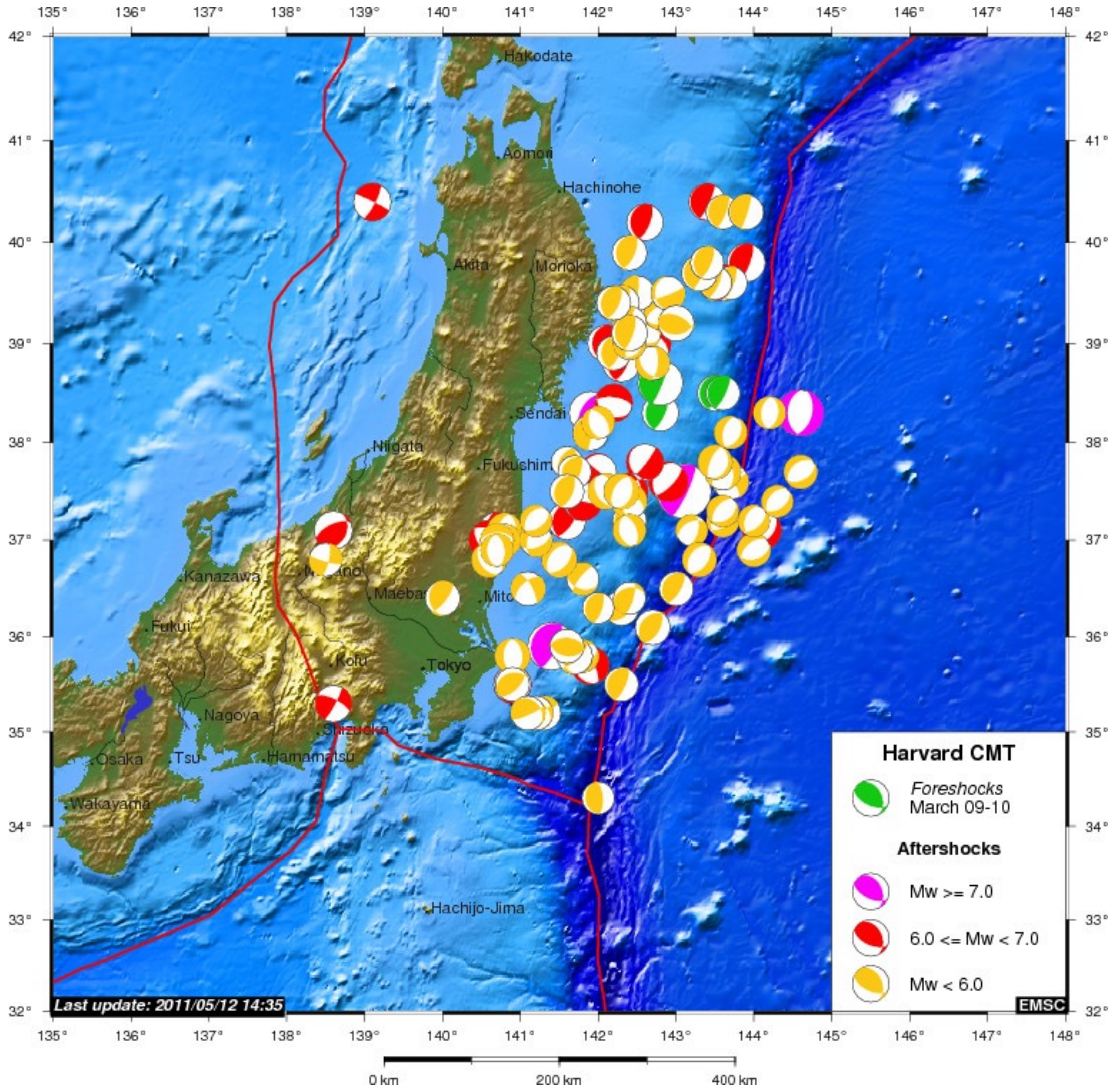
MÉCANISMES AU FOYER



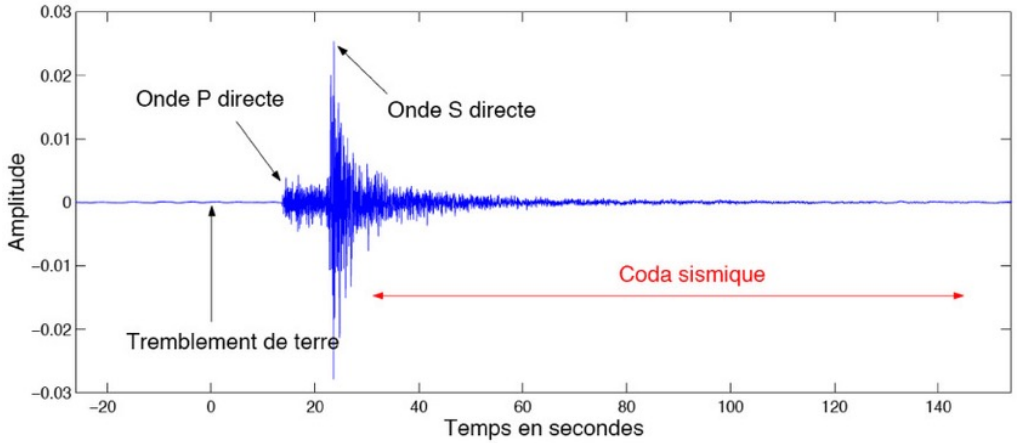
Sophie Peyrat
sophie.peyrat@umontpellier.fr

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, azimut (strike, dip, rake)
- Notion de double couple
- Savoir relier mécanisme au foyer et géodynamique d'une région

UMR Géosciences Montpellier

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)

