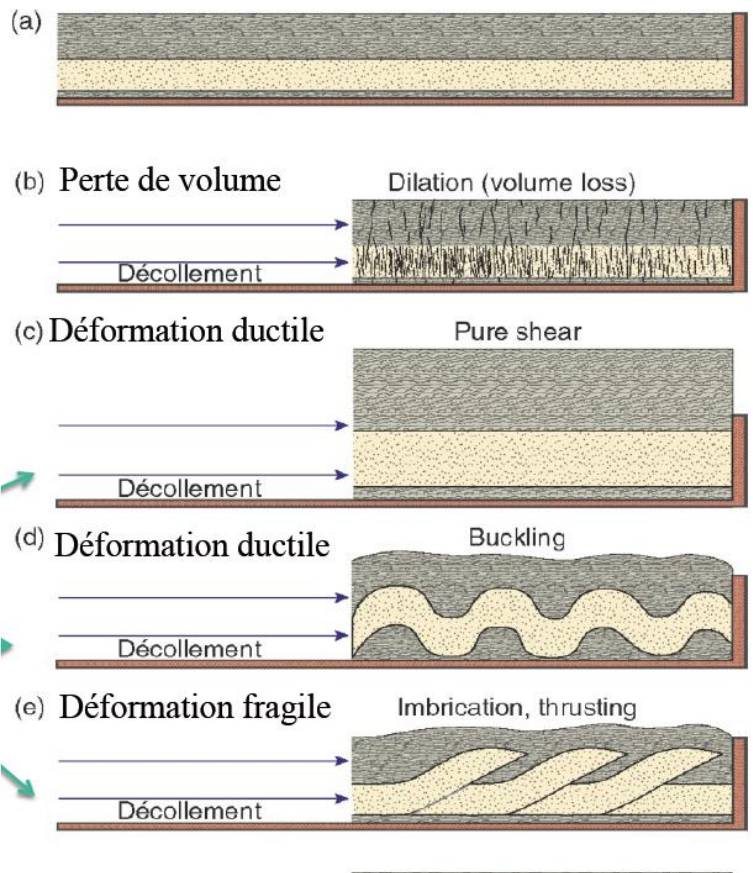


Rôle du gypse du Trias en France

<https://planet-terre.ens-lyon.fr/>



Photographie : Pierre Thomas



Prise de notes :

IV – Rampes, imbrications et duplex

Plats, rampes frontales, obliques et latérales

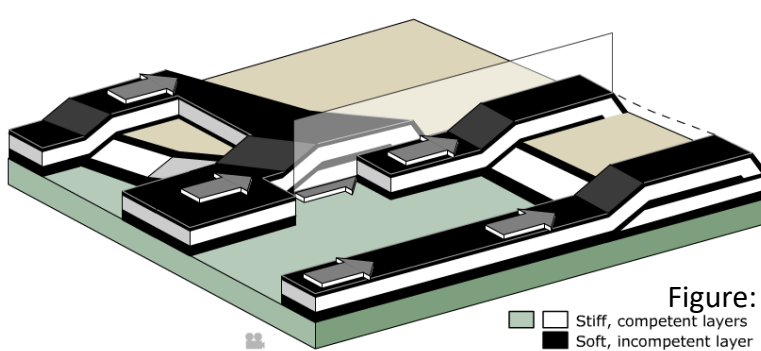
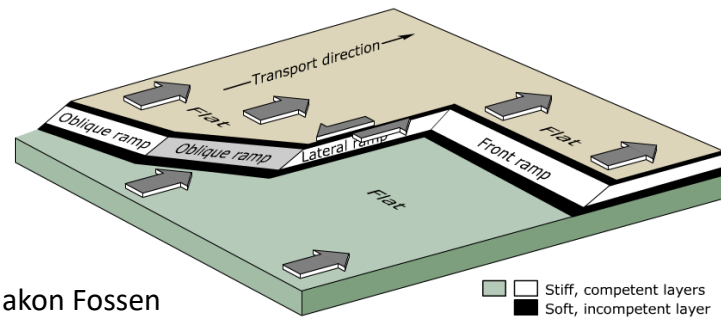


Figure: Haakon Fossen



Les systèmes de chevauchement imbriqués

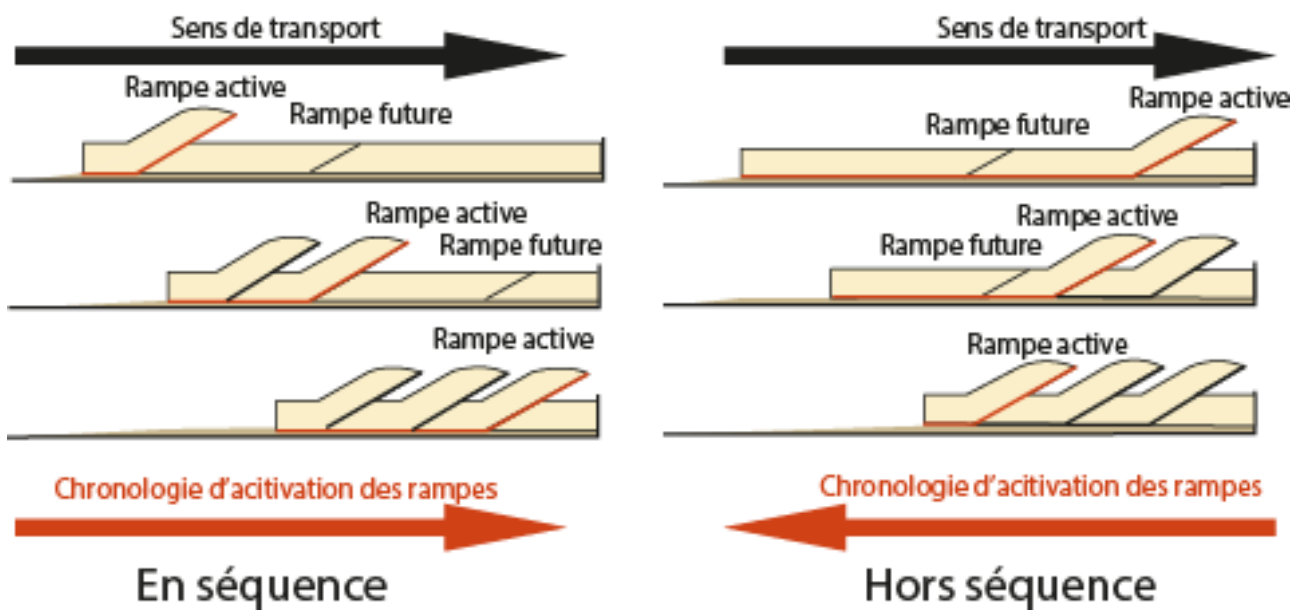


Figure modifiée d'après Haakon Fossen

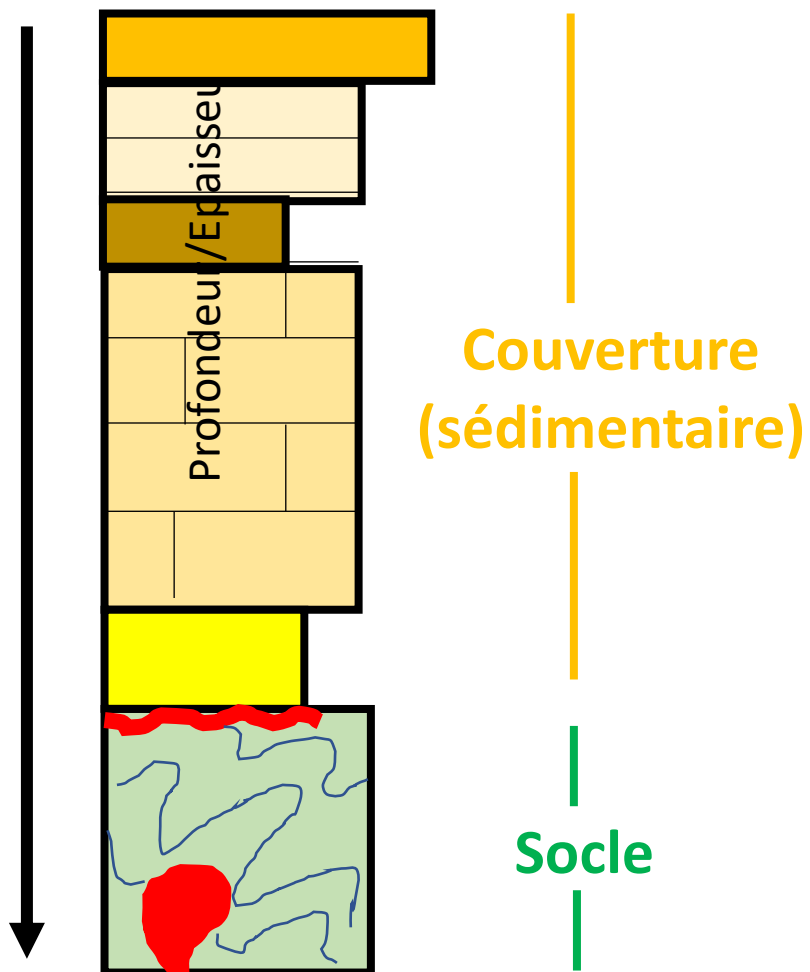


Figure: Haakon Fossen

Duplex :

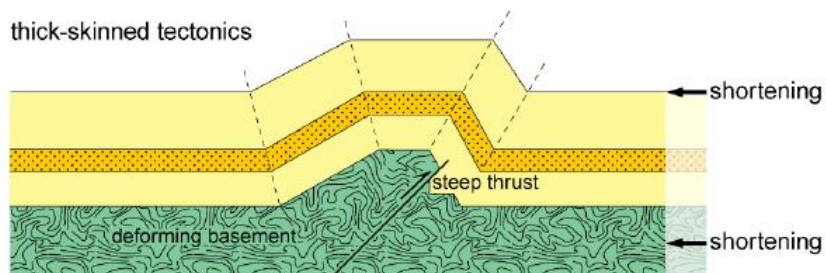
Prise de notes :

V – Socle et couverture

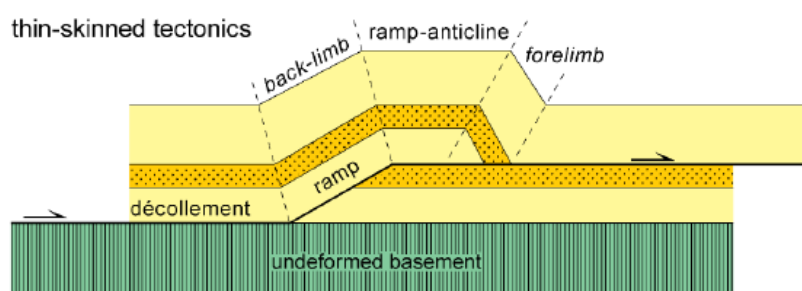


Couverture :

Socle :



