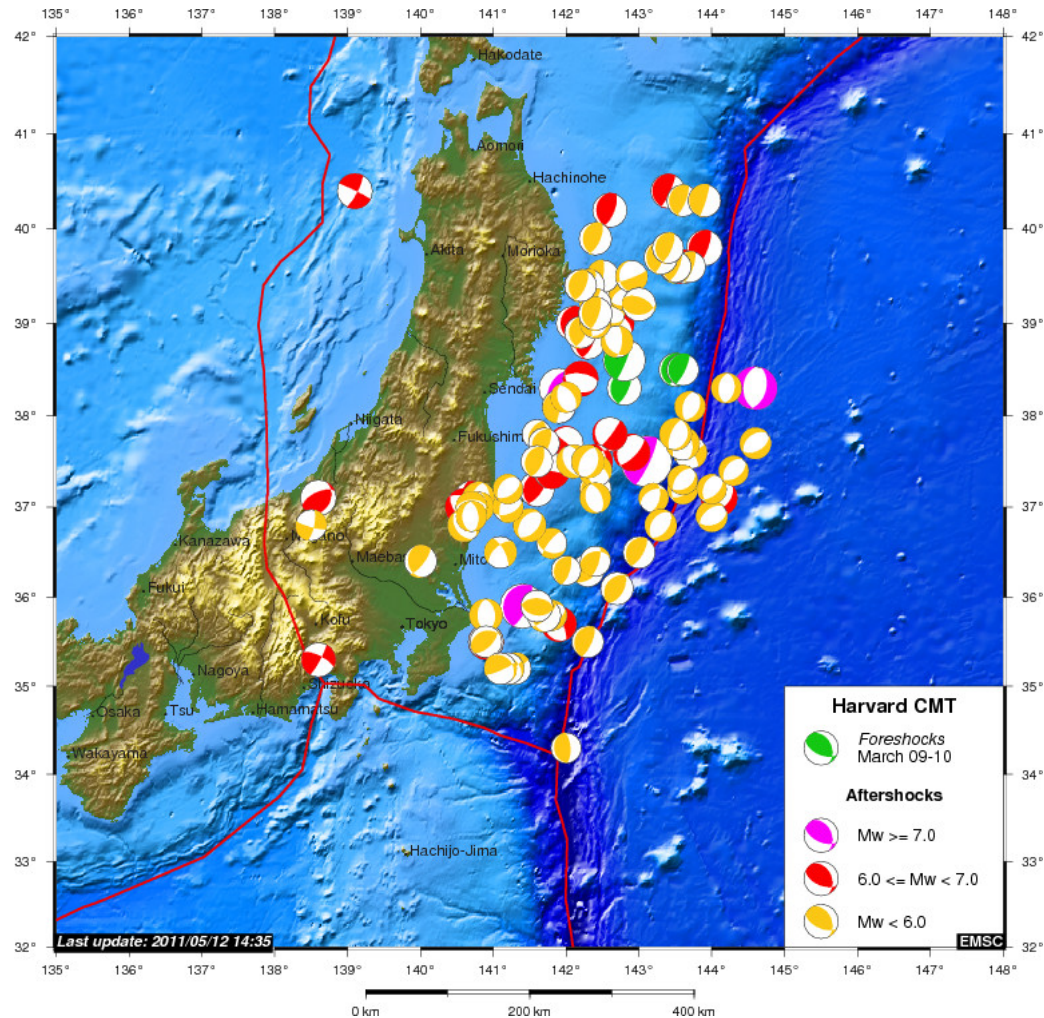


MÉCANISMES AU FOYER



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)
 - Savoir relier mécanisme au foyer et géodynamique d'une région
-
- Notion de double couple

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*)

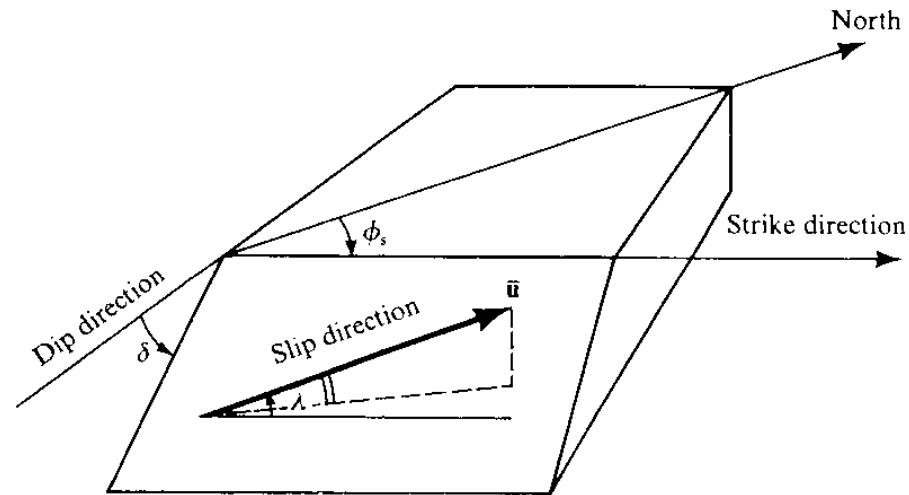
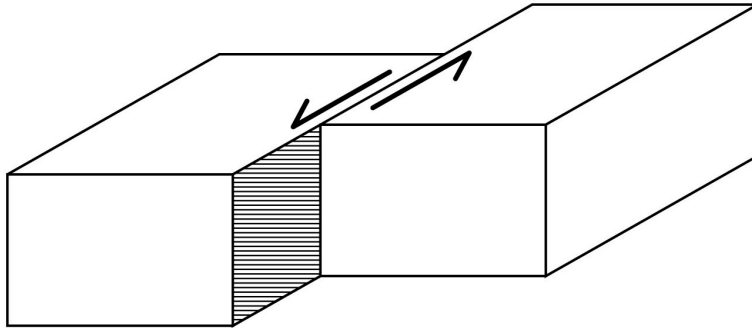


FIGURE 4.13

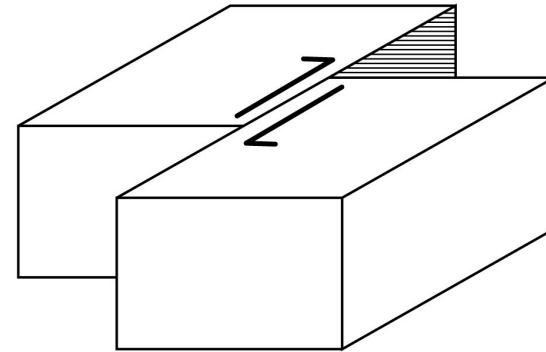
Definition of the fault-orientation parameters (strike ϕ_s , dip δ) and the slip-direction parameter (rake λ). ϕ_s is measured clockwise round from North, with the fault dipping down to the right of the strike direction: $0 \leq \phi_s < 2\pi$. The dip angle δ is measured down from the horizontal: $0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

Angle du glissement λ caractérise le type de faille



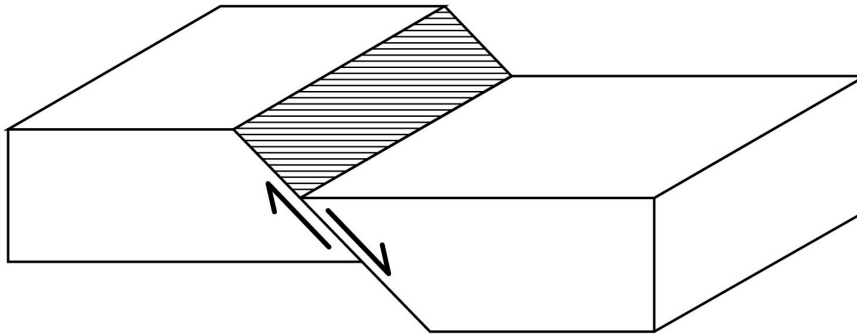
Left-lateral strike-slip fault
($\lambda = 0^\circ$)

Décrochement sénestre



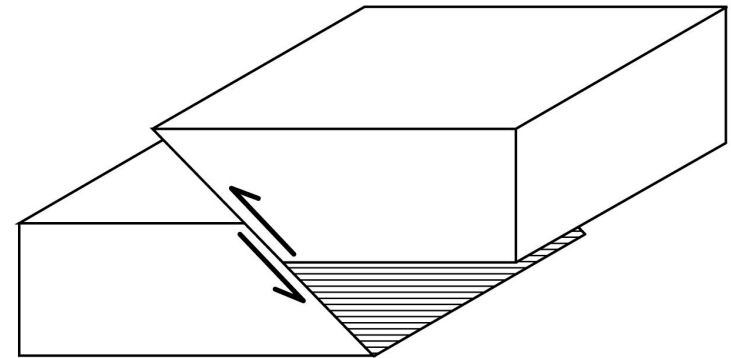
Right-lateral strike-slip fault
($\lambda = 180^\circ$)

Décrochement dextre



Normale

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

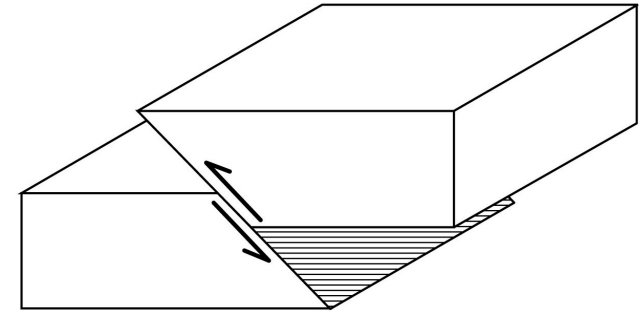


Inverse

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

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

Faïlle inverse



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)



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

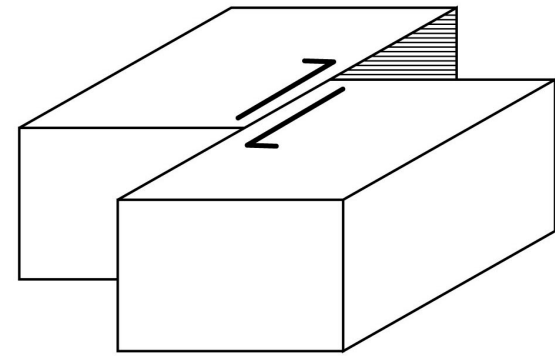


Faïlle en décrochement

Landers, Californie, 1992



Denali, Alaska, 2002



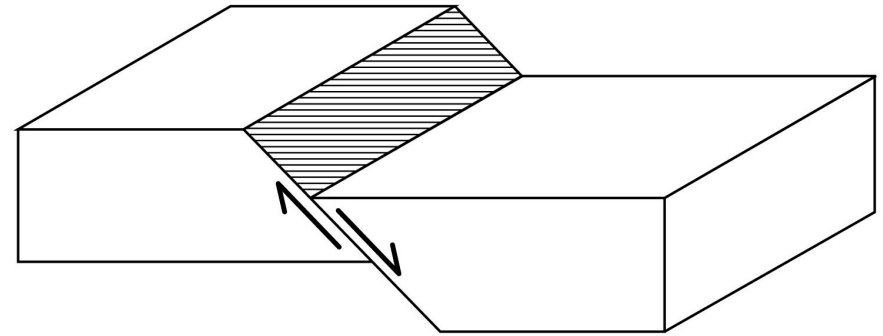
Right-lateral strike-slip fault
($\lambda = 180^\circ$)



San Francisco, Californie 1906

Faïlle normale

Crowley Lake, California

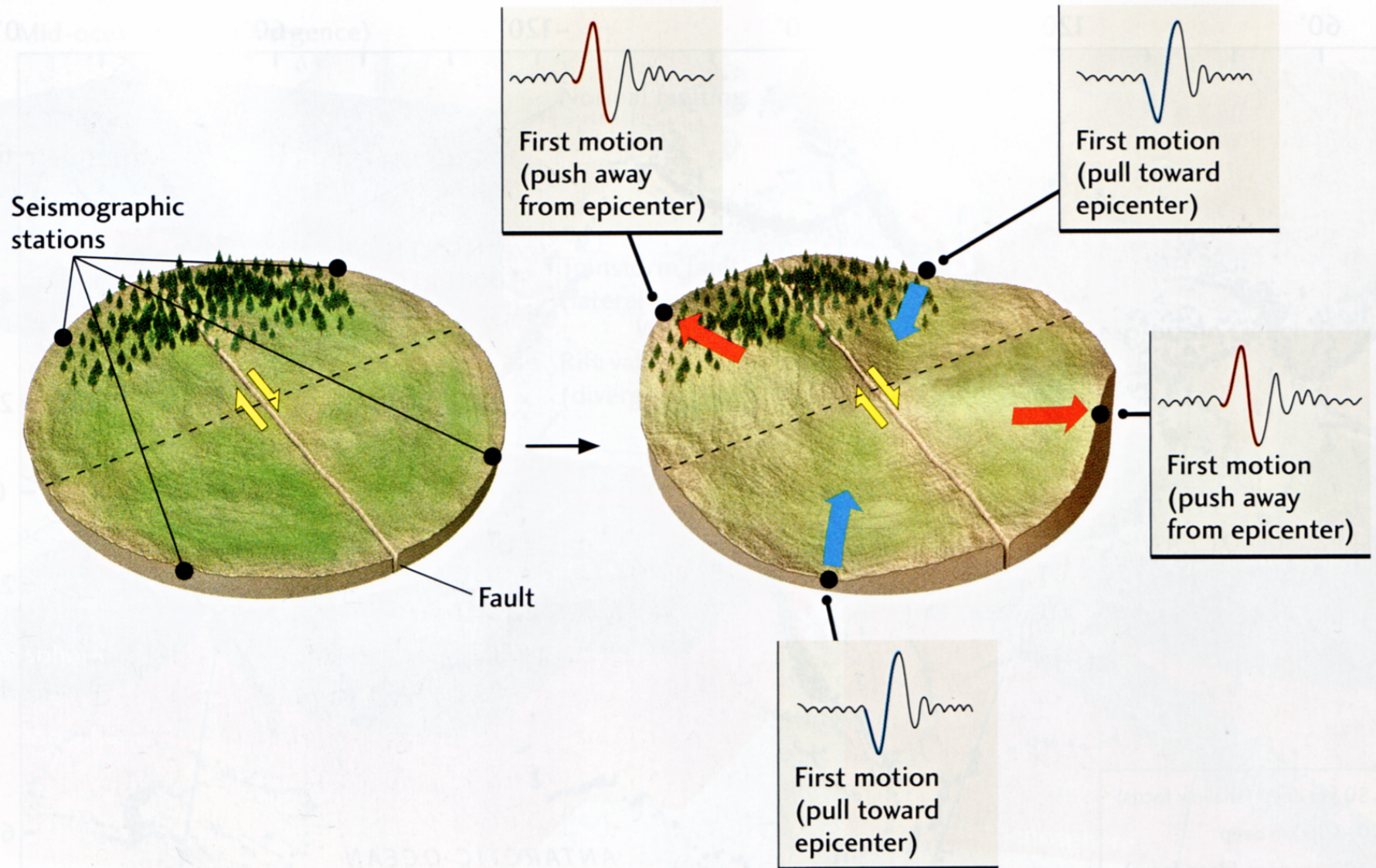


Normal dip-slip fault
($\lambda = -90^\circ$)

