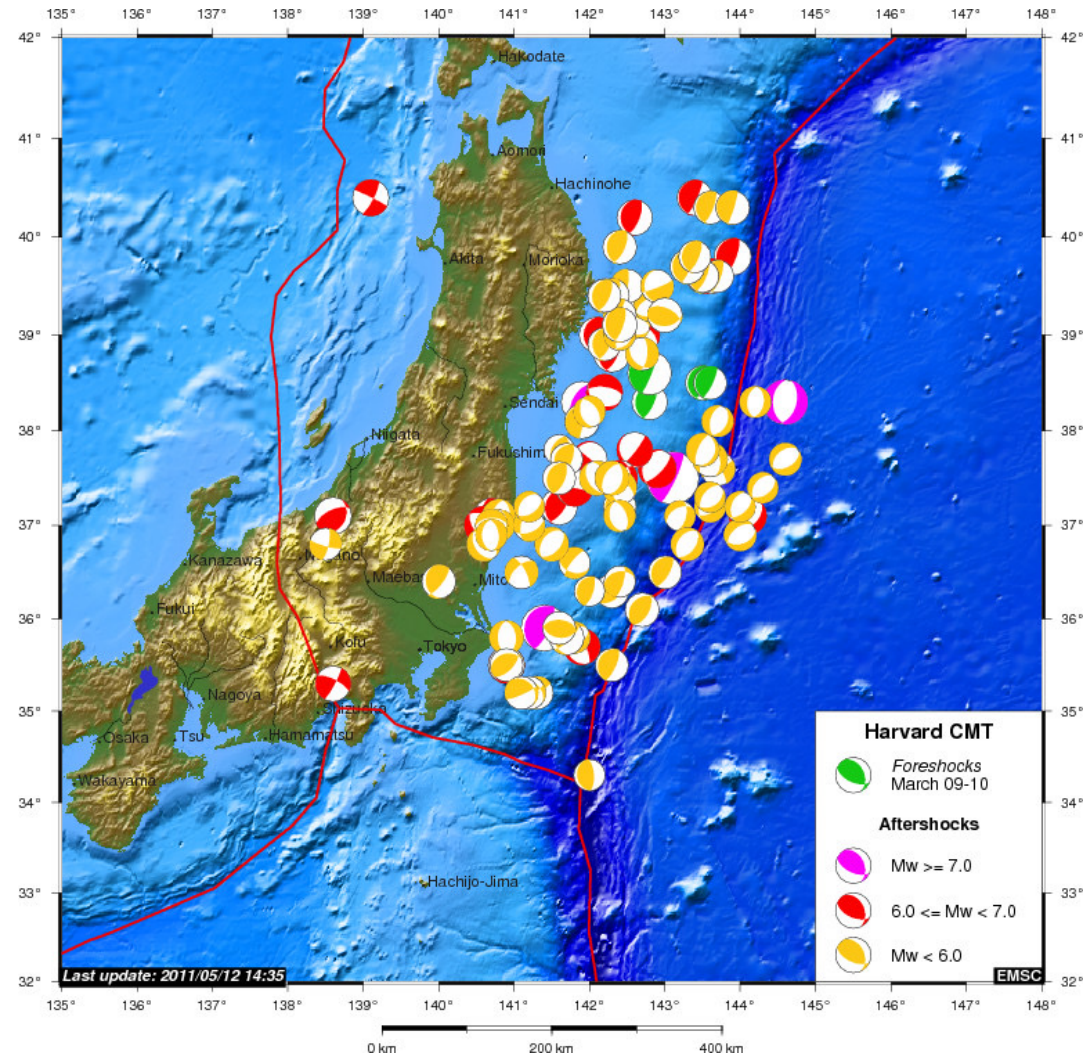


MÉCANISMES AU FOYER



Sophie Peyrat

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um2

CNRS
CENTRE NATIONAL
DE RECHERCHES
SCIENTIFIQUES

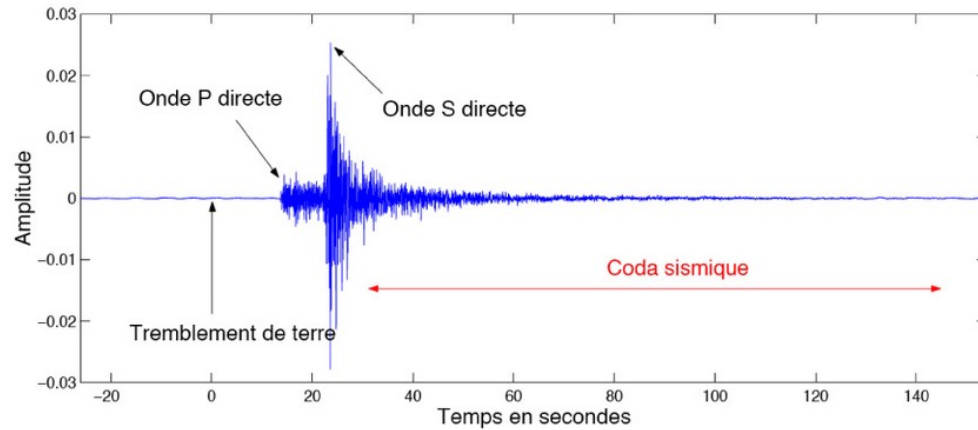
Géosciences
Montpellier

Objectifs & Notions à acquérir

- Définition d'un mécanisme au foyer
- Les 3 types de mécanisme au foyer
- Construire un mécanisme au foyer
- Notion de plan nodal, de faille, auxiliaire
- Glissement, pendage, azimuth (strike, dip, rake)
- Notion de double couple
- Savoir relier mécanisme au foyer et géodynamique d'une région



ONDES RADIÉES AUX STATIONS



Temps d'arrivées et amplitudes →

Localisation et magnitude du séisme

Amplitudes et "formes" des ondes radiées:

- Géométrie de la faille
- Direction et taille du glissement

Mécanisme au foyer

- > TECTONIQUE DE LA RÉGION
- > CONTEXTE GÉODYNAMIQUE

Les paramètres de la faille sont:
 ϕ Azimut (strike)
 δ Pendage (dip)
 λ Direction du glissement (rake)

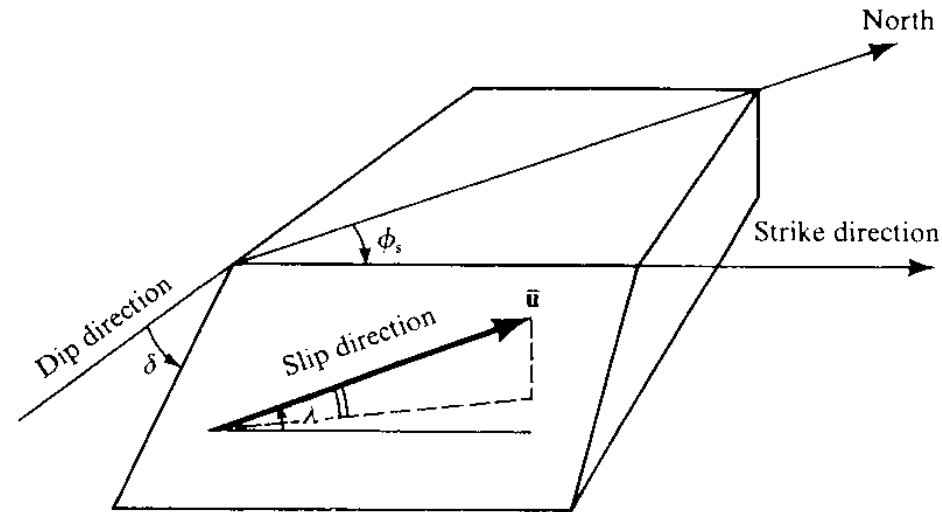
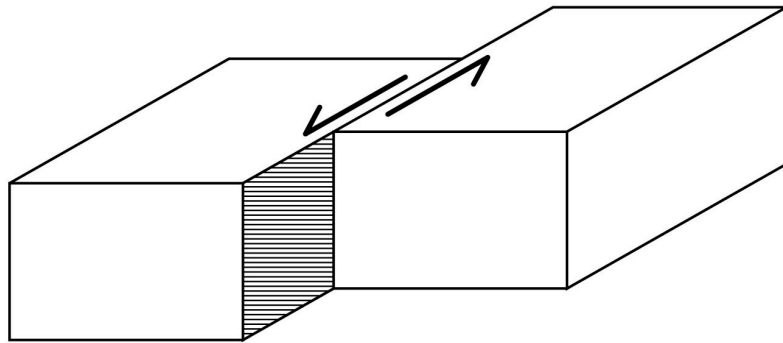


FIGURE 4.13

Definition of the fault-orientation parameters (strike ϕ_s , dip δ) and the slip-direction parameter (rake λ). ϕ_s is measured clockwise round from North, with the fault dipping down to the right of the strike direction: $0 \leq \phi_s < 2\pi$. The dip angle δ is measured down from the horizontal: $0 \leq \delta \leq \pi/2$. The slip direction is specified by the rake λ , measured in the fault plane as the angle between the directions of strike and slip.

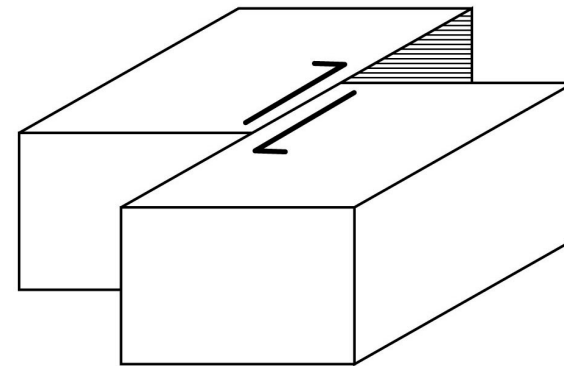
Convention de Aki and Richards

Angle du glissement λ caractérise le type de faille



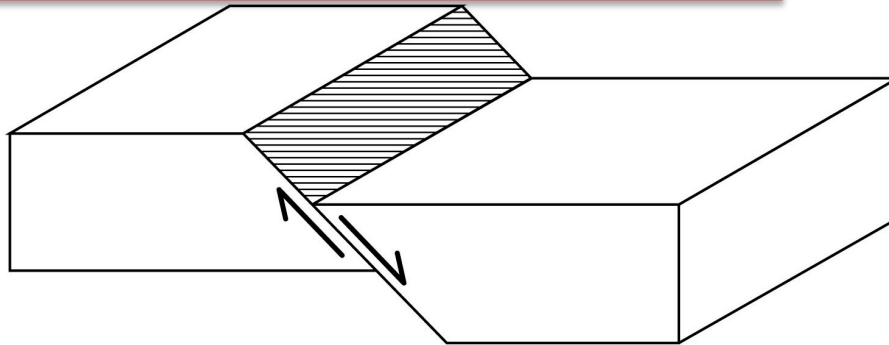
Left-lateral strike-slip fault
($\lambda = 0^\circ$)

Décrochement sénestre
(pied gauche part en arrière)



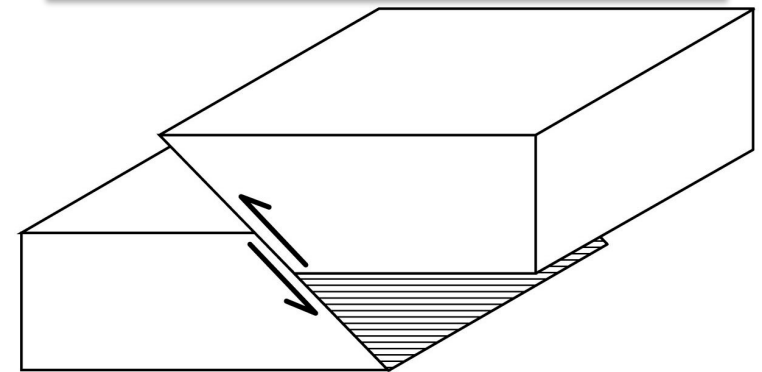
Right-lateral strike-slip fault
($\lambda = 180^\circ$)

Décrochement dextre



Normale

Normal dip-slip fault
($\lambda = -90^\circ$)



Inverse

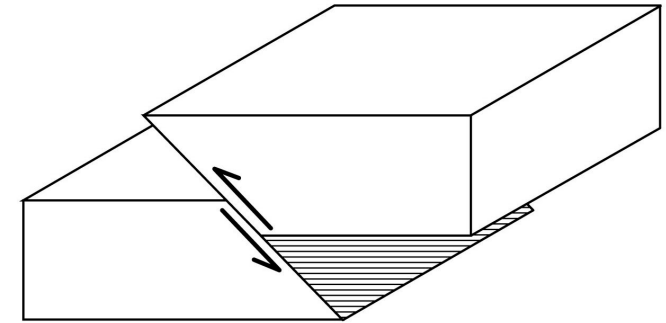
Reverse dip-slip fault
($\lambda = 90^\circ$)

La plupart de séismes est une combinaison de ces différents mouvements. (λ entre ces valeurs)

Faïlle inverse



offset de 2 m dans un stade
(maintenant un musée)



Reverse dip-slip fault
($\lambda = 90^\circ$)

Séisme de Chi-Chi 1999

Faïlle de Chelungpu

-> chutes d'eau de 6 m sur Ta-Chia River,
(photo LeonTeng, USC)

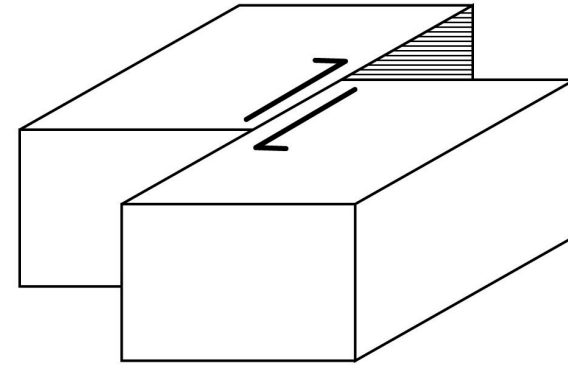


Faïlle en décrochement

Landers, Californie, 1992



Denali, Alaska, 2002



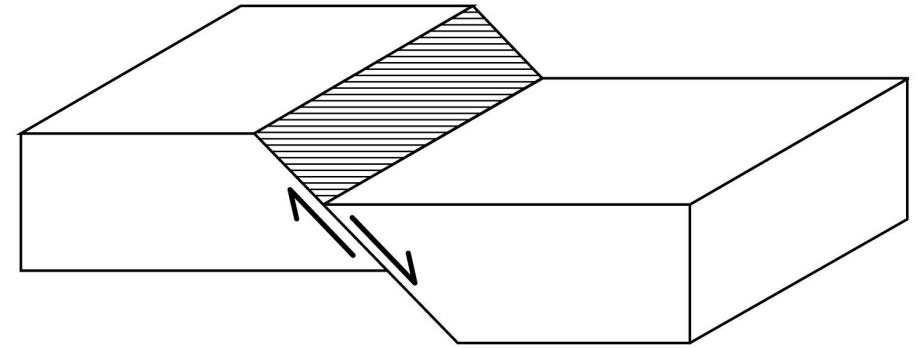
Right-lateral strike-slip fault
($\lambda = 180^\circ$)



San Francisco, Californie 1906

Faïlle normale

Crowley Lake, California

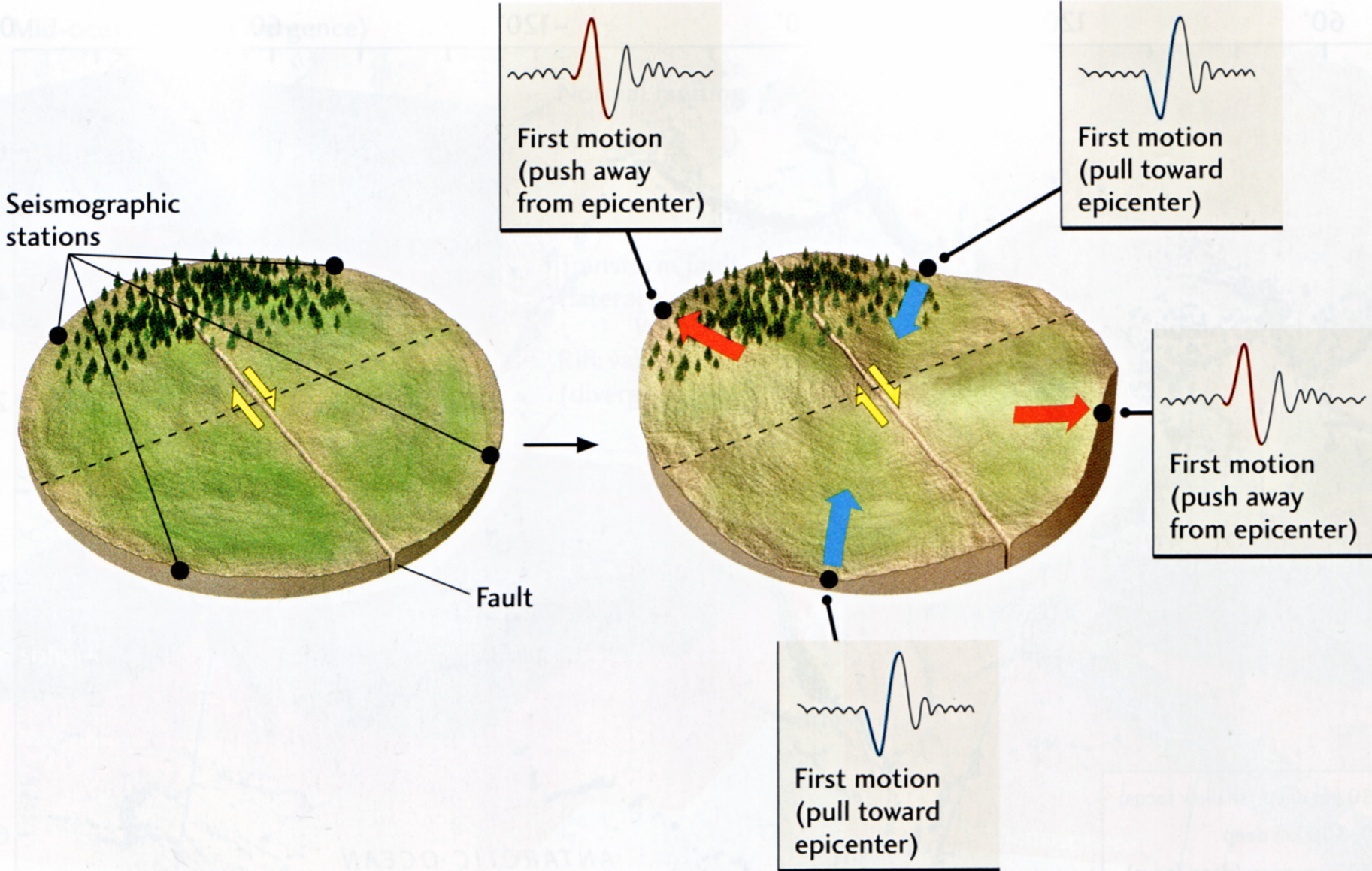


Normal dip-slip fault
($\lambda = -90^\circ$)