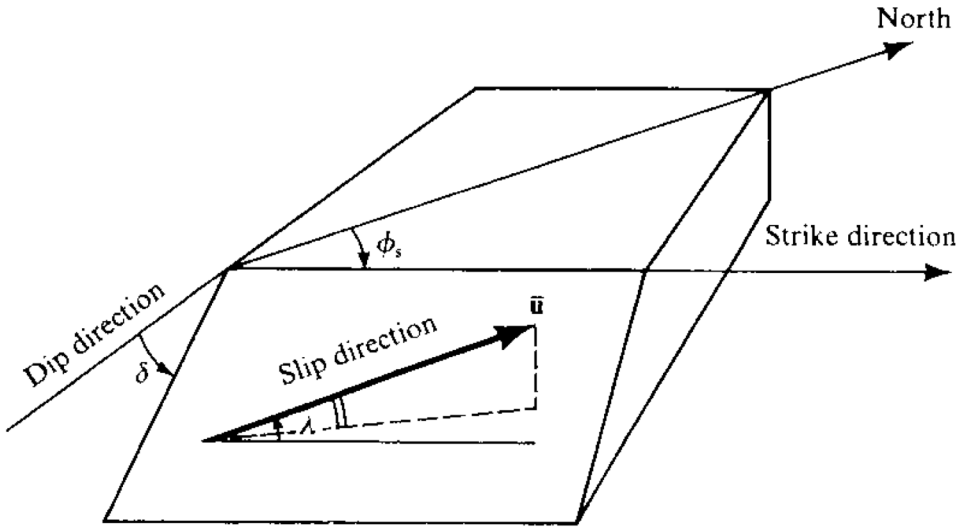
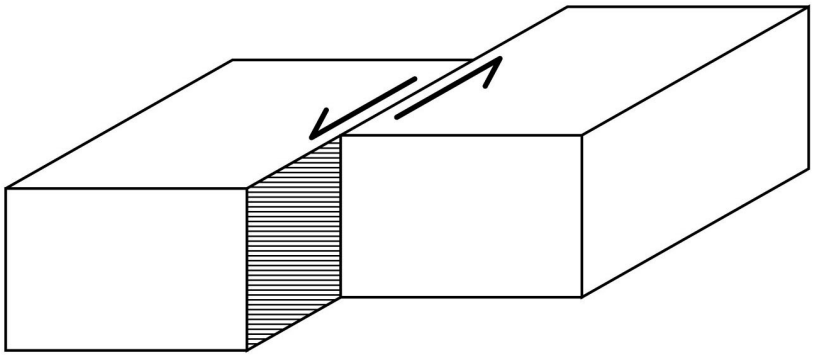


FIGURE **4.13**
Definition of the fault-orientation parameters (strike ϕ_s, dip δ) and the slip-direction parameter (rake λ). ϕ_s is measured clockwise round from North, with the fault dipping down to the right of the strike direction: $0 \leq \phi_s < 2\pi$. The dip angle δ is measured down from the 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.

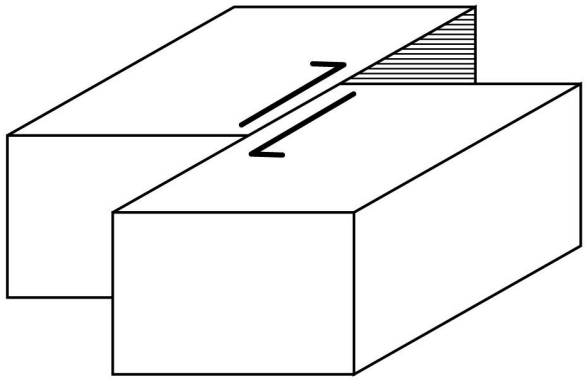
Convention de Aki and Richards

Angle du glissement λ caractérise le type de faille



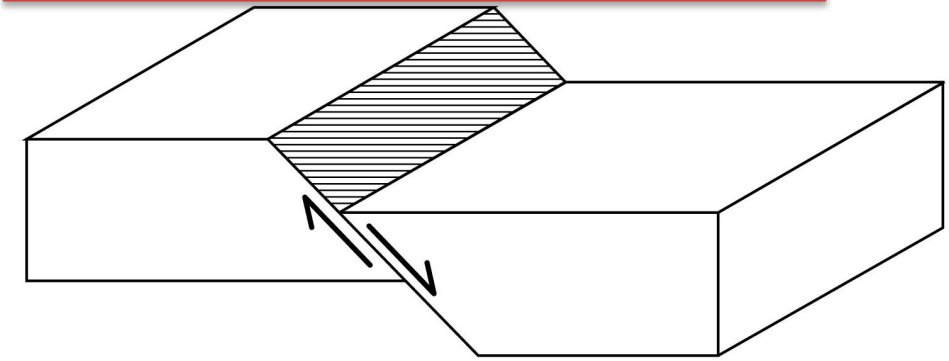
Left-lateral strike-slip fault
($\lambda = 0°$)

Décrochement sénestre
(pied gauche part en arrière)



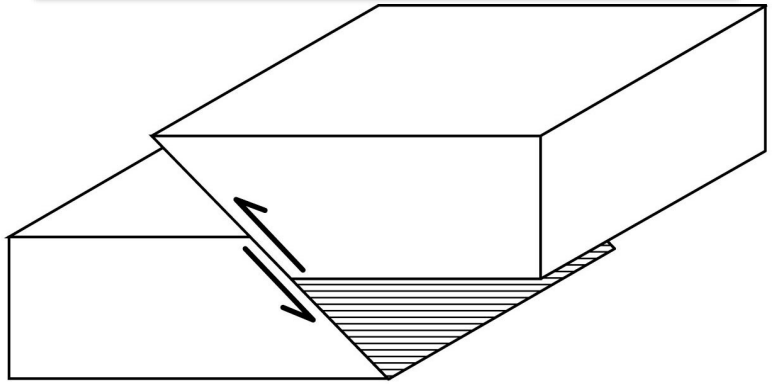
Right-lateral strike-slip fault
($\lambda = 180°$)