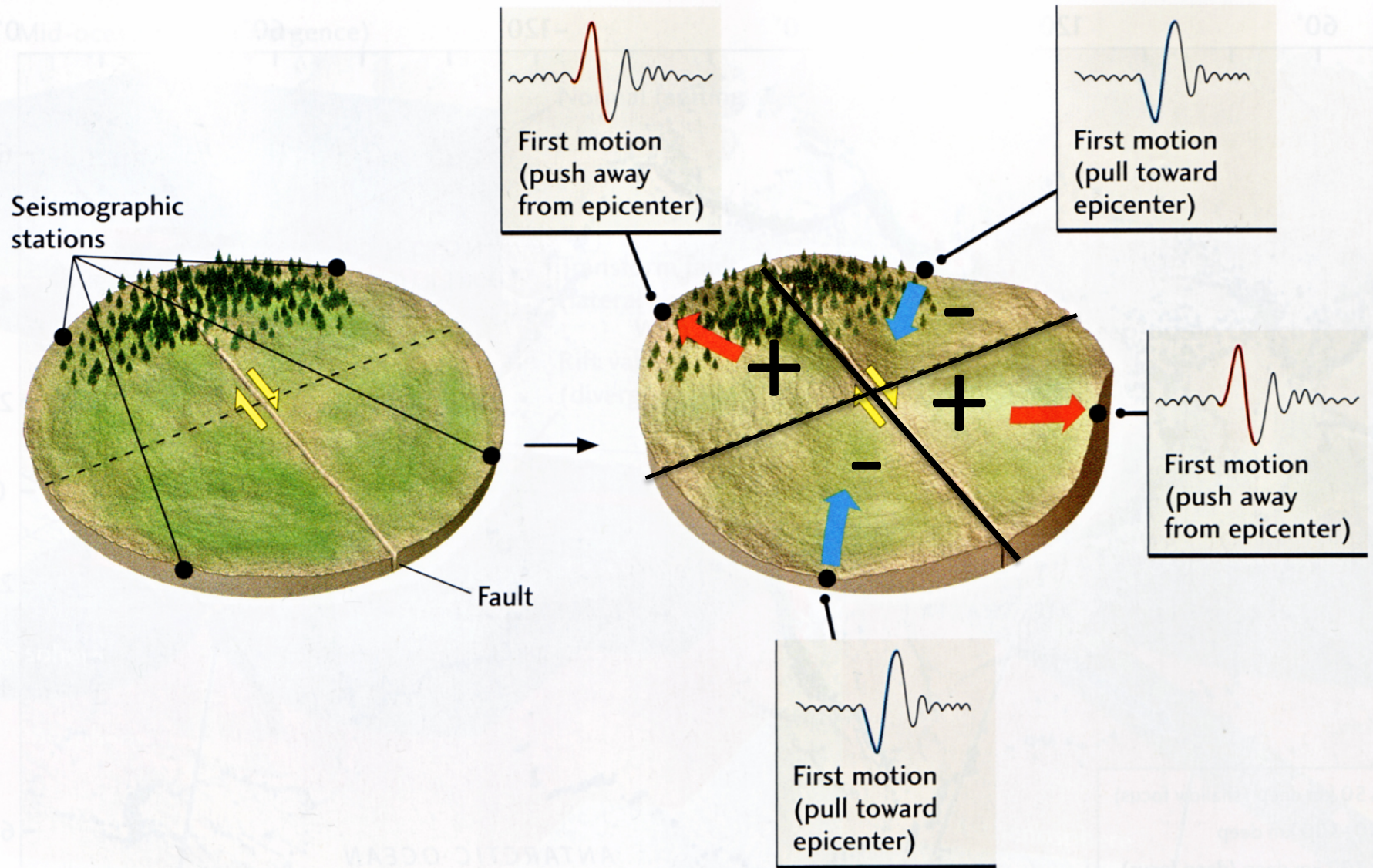
Arkitsa, Grèce



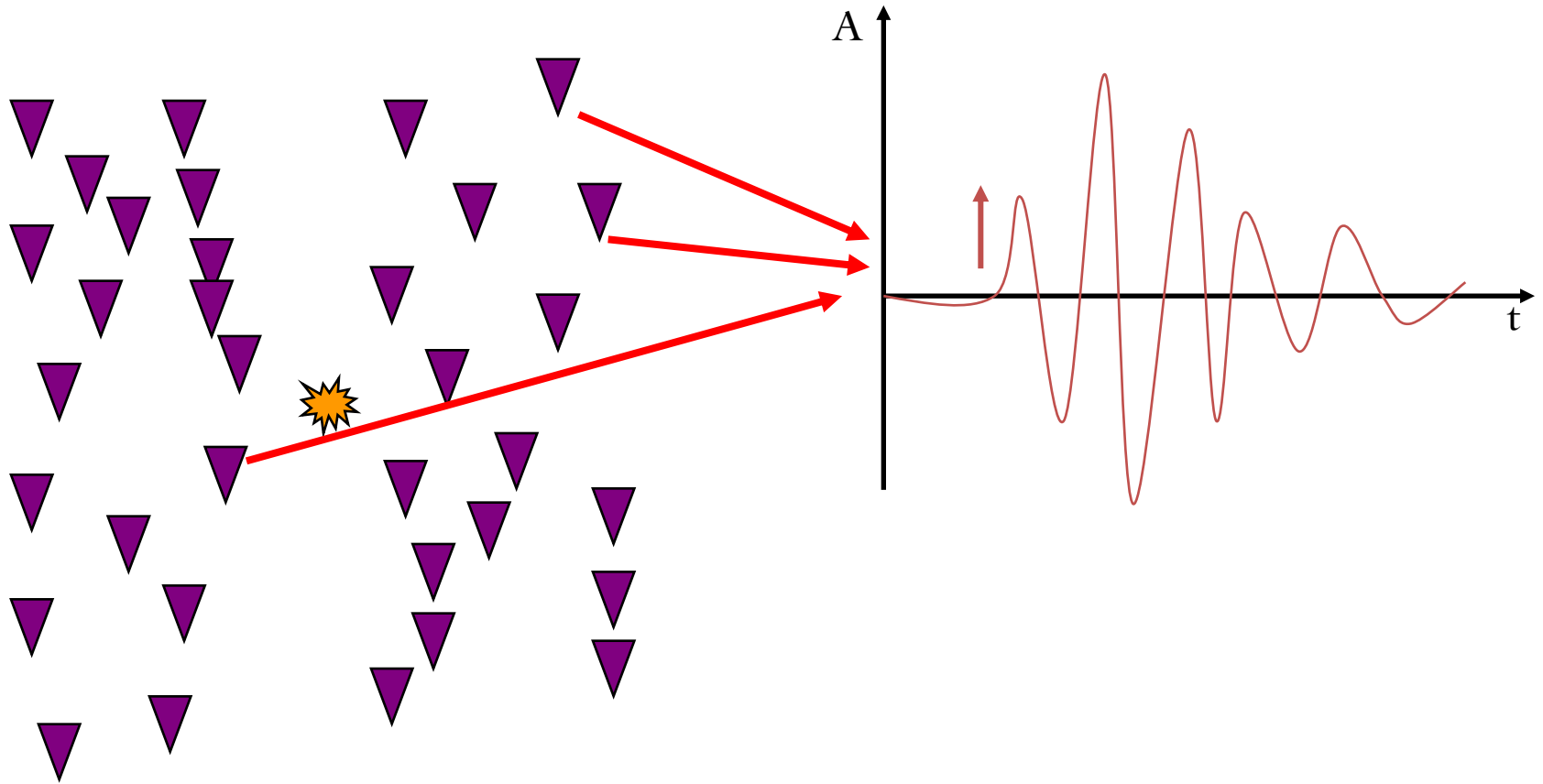
Comment caractériser une faille ?



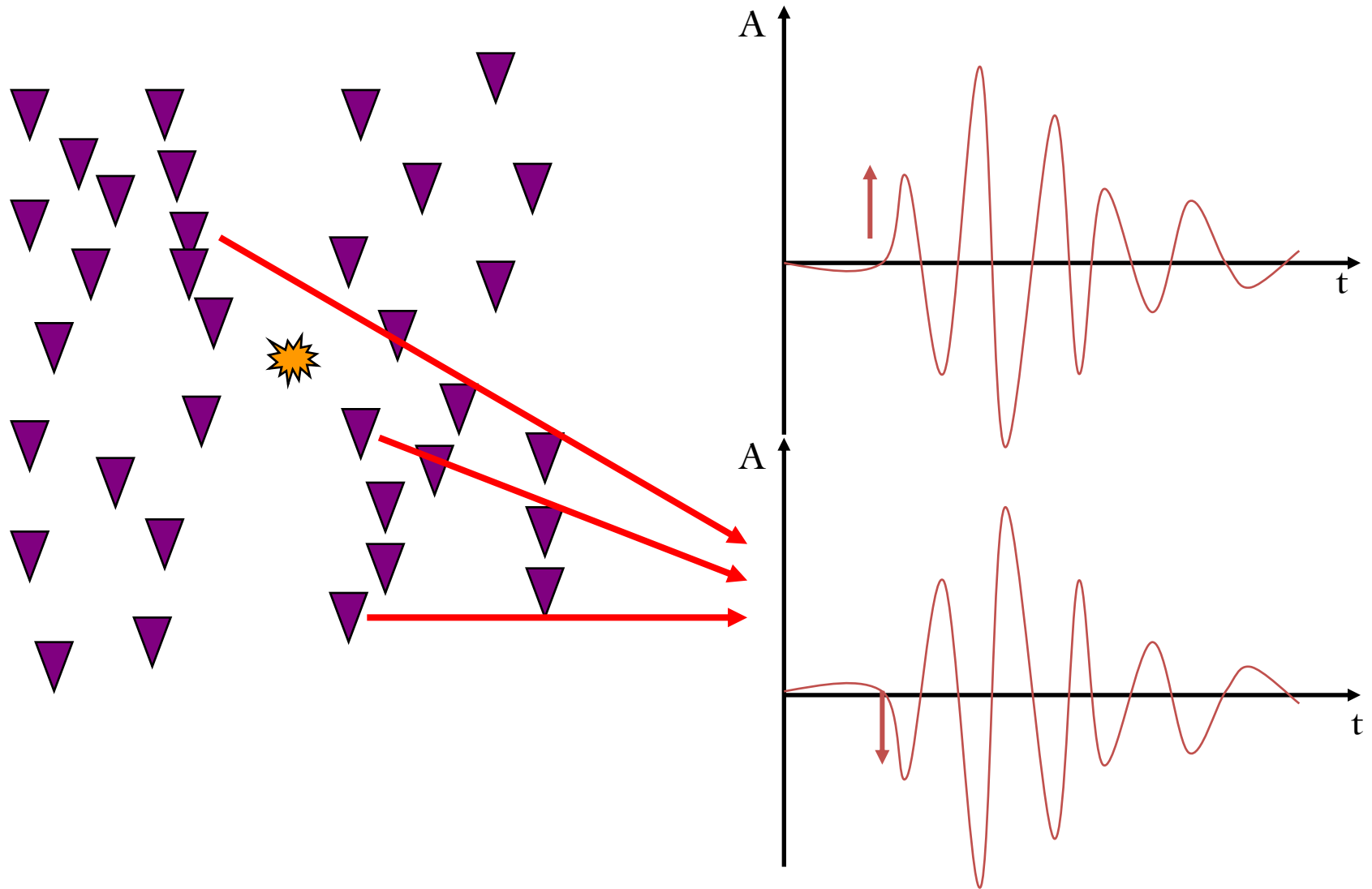
Comment caractériser une faille ?



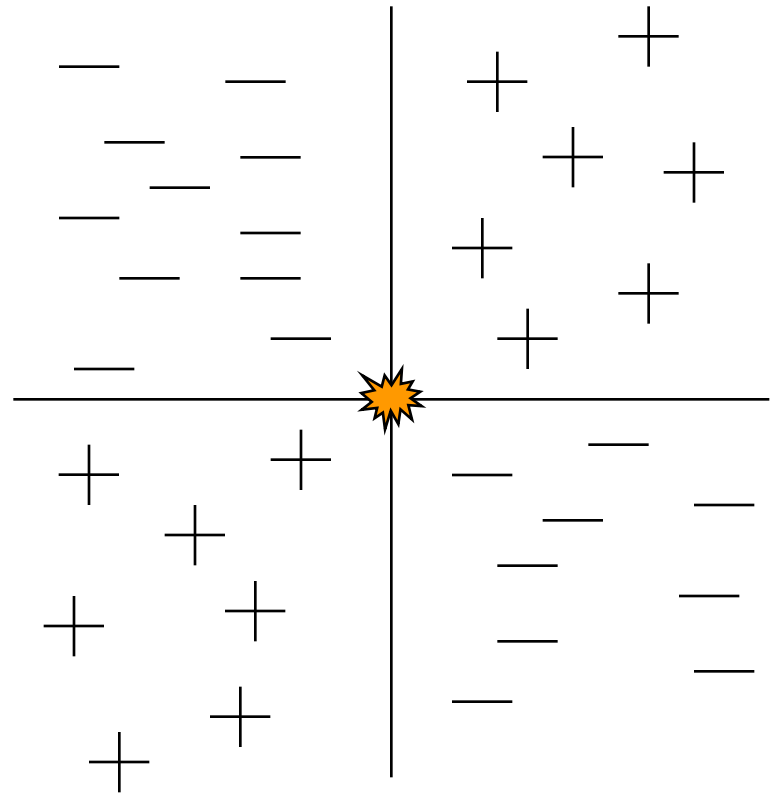
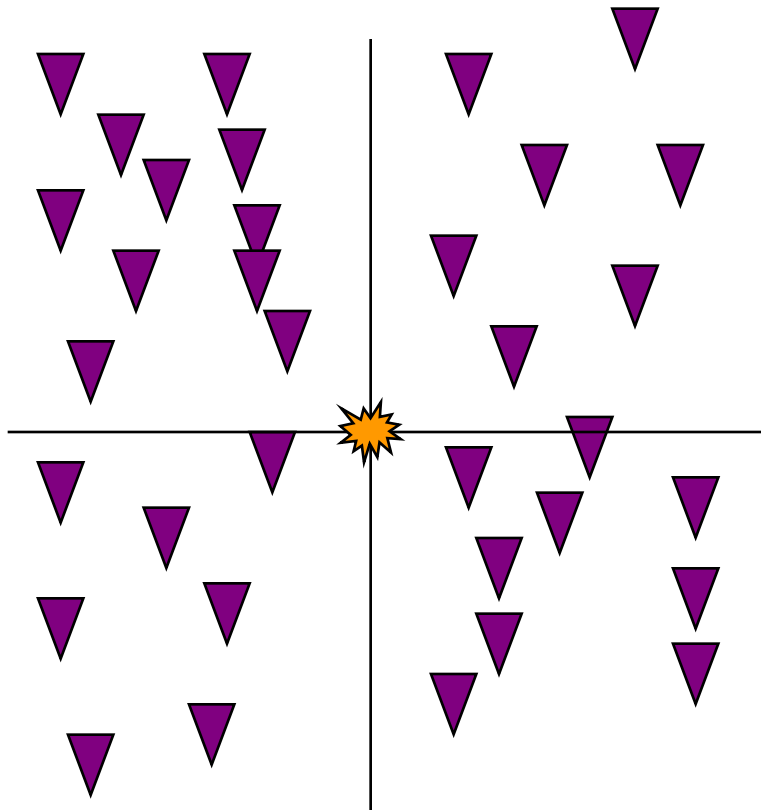
Comment caractériser une faille ?