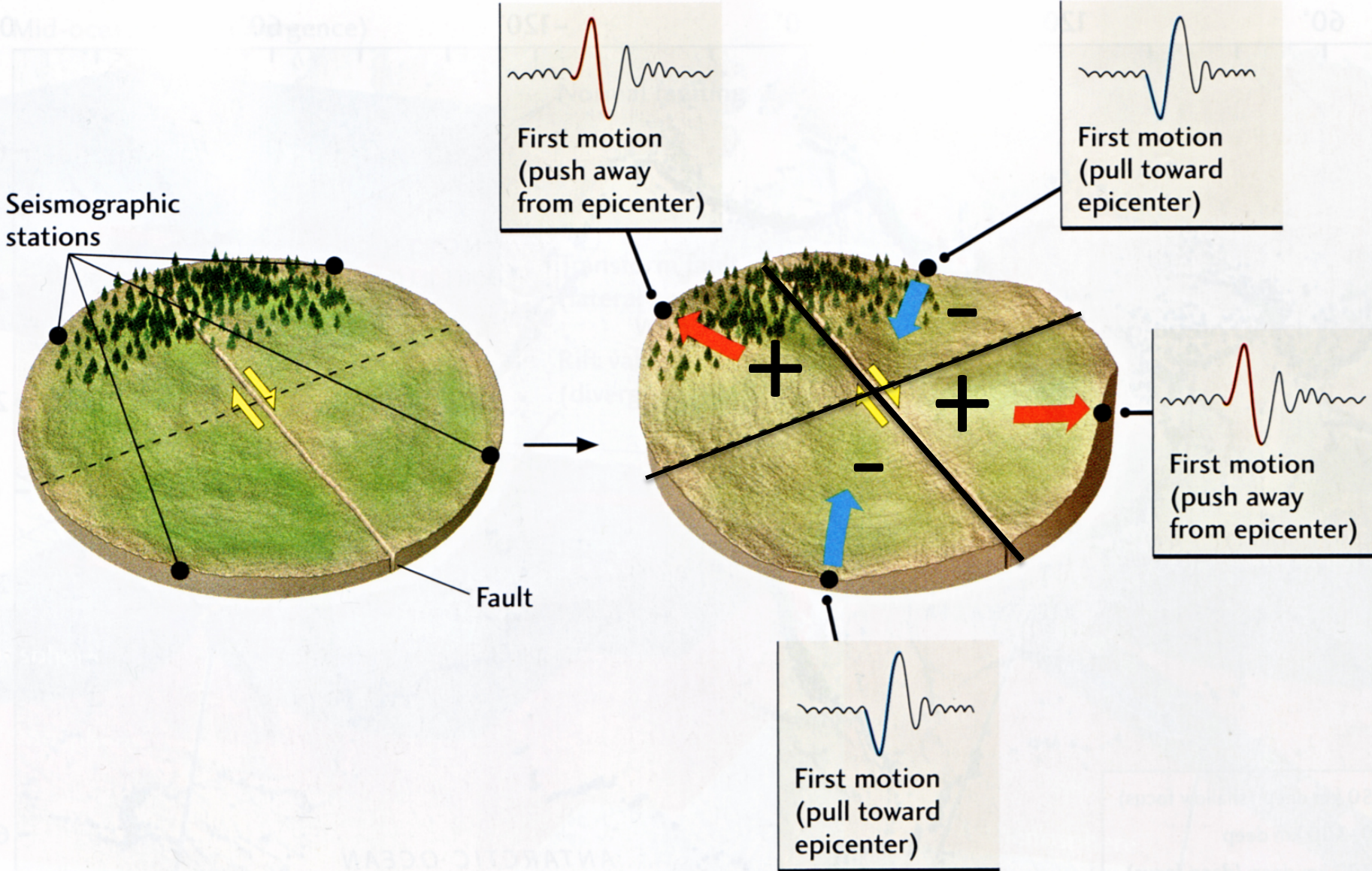
Arkitsa, Grèce



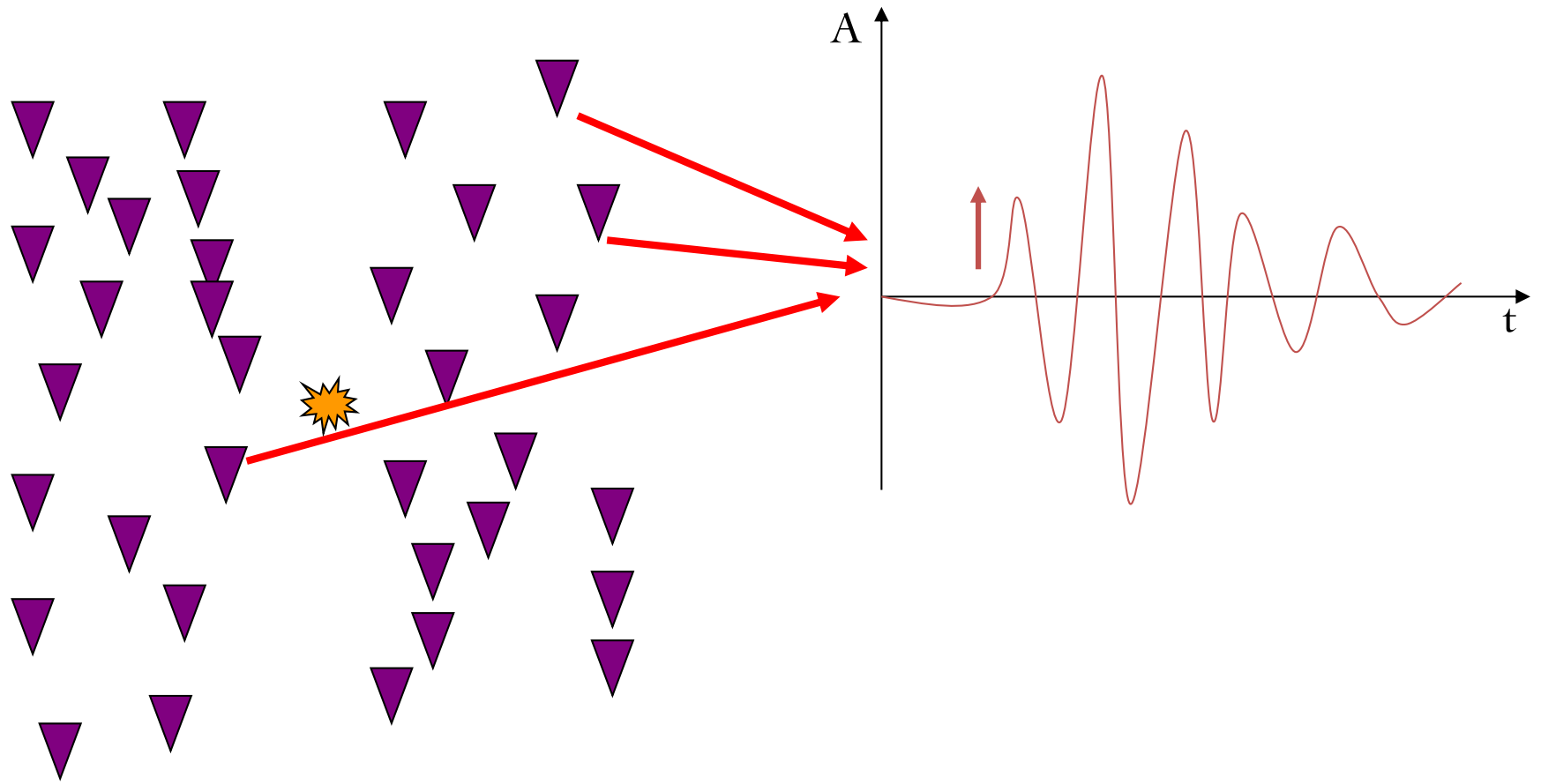
Comment caractériser une faille ?



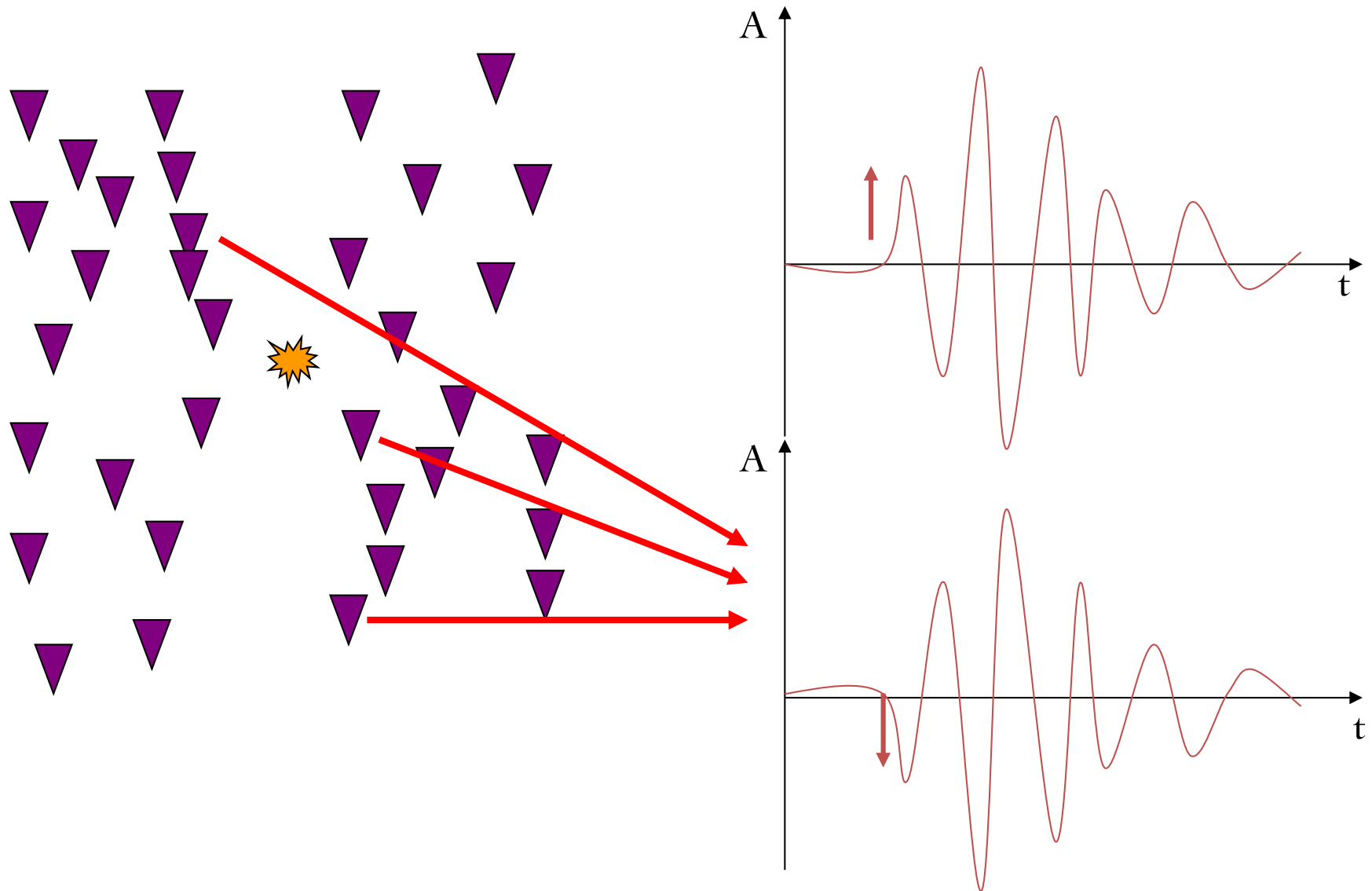
Comment caractériser une faille ?



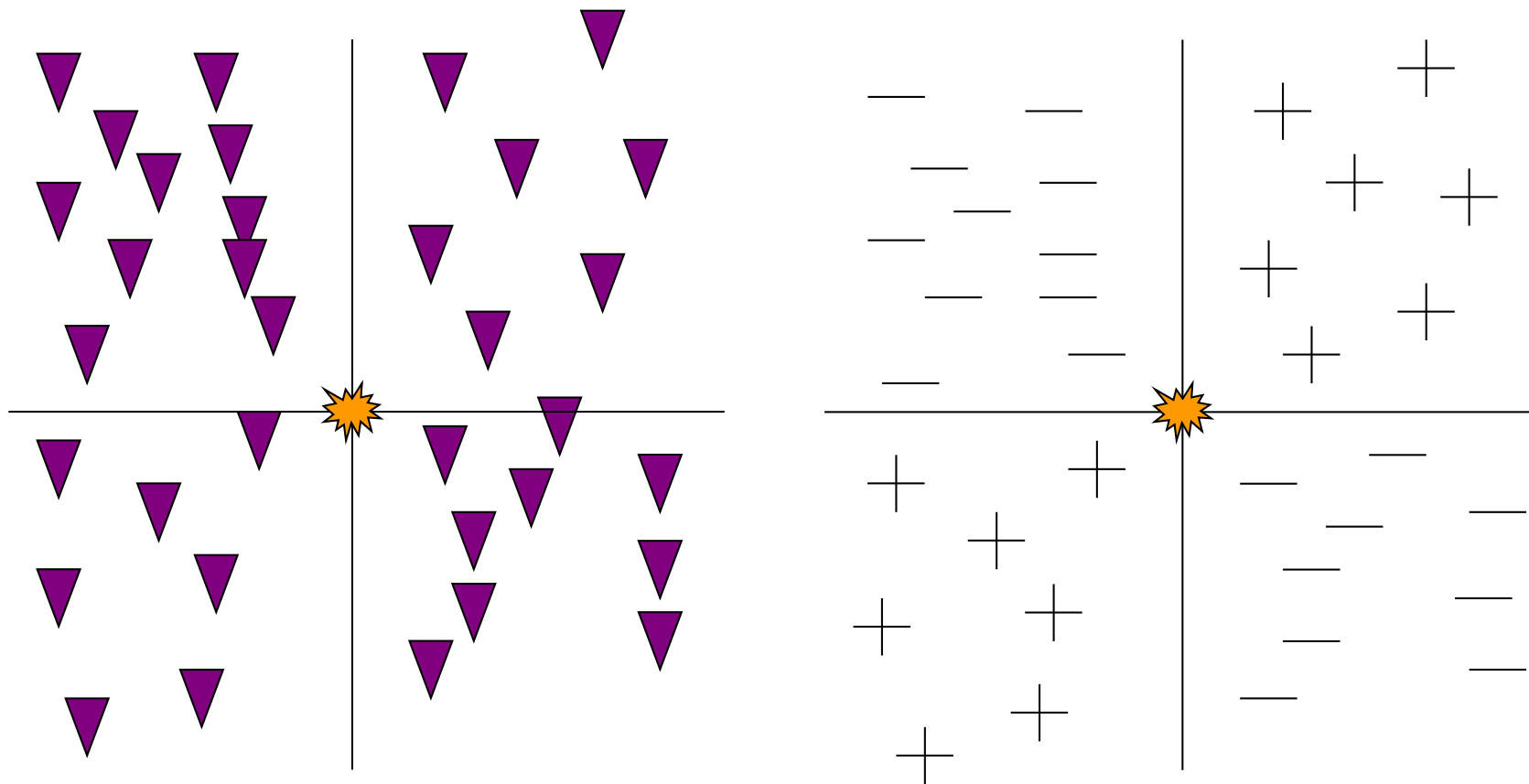
Comment caractériser une faille ?



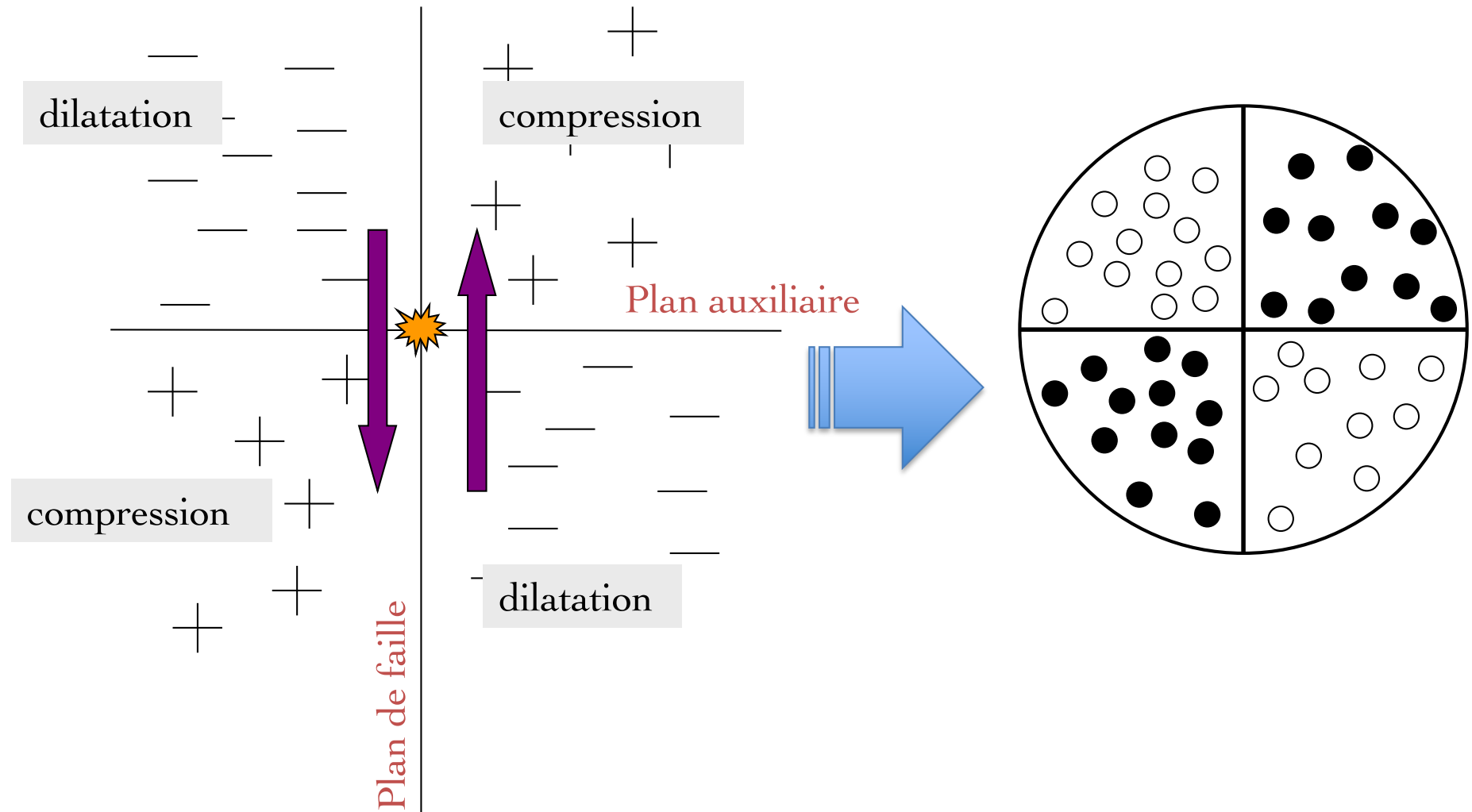
Comment caractériser une faille ?