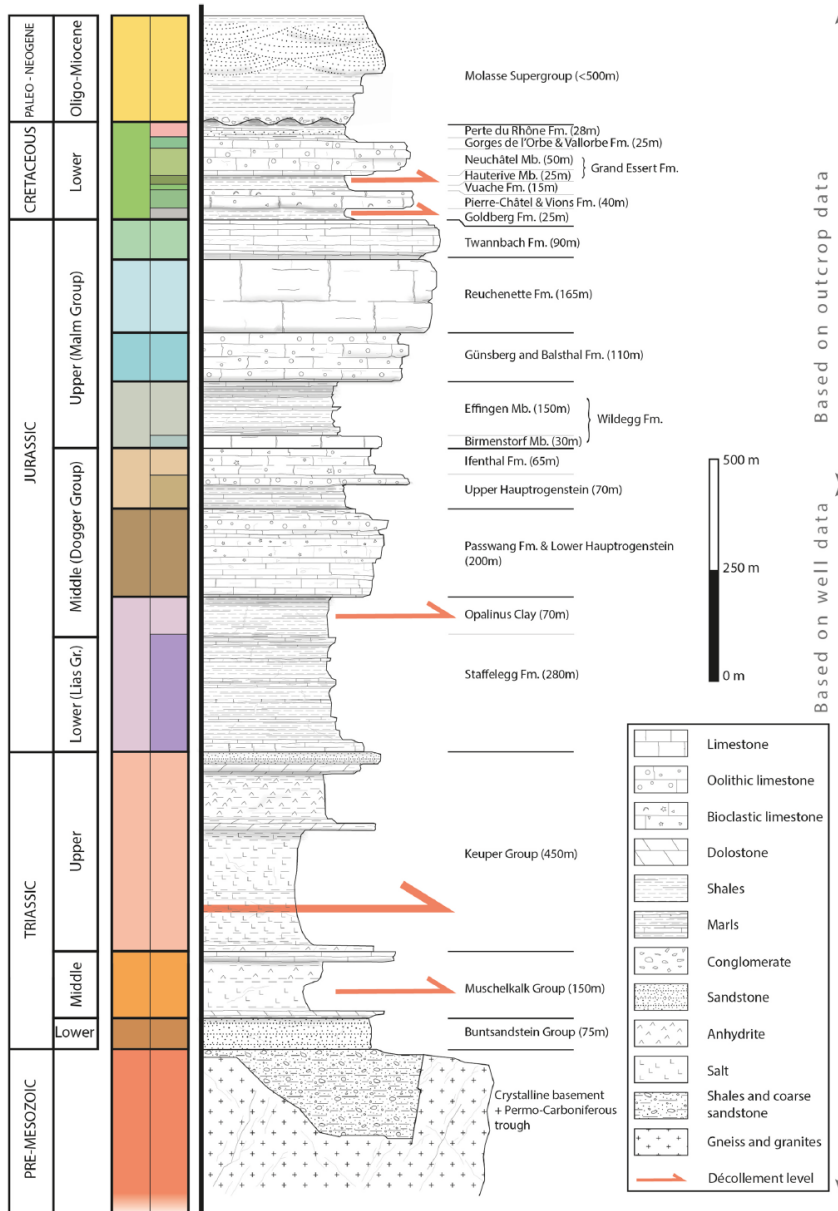
Tectonique de socle (thick skin) :



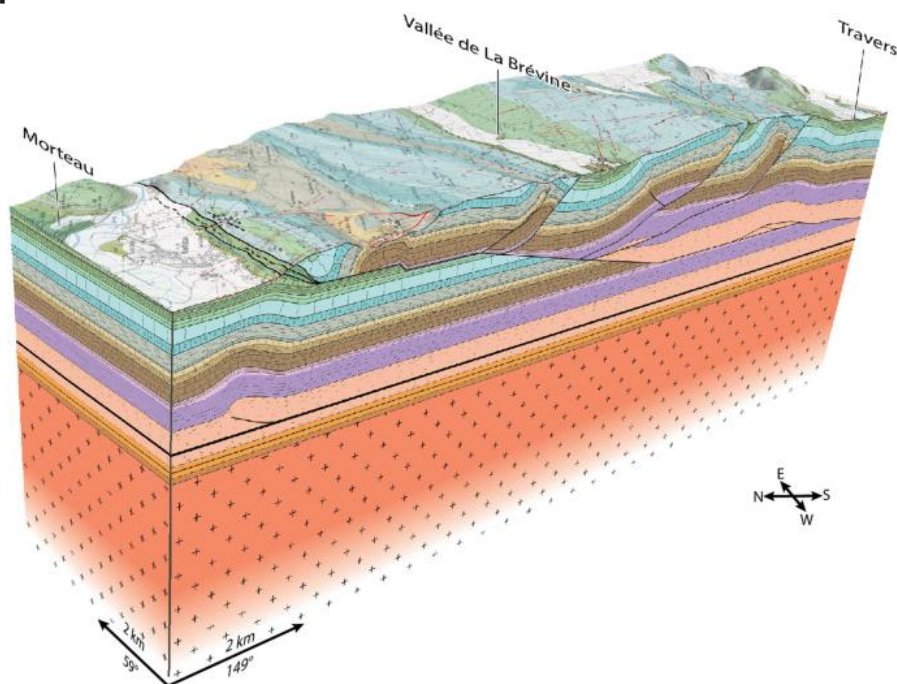
Tectonique de couverture (thin skin) :

Prise de notes :

Exemple du Jura

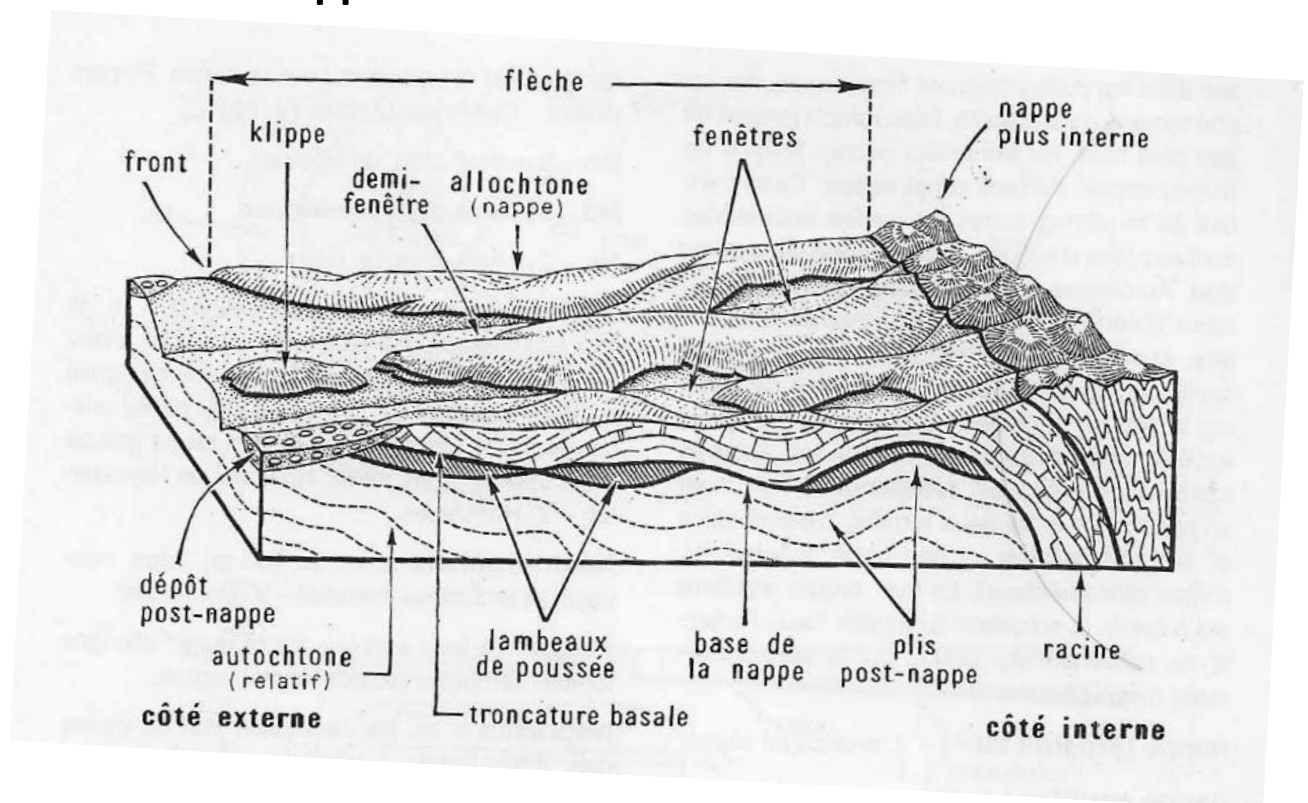


Rime et al. (2019)



Prise de notes :

VI – Les nappes



Source: Dictionnaire de géologie (Foucault et Raoult)

Nappe (de charriage) :

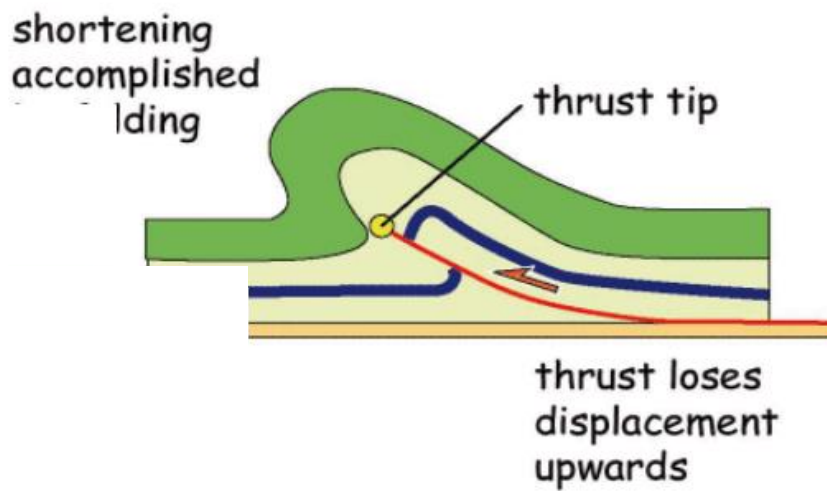
Les fenêtres :

Les klippes :

Prise de notes :