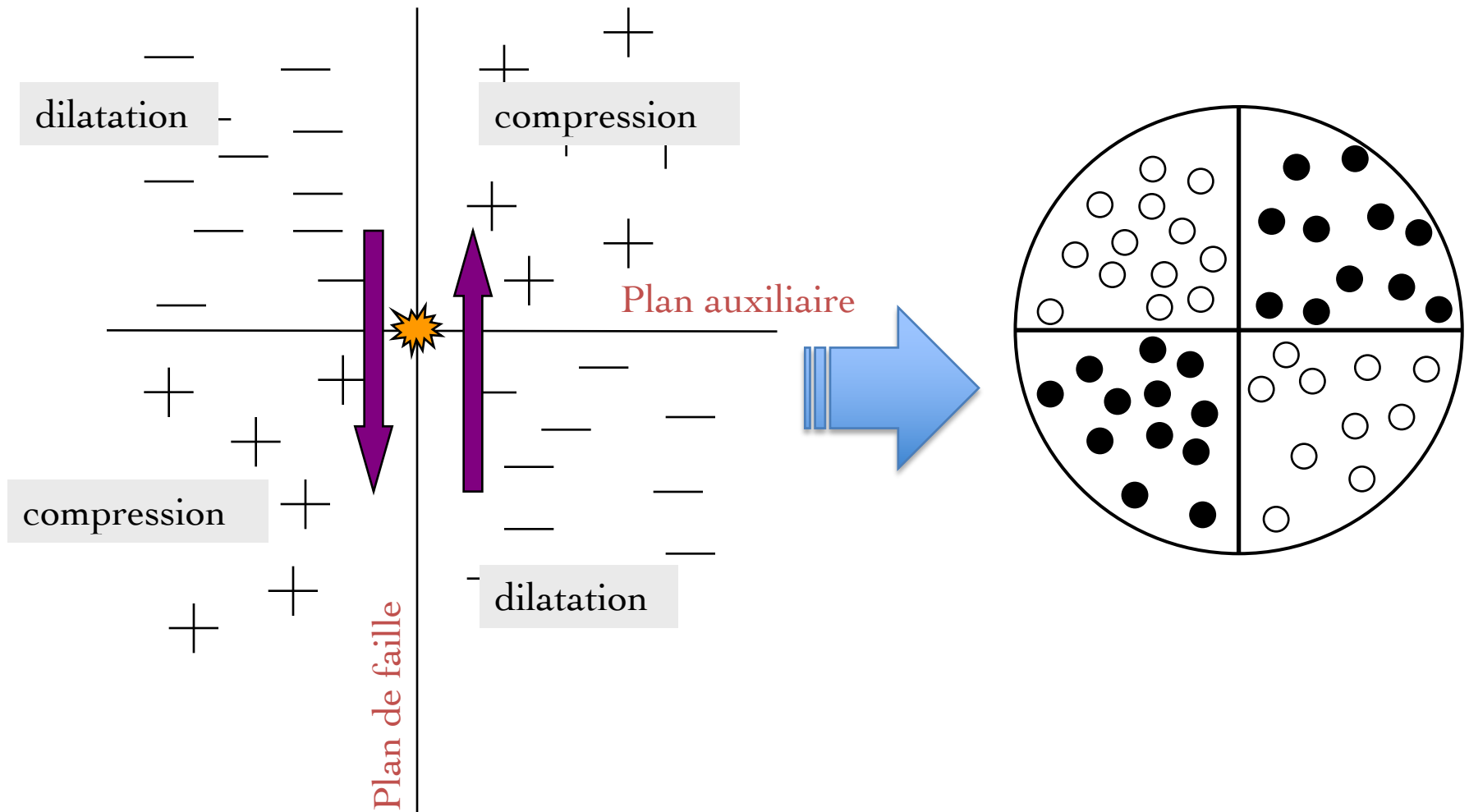
Comment caractériser une faille ?



Comment caractériser une faille ?

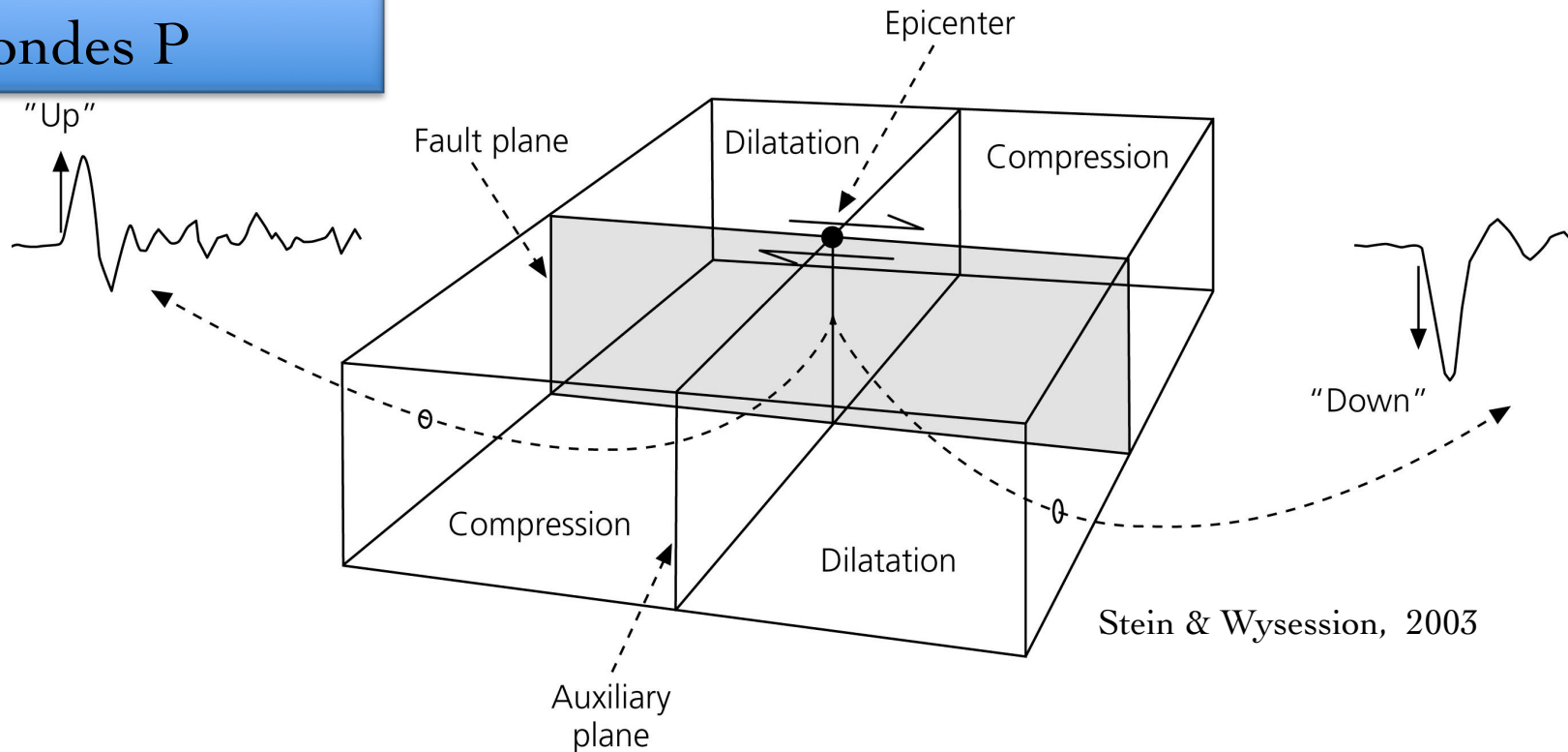


Mécanismes au foyer



FAILLE EN DÉCROCHEMENT

Premiers mouvements des ondes P



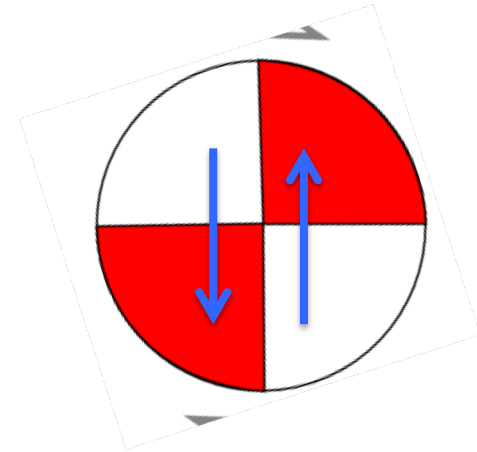
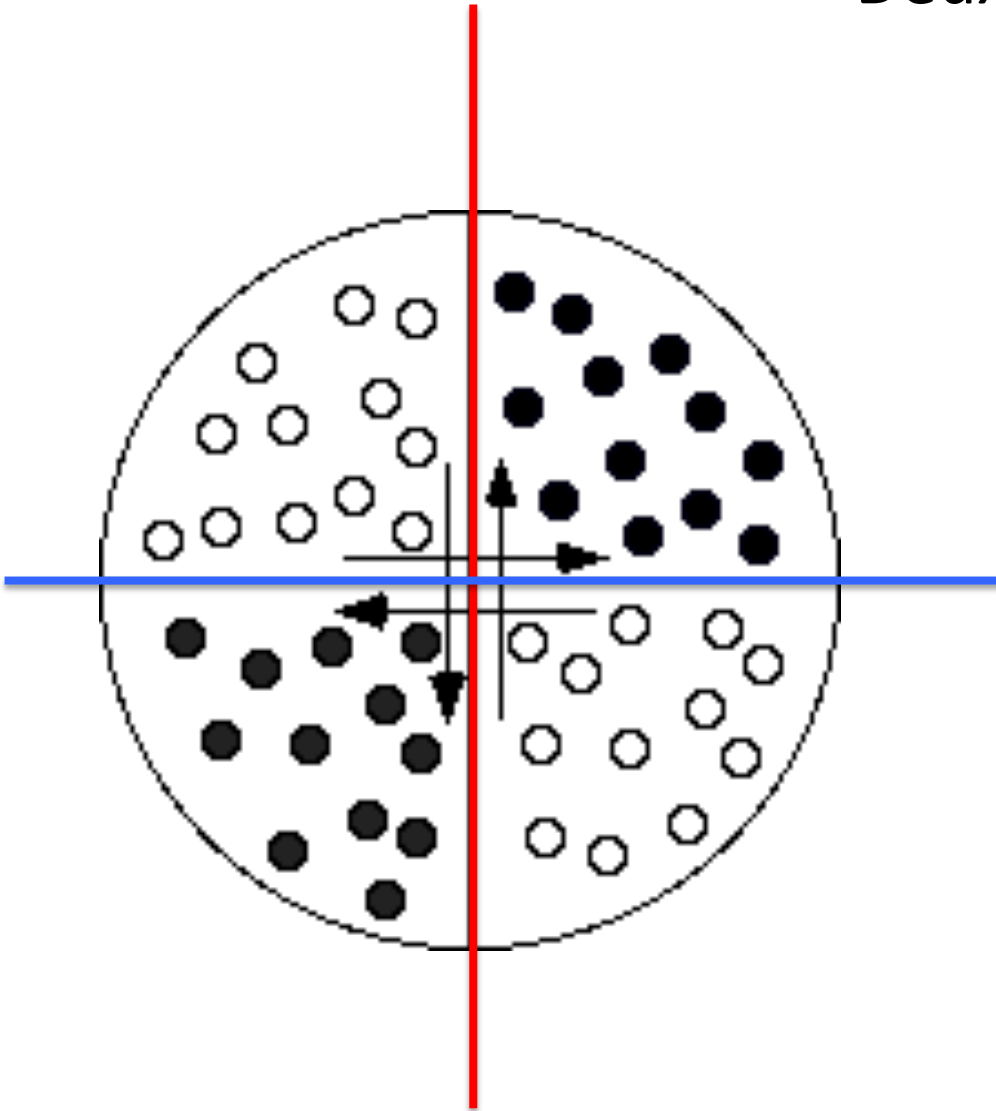
La POLARITÉ des ondes P varie entre les stations en fonction de leur direction.
Le premier mouvement est:

en HAUT : Compression
en BAS : Dilatation

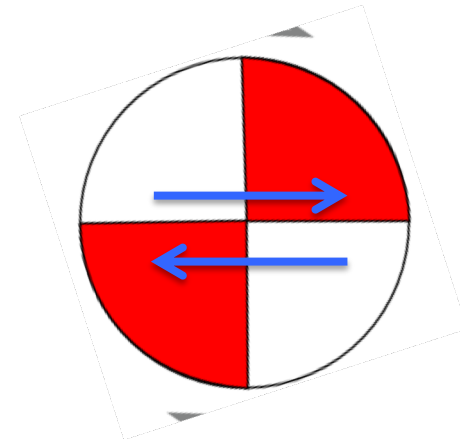
- > 4 quadrants
- > 2 plans nodaux (faille et auxiliaire)
- > les 1^{er} mouvements ne permettent pas de déterminer le plan de faille

Comment caractériser une faille ?

Deux couples de forces possibles



ou

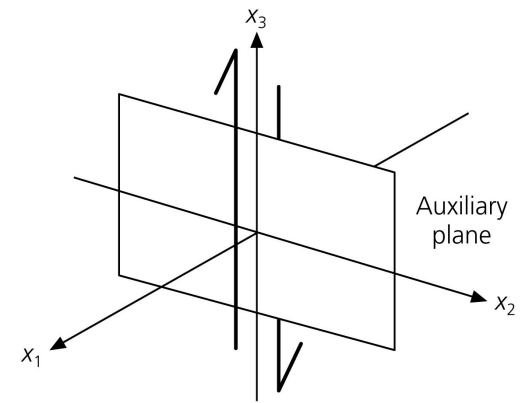
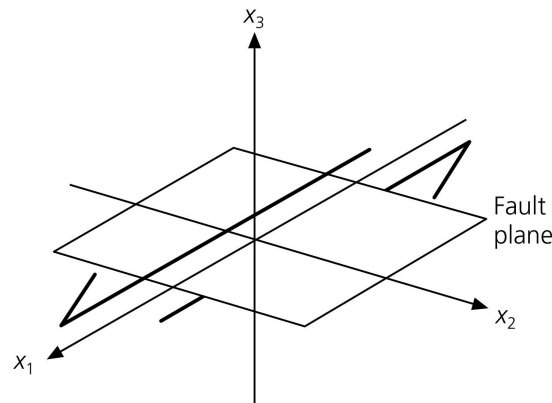


ONDES RADIÉES DEPUIS UNE FAILLE ÉQUIVALENTE À UN DOUBLE COUPLE?