Comment caractériser une faille ?

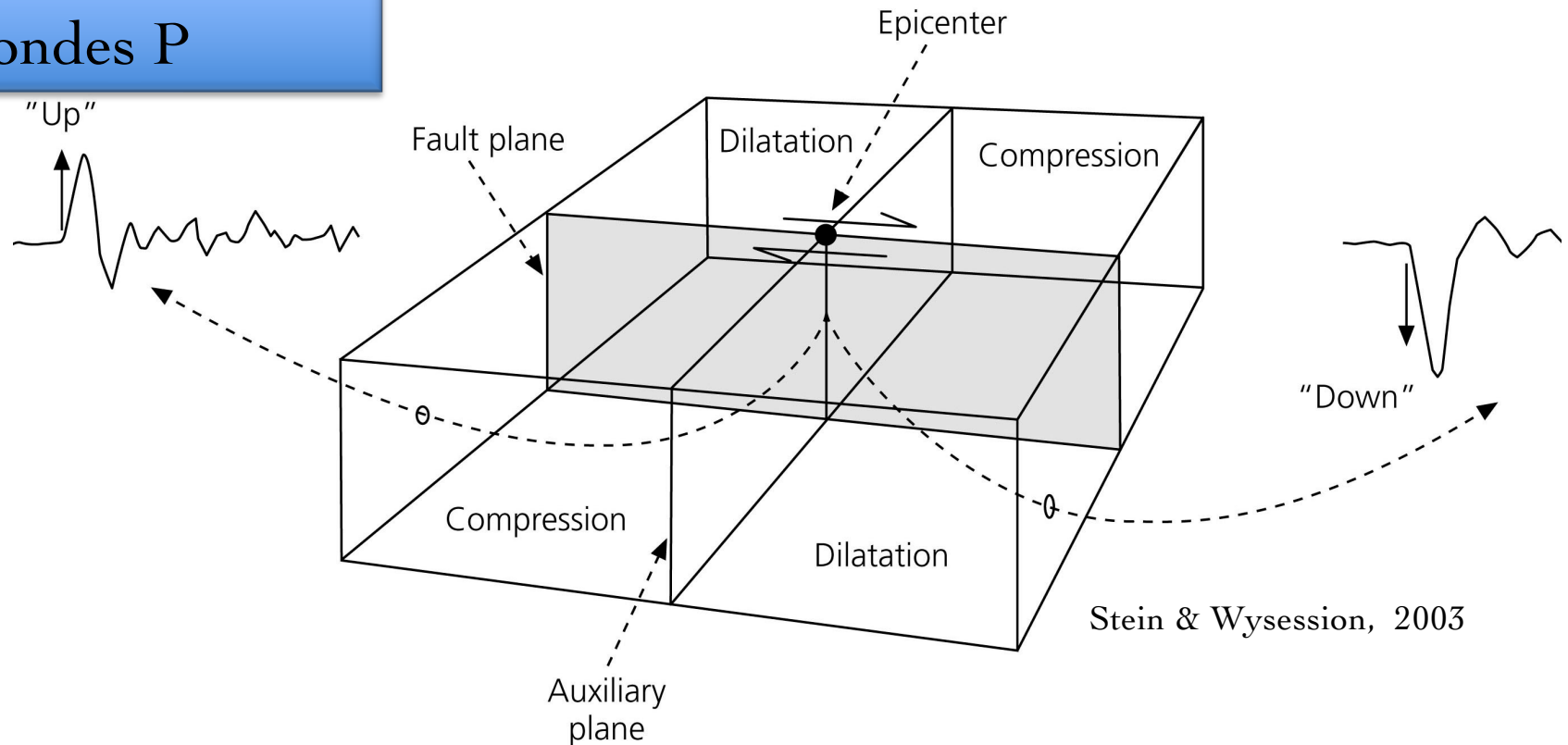


Mécanismes au foyer



FAILLE EN DÉCROCHEMENT

Premiers mouvements des ondes P



La POLARITÉ des ondes P varie entre les stations en fonction de leur direction.

Le premier mouvement est:

en HAUT : Compression

en BAS : Dilatation

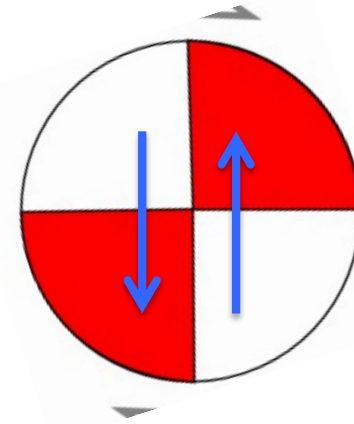
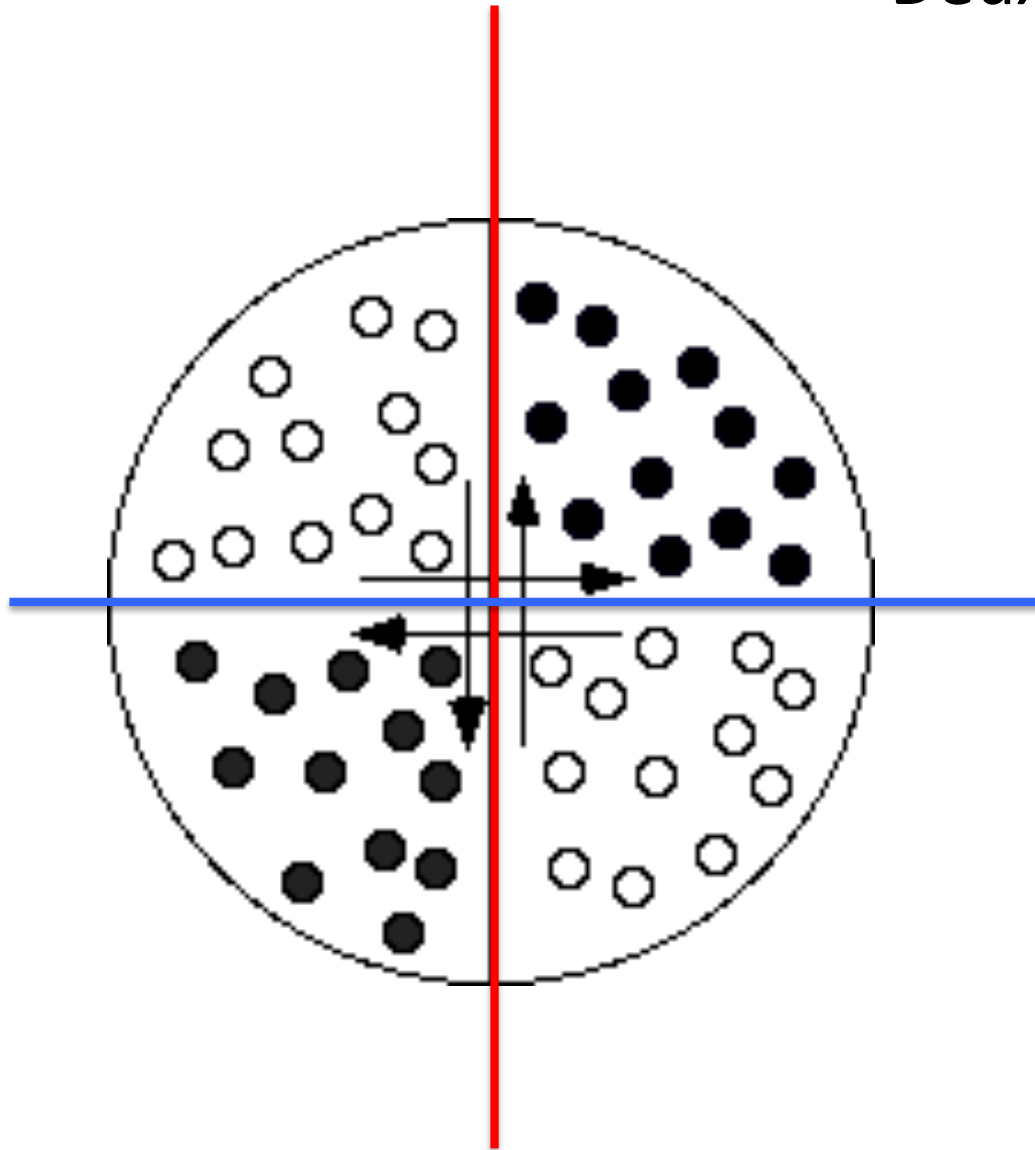
-> 4 quadrants

-> 2 plans nodaux (faille et auxiliaire)

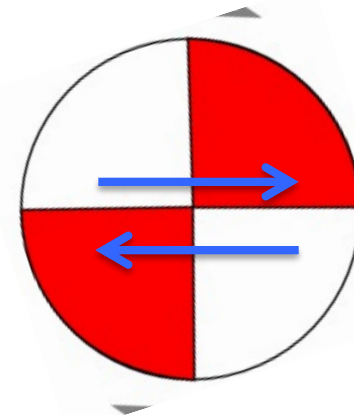
-> les 1^{er} mouvements ne permettent pas de déterminer le plan de faille

Comment caractériser une faille ?

Deux couples de forces possibles



ou

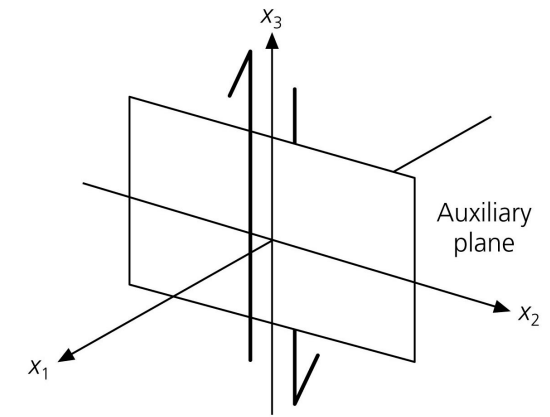
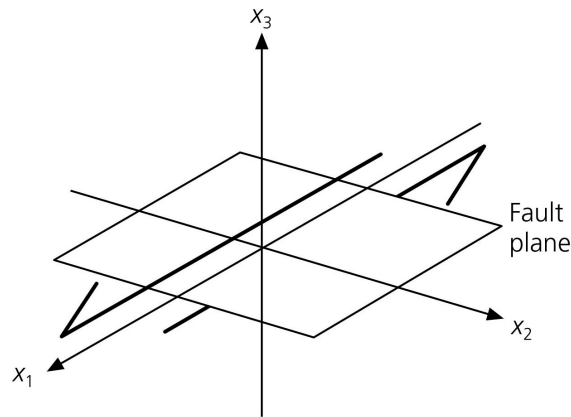


ONDES RADIÉES DEPUIS UNE FAILLE ÉQUIVALENTE

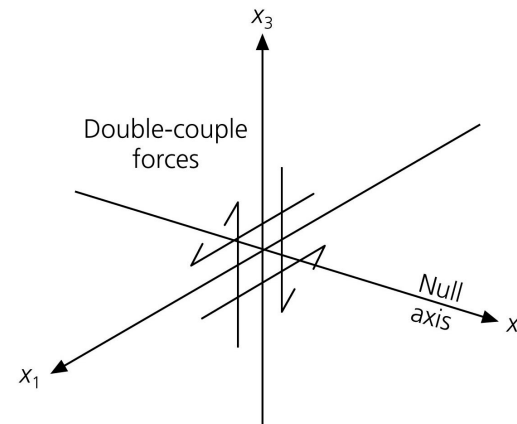
À UN DOUBLE COUPLE?

Les radiations sont dues à:

- un couple de forces dans des directions opposées correspondant au plan de faille (direction réelle du glissement)
- un couple correspondant au plan auxiliaire



Pourquoi un DOUBLE-COUPLE :
Equilibre des forces
Pas de rotation

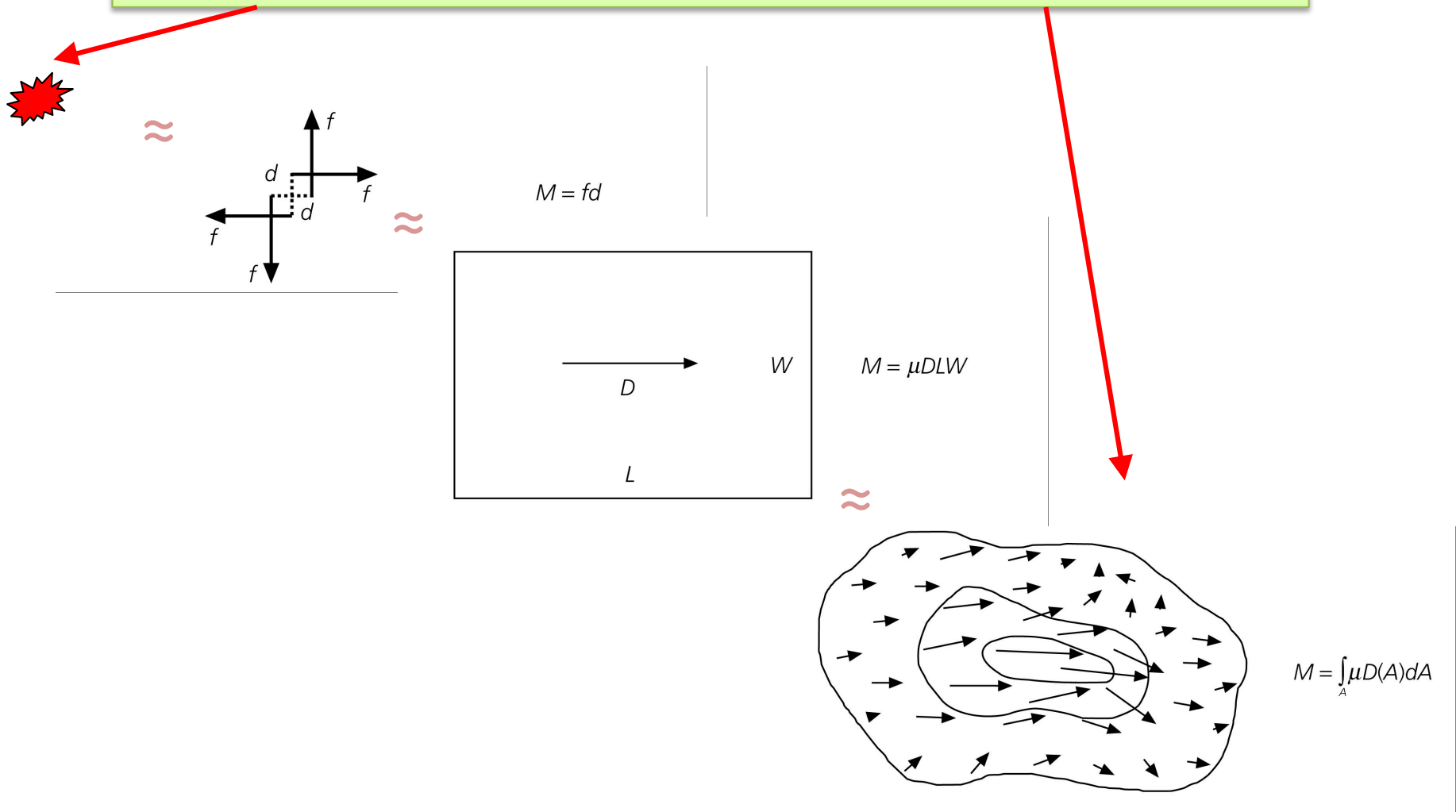


Pearce, 1977

(*)

QUELLES SONT LES FORCES ÉQUIVALENTES QUI REPRÉSENTENT LE PROCESSUS DE RUPTURE COMPLEXE SUR FAILLE ?

Séisme = déplacement fini sur une faille étendue



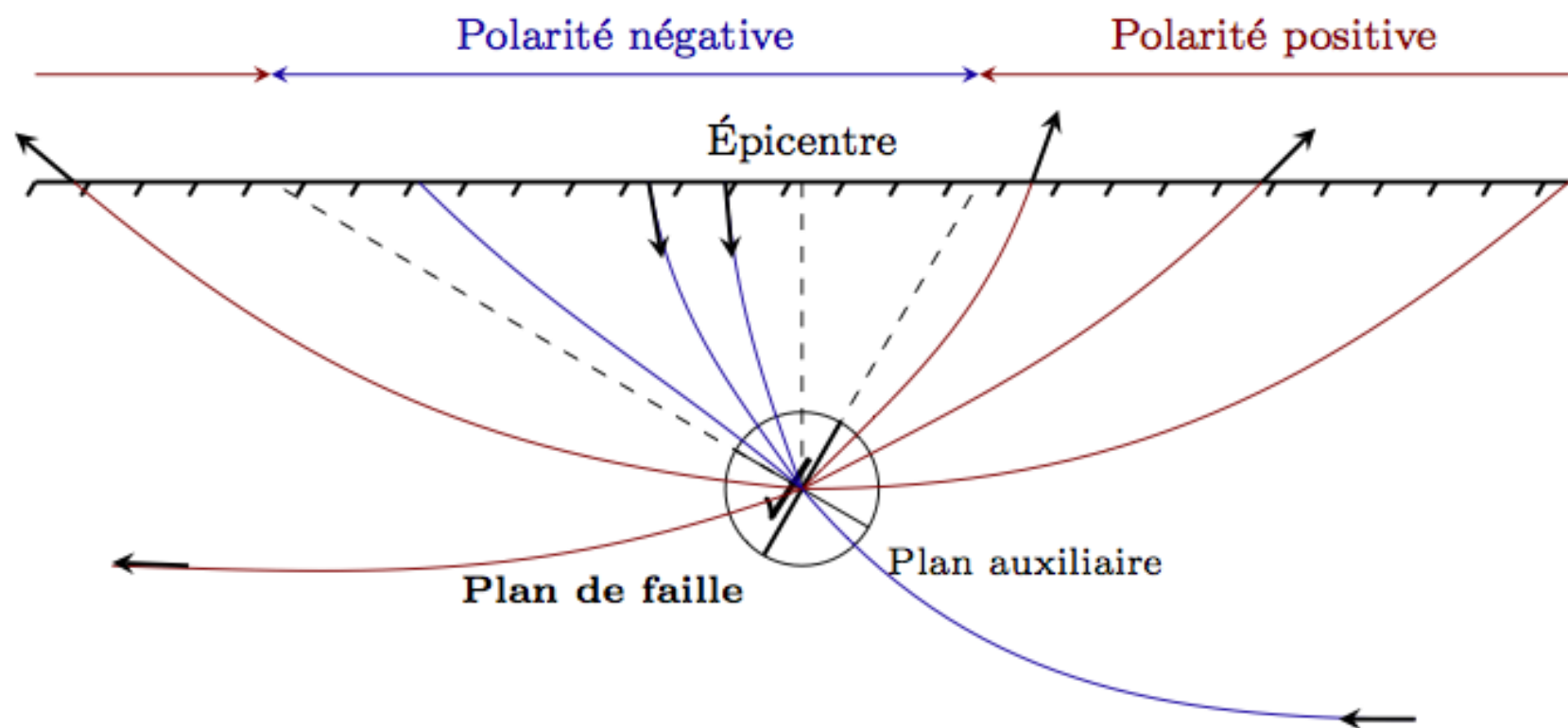
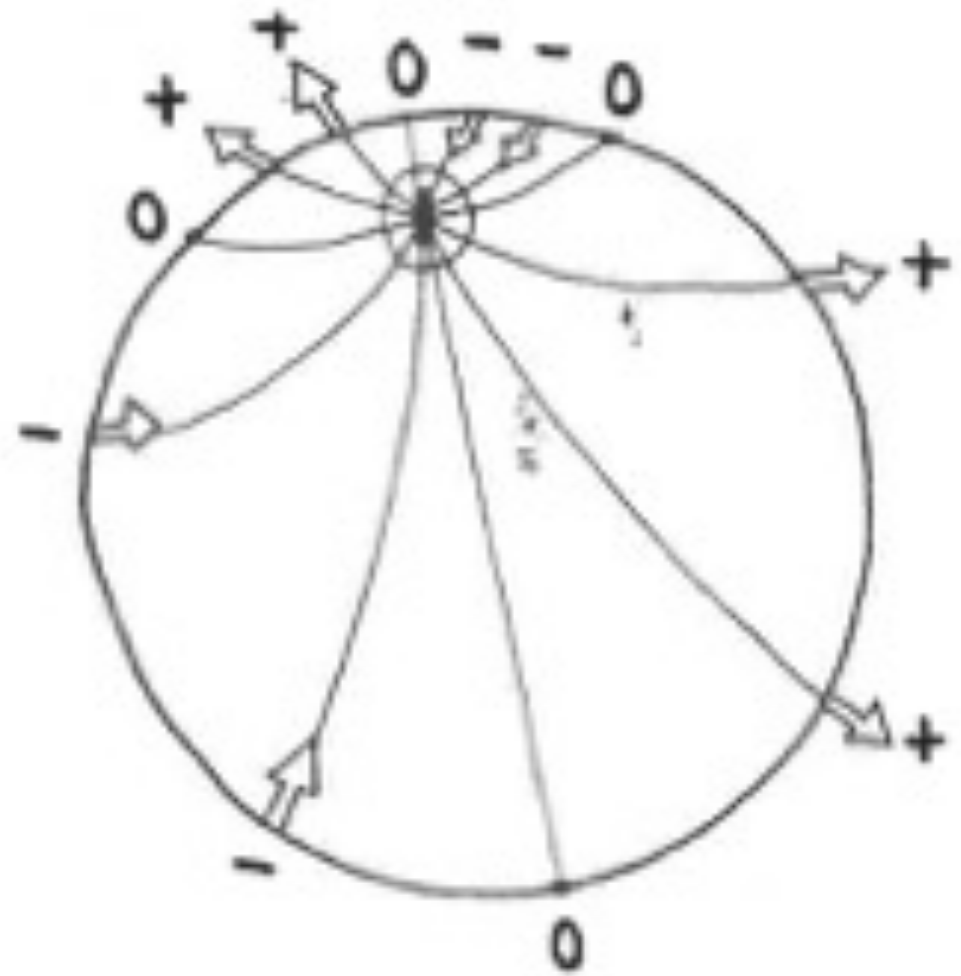