VII – Les plis sur faille

Pli par propagation de faille



Pli sur faille coudée

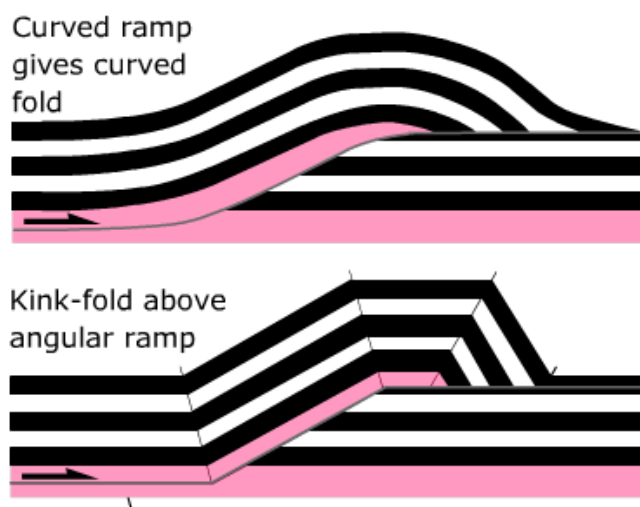


Figure Haakon Fossen

Pli de détachement

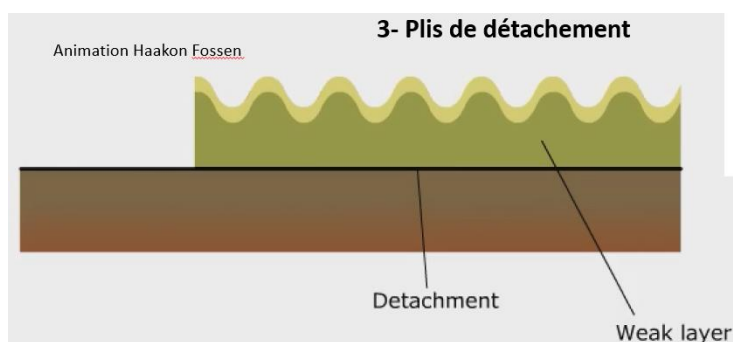
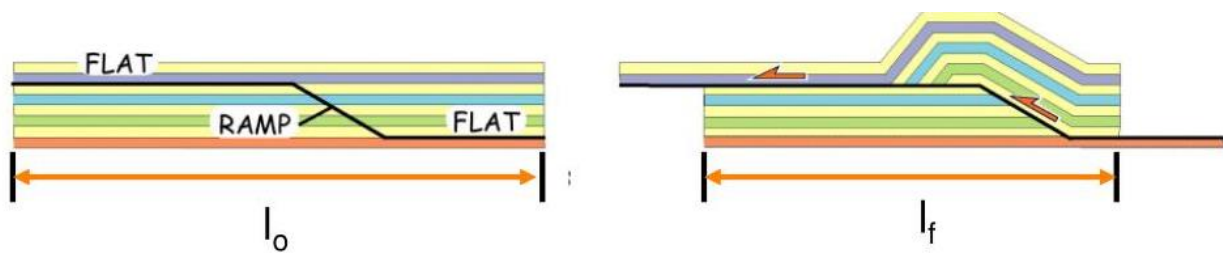


Figure Haakon Fossen

Prise de notes :

VIII – Quantification de la compression



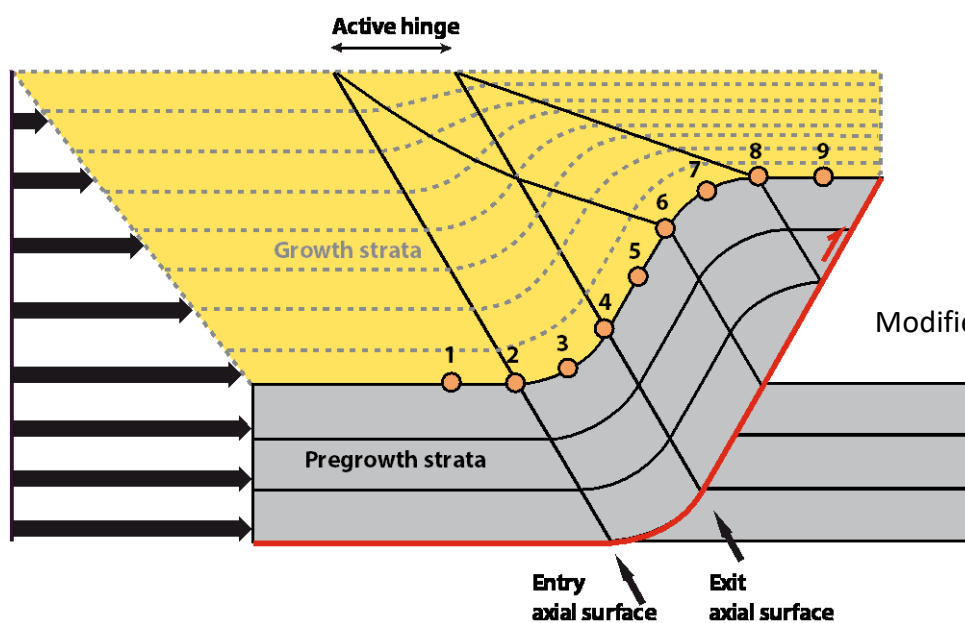
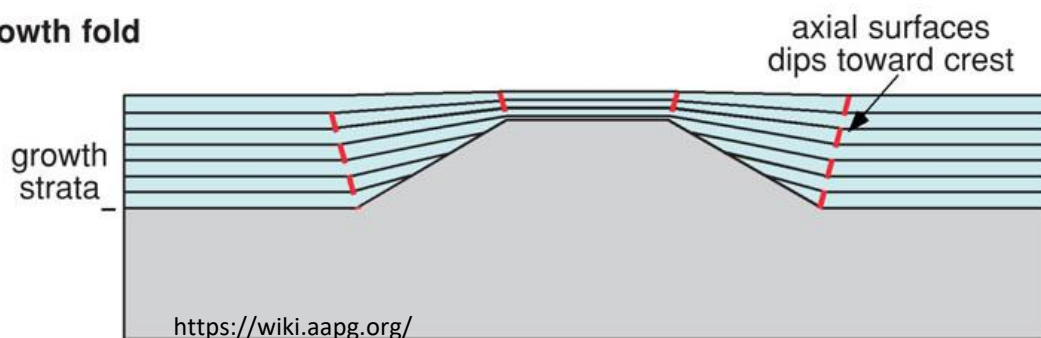
Raccourcissement :

R =

IX – La sédimentation associée

Strates de croissance (growth strata)

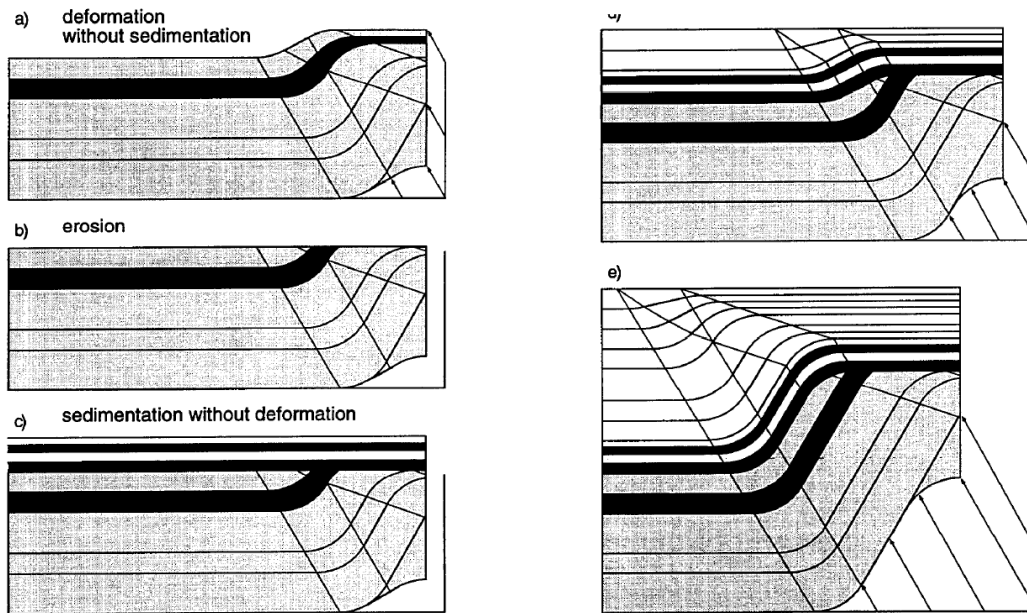
Growth fold



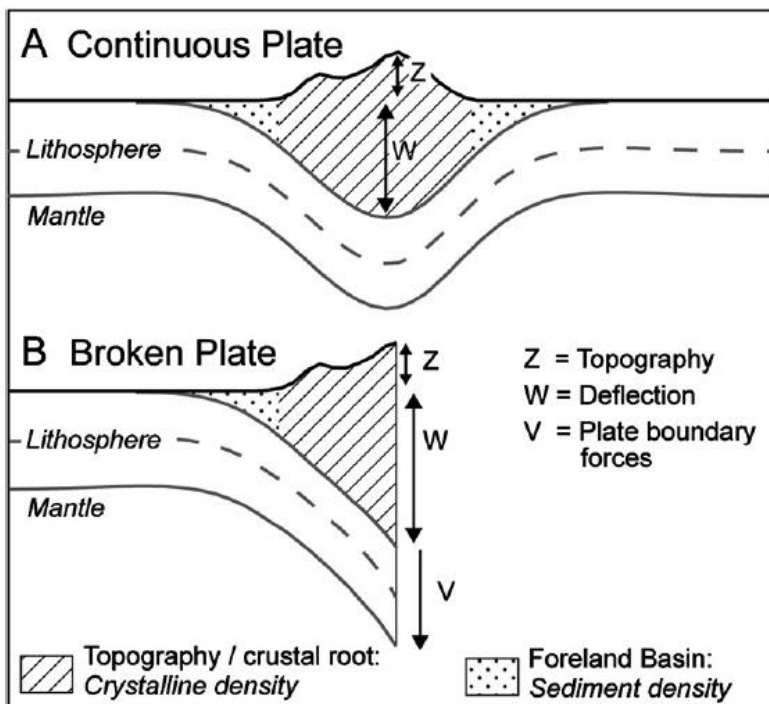
Modifié d'après Suppe, 1997

Prise de notes :

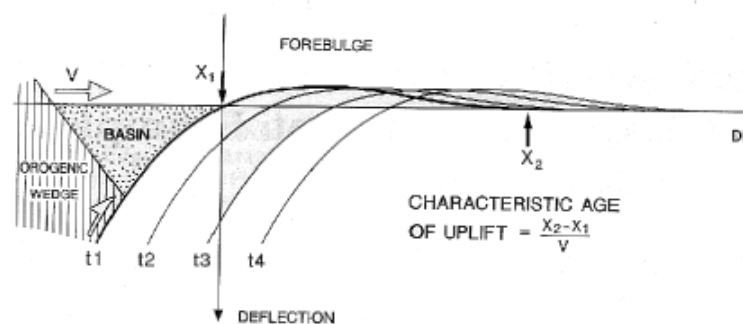
Exemple des plis de Sant Llorenç (Pyrénées, Espagne)