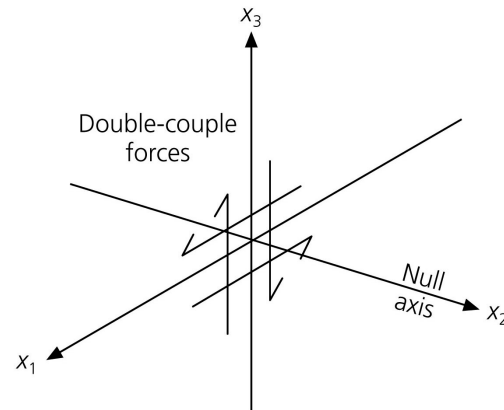
Les radiations sont dues à:

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

- un couple correspondant au plan auxiliaire



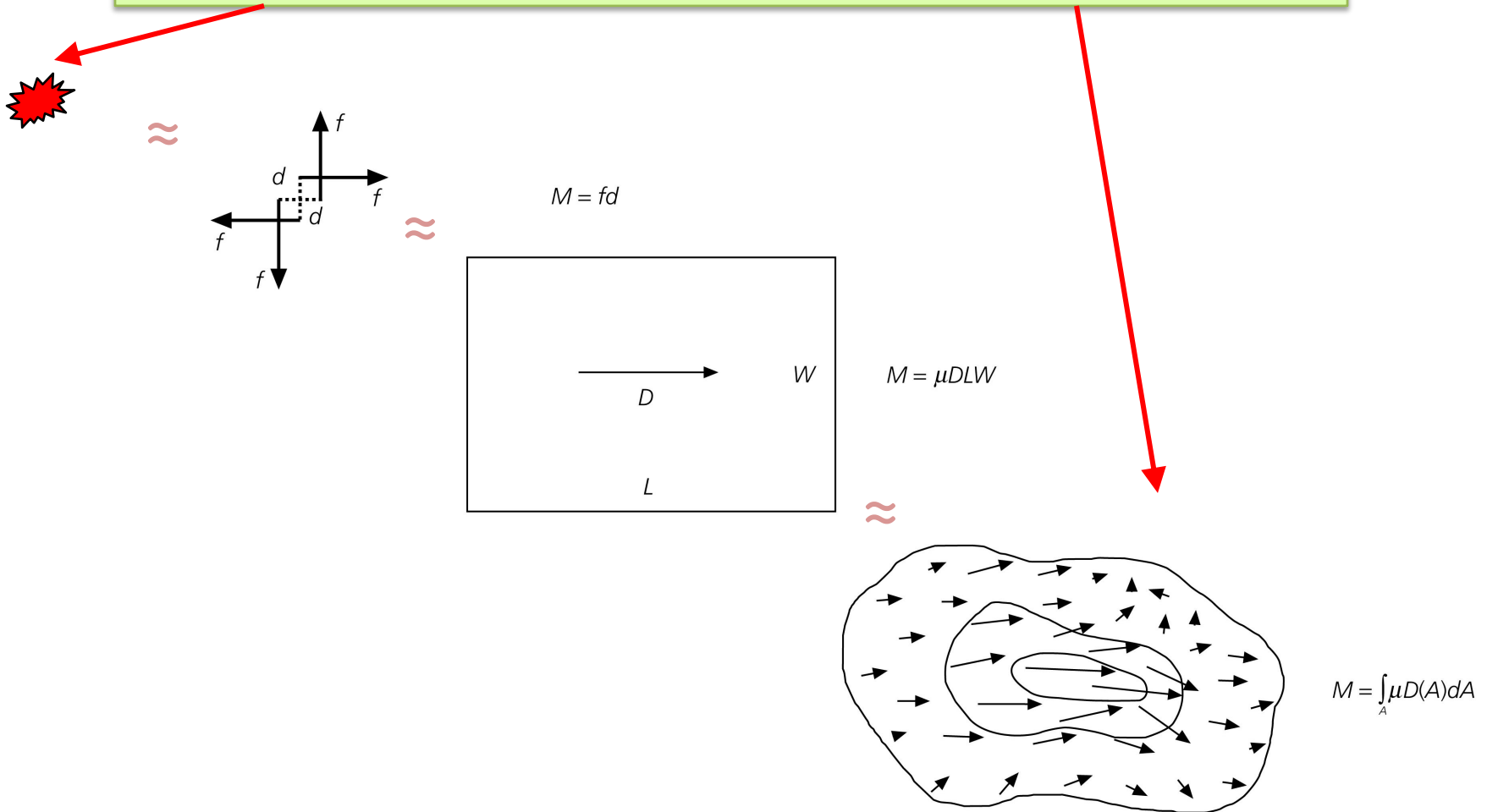
Pourquoi un DOUBLE-COUPLE :
Equilibre des forces
Pas de rotation



Pearce, 1977

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

Séisme = déplacement fini sur une faille étendue



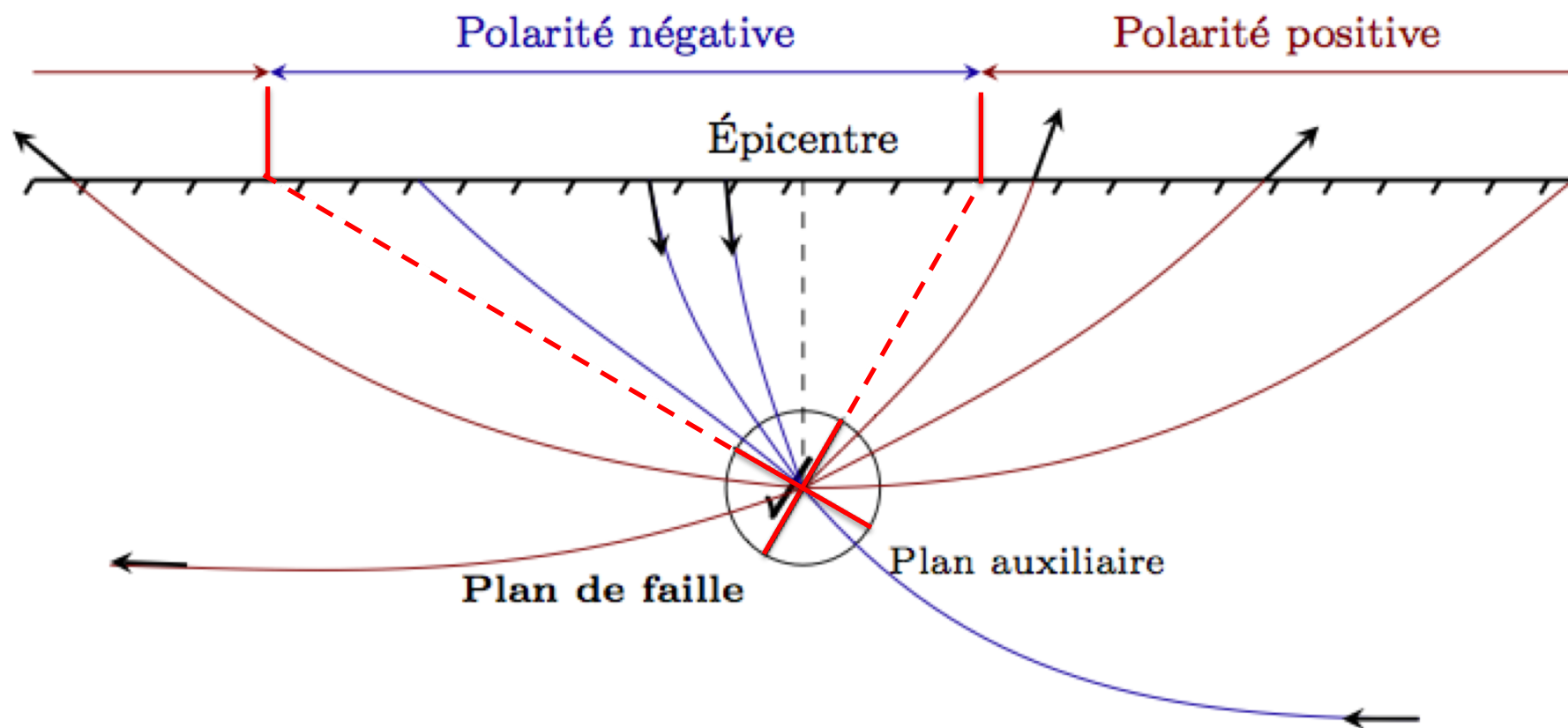
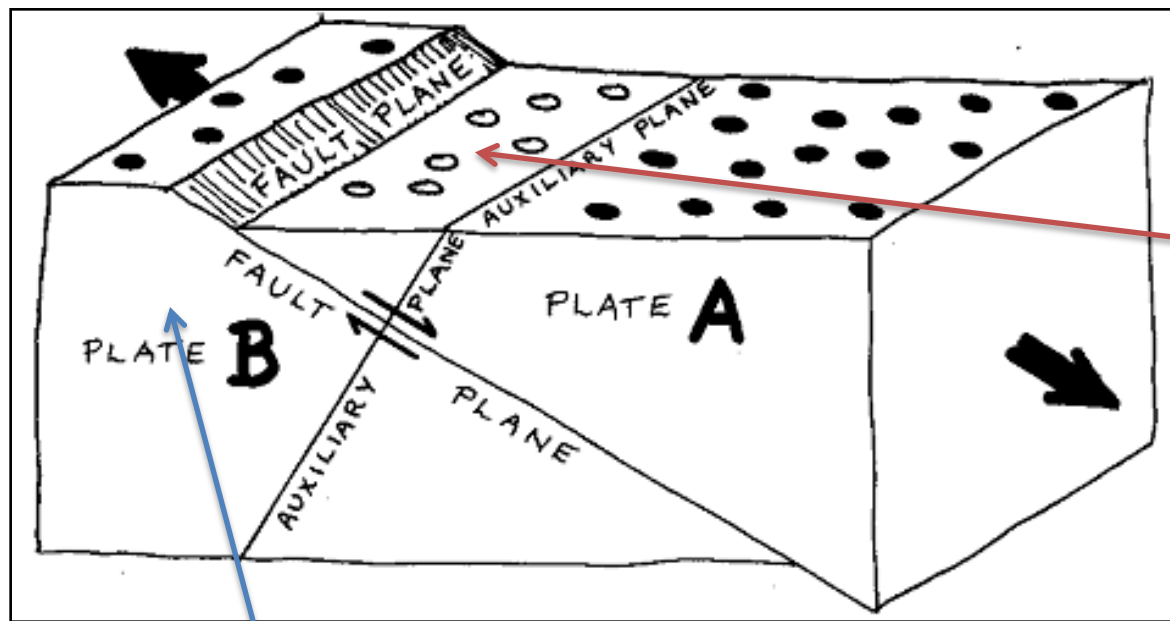
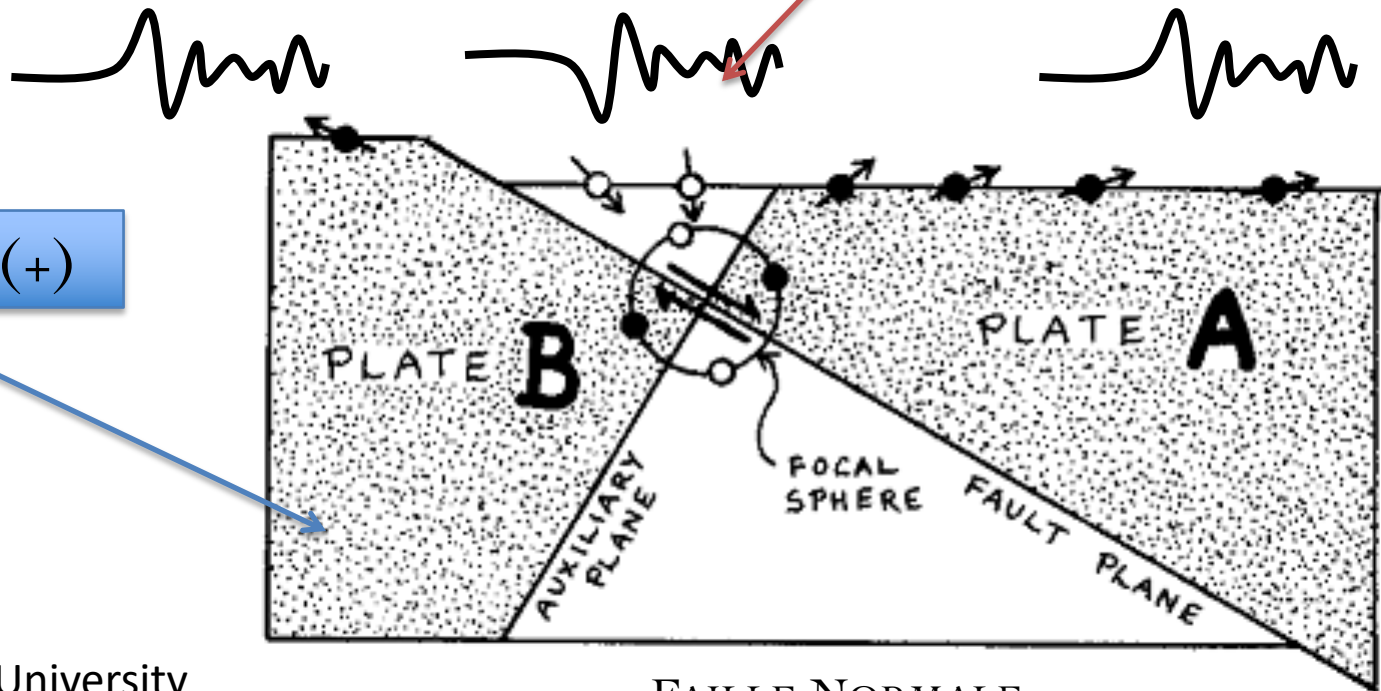


Schéma 2D du foyer sismique et des quadrants compressifs et extensifs.



Dilatation (-)

Compression (+)



FAILLE NORMALE

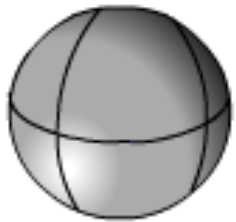
Comment représenter le mécanisme?

On projette une demi-sphère (inférieure) sur le plan équatorial (cercle).