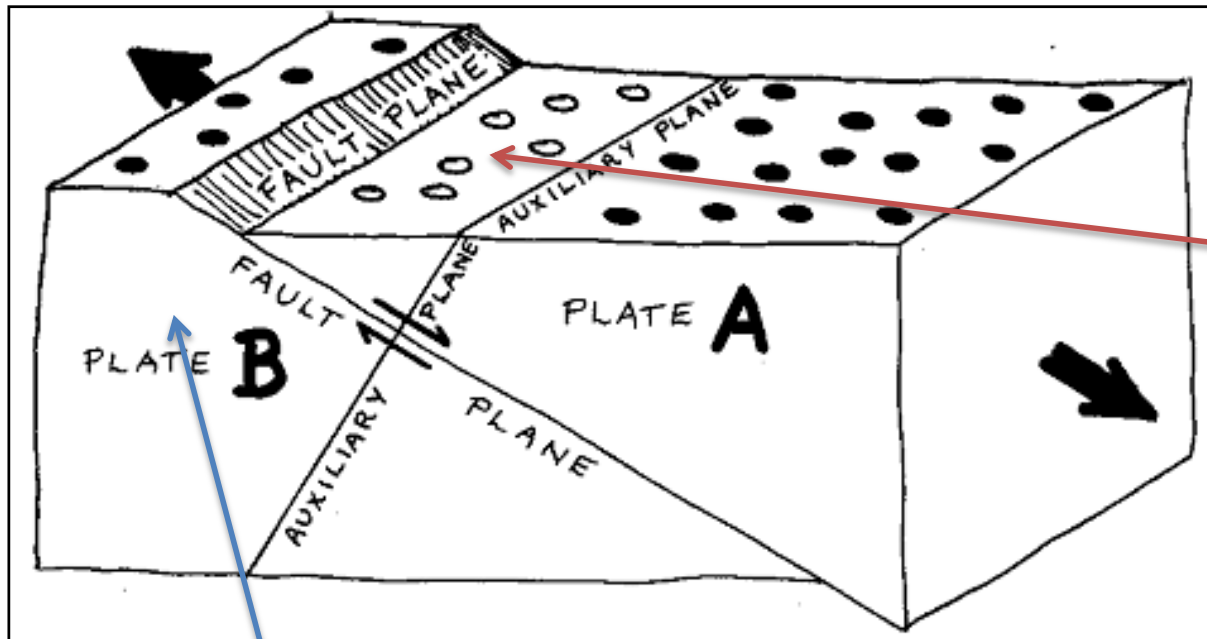
Schéma 2D du foyer sismique et des quadrants compressifs et extensifs.

(*)

glissement



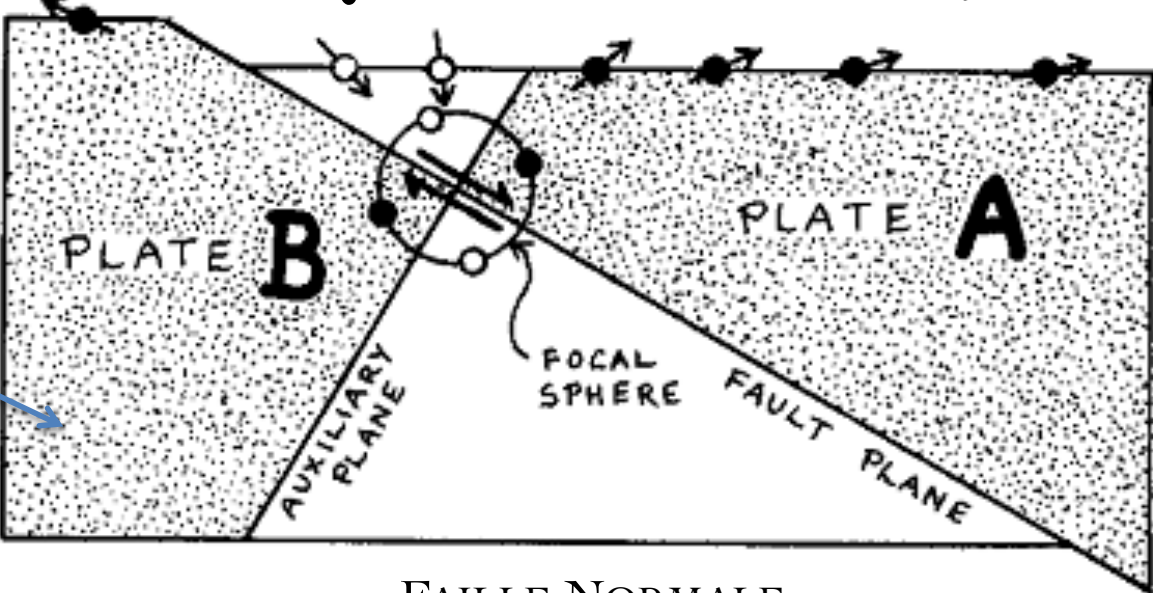
(*)



Dilatation (-)



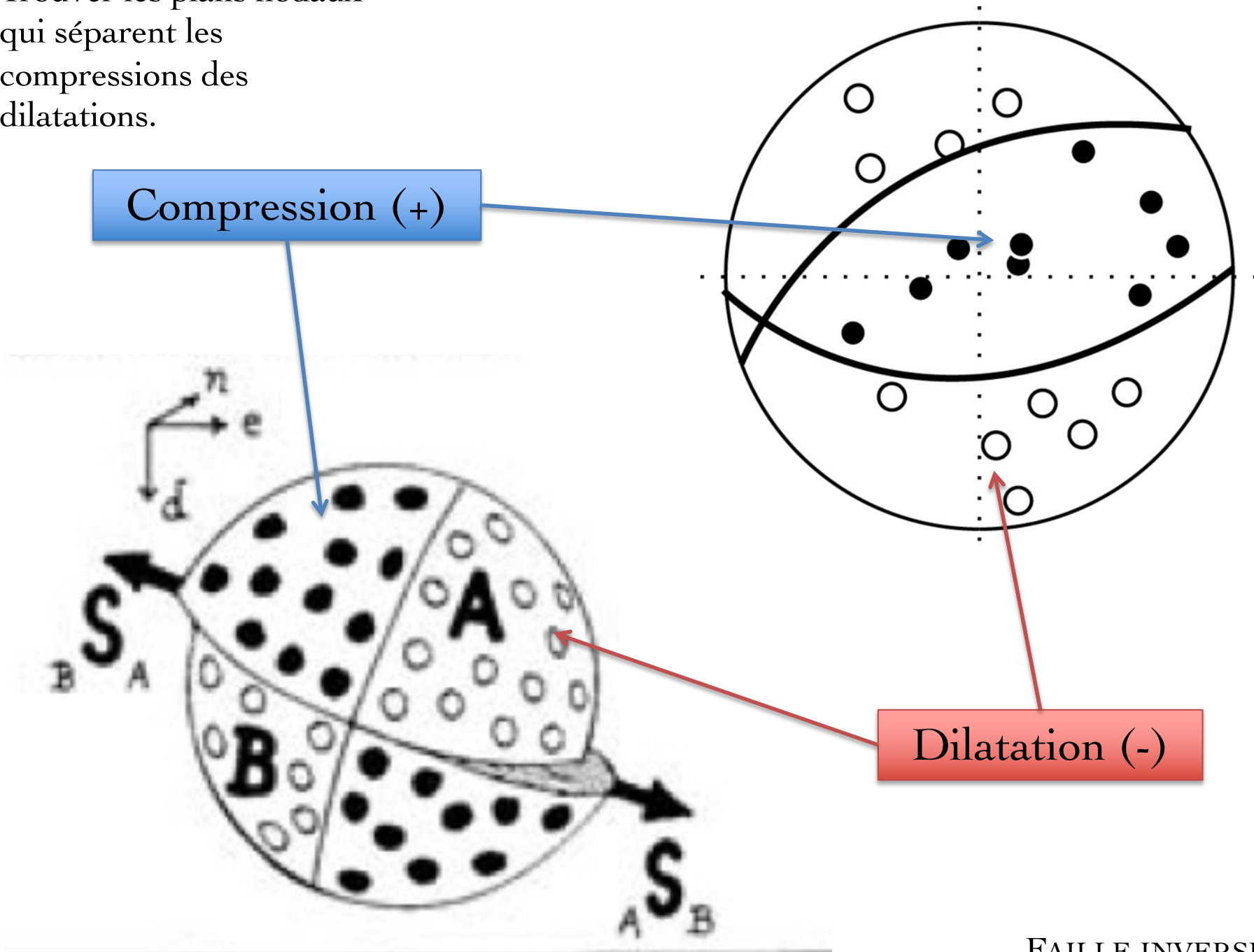
Compression (+)



FAILLE NORMALE

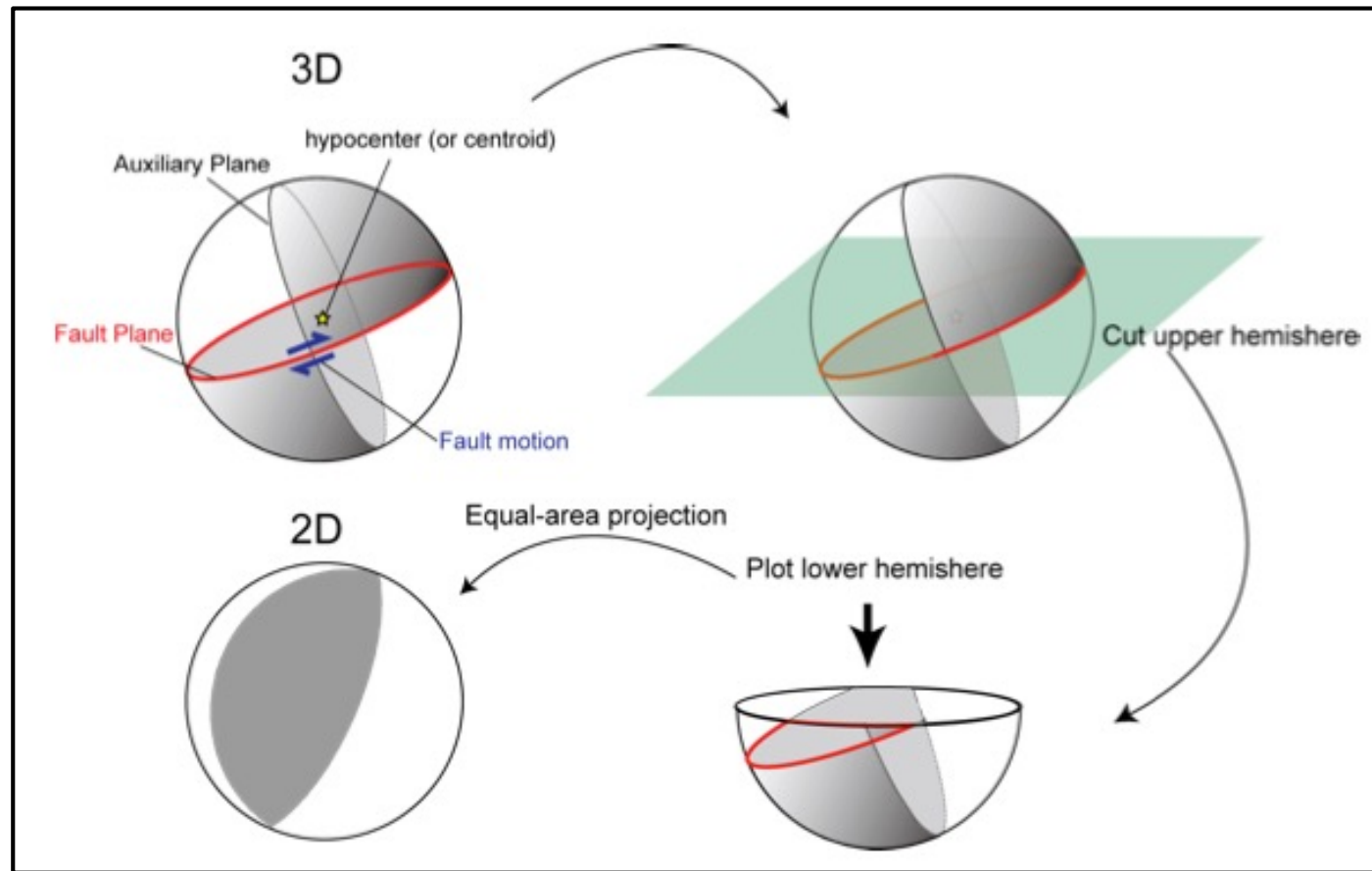
courtesy of Ian Hill, University of Leicester, UK

Trouver les plans nodaux
qui séparent les
compressions des
dilatations.

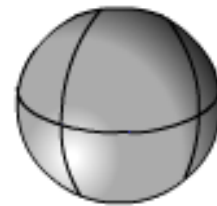


FAILLE INVERSE

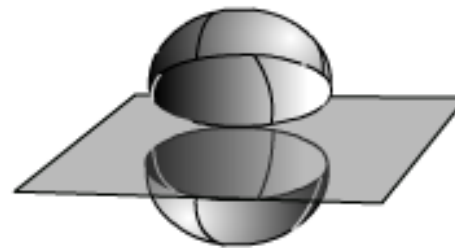
Comment représenter le mécanisme?