Bassin d'avant pays/basin flexural/foreland basin



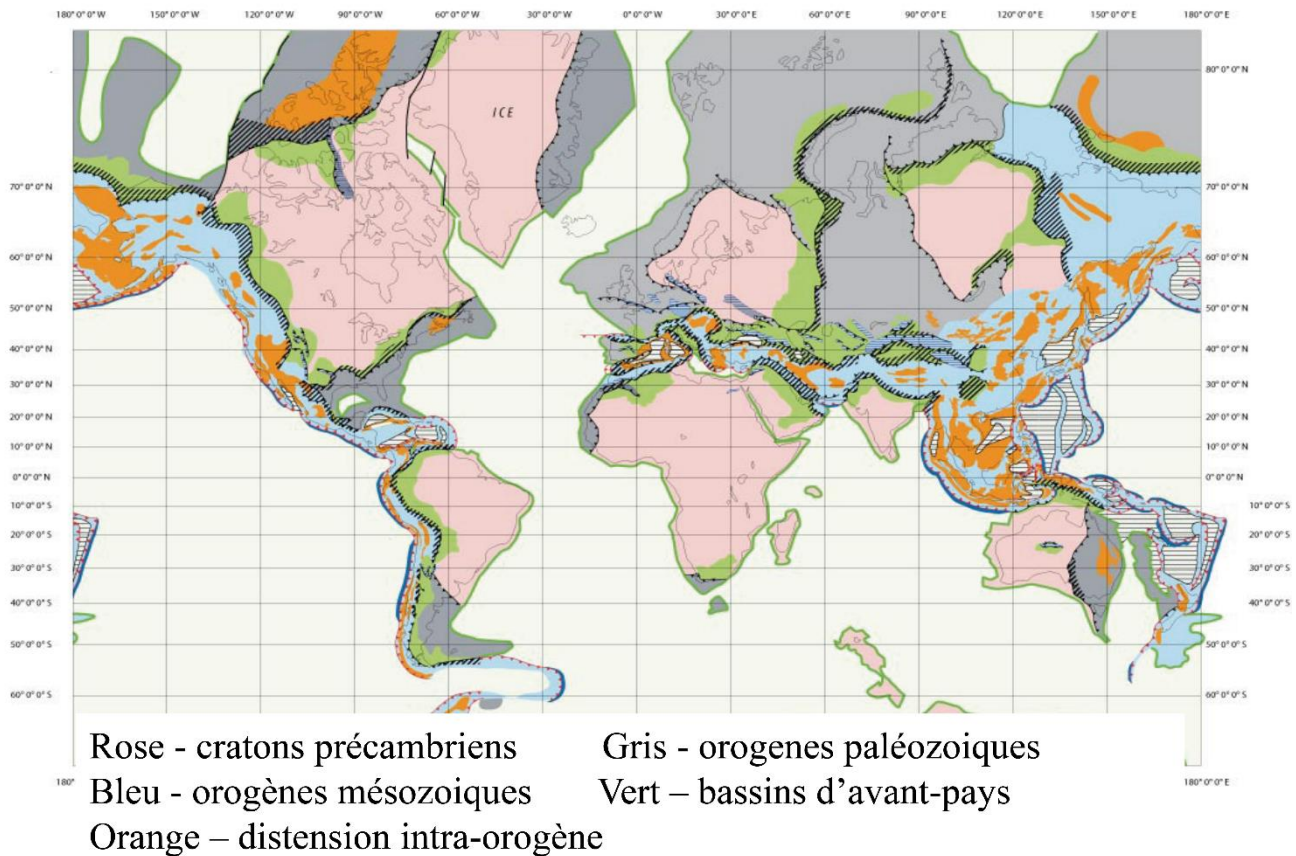
Molasse :



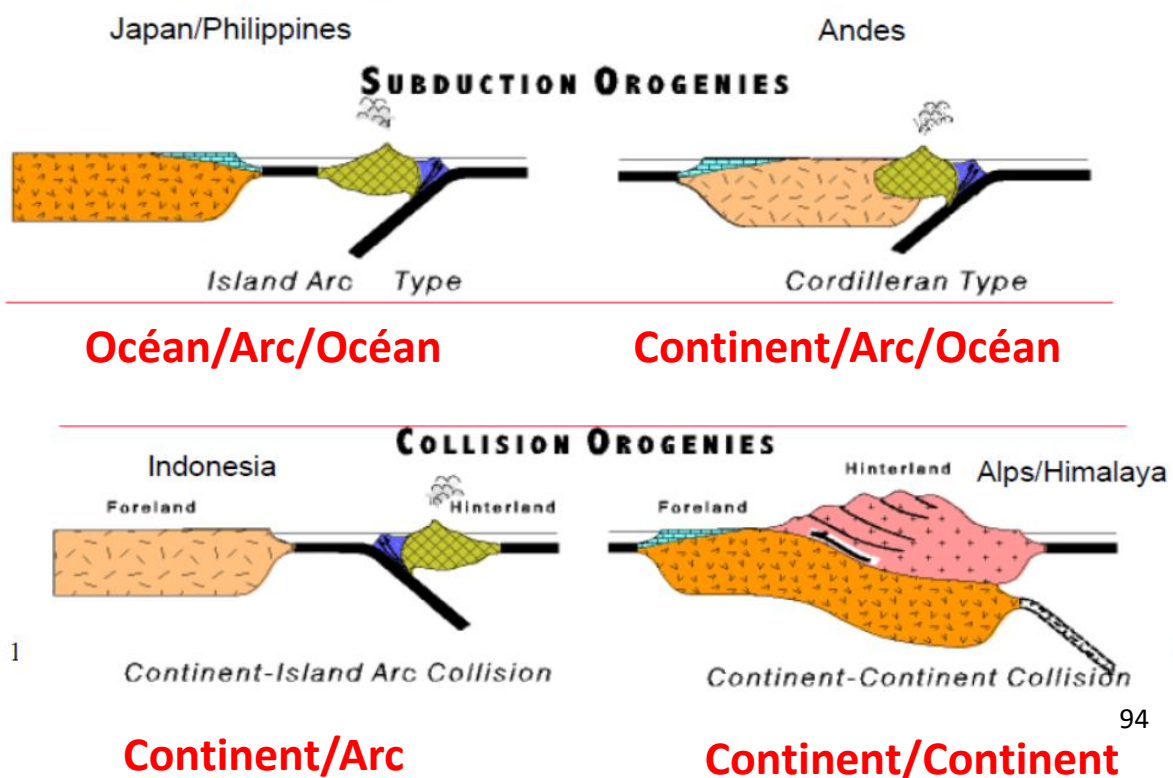
Prise de notes :

IX – Origine et distribution des failles inverses

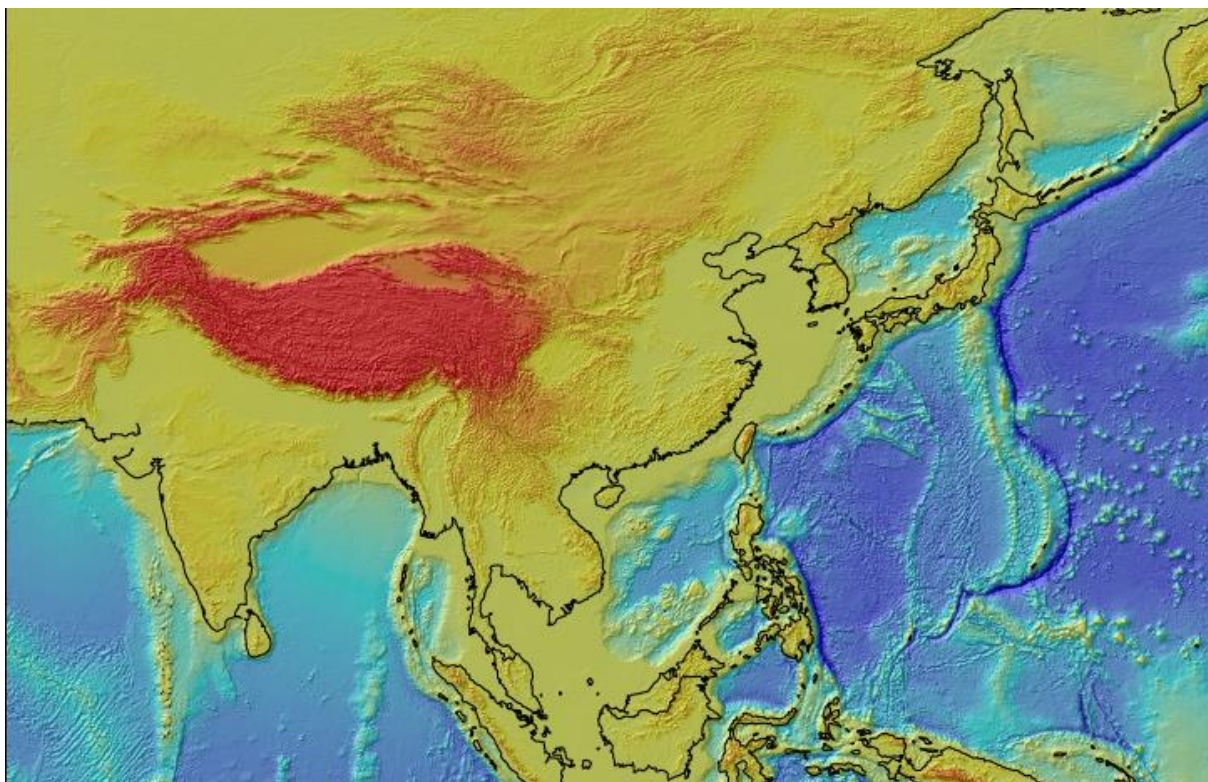
Distribution des zones de convergence



Les grands types de zones de convergence

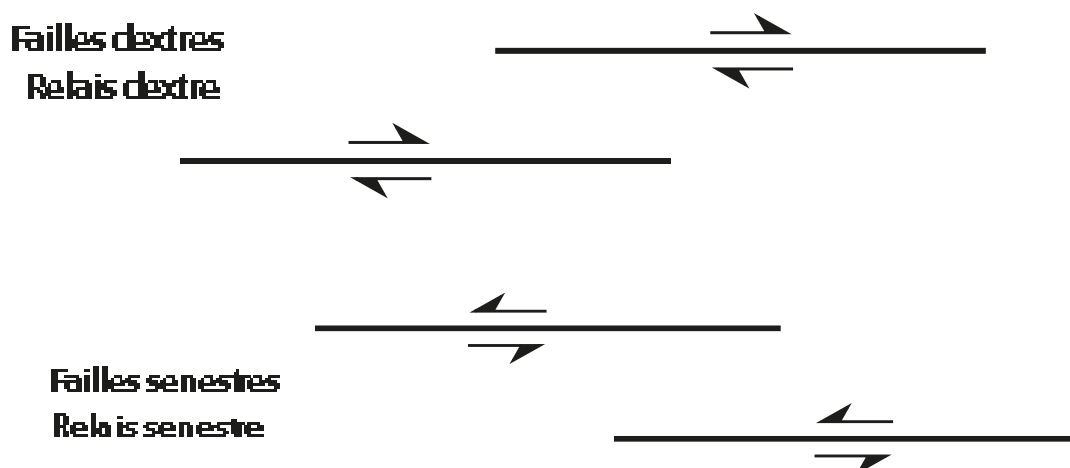


Prise de notes :