Décrochement dextre



Normale

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

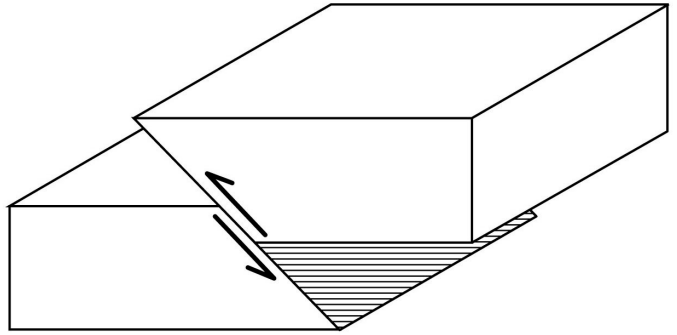


Inverse

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

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

Faille inverse



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

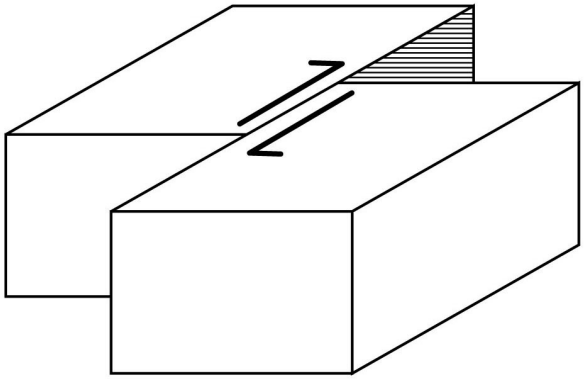


offset de 2 m dans un stade
(maintenant un musée)

Séisme de Chi-Chi 1999
Faille de Chelungpu
-> chutes d'eau de 6 m sur Ta-Chia River,
(photo LeonTeng, USC)



Faille en décrochement



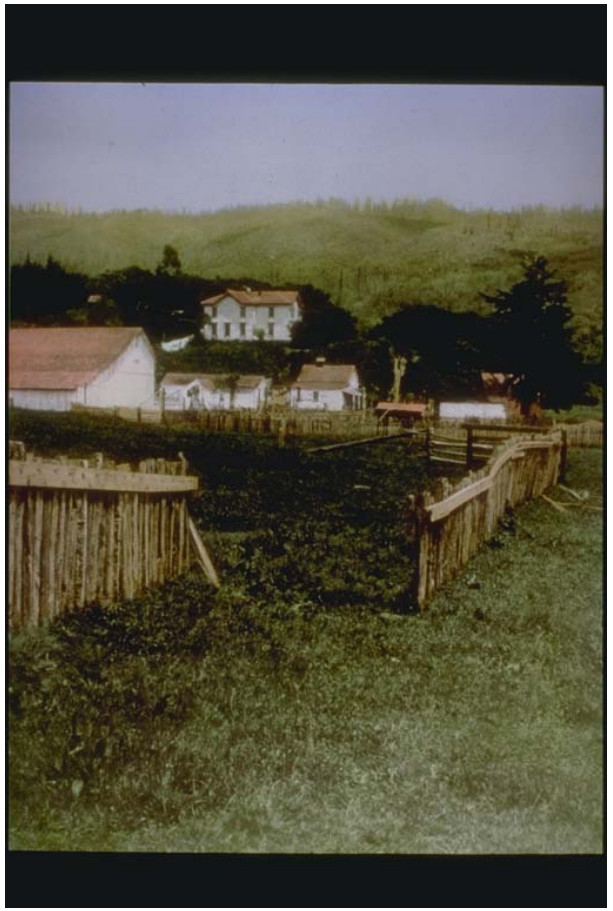
Right-lateral strike-slip fault
($\lambda = 180°$)

Landers, Californie, 1992



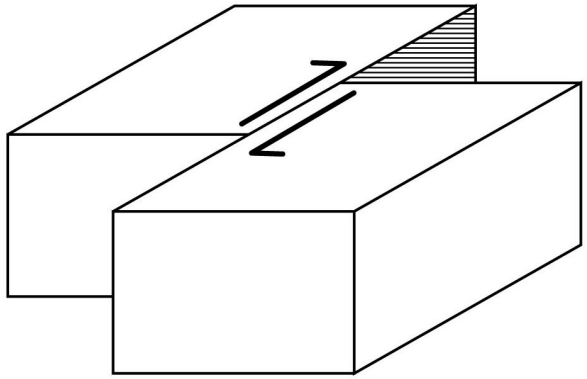
Denali, Alaska, 2002





San Francisco, Californie 1906

Faille en décrochement



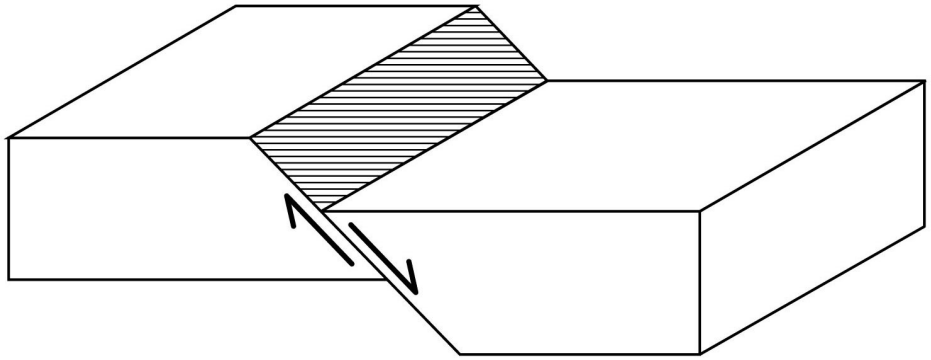
Right-lateral strike-slip fault
($\lambda = 180°$)