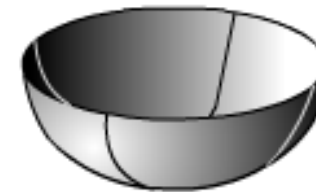
Exemple : Faille décrochante



Sphere



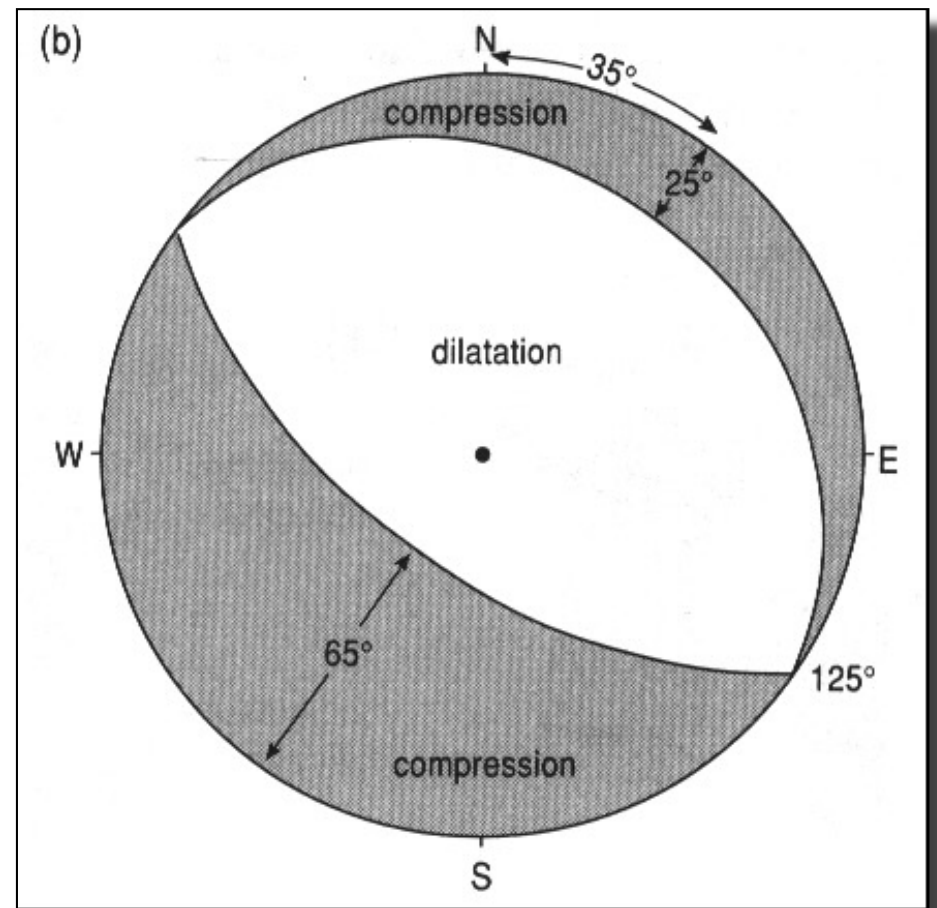
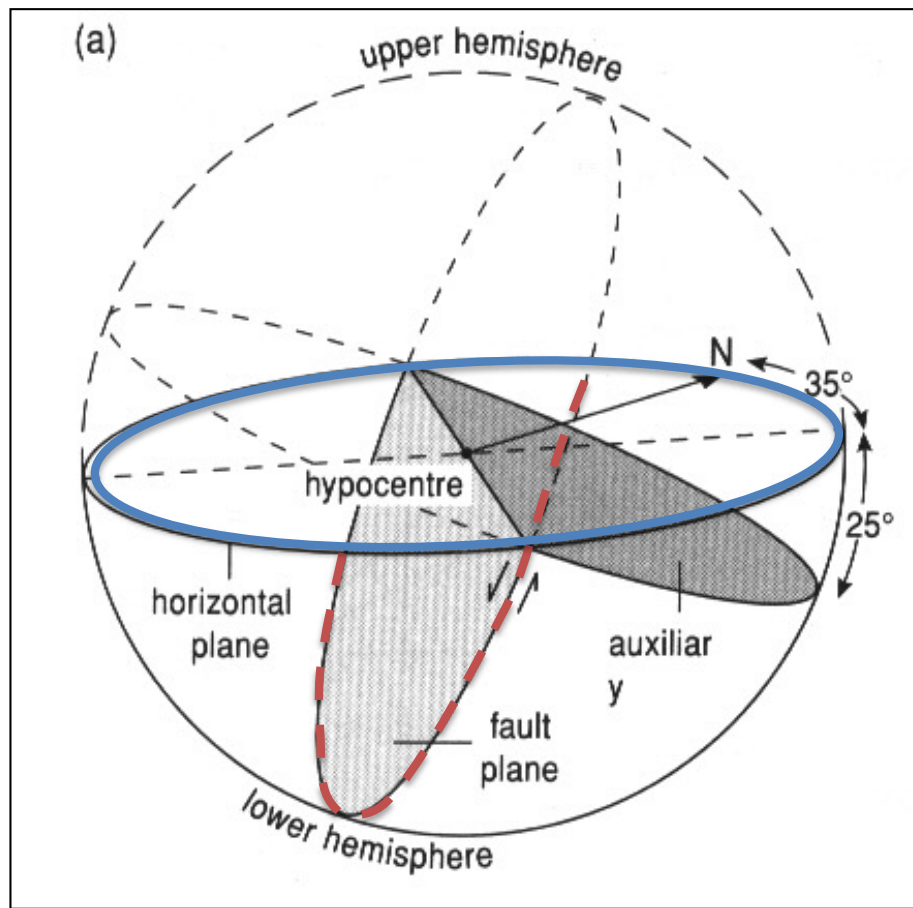
Sphere cut by horizontal plane



Projection of one half of the sphere

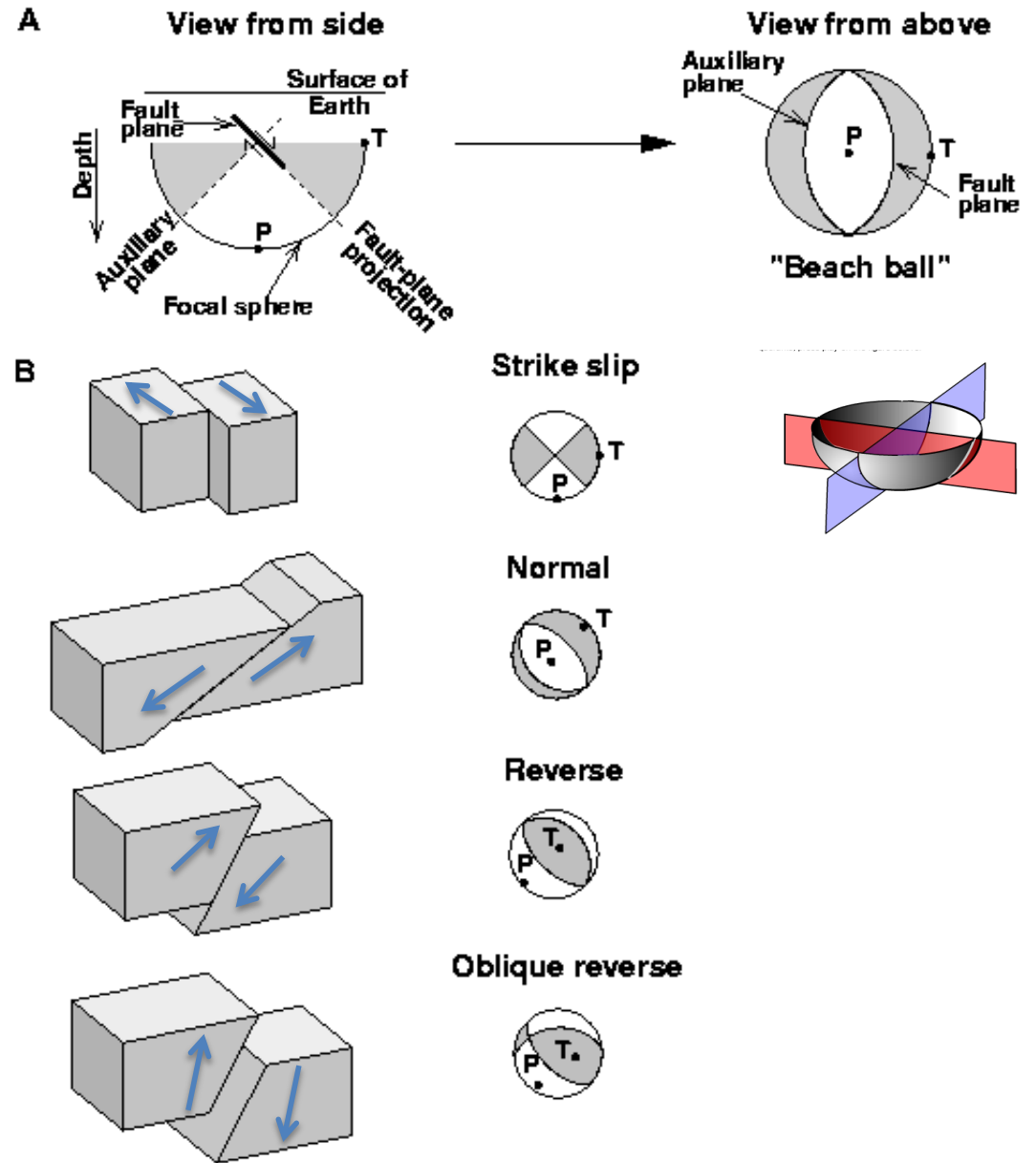


Circle



MÉCANISMES AU FOYER

Schematic diagram of a focal mechanism

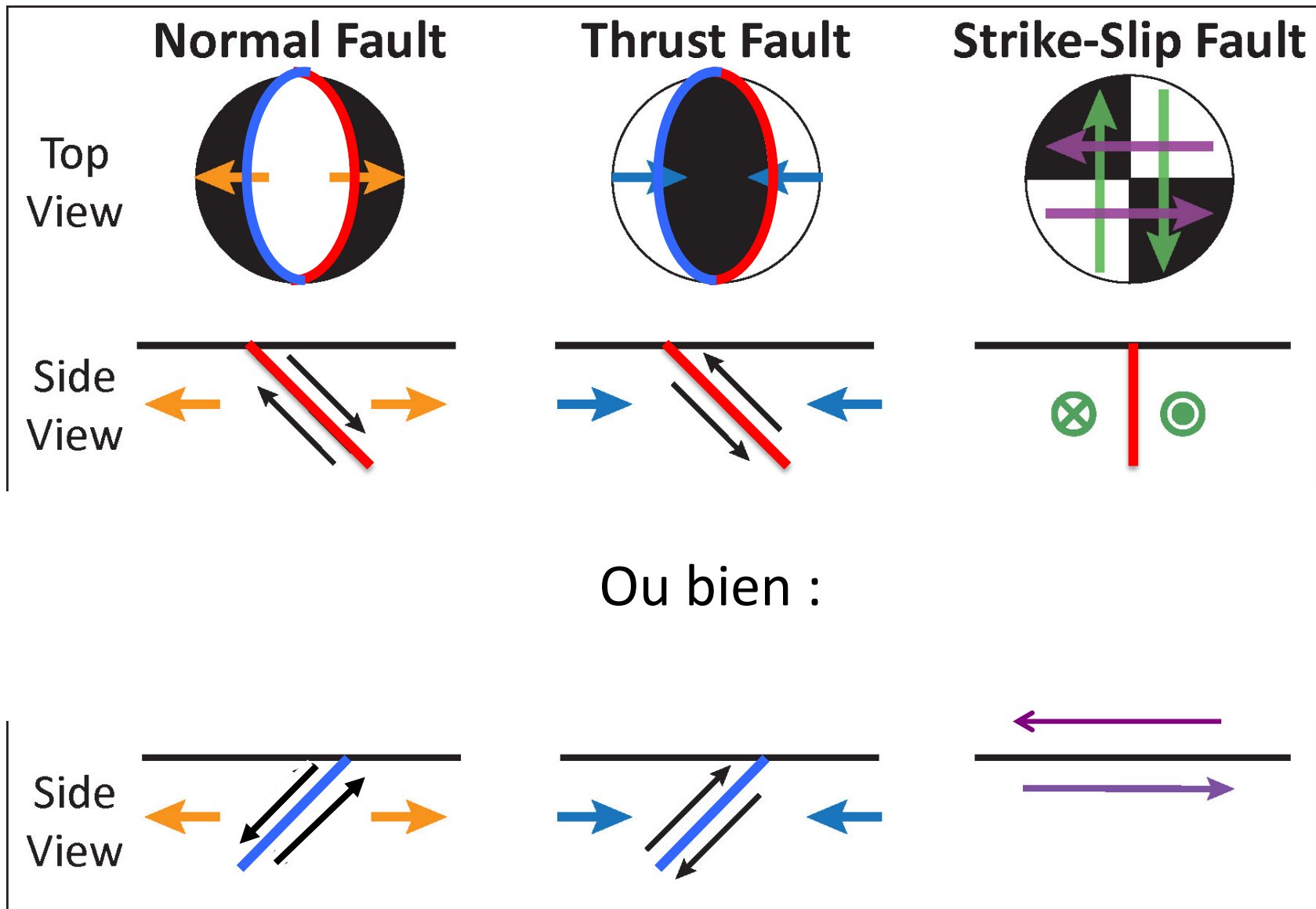




FAILLE DECROCHANTES
(TRANSFORMANTES)

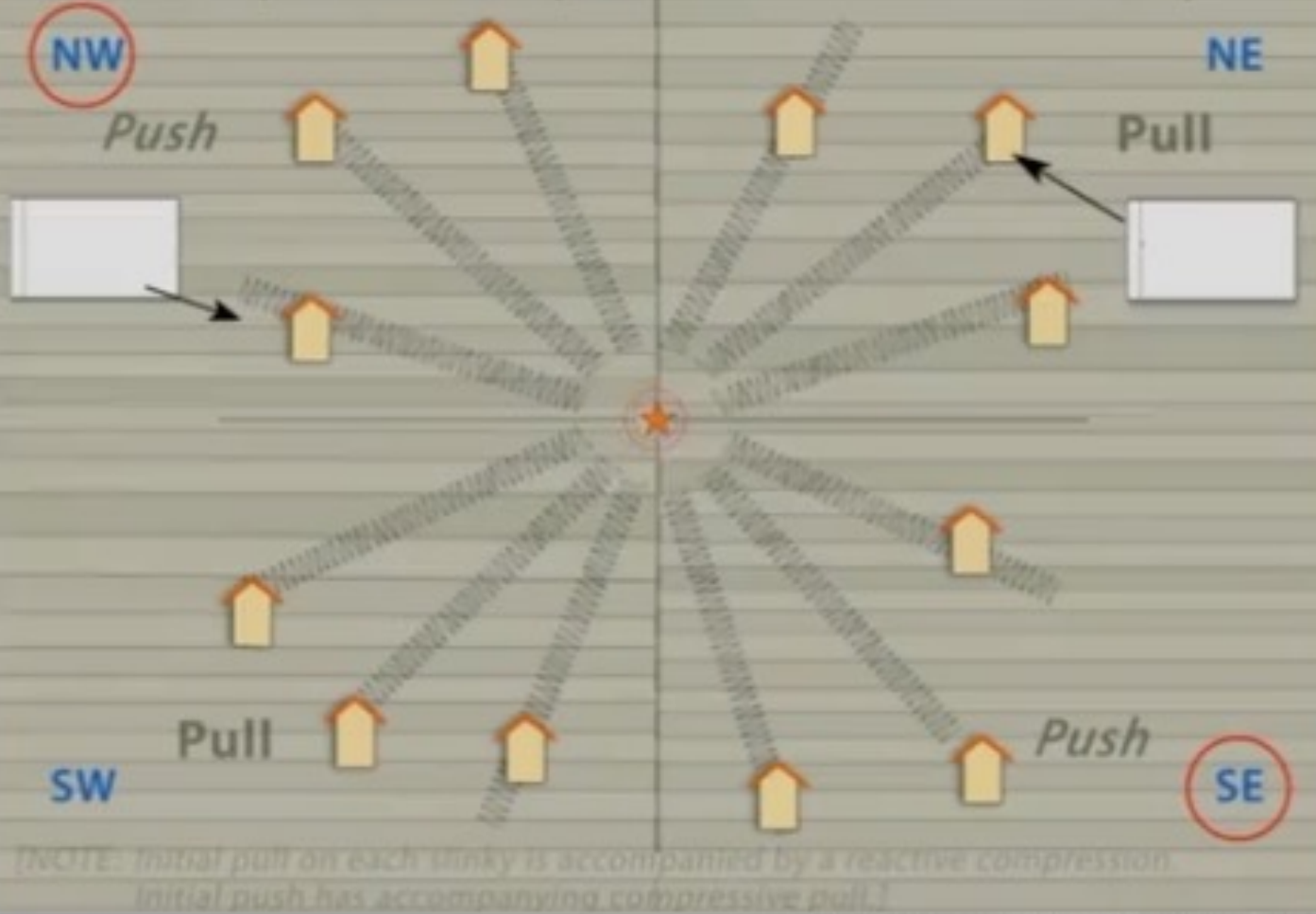
FAILLE NORMALE

FAILLE INVERSE

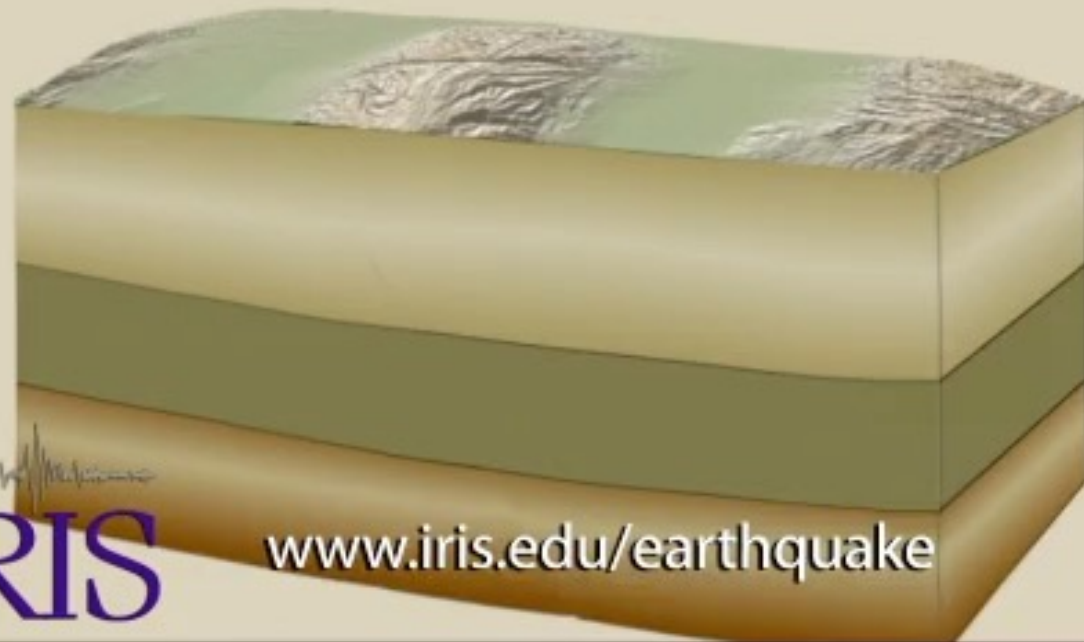
FAILLE OBLIQUE



Initial compression ( = push). *Initial dilatation* ( = pull)