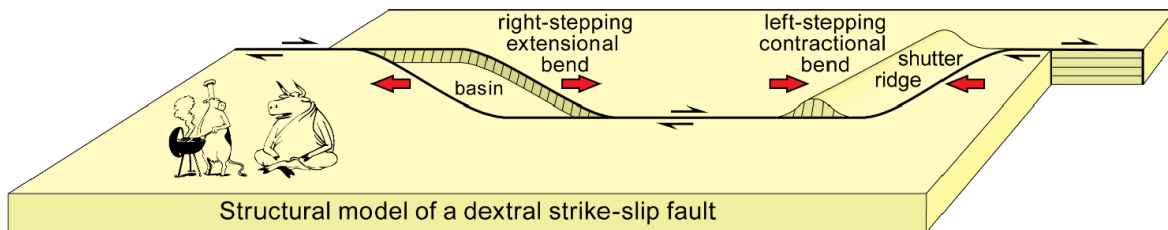


Les zones de relais : push-up

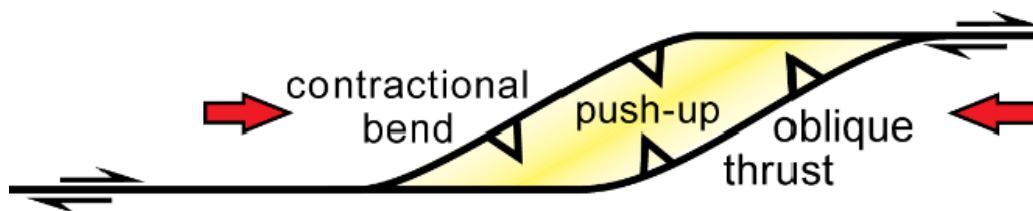
Exercice: déterminer la nature de la zone de relais et tracer les failles transverses aux décrochement avec une légende appropriée. Indiquer les zones qui se soulèvent ou subsidient



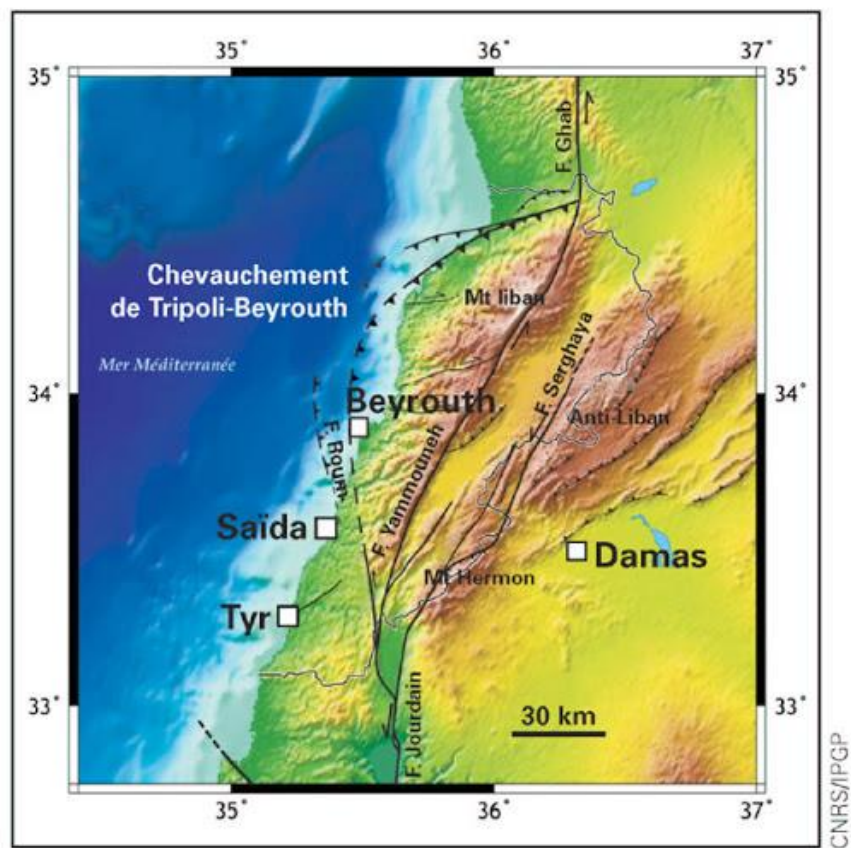
Prise de notes :



Figures: JP Brun (Univ Rennes)



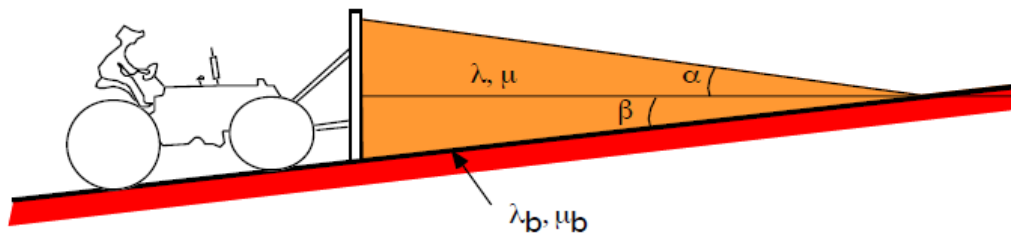
Exemple de la faille du Levant et de la chaîne du Liban



Prise de notes :

La notion de prisme d'accrétion et critique

Prisme d'accrétion :



$$\alpha + \beta = \mu_b \left(\frac{1 - \sin \phi}{1 + \sin \phi} \right)$$

Davis et al. 1983

Dahlen 1990

α = Topographic slope of wedge

β = Dip of basal detachment

μ_b = coefficient of friction of basal detachment

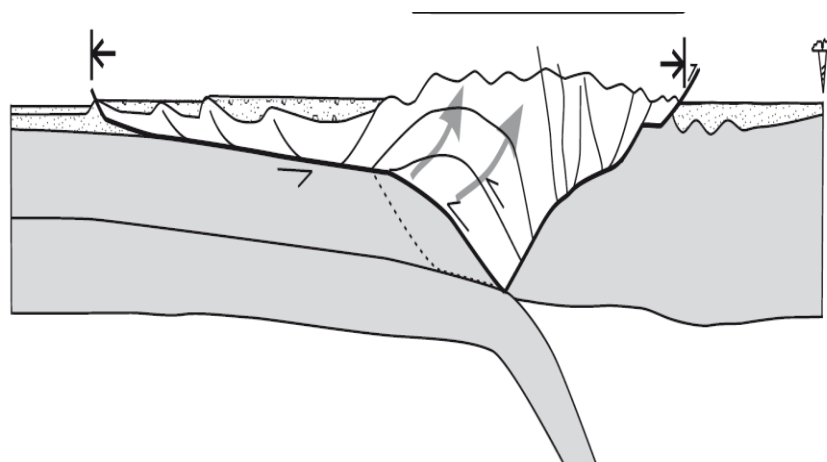
μ = coefficient of friction of wedge (Tan $\phi = \mu$)

ϕ = angle of internal friction of wedge

ϕ_b = angle of internal friction of basal detachment

Anatomie et exemple de chaînes de collision

Sinclair et al. (2005)



Prise de notes :

Prise de notes :

Exemple de l'Himalaya

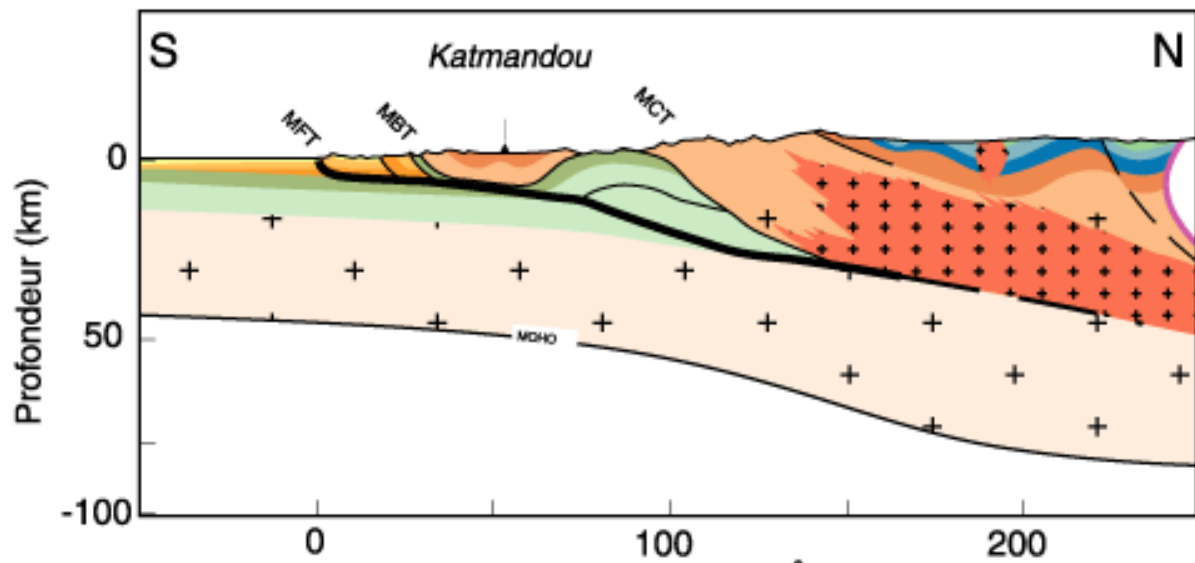
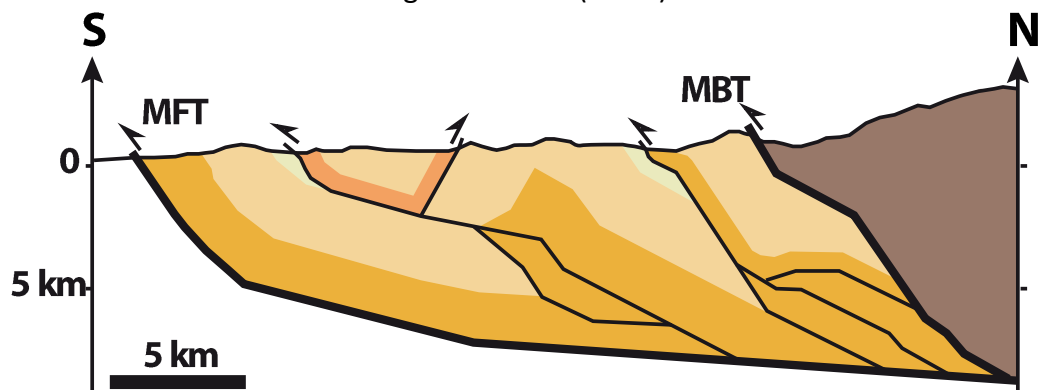
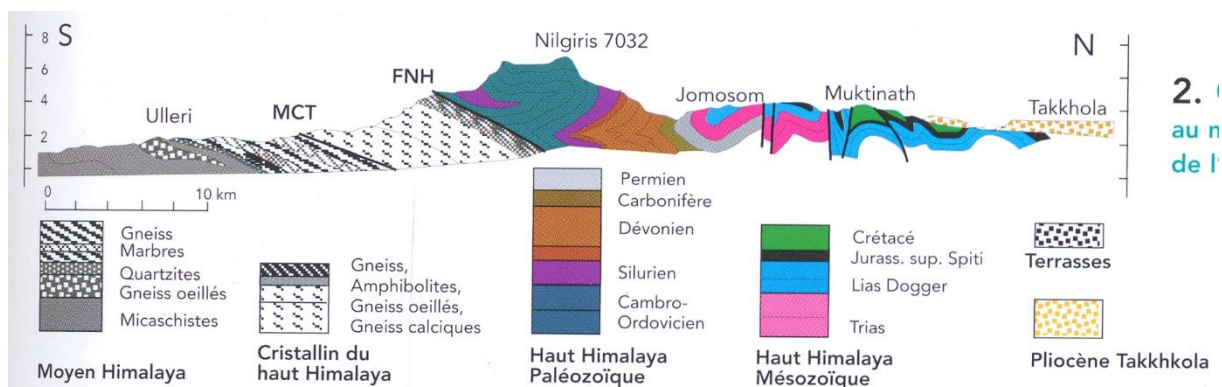


Figure : J. Lavé (CRPG)



Coupe dans l'avant pays, d'après Mugnier et al.