M 7.7 – 2025 Mandalay, Burma (Myanmar) Earthquake

2025-03-28 06:20:52 (UTC) | 22.011°N 95.936°E | 10.0 km depth

Faille normale



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

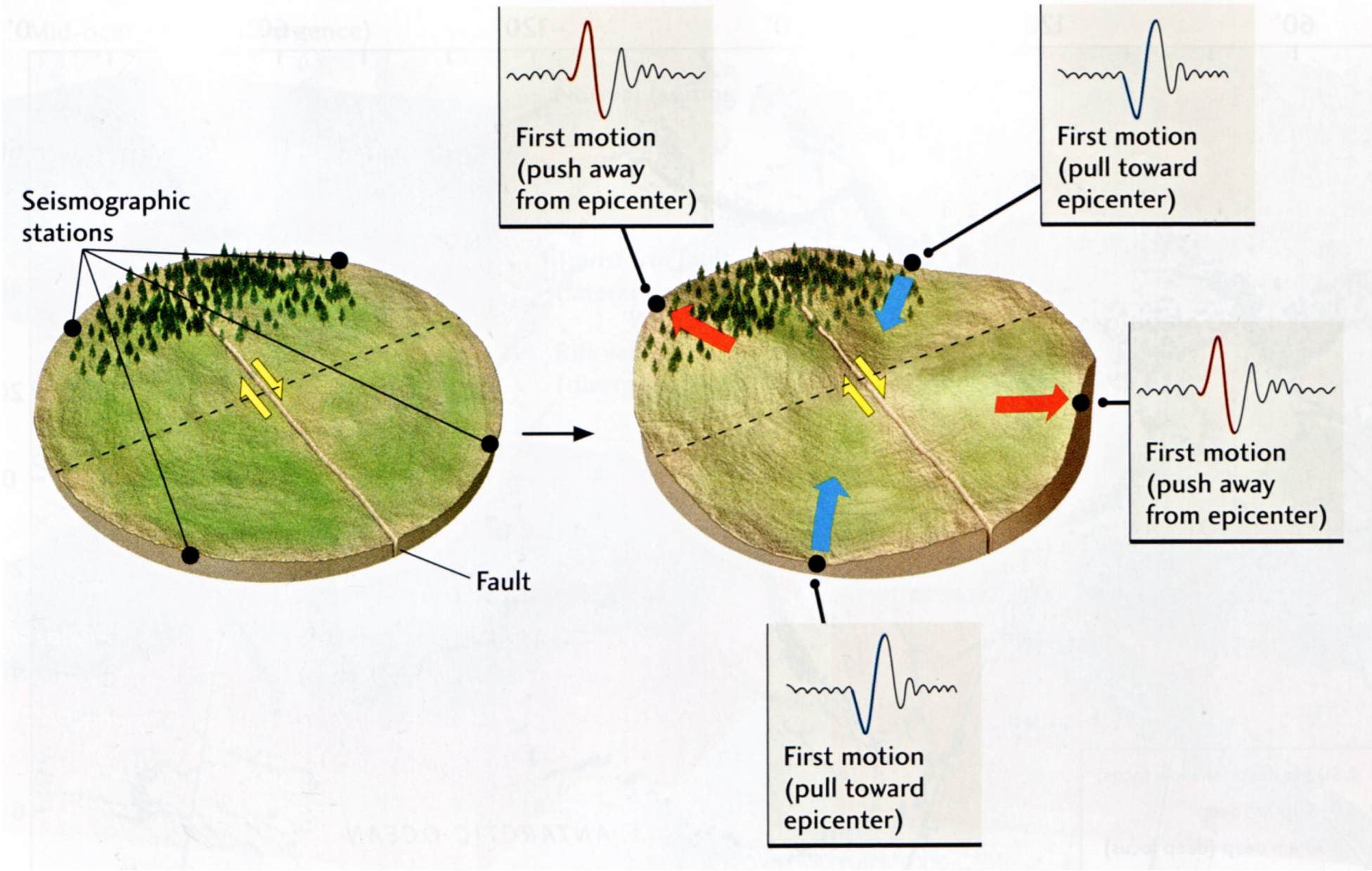
Crowley Lake, California



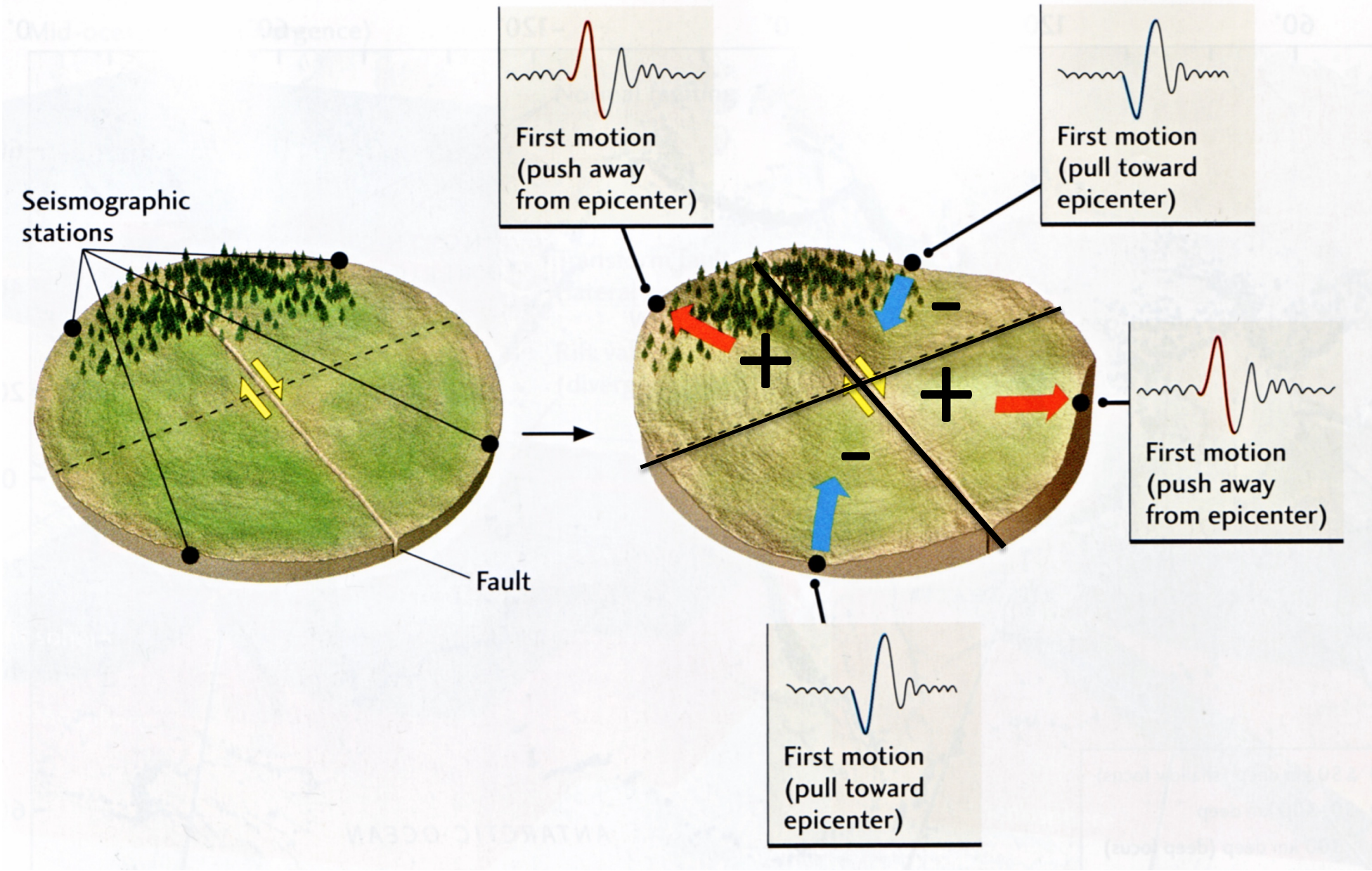
Arkitsa, Grèce



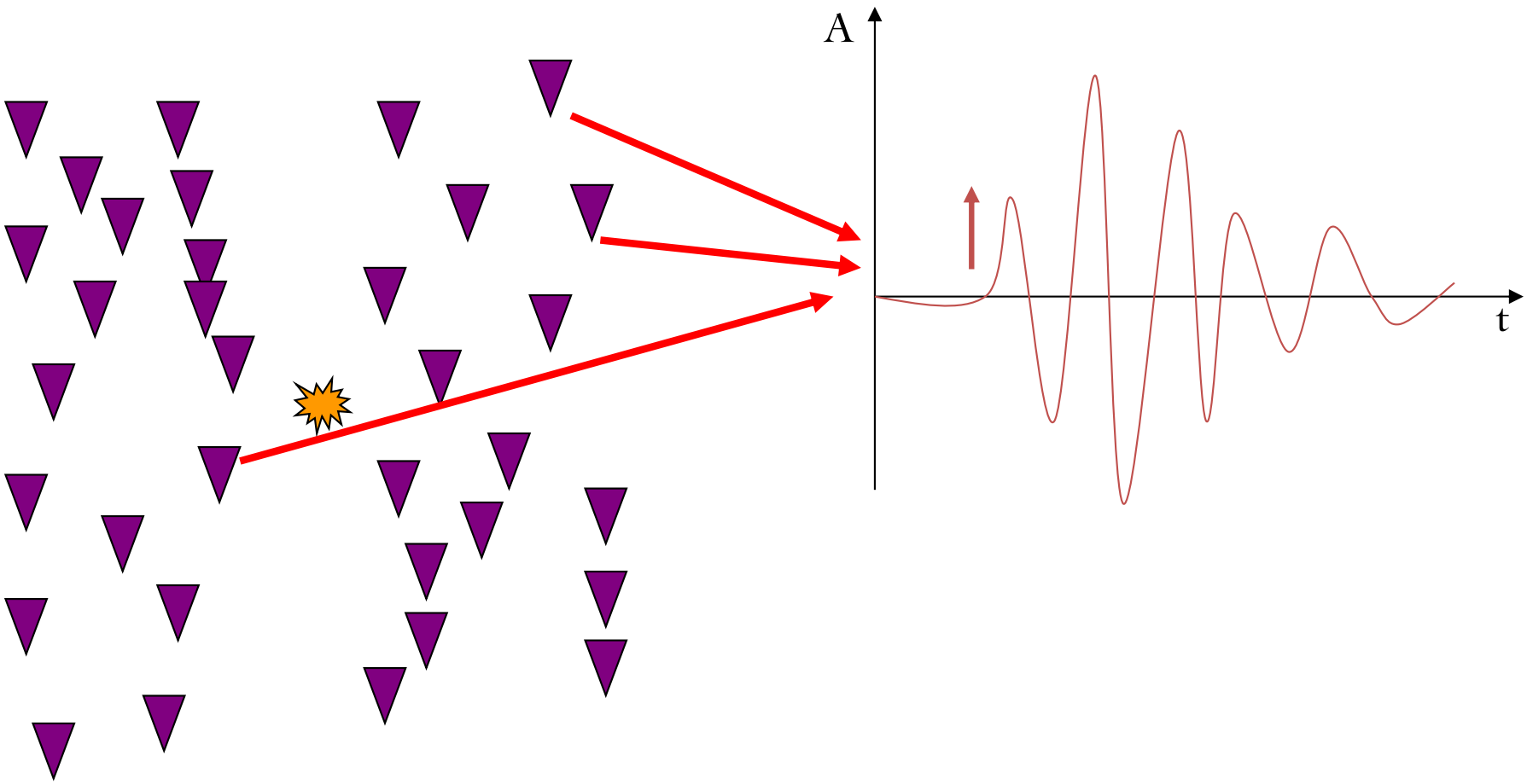
Comment caractériser une faille ?