Focal mechanism for thrust fault



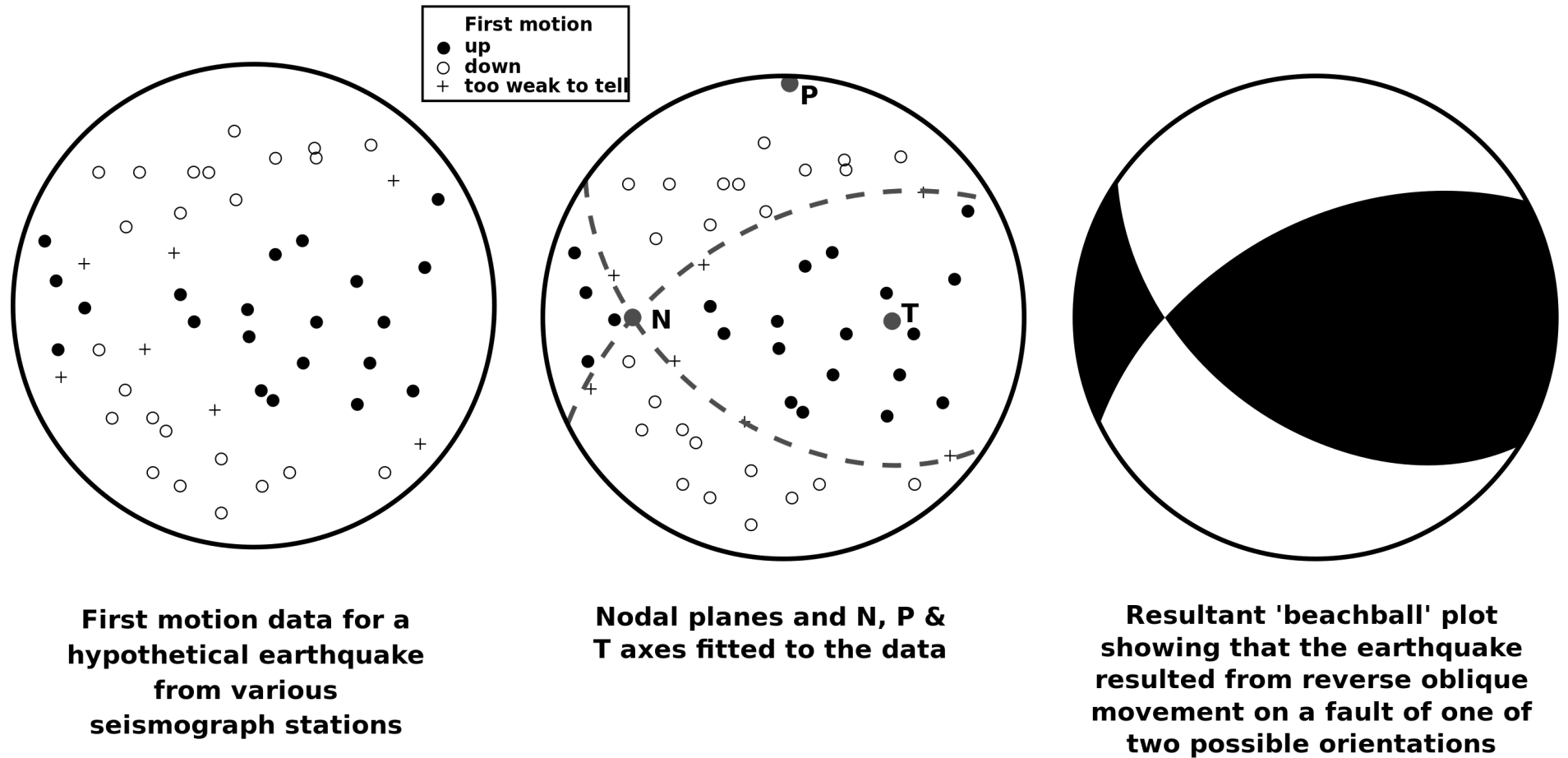
 IRIS

www.iris.edu/earthquake

Focal mechanism for a normal fault

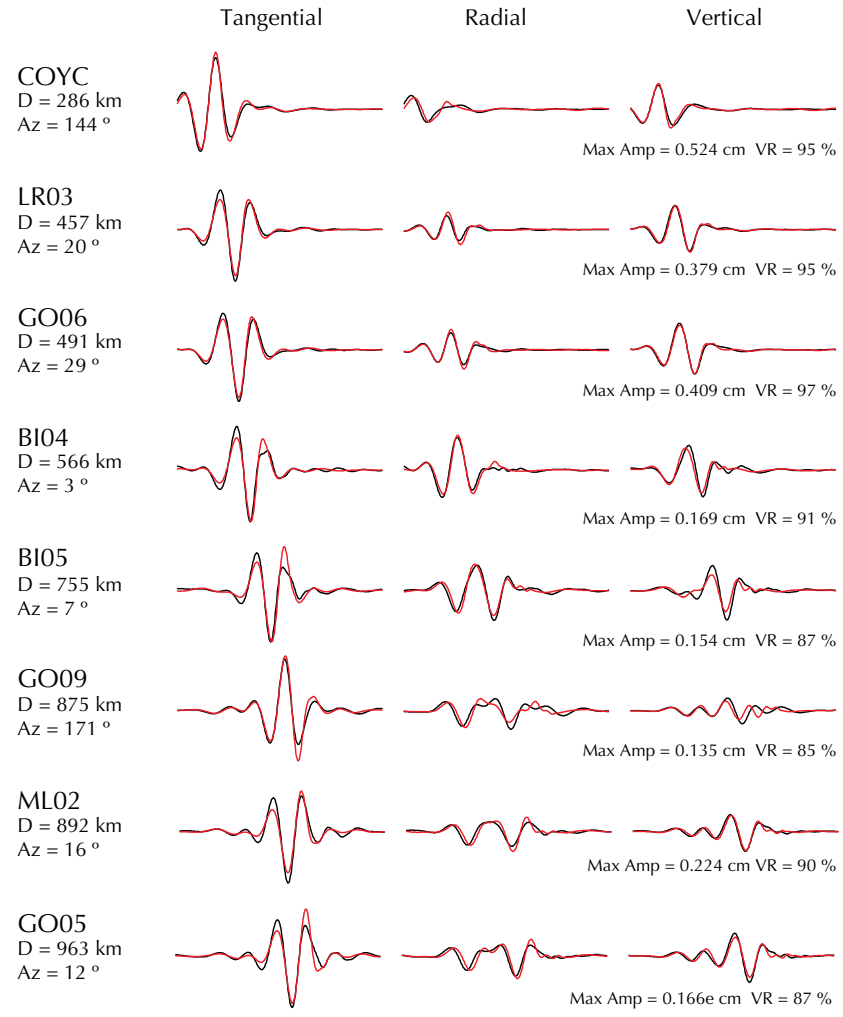
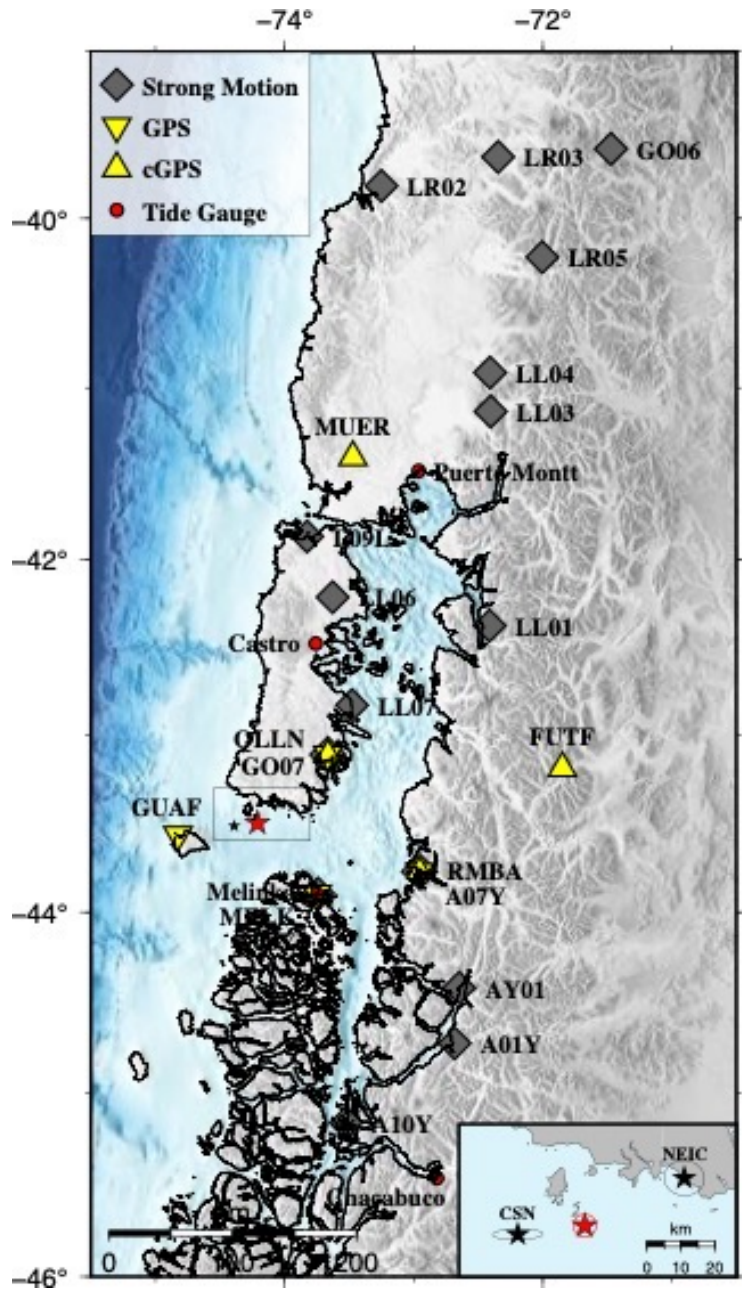


Méthode par les premières arrivées

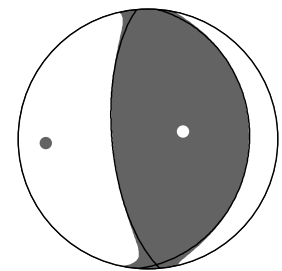


Méthode

par modélisation des formes d'ondes



Depth = 27 km
 Strike = 175° ; 4°
 Rake = 86° ; 99°
 Dip = 67° ; 23°
 Mo = 2.10e+27 dyne.cm
 Mw = 7.48
 Percent DC = 94 %
 Percent CLVD = 6 %
 Percent ISO = 0 %
 Variance = 1.83e-04
 Var. Red. = 93.3 %

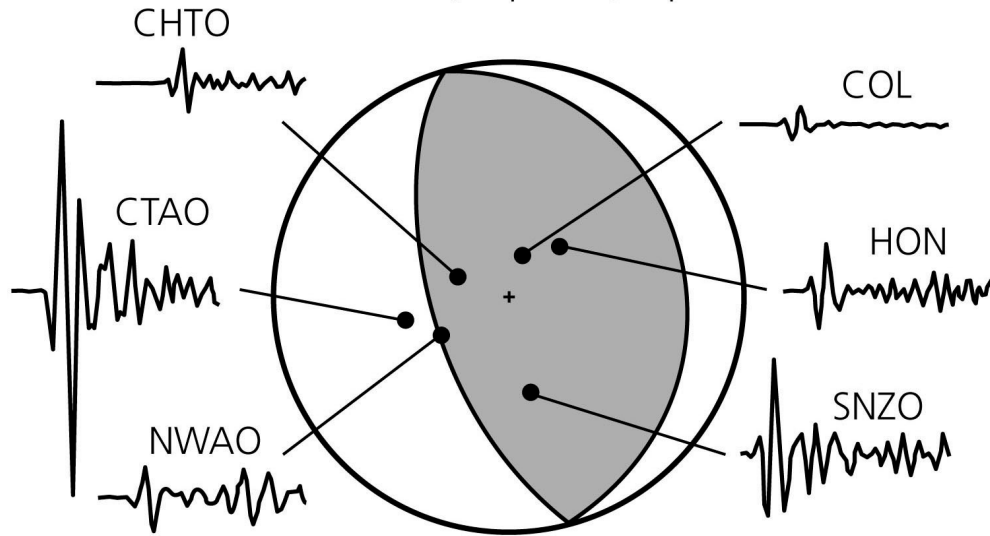


100.00 sec

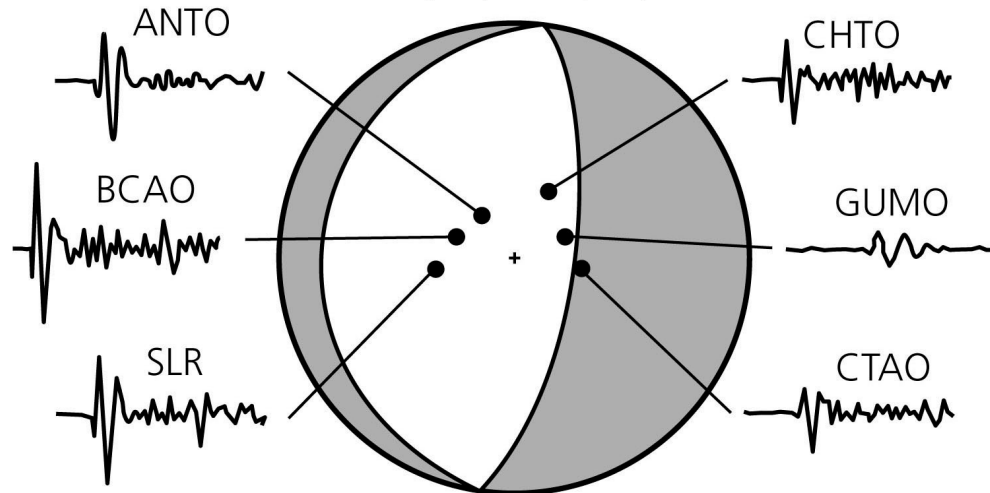
Chiloe 2016

Figure 4.2-17: Examples of focal mechanisms and first motions.

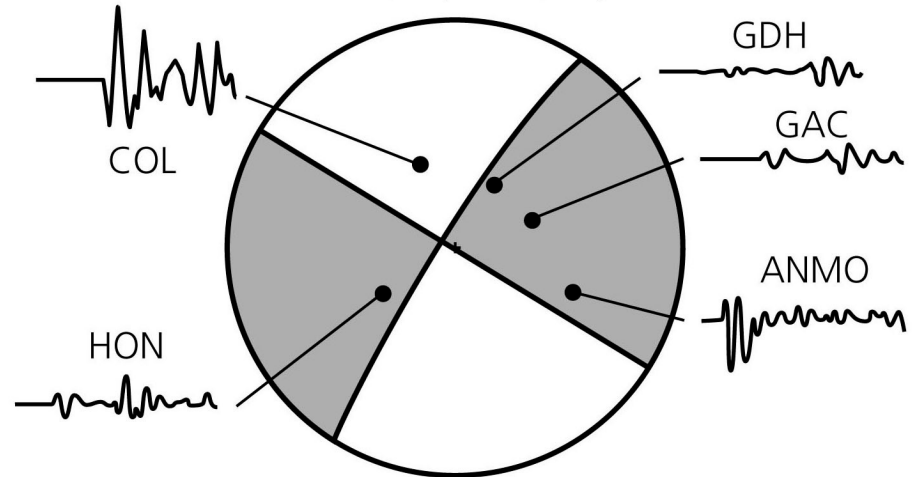
Thrust faulting, Vanuatu Islands, July 3, 1985
 Location: 17.2°S, 167.8°E. Depth: 30 km
 Strike: 352°, Dip: 26°, Slip: 97°



Normal faulting, mid-Indian rise, May 16, 1985
 Location: 29.1°S, 77.7°E. Depth: 10 km
 Strike: 8°, Dip: 70°, Slip: 270°

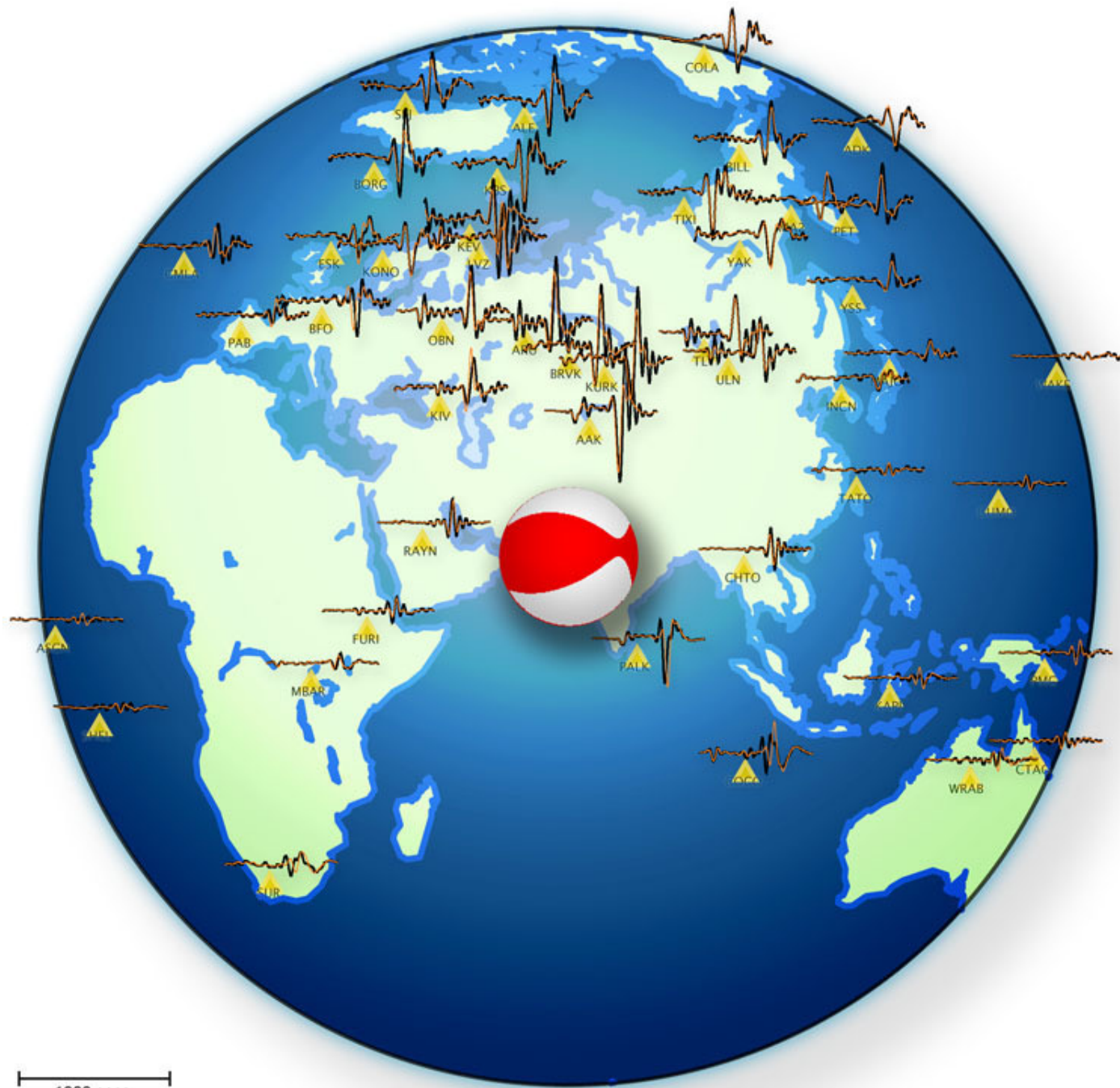


Strike-slip faulting, west of Oregon, March 13, 1985
 Location: 43.5°N, 127.6°W. Depth: 10 km
 Strike: 302°, Dip: 90°, Slip: 186°



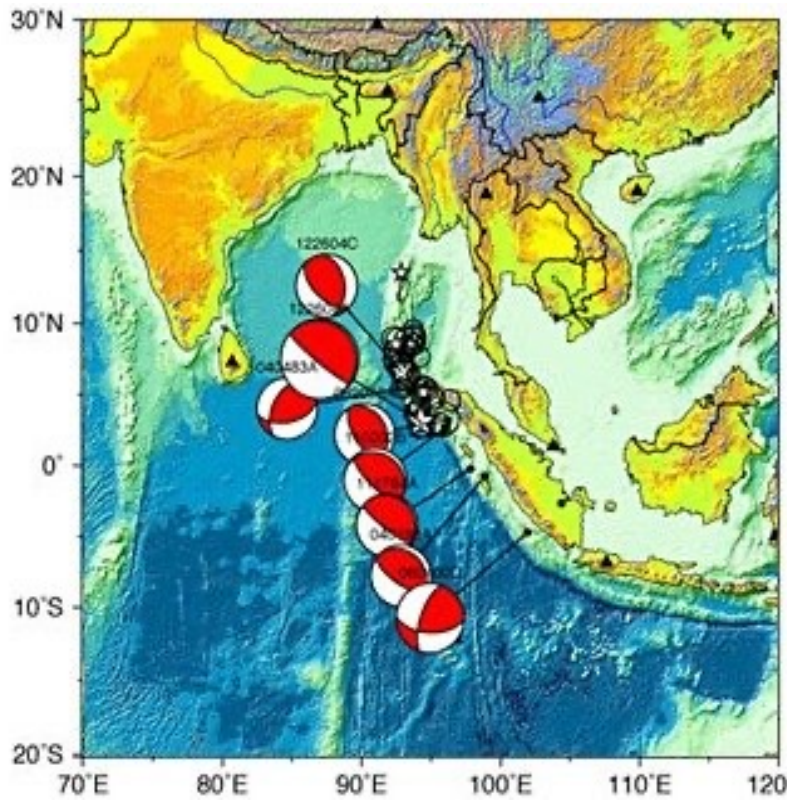
0 120 240
 (s)