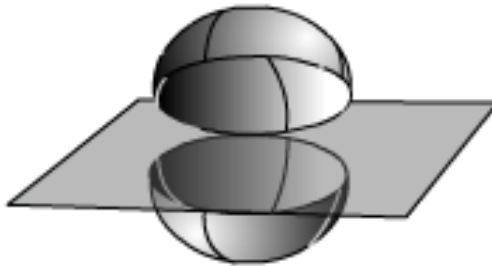


des plans verticaux sont vus comme des lignes droites

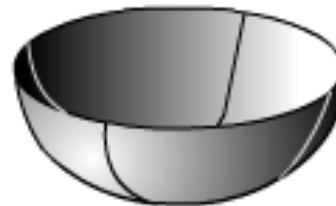
des plans inclinés sont vus comme des courbes



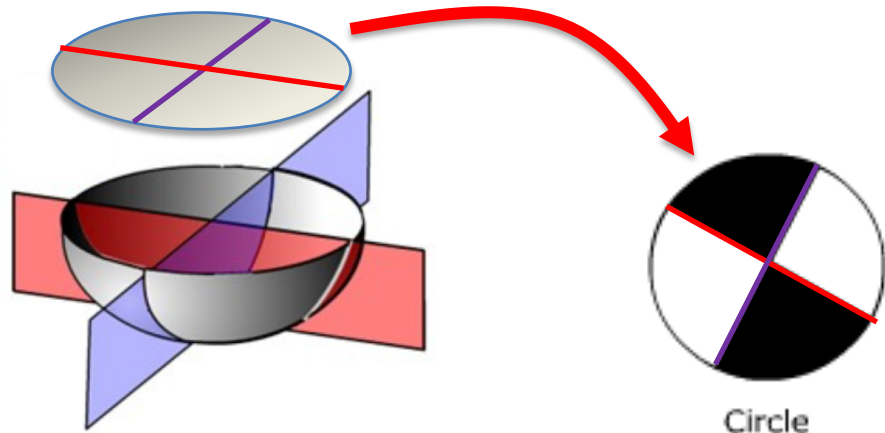
Sphere



Sphere cut by
horizontal plane



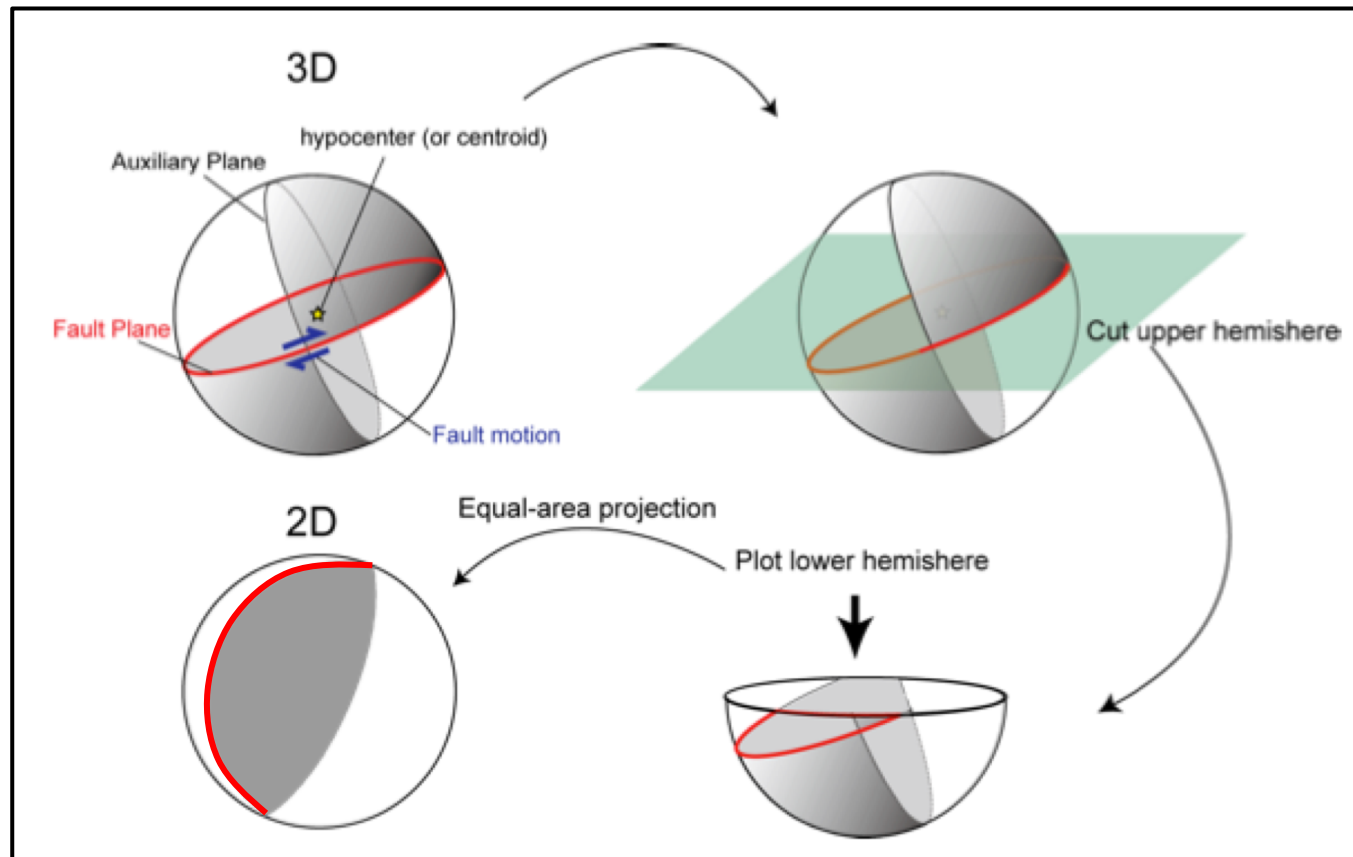
Projection of one
half of the sphere



Circle

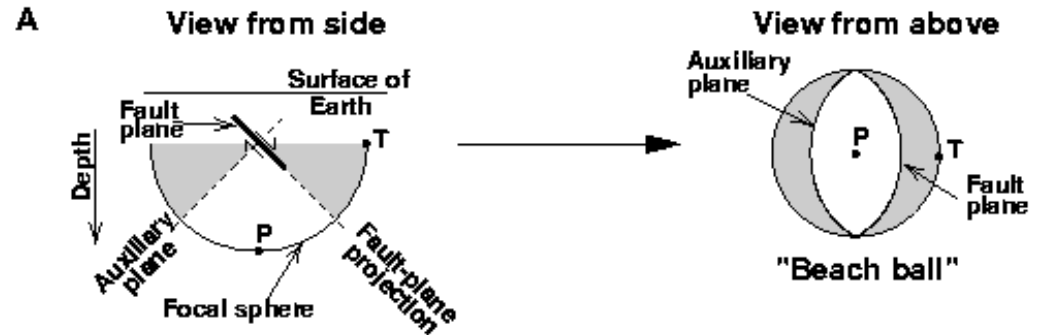
Comment représenter le mécanisme?

On projette une demi-sphère (inférieure) sur le plan équatorial (cercle).
des plans verticaux sont vus comme des lignes droites
→ des plans inclinés sont vus comme des courbes

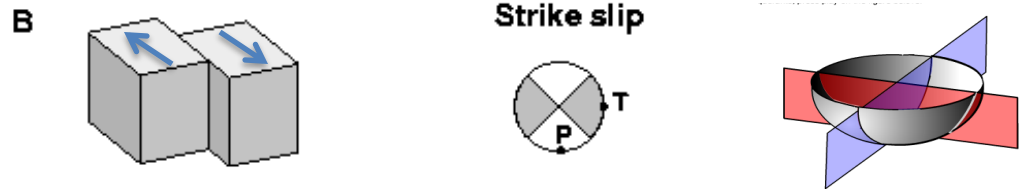


Schematic diagram of a focal mechanism

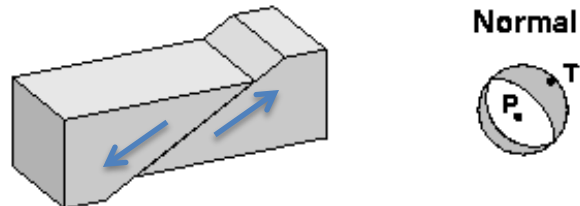
MÉCANISMES AU FOYER



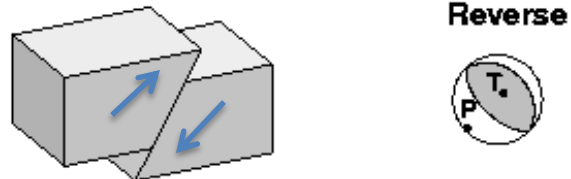
FAILLE DECROCHANTES (TRANSFORMANTES)



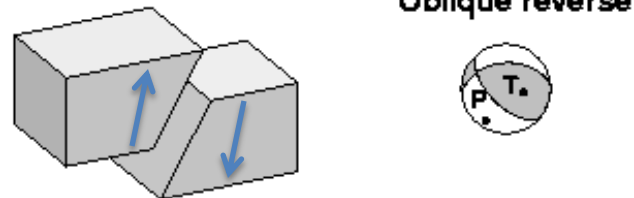
FAILLE NORMALE



FAILLE INVERSE

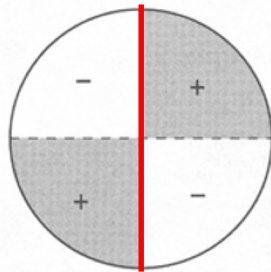
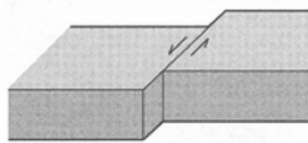


FAILLE OBLIQUE

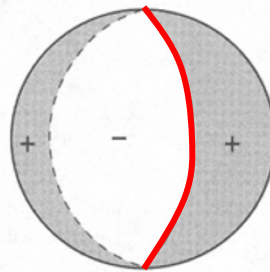
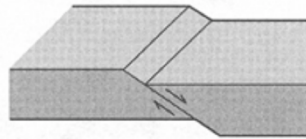


Types de faille et mécanismes associés

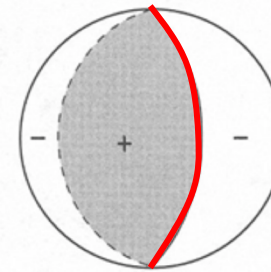
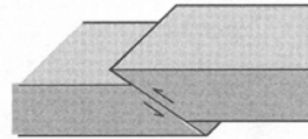
Décrochante



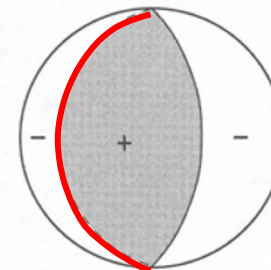
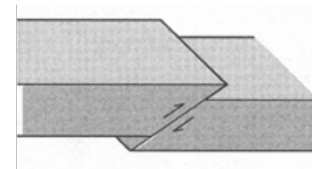
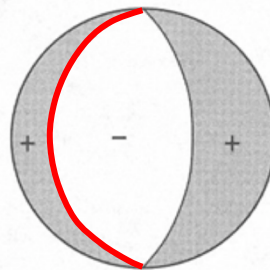
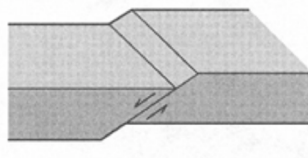
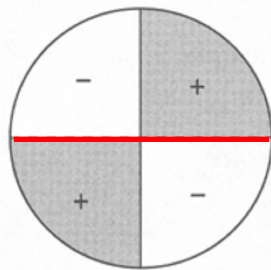
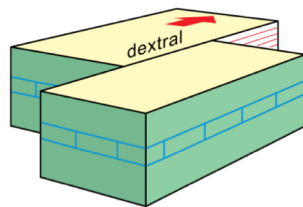
Normale



Inverse

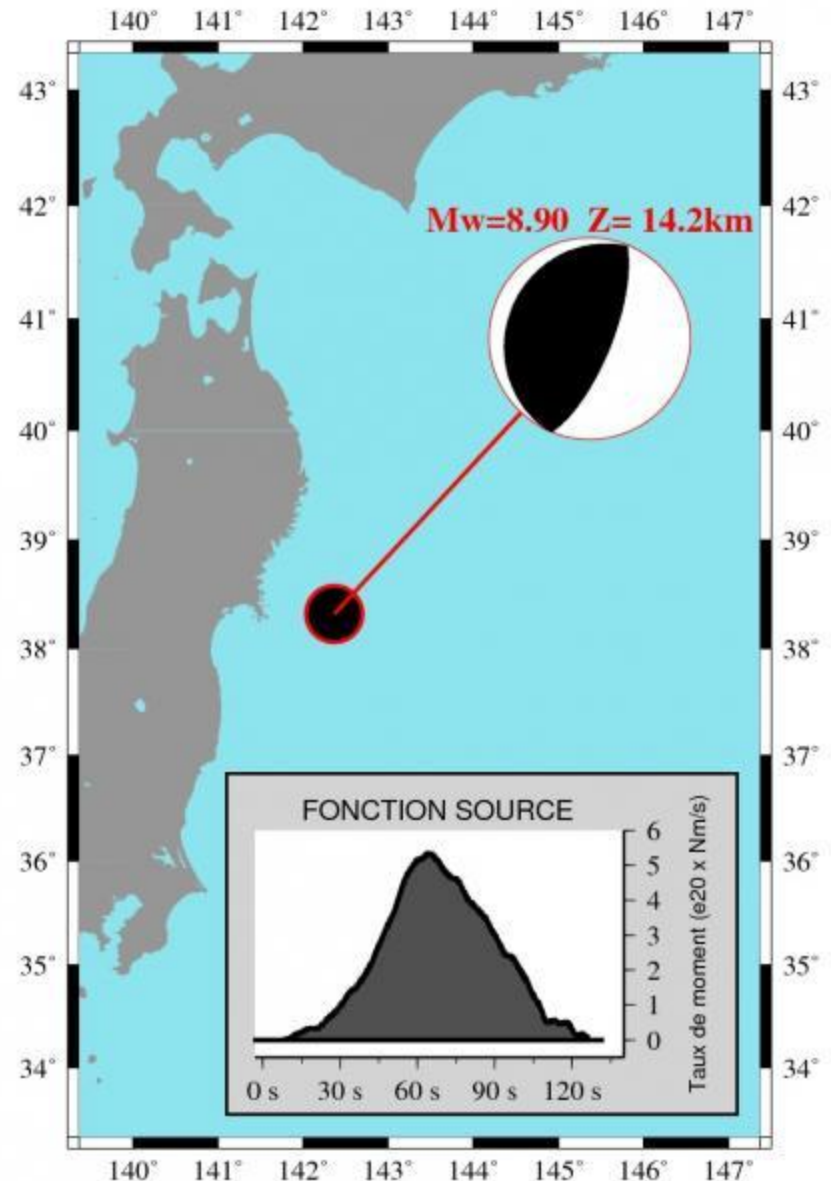
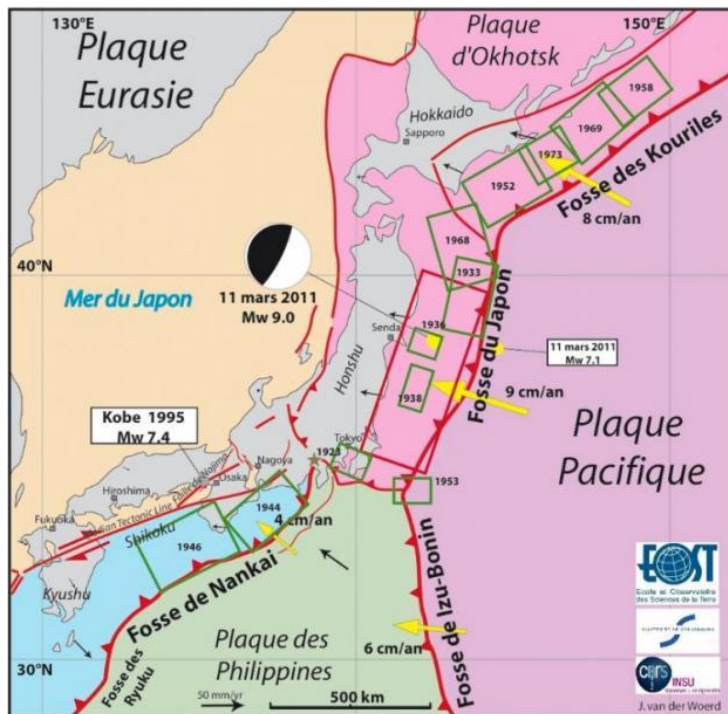