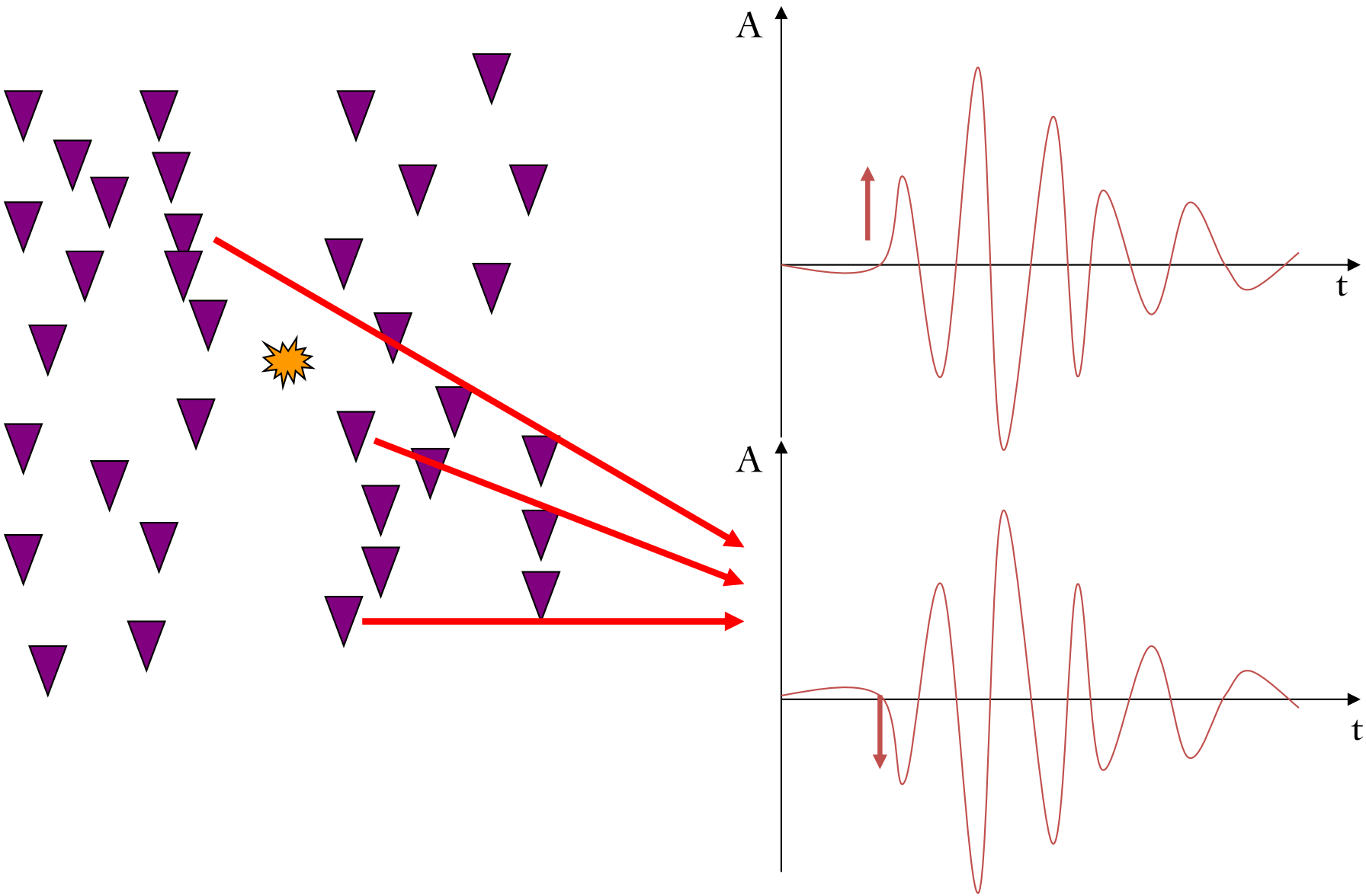
Comment caractériser une faille ?



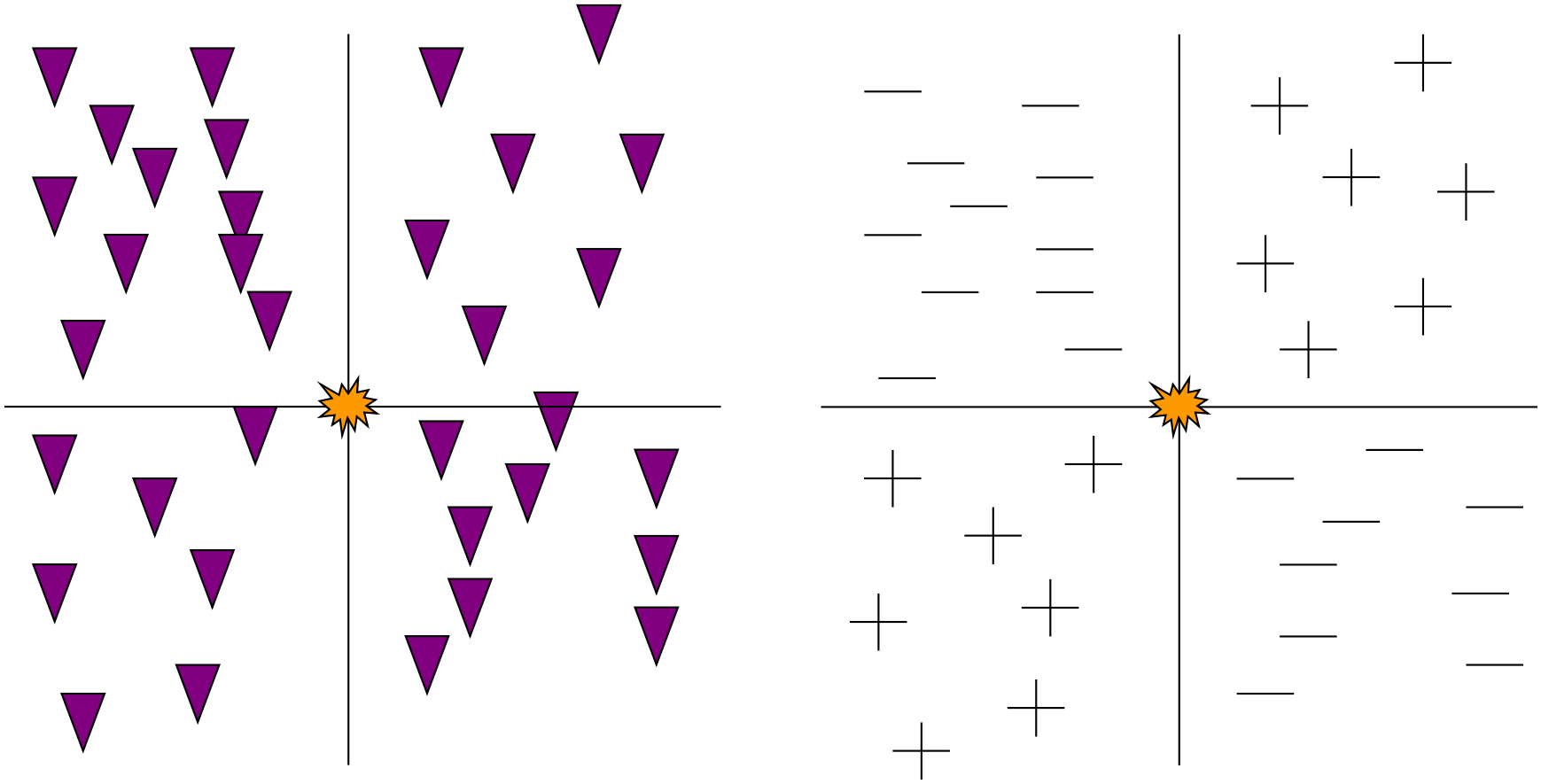
Comment caractériser une faille ?