Coupe de la Takkhola (livre le Choc des Continents)

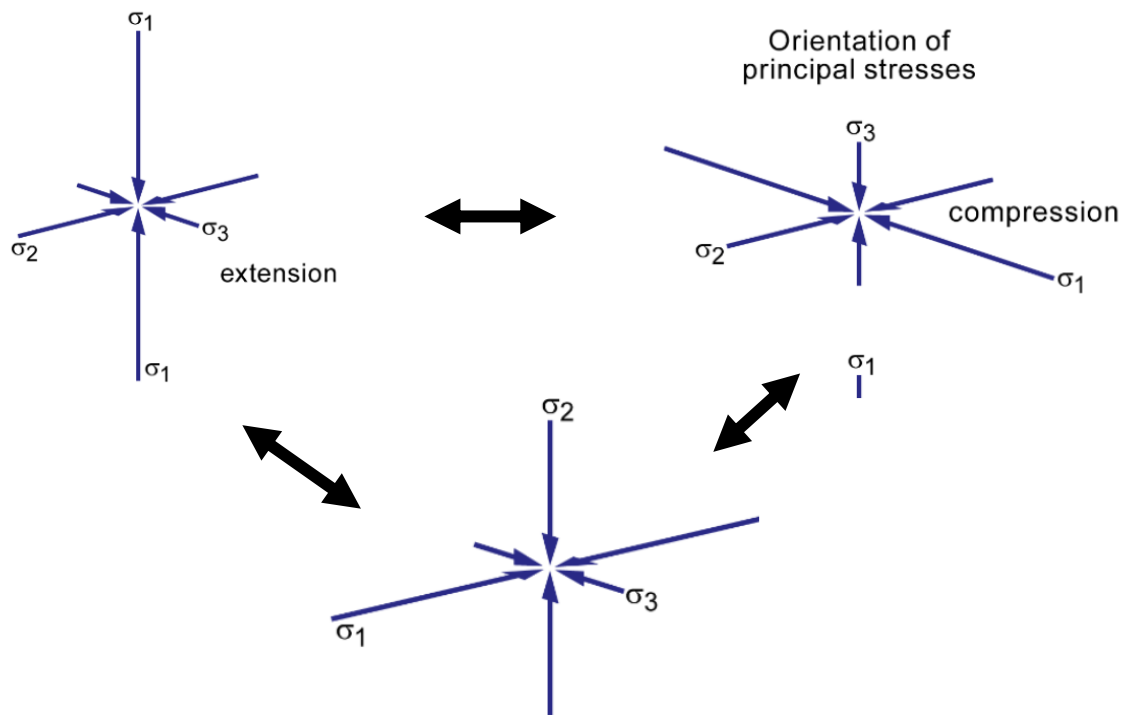
Prise de notes :

Cours 9 : Les systèmes décrochants

Cours 9 : Les systèmes décrochants

I-Rappels et remarque sur l'état de contrainte

Exercice : quelles contraintes doivent être interverties pour passer d'un des 3 états de contraintes à un autre ?



II-Les types de failles décrochantes

Senestre vs dextre

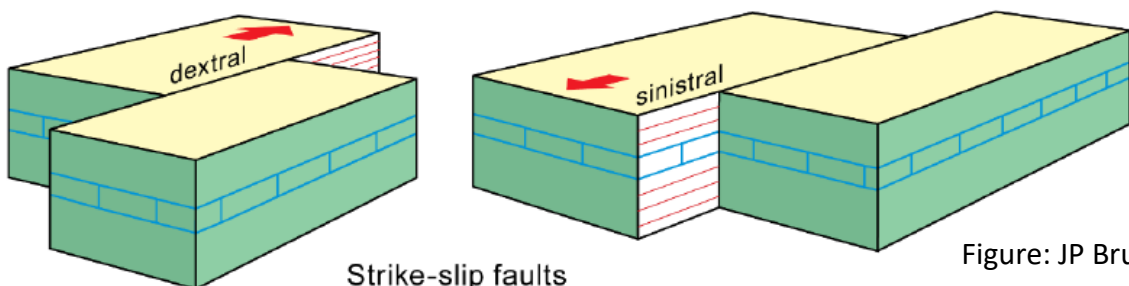
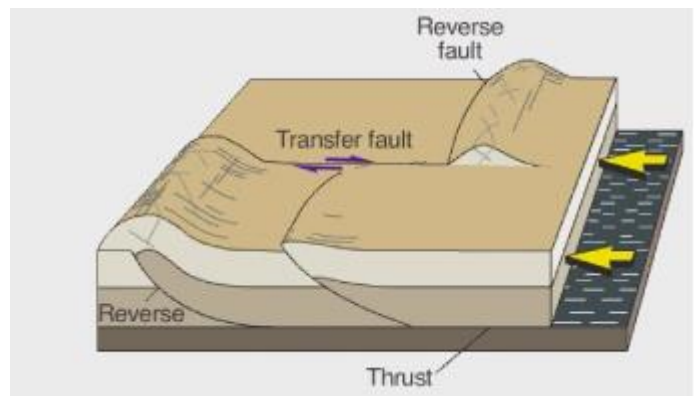
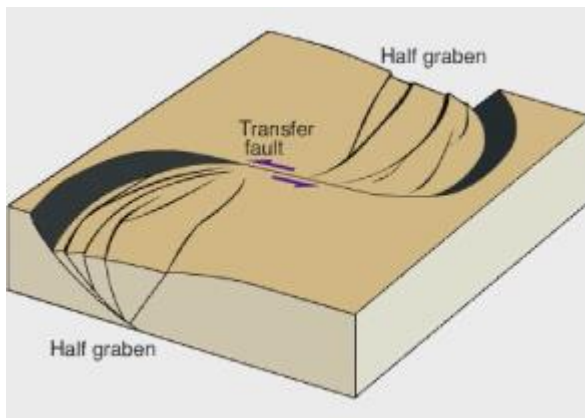


Figure: JP Brun

Prise de notes :

Failles de transfert

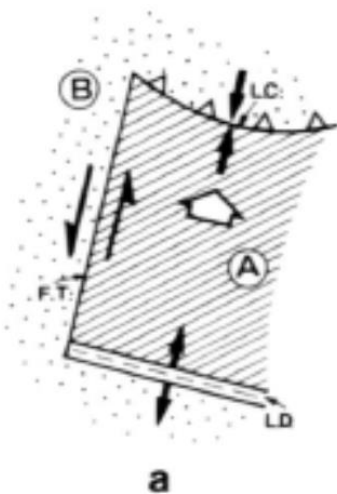


Failles transformantes

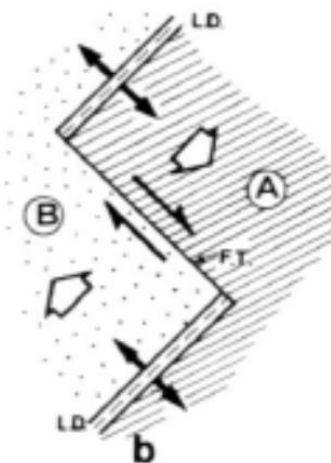
Failles transformantes :

Propriétés des failles transformantes :

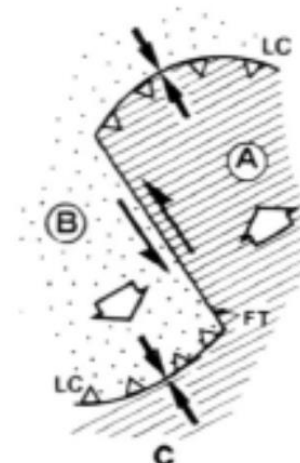
Fosse-Ride



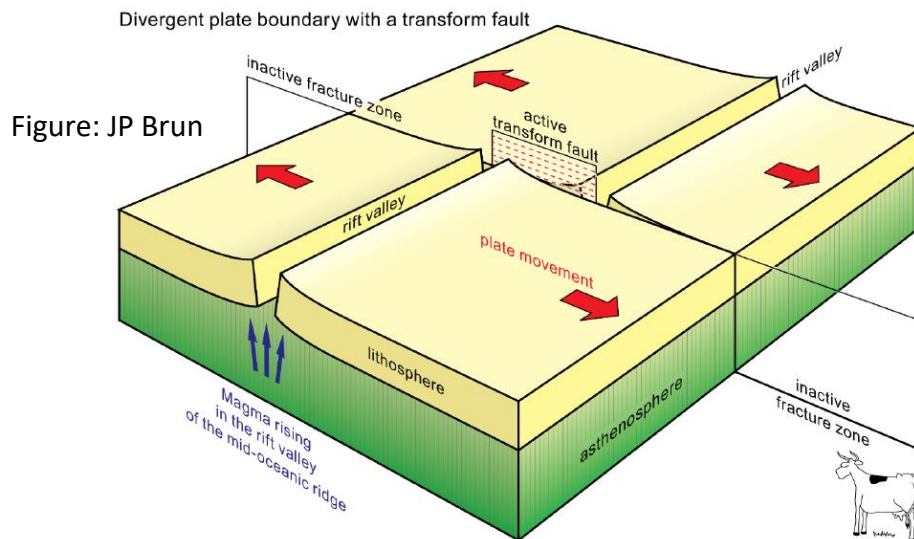
Ride-Ride



Fosse-Fosse



Prise de notes :