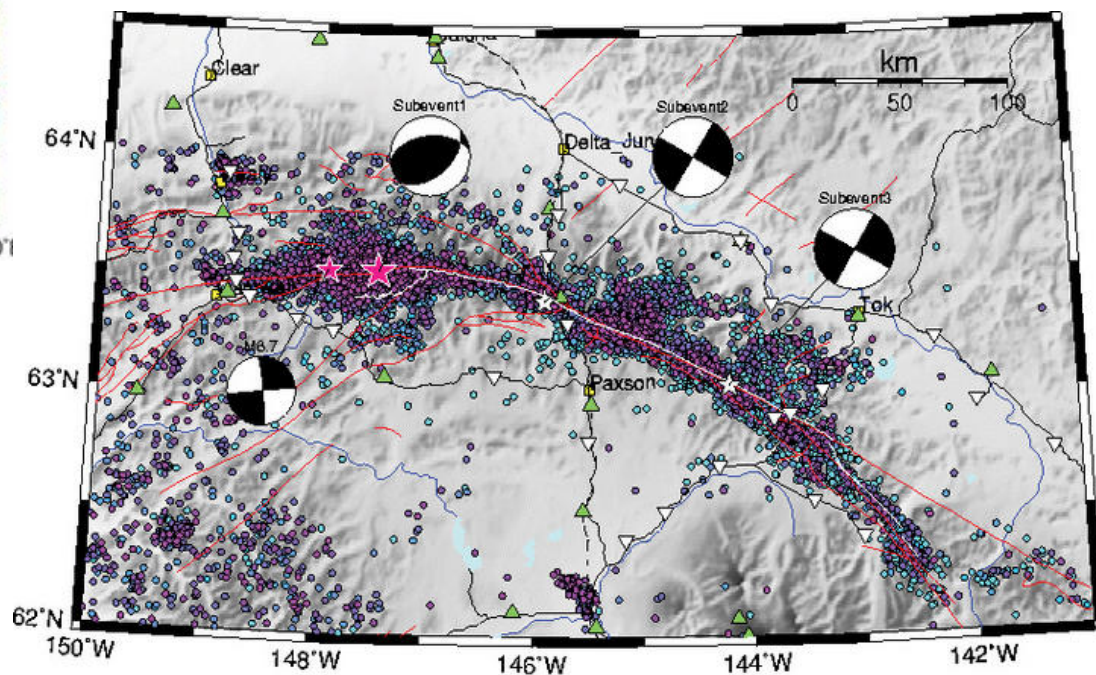
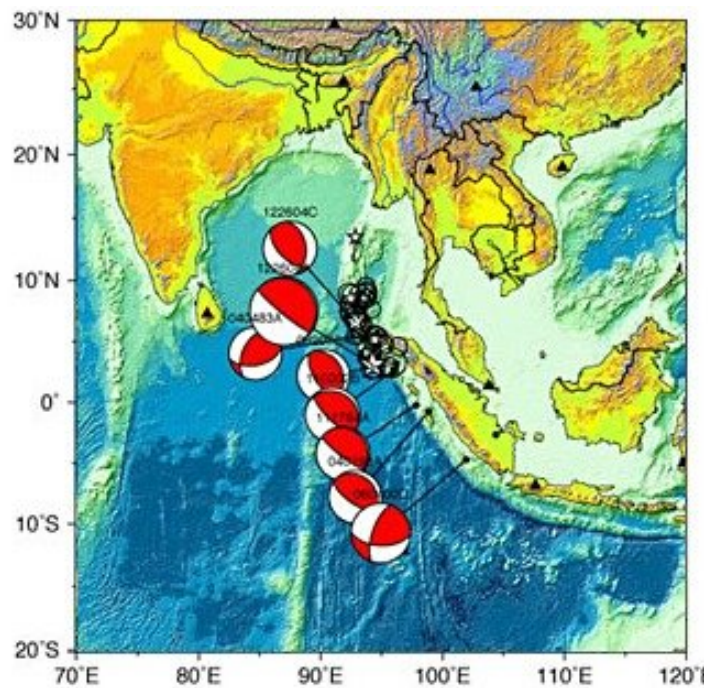
Ou bien



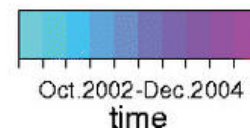
Exemple du Séisme de Tohoku

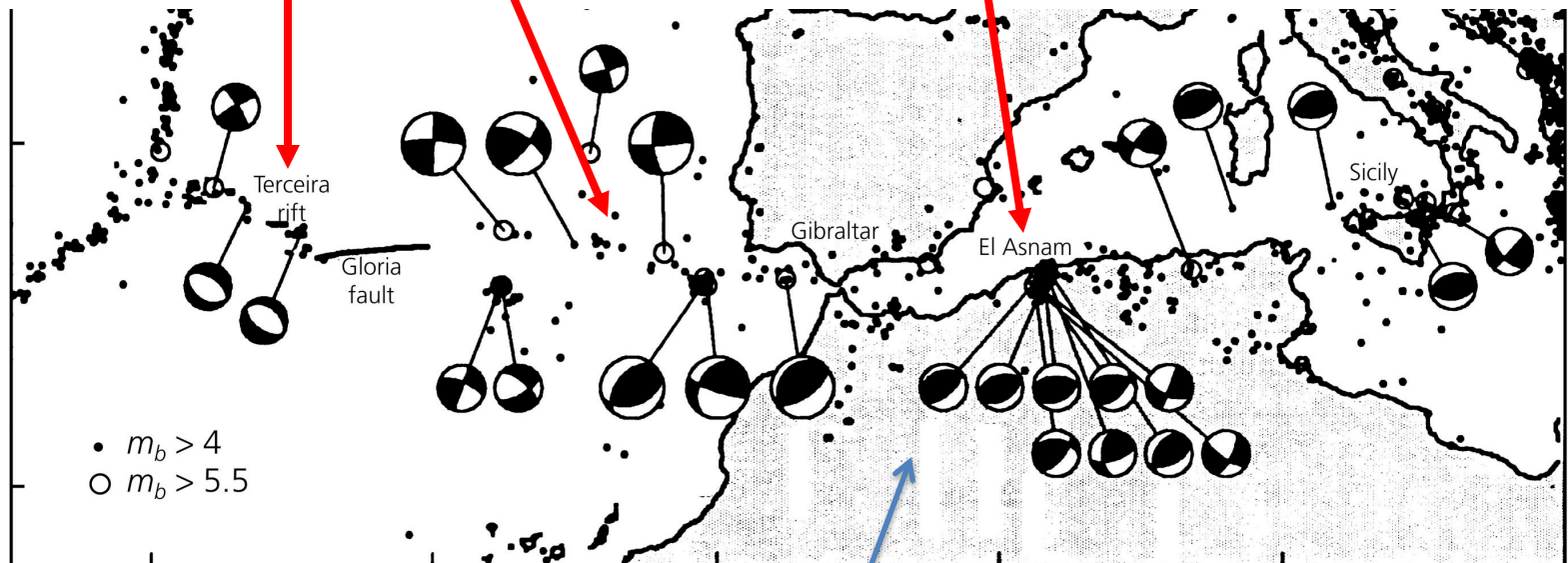
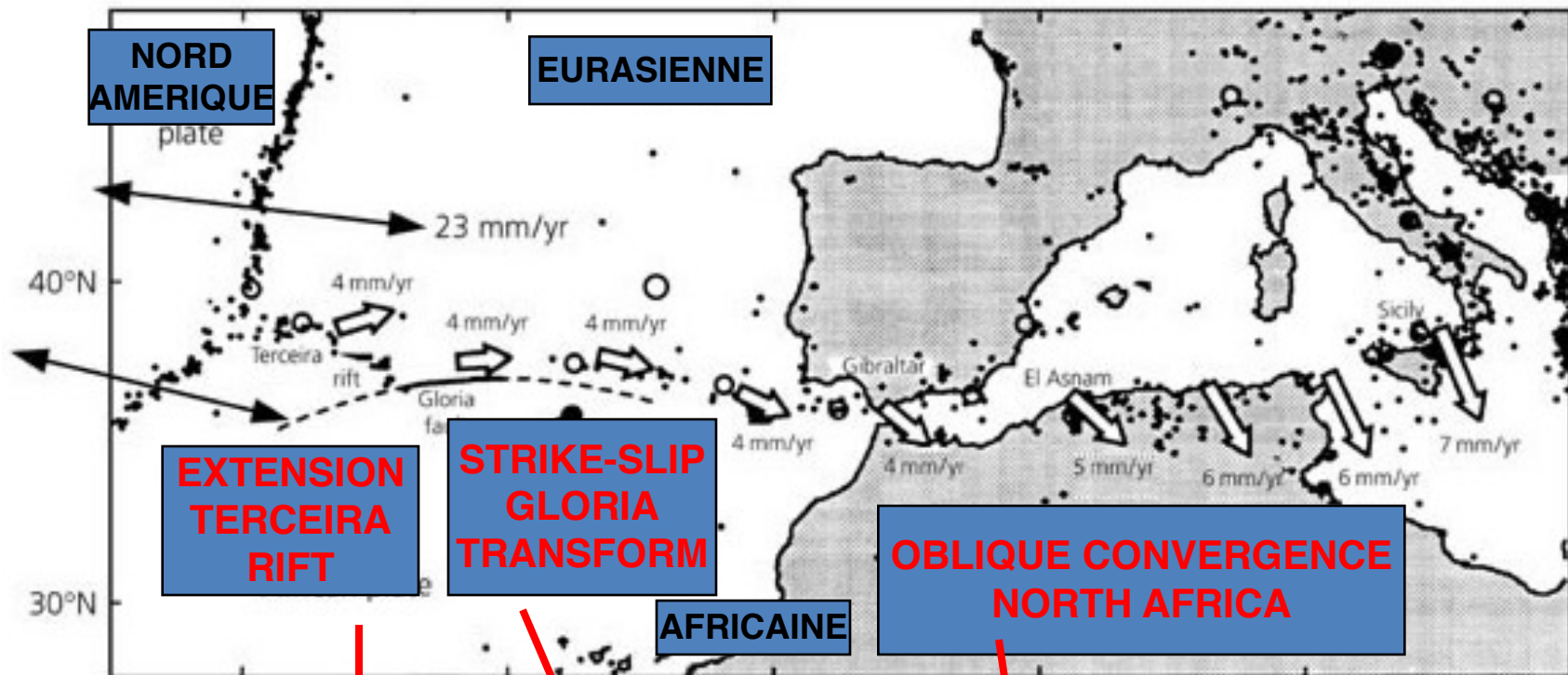
Mw 9.1, 2011





- ★ M6.7 Oct.23, 2002
- ★ M7.9 Nov.3, 2002
- ▲ temporary site
- ▽ permanent station







Earthquake Hazards Program

USGS Body-Wave Moment Tensor Solution

EASTERN TURKEY

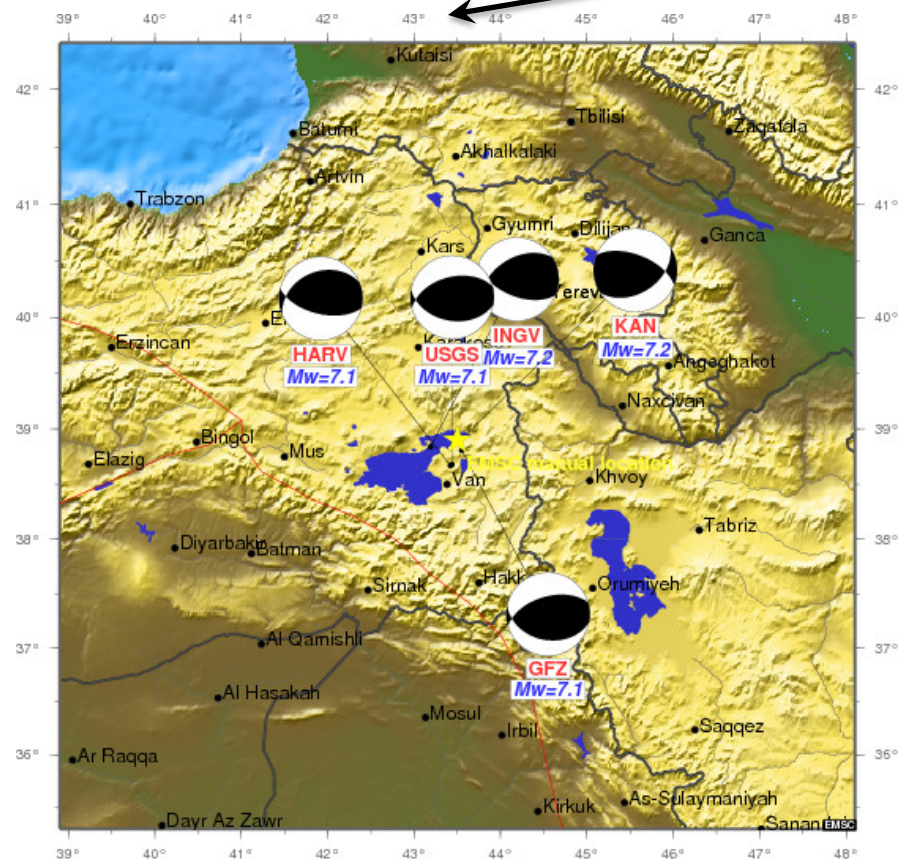
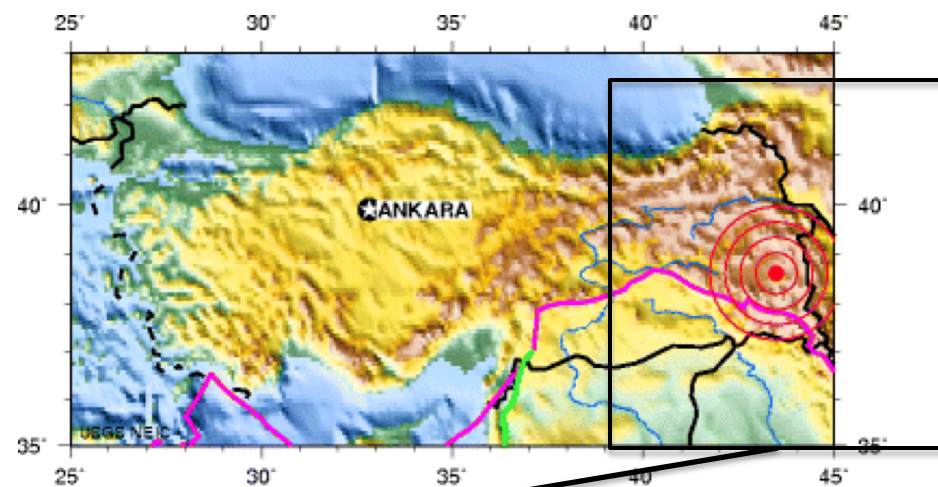
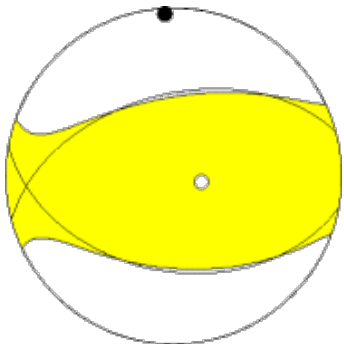
11/10/23 10:41:22.26