Stein & Wyession, 2003

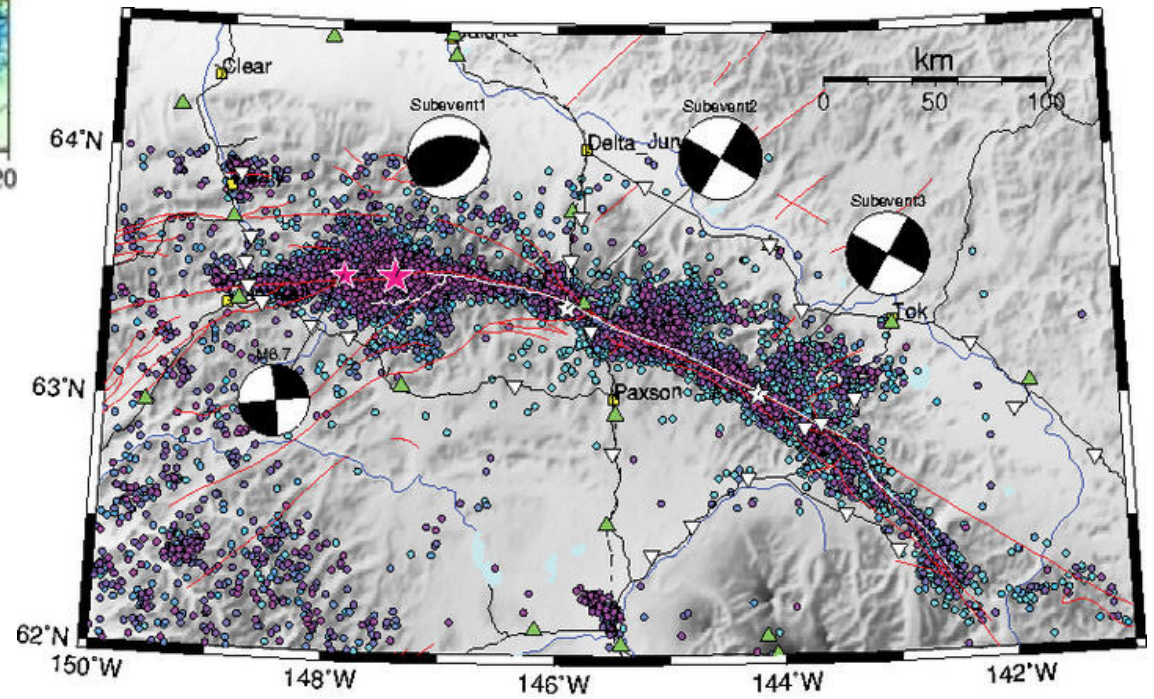


1000 secs.
 $\text{Time} = \text{distance} / 3.8(\text{km/s}) \text{ (s)}$

2001 Séisme de Bhuj, Inde (Mw 7.7) , inverse - oblique

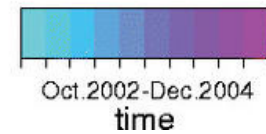


Sumatra 2004

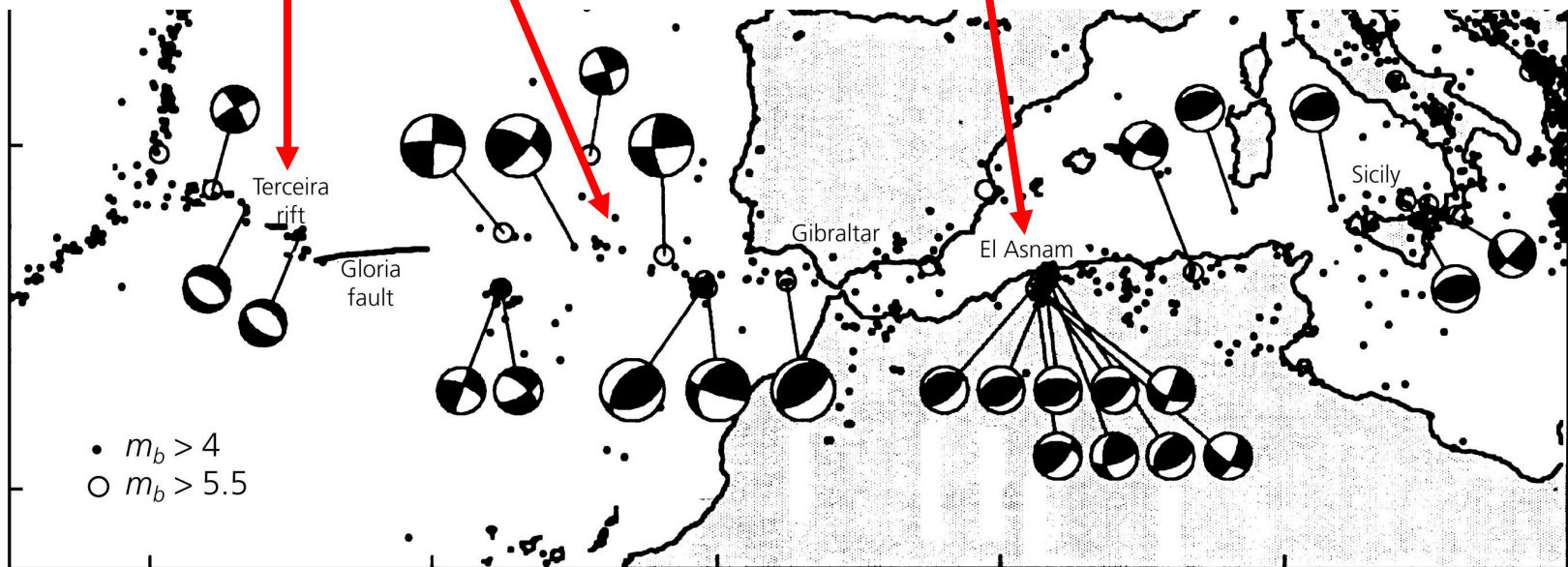
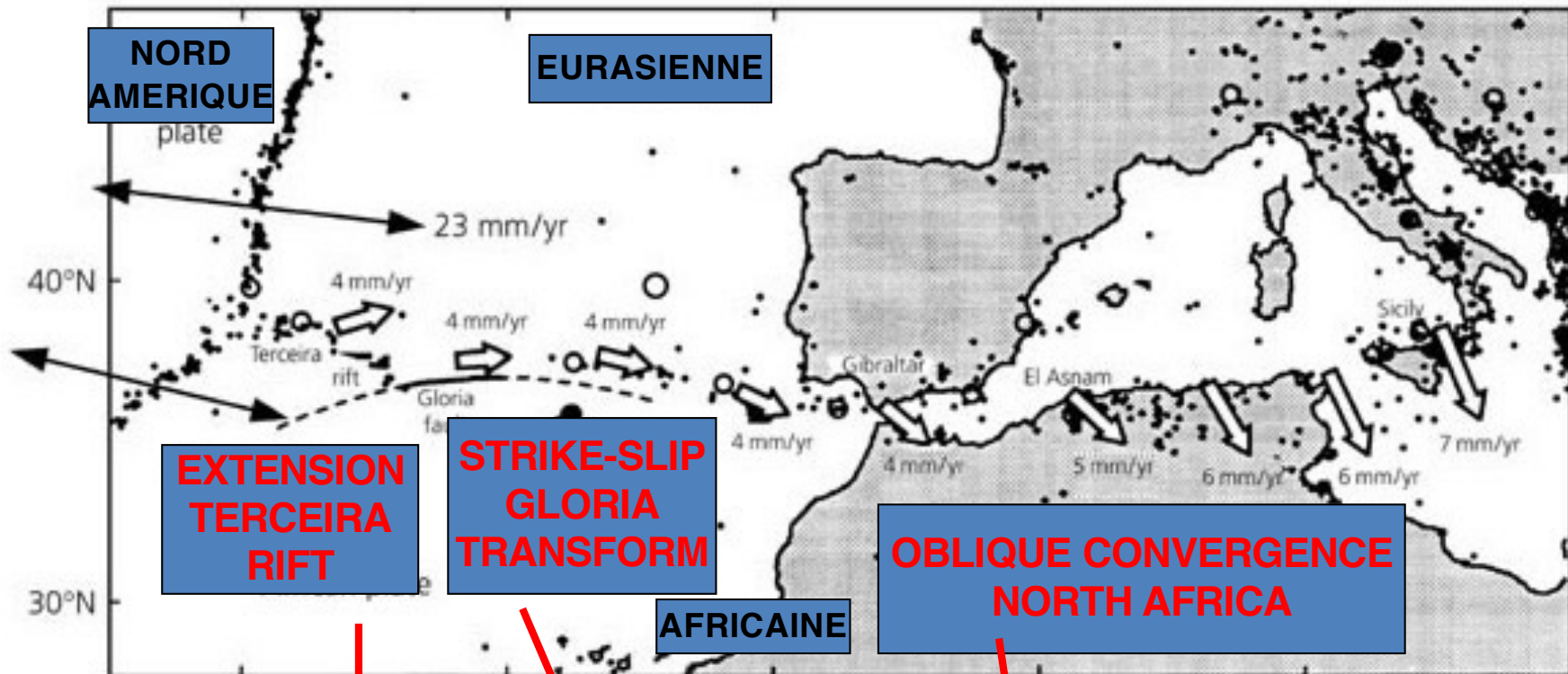


★ M6.7 Oct.23, 2002
 ★ M7.9 Nov.3, 2002

▲ temporary site
 ▼ permanent station



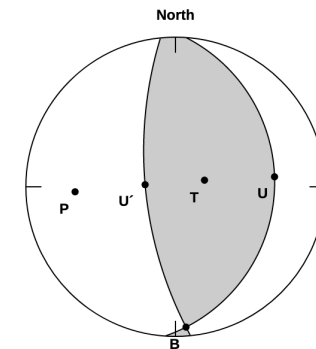
Denali 2002



Limites de plaques Divergentes / Transformantes / Convergentes

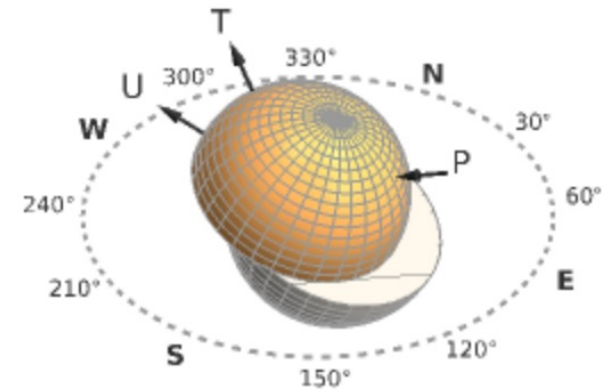
<https://demonstrations.wolfram.com/EarthquakeFocalMechanism/>

P axis (ϕ / δ) in degrees: 87.14 / -22.21
T axis (ϕ / δ) in degrees: 257.21 / -67.49



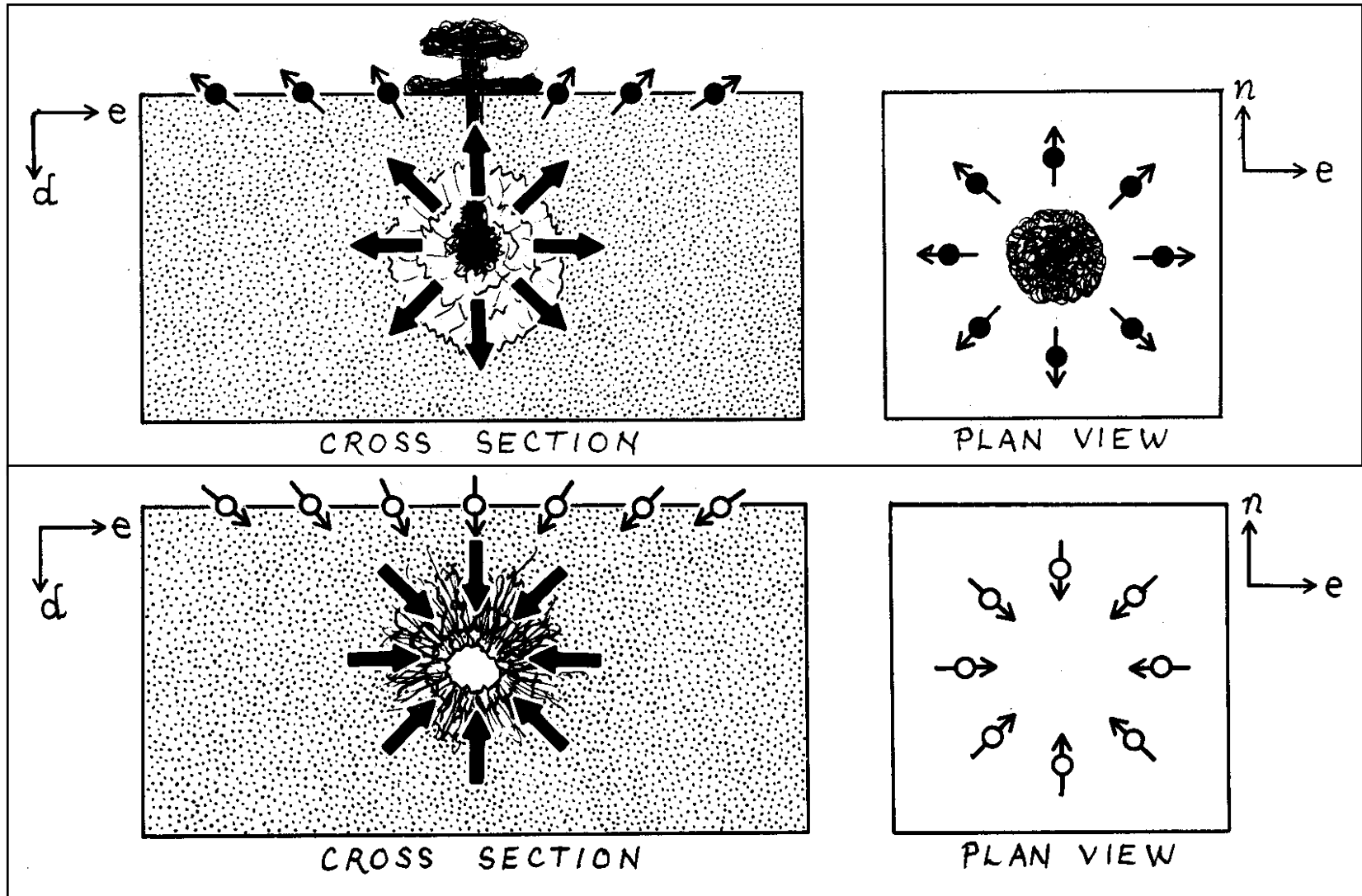
stereographic/lower
fault plane ($\phi / \delta / \lambda$) in degrees: 4.00 / 23.00 / 99.00
auxiliary plane ($\phi / \delta / \lambda$) in degrees: 174.24 / 67.30 / 86.2

<https://demonstrations.wolfram.com/StylesOfFaulting/>




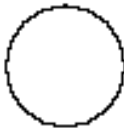


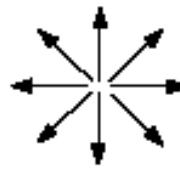
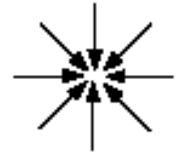

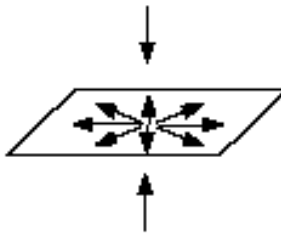
http://geosciences3d.univ-lyon1.fr/resources.php#MECA_FOYER

Premier mouvement



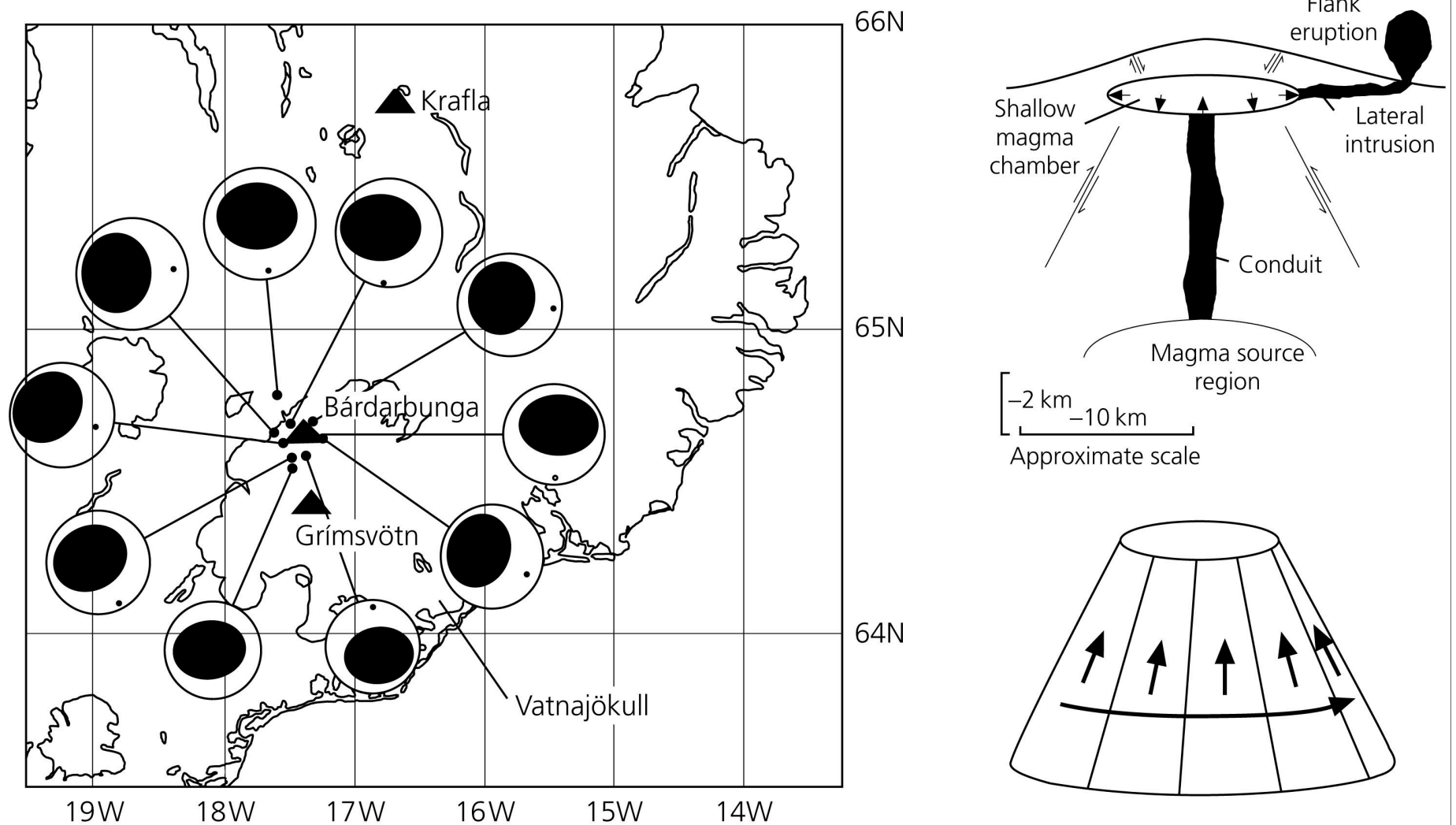
SOURCES QUI ONT UNE COMPOSANTE NON - DOUBLE COUPLE:

- Isotropes: Explosions – Implosions
- Compensated Linear Vector Dipoles (CLVD's) (double couple + 1 composante volumétrique), souvent le cas pour les très gros séismes.