III-Les structures en fleur

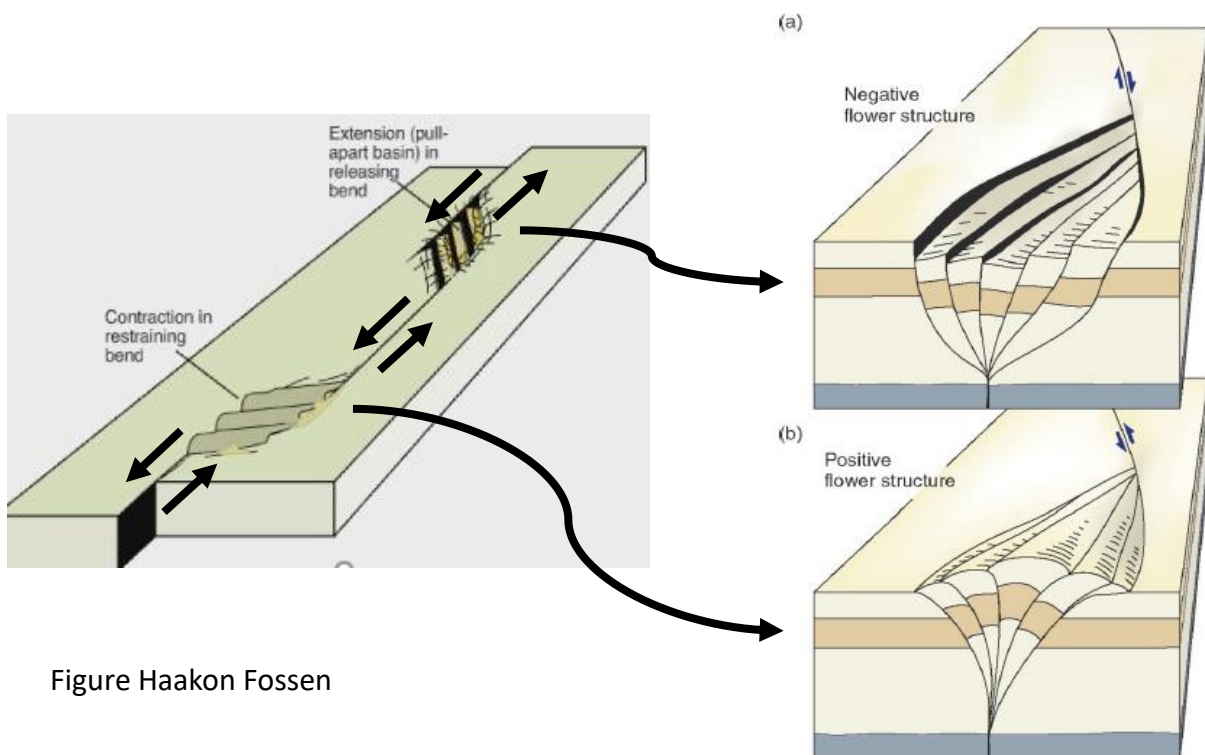
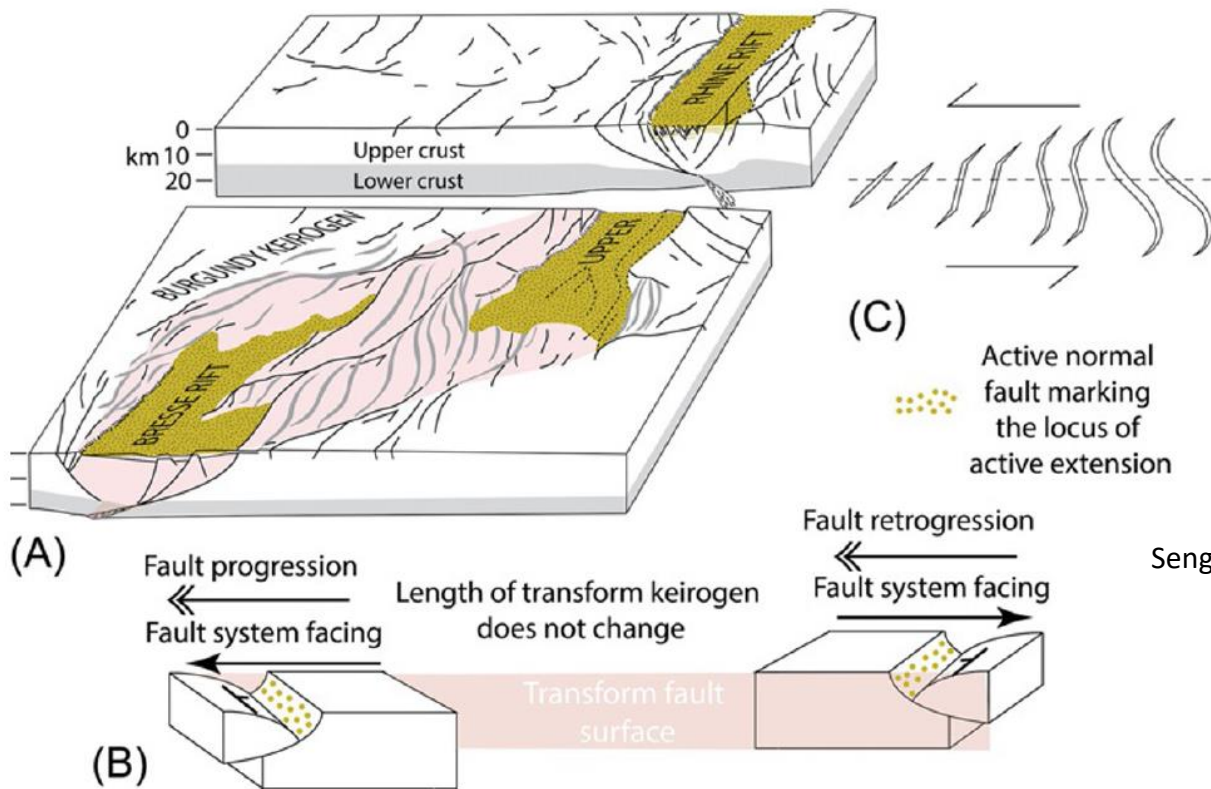


Figure Haakon Fossen

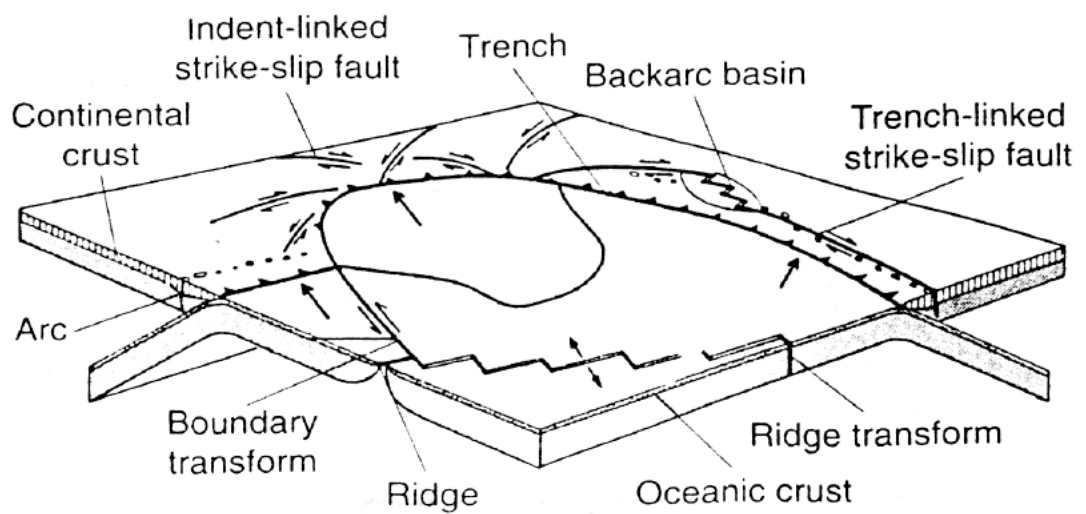
Prise de notes :