Epicenter: 38.681 43.442
MW 7.1

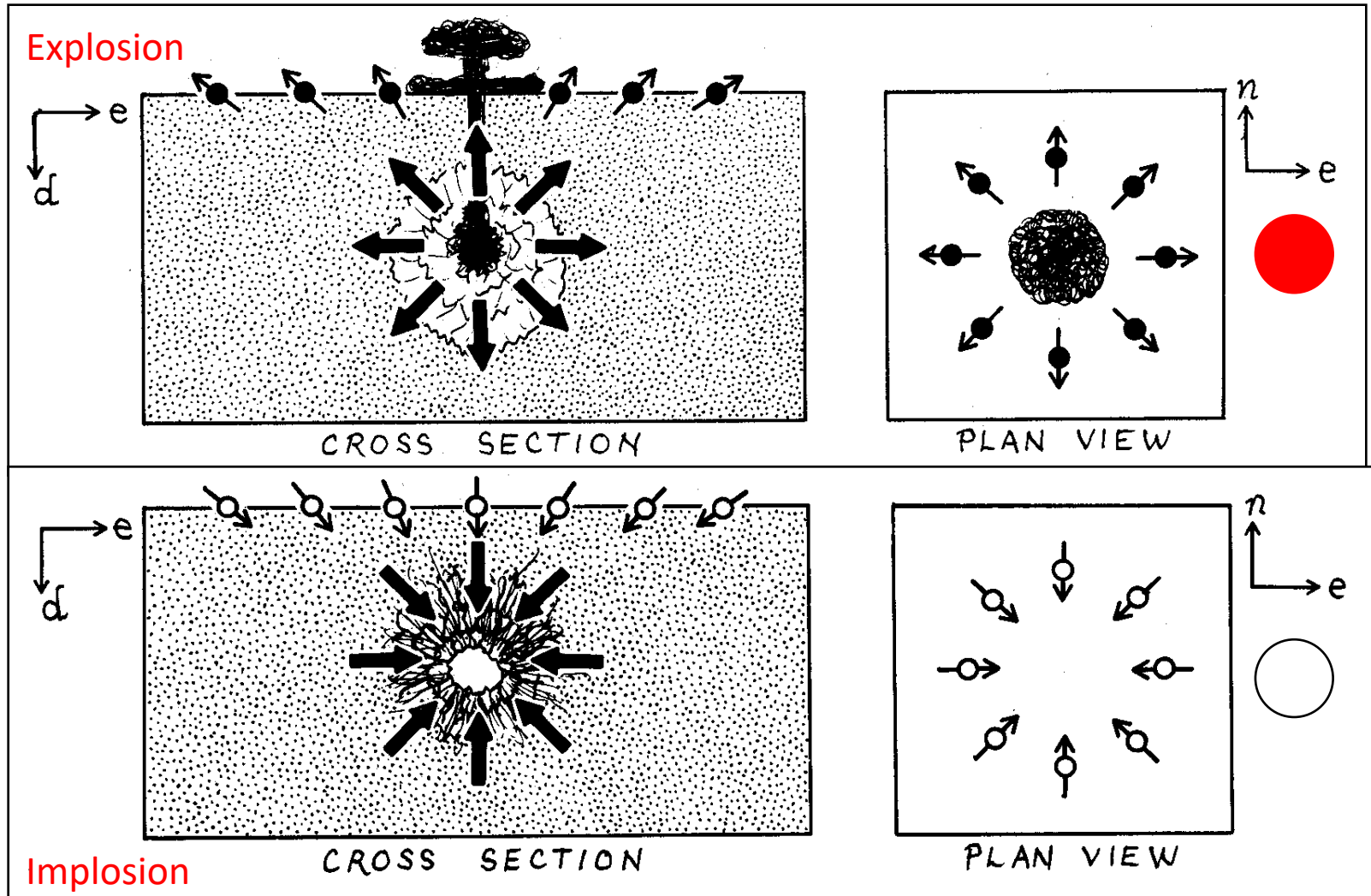
USGS MOMENT TENSOR SOLUTION

Depth 20 No. of sta: 85
Moment Tensor; Scale 10^{19} Nm
Mrr= 5.59 Mtt=-6.74
Mpp= 1.15 Mrt=-0.72
Mrp=-1.14 Mtp=-0.35
Principal axes:
T Val= 5.89 Plg=76 Azm=102
N 0.91 13 266
P -6.80 4 357

Best Double Couple: $M_0=6.4 \times 10^{19}$
NP1: Strike=255 Dip=50 Slip= 73
NP2: 101 43 109

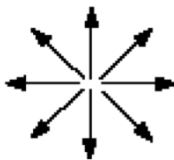
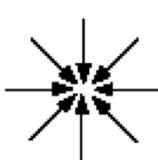
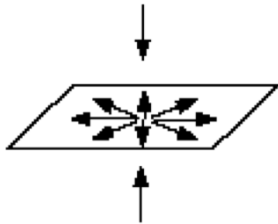


Cas particuliers / non double couple



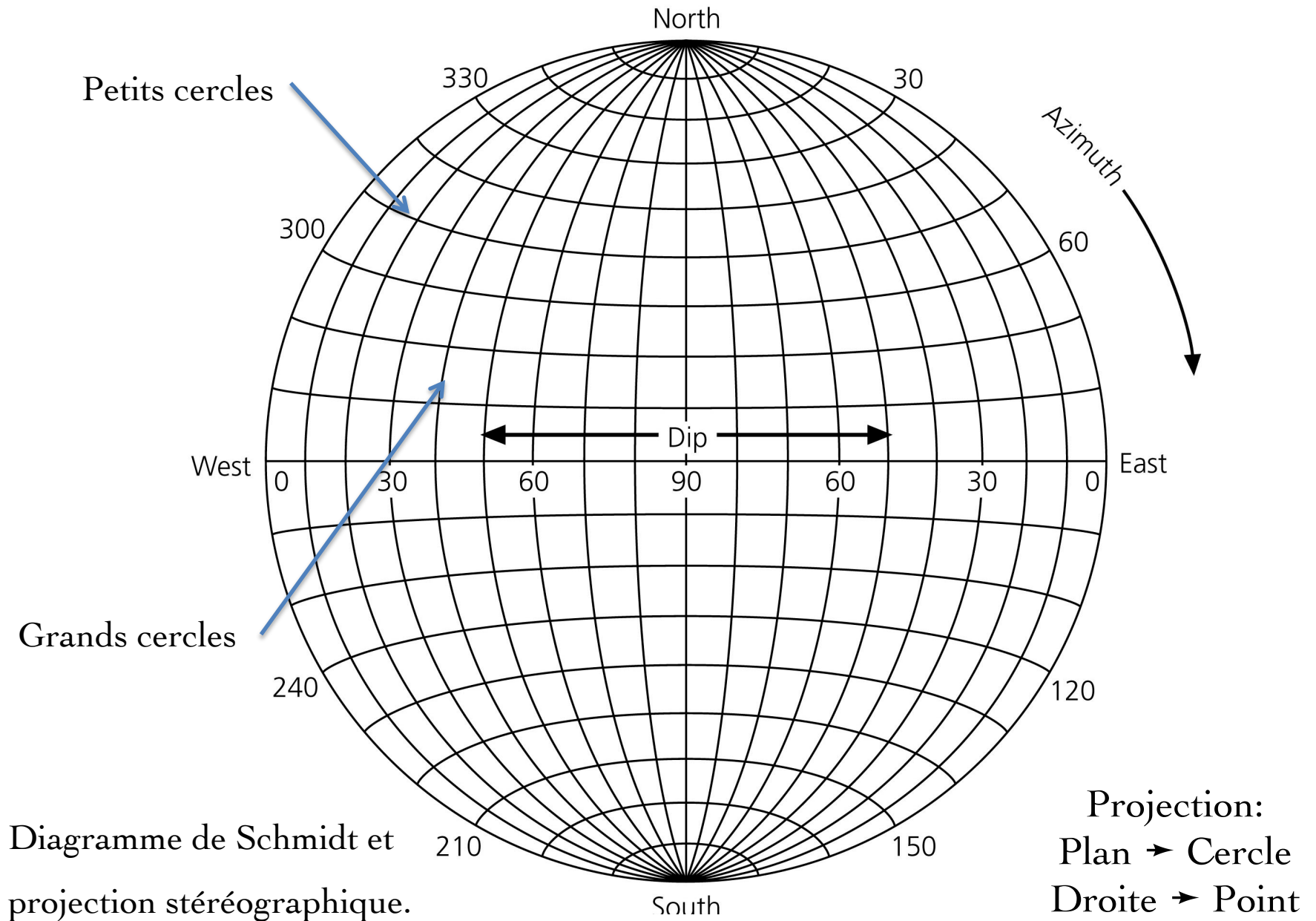
SOURCES QUI ONT UNE COMPOSANTE NON - DOUBLE COUPLE:

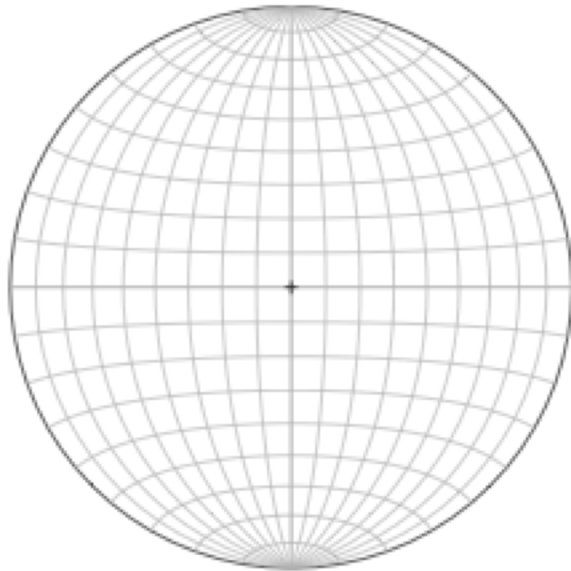
- Isotropes: Explosions – Implosions
- Compensated Linear Vector Dipoles (CLVD's) (double couple + 1 composante volumétrique), souvent le cas pour les très gros séismes.

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

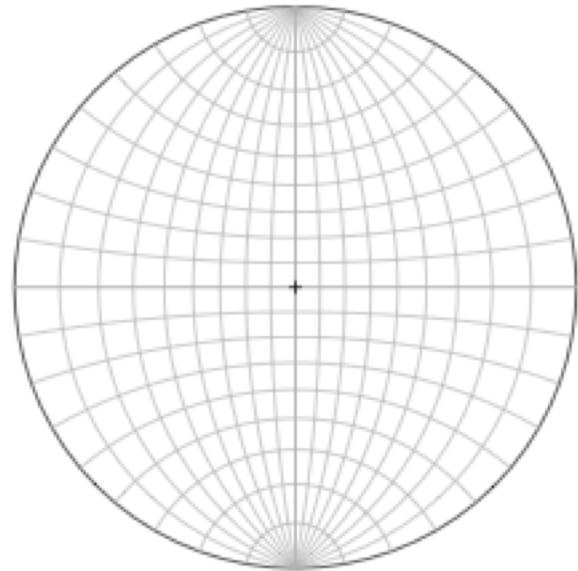
TD

PROJECTION STÉRÉOGRAPHIQUE: HÉMISPHÈRE FOCAL INFÉRIEURE





Schmidt Equal Area Net



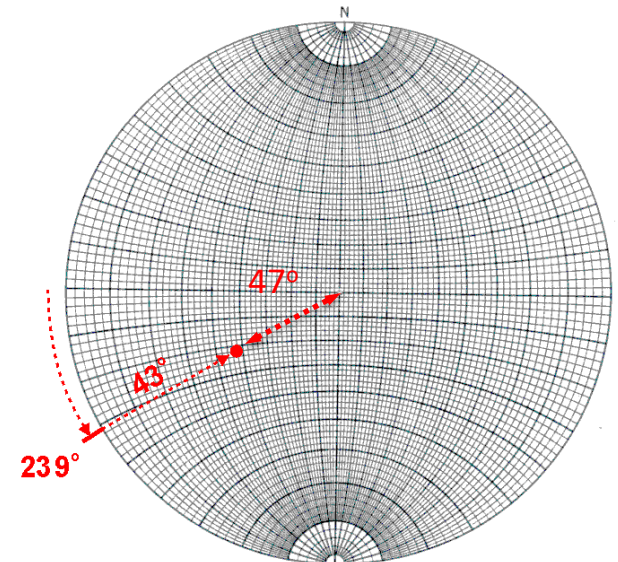
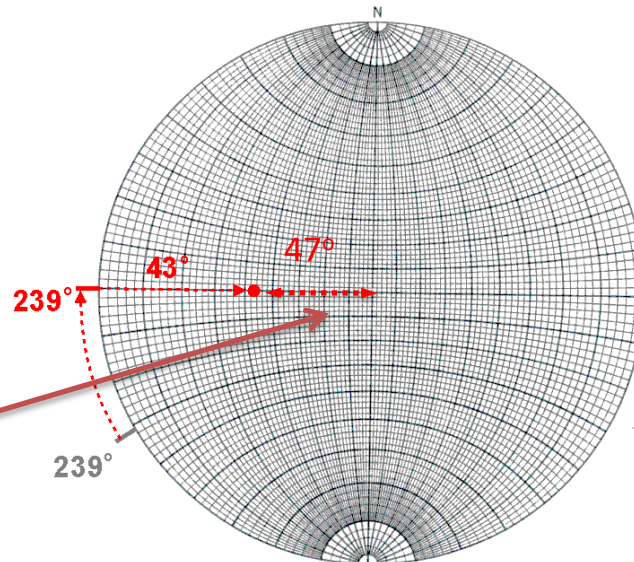
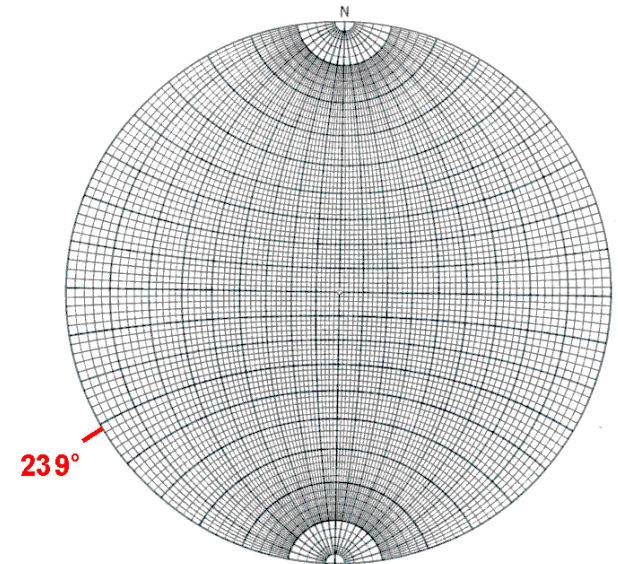
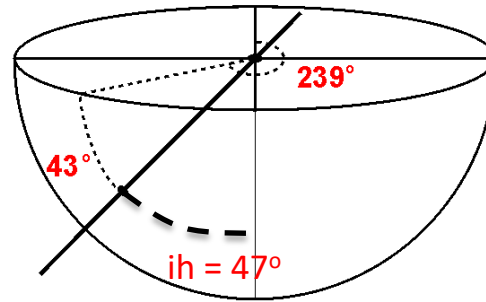
Wulff Equal Angle Net