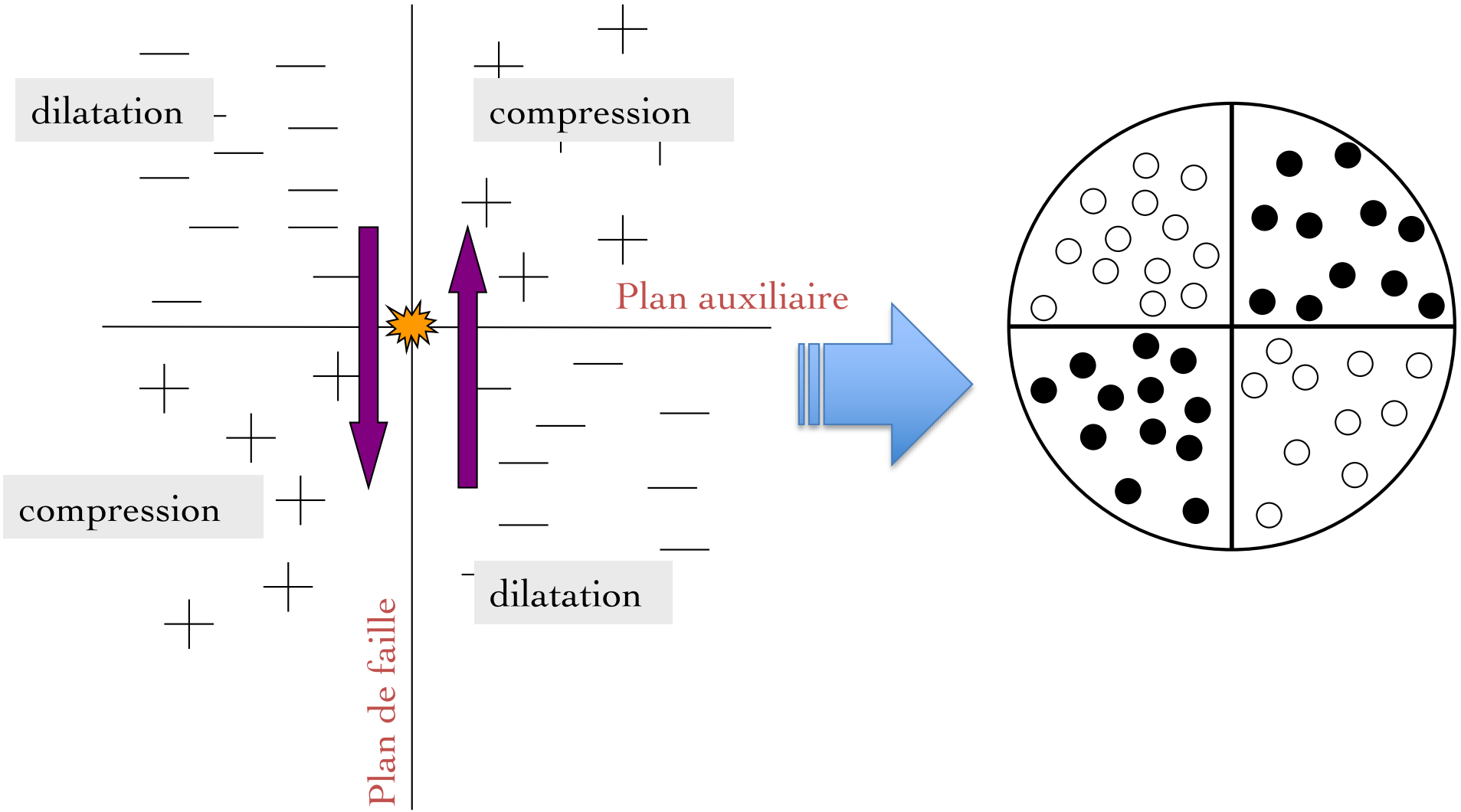
Comment caractériser une faille ?



Comment caractériser une faille ?