III-Origines et distributions des failles décrochantes

Systèmes compressifs/distensifs

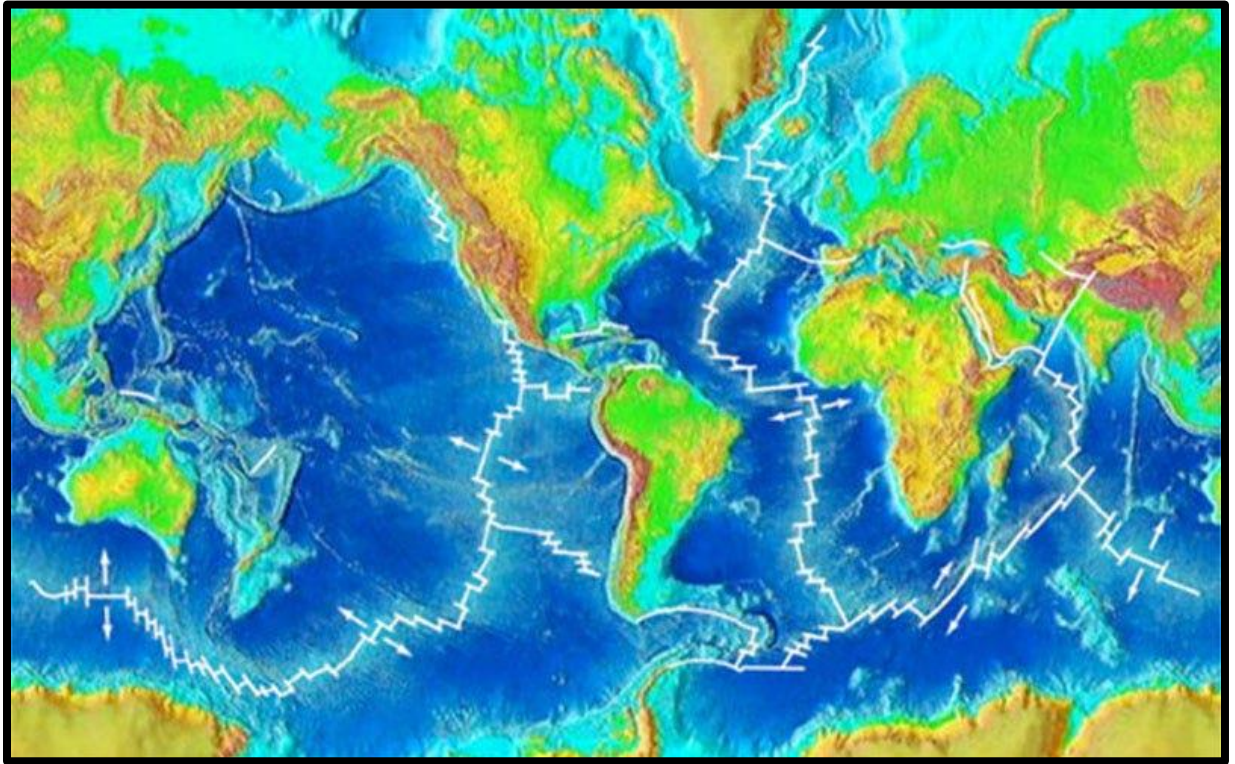


Les autres grands contextes géodynamiques

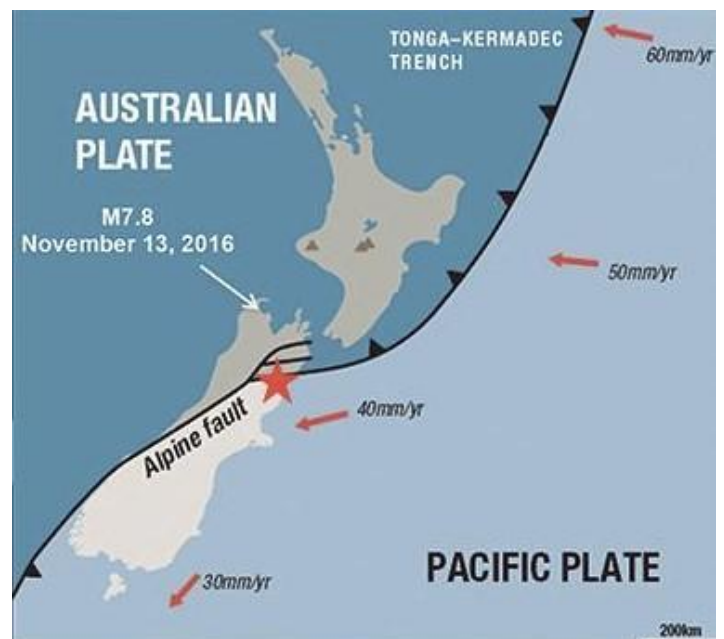
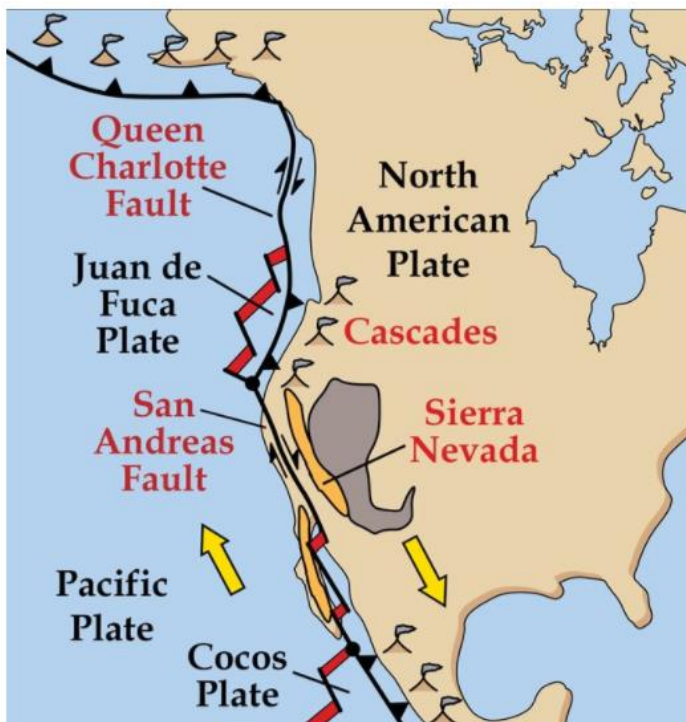


Prise de notes :

Les failles transformantes médio-océaniques



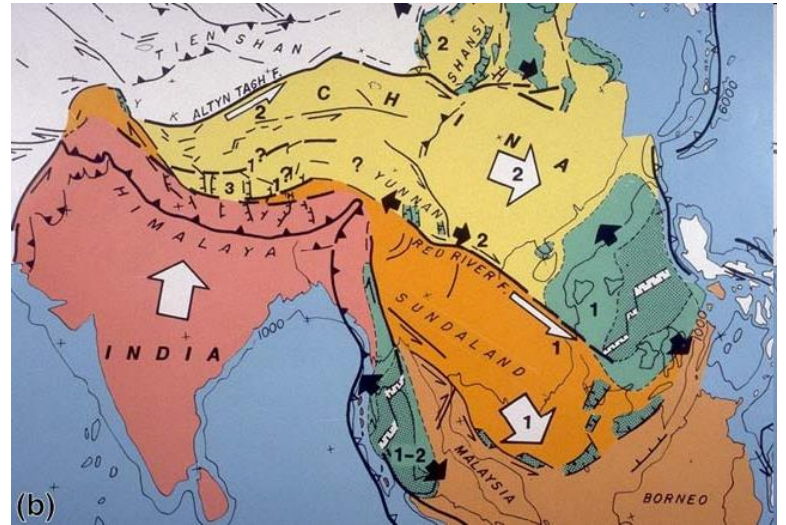
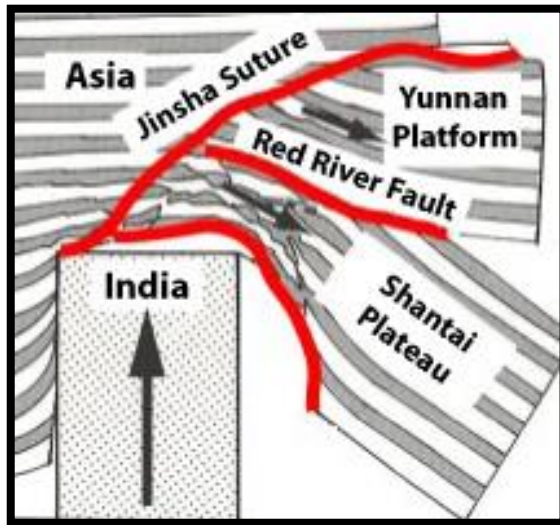
Les failles transformantes continentales



Exercice : déterminer le sens de mouvement de la faille Alpine en Nouvelle Zélande

Prise de notes :

Les zones d'indentation continentale

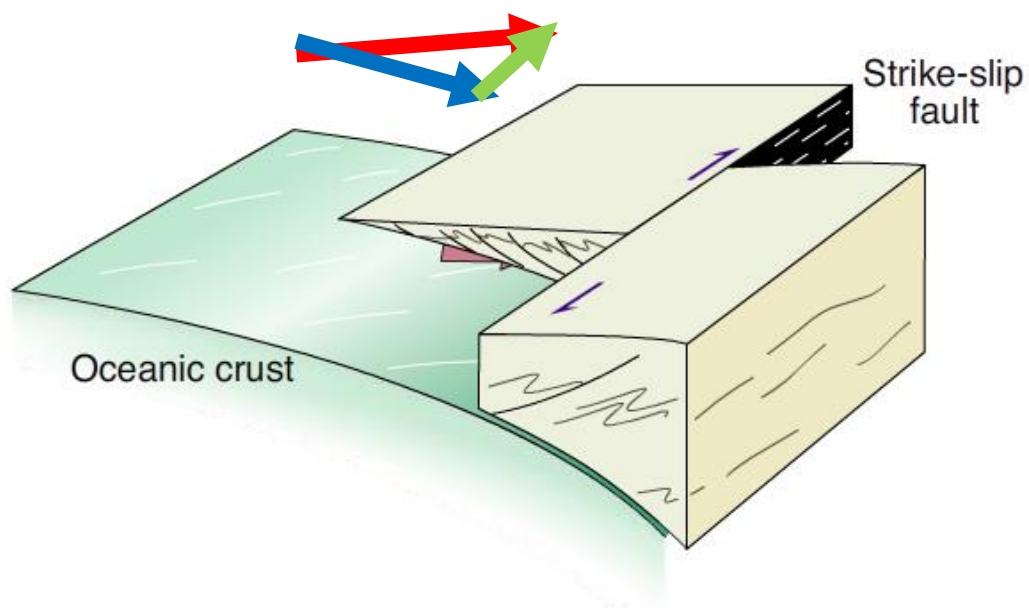


Tapponnier et al. (1986)

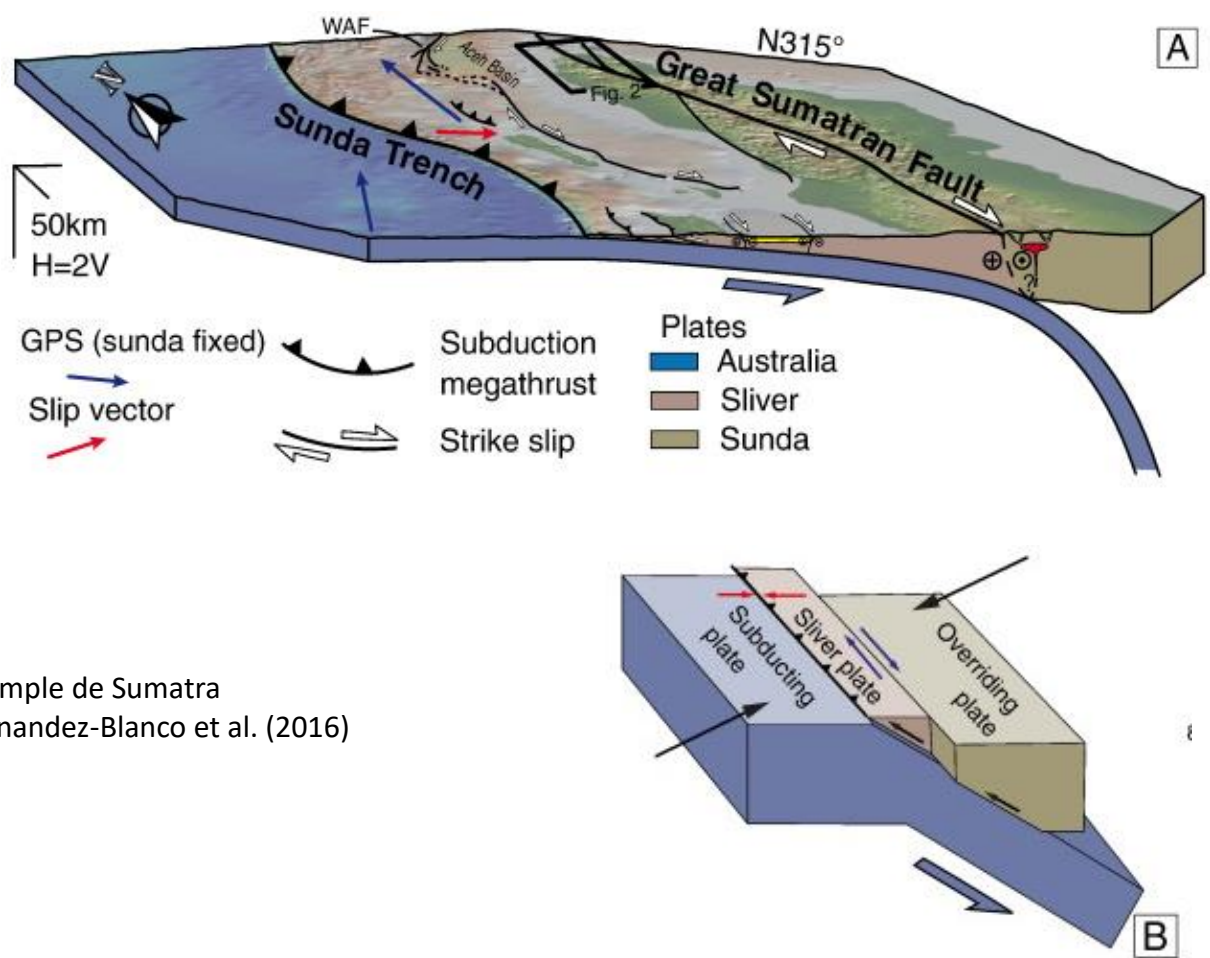
Les zones de convergence oblique

Notion de transpression/transtention :

Notion de partitionnement :



Prise de notes :



Exemple de Sumatra
Fernandez-Blanco et al. (2016)

Prise de notes :