Projection Stéréographique

Tracer un rai
(une ligne)

$$Az = 239^\circ$$

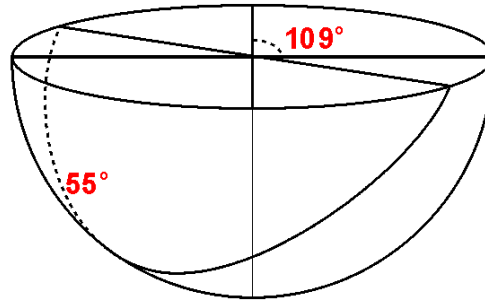
$$ih = 47^\circ$$



Attention: ih à
partir de la
verticale

Projection Stéréographique

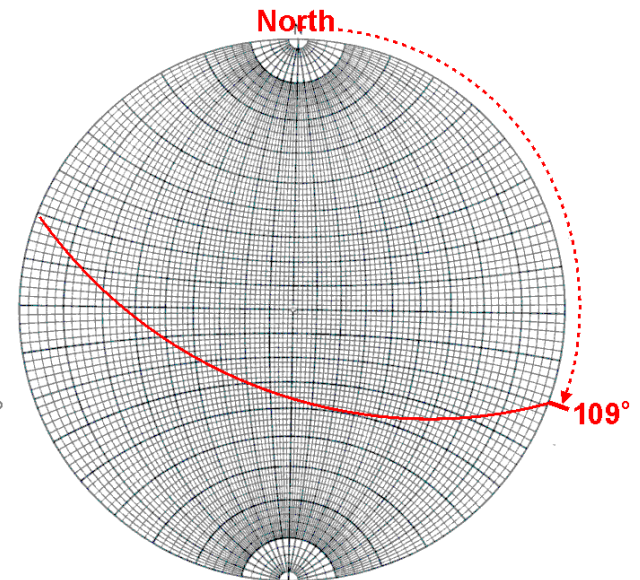
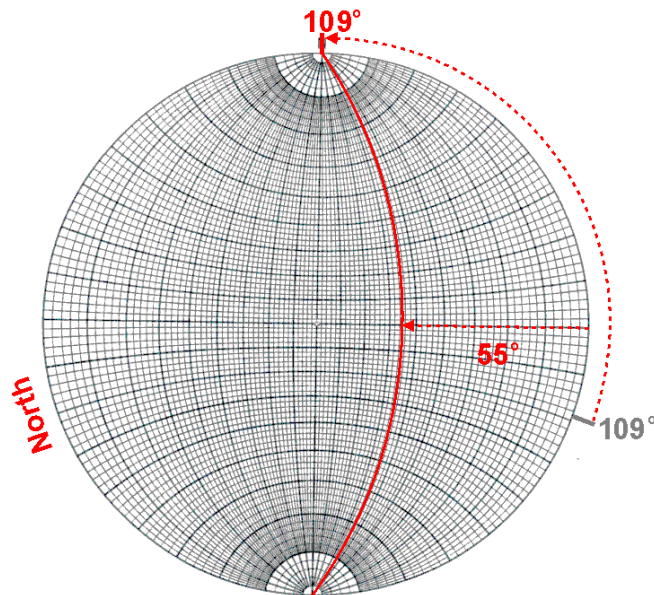
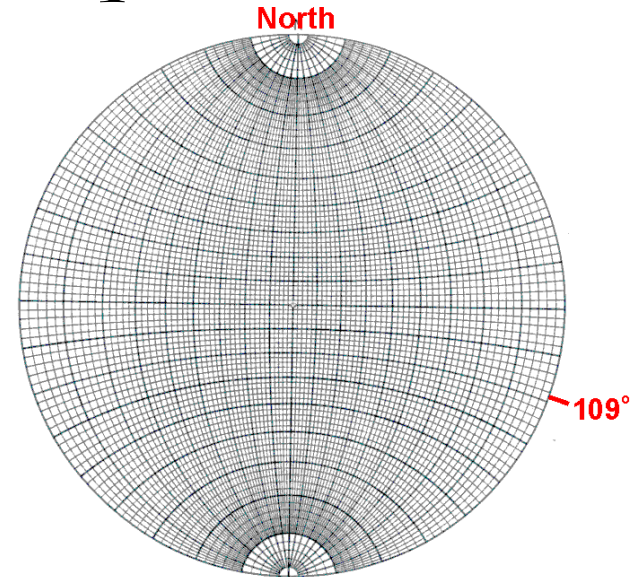
Fault strike 109° dip 55° SW



Tracer une faille
(un plan)

$$Az = 109^\circ$$

$$\delta = 55^\circ$$



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, +).

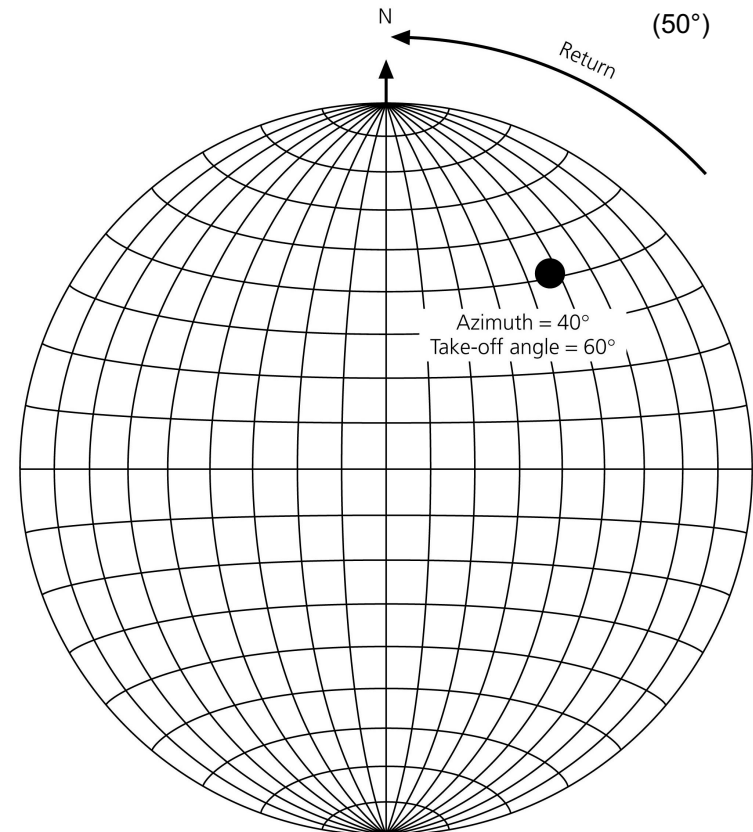
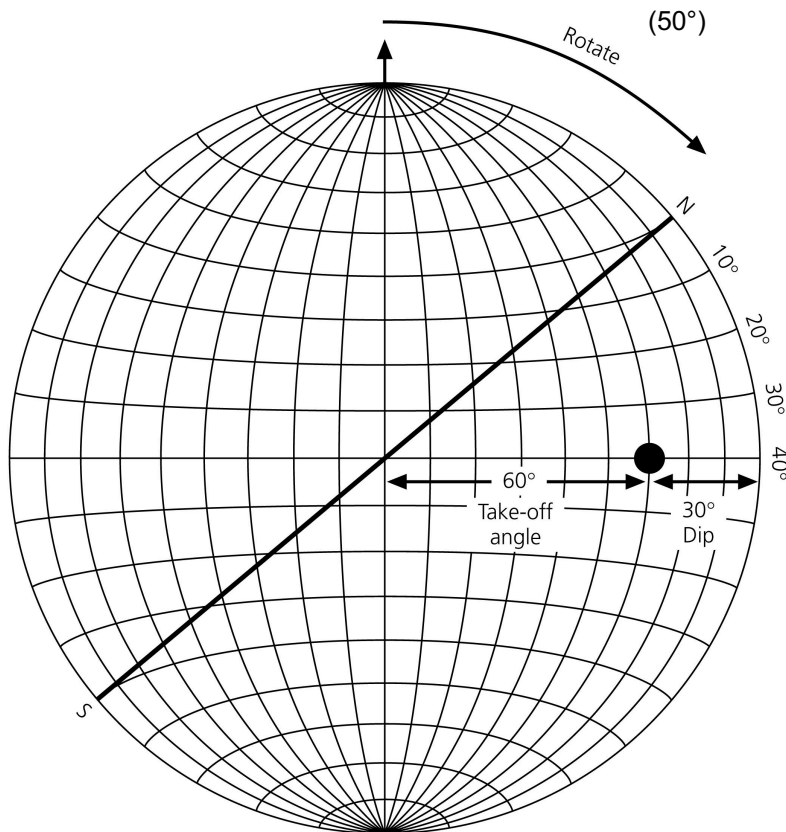
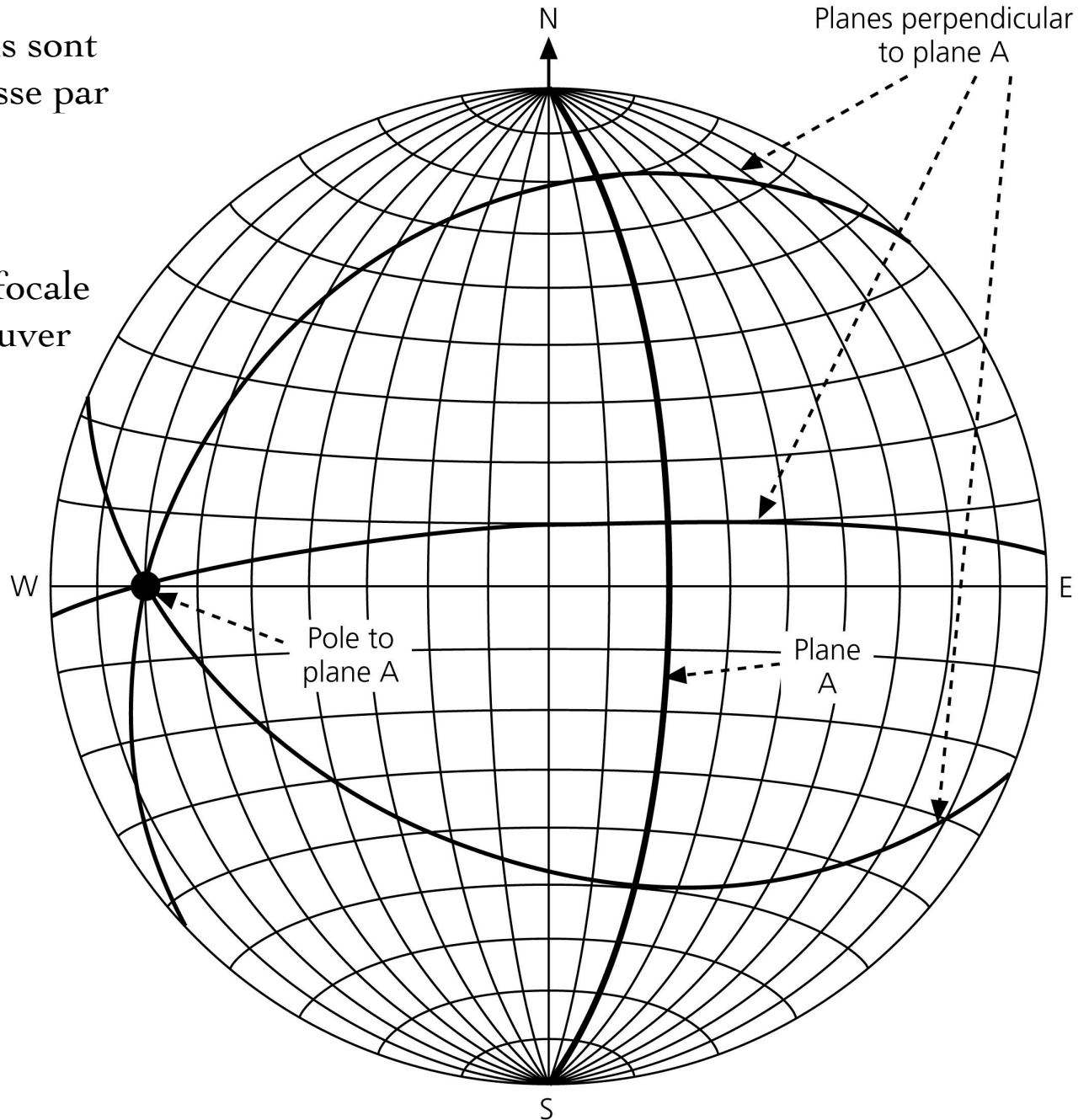


Figure 4.2-12: Example of plotting perpendicular planes on a stereonet.

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



TD Mécanisme au foyer

Déterminer le mécanisme au foyer du séisme suivant:
(L'angle d'incidence est celui au foyer)

Station	Sens du premier mouvement	Distance (°)	Azimut (°)	Angle d'incidence (°)
WIN	-	37.85	126	38
BUL	-	46.77	116	35
PRE	-	48.34	124	34
LPA	+	51.68	225	33
CAR	+	52.67	284	32.5
NAI	-	52.15	90	33
LPB	+	53.98	251	32
SJG	- (ou +?)	53.63	294	32
VAL	+	53.43	4	32
STU	+	54.42	20	32
AAE	-	54.94	78	31
ARE	+	57.18	251	31
IST	+	58.43	38	30.5
BOG	+	58.96	276	30
PEL	+	60.56	232	30
COP	+	61.37	18	30
QUI	+	63.14	271	29
KOM	+	64.06	14	29
BHP	+	64.79	281	28
NUR	+	69.15	20	27
TAB	+	69.02	48	27
UME	+	70.31	16	27
SCP	-	70.54	314	27
KTG	+	71.94	358	26
SHI	+	71.67	58	26
LPS	+	74.69	285	25
AAM	-	75.13	315	25
QUE	-	84.11	60	22
LIB	-	87.91	304	21
GOL	-	90.96	310	20
ALQ	-	91.76	305	20
TUC	-	95.39	302	20
BEC	-	57.49	310	31

- : vers le bas, dilatation (matière attirée vers l'hypocentre)

+ : vers le haut, compression (matière repoussée de l'hypocentre)

- 1) Reporter les stations sur la sphère focale avec les sens du premier mouvement.
- 2) Déterminer les plans nodaux.
- 3) Quel type de faille est-ce?