	ISOTROPIC		DOUBLE COUPLE			CLVD - compensate linear vector dipole			
Moment Tensor	M_{xx}	0	0	$-M_{xx}$	0	0	M_{xx}	0	0
	0	M_{yy}	0	0	$-M_{yy}$	0	0	$-2M_{yy}$	0
	0	0	M_{zz}	0	0	$-M_{zz}$	0	0	M_{zz}
First Motions									
	Explosion	Implosion	slip on a fault				uniform outward motion in plane due to normal shortening		
Particle Motion									

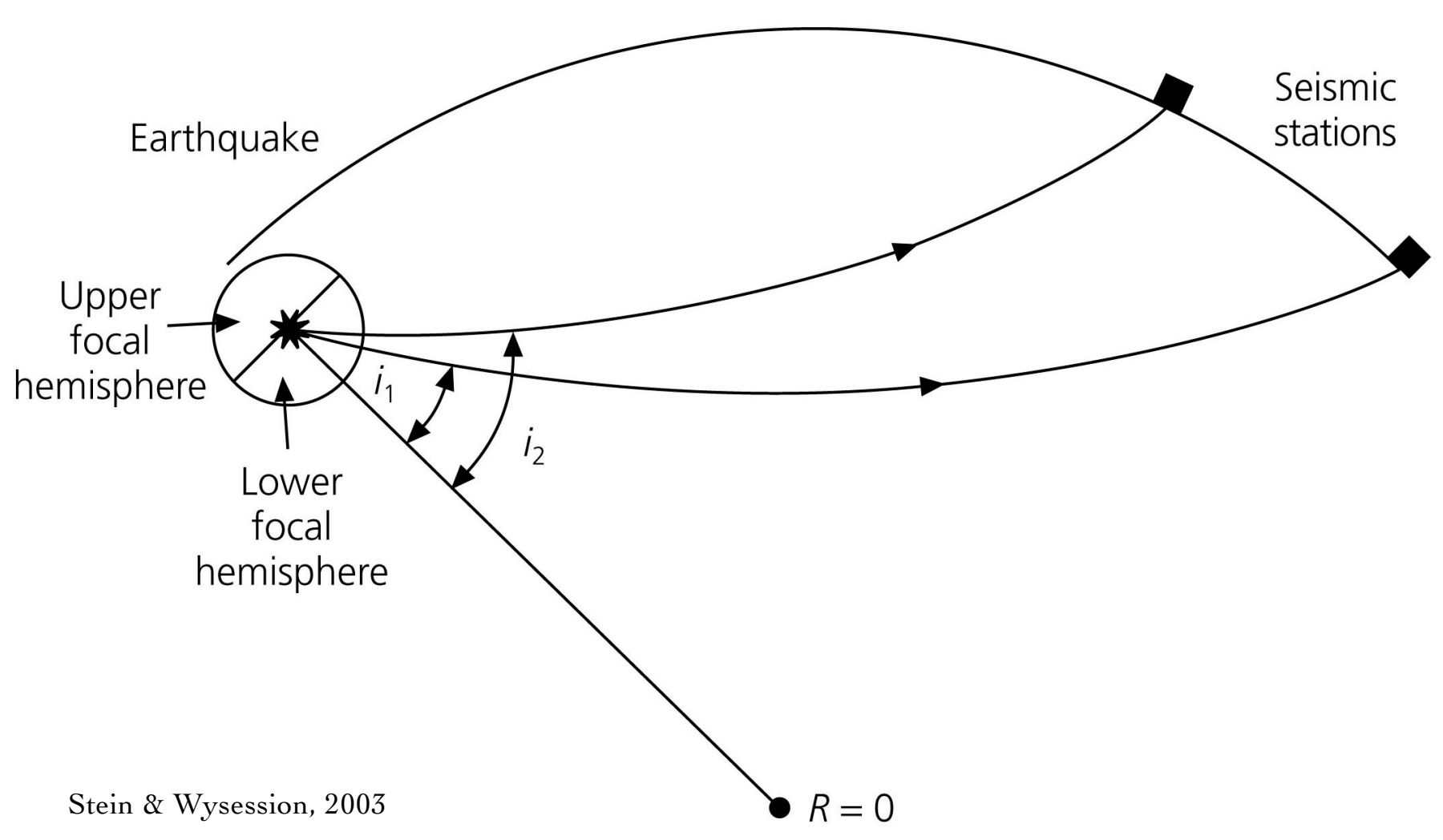
FAILLES INVERSES EN FORME DE CÔNE ET DIKES (CRACKS) QUI S'OUVRENT AVEC LE MAGMA

Figure 4.4-8: Example of CLVD-type focal mechanisms for caldera earthquakes.



TD

Les rais sismiques sont courbés à cause de l'augmentation de vitesse avec la profondeur.

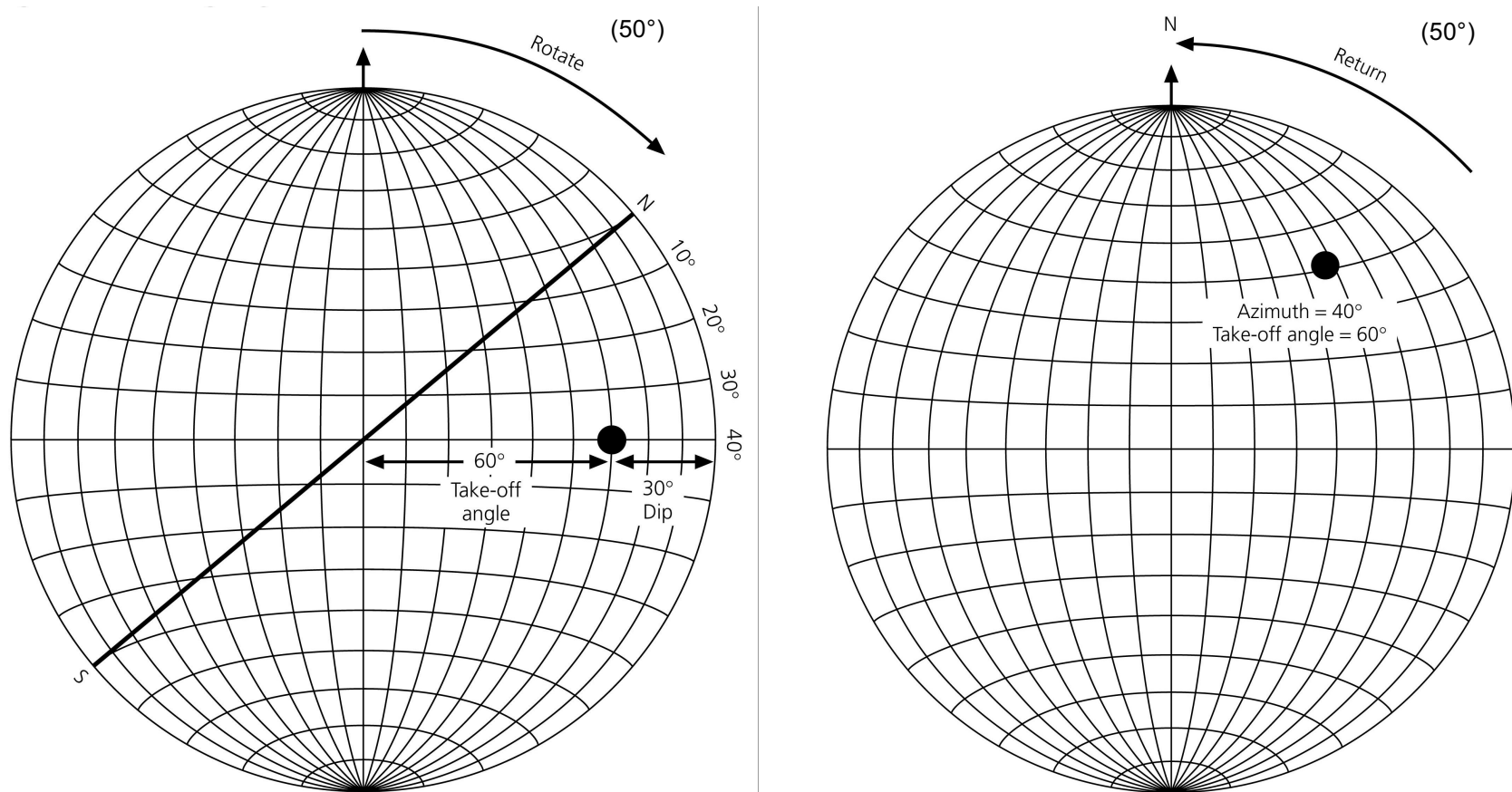


PROJECTION STÉRÉOGRAPHIQUE: TRACER LE PREMIER MOUVEMENT

Le mouvement à la station sismique est défini par:

- l'azimut source/ station
- l'angle d'incidence du rai
- la polarité de la première arrivée (vers le haut ou vers la bas)

La station correspond donc à un point sur la sphère focale (azimut, angle).
Reporter sur la projection la station et marquer si dilatation (bas, -) ou compression (haut, +).

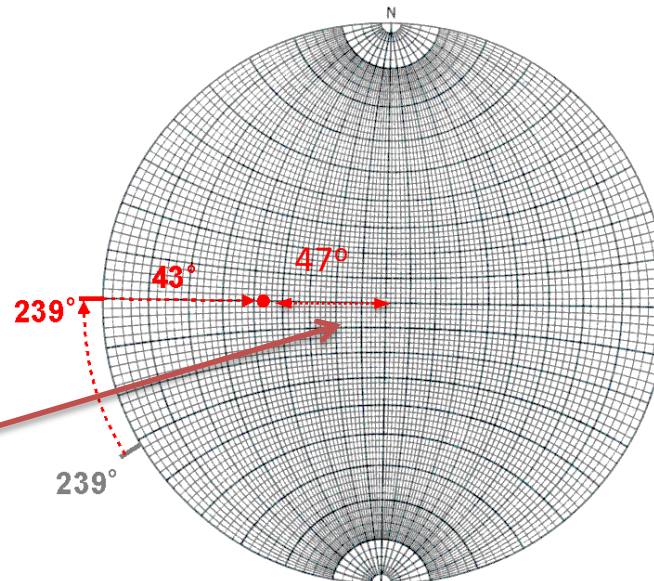
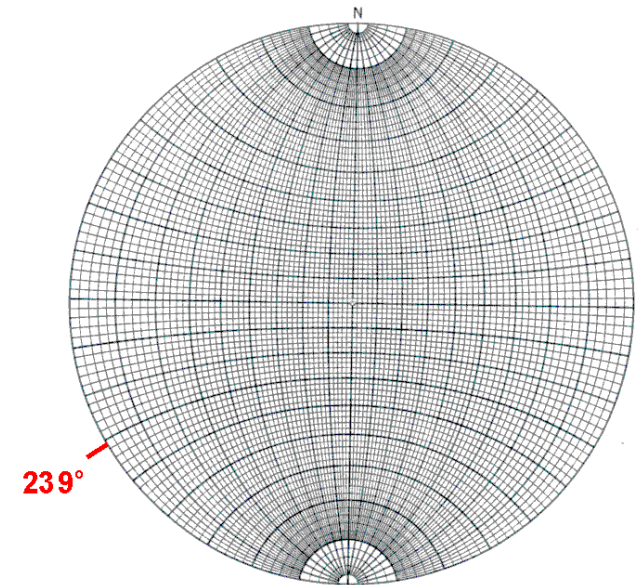
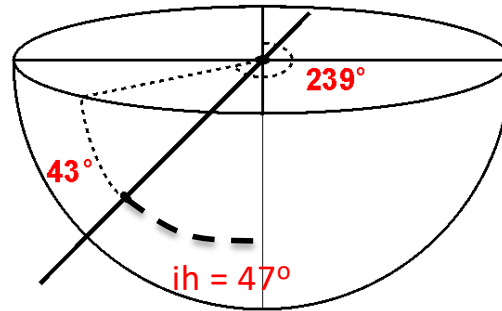


Projection Stéréographique

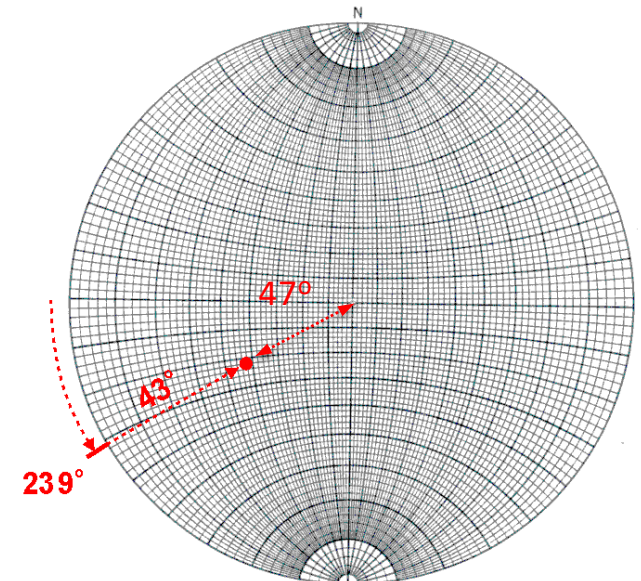
Tracer une ligne
(ex. un rai)

$$Az = 239^\circ$$

$$ih = 47^\circ$$



Attention: ih à partir de la verticale



Projection Stéréographique

Tracer un
plan(ex. une
faille)

$$Az = 109^\circ$$

$$\delta = 55^\circ$$

Fault strike 109° dip 55° SW

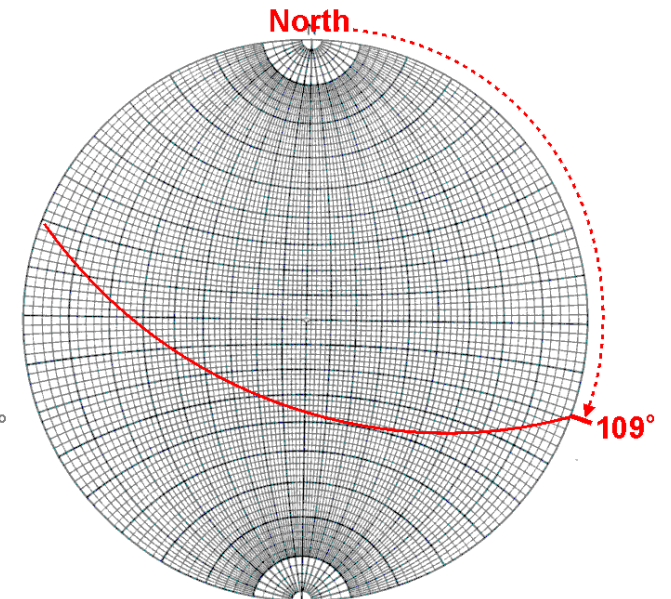
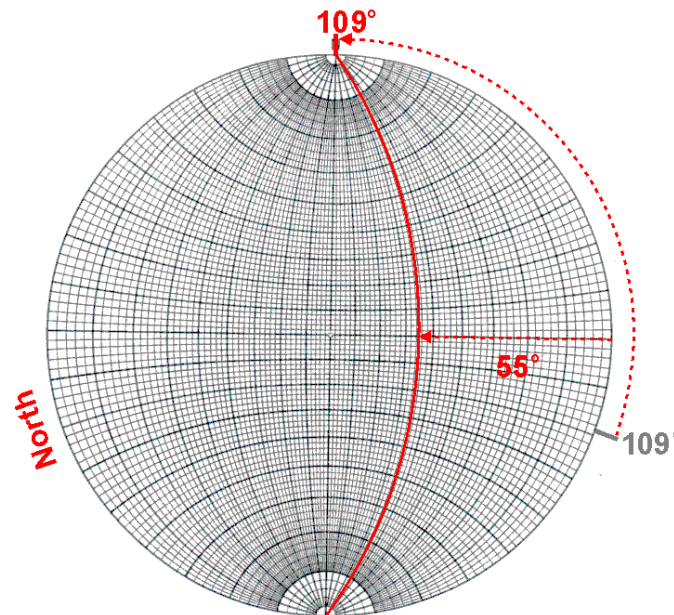
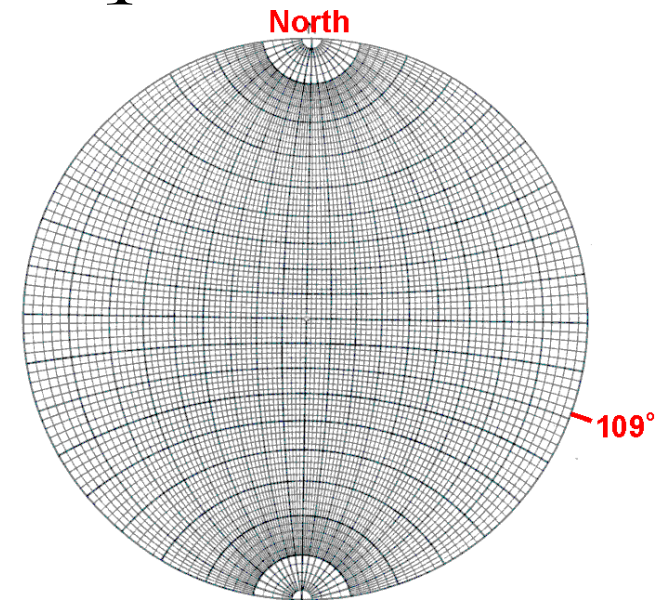
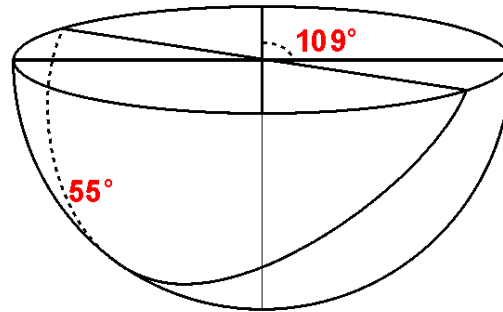


Figure 4.2-12: Example of plotting perpendicular planes on a stereonet.

Vérifiez que les 2 plans sont bien orthogonaux (passe par le pôle de l'autre)

Si la distribution des stations sur la sphère focale est bonne, on peut trouver les 2 plans nodaux:
-Plan de faille
-Plan auxiliaire