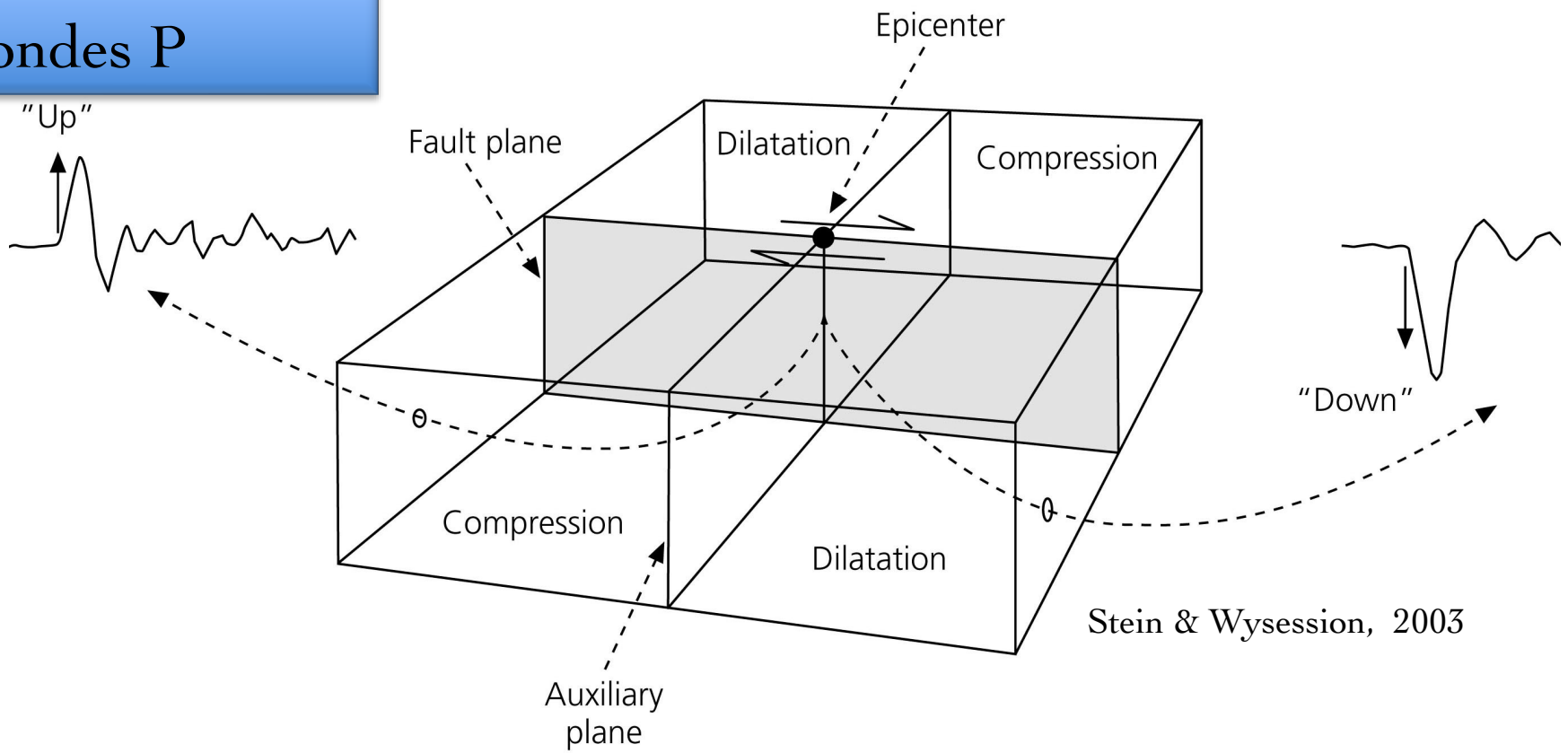


Mécanismes au foyer



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

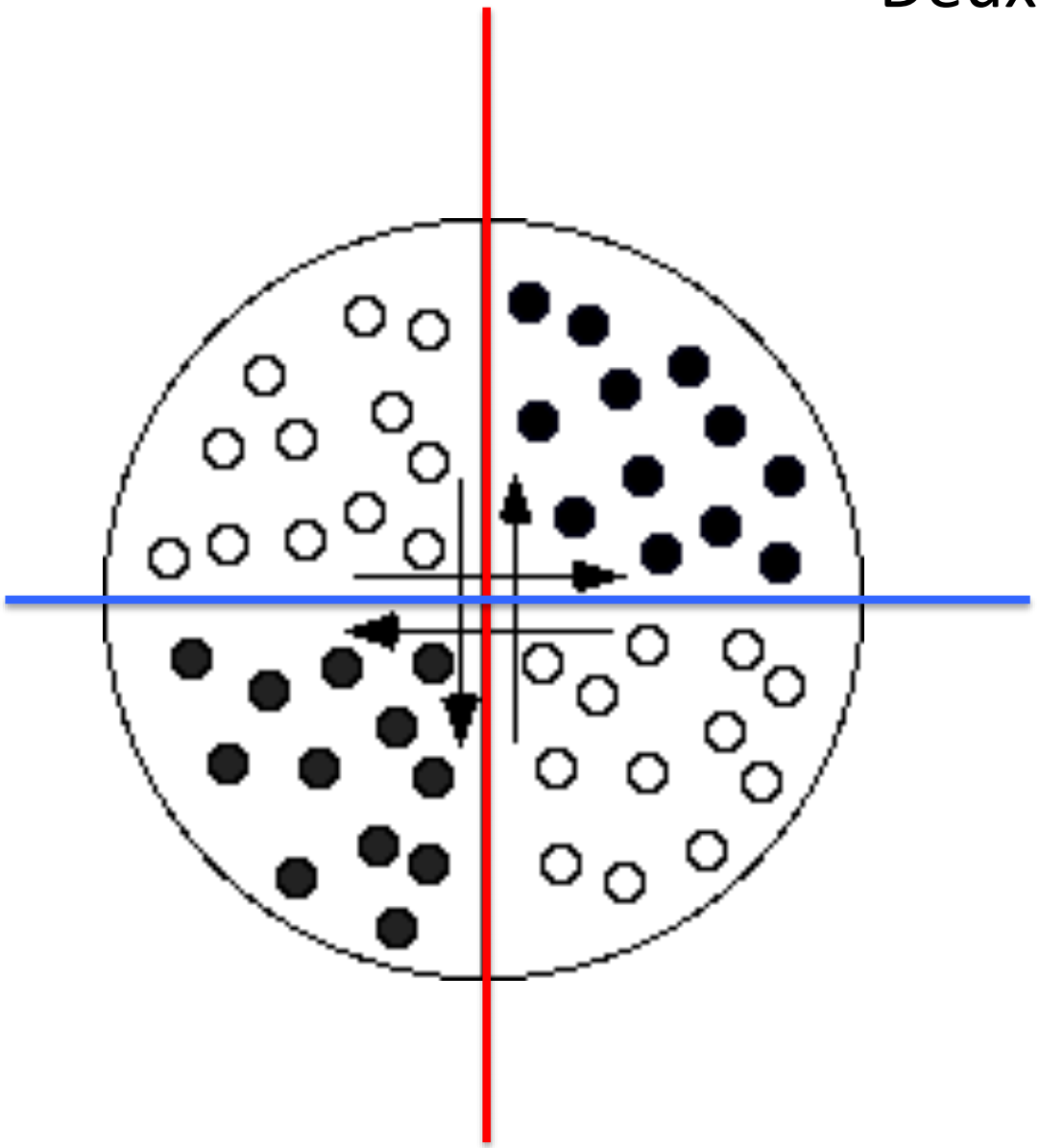
-> 4 quadrants

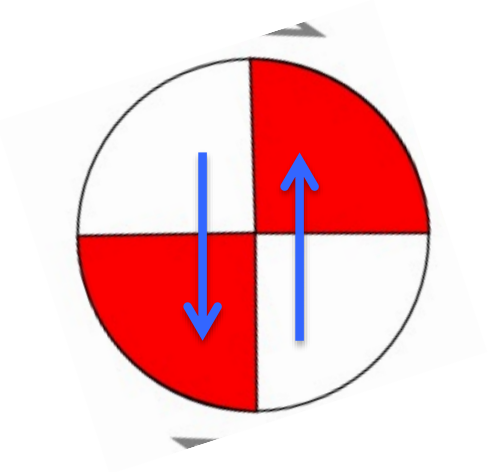
-> 2 plans nodaux (faille et auxiliaire)

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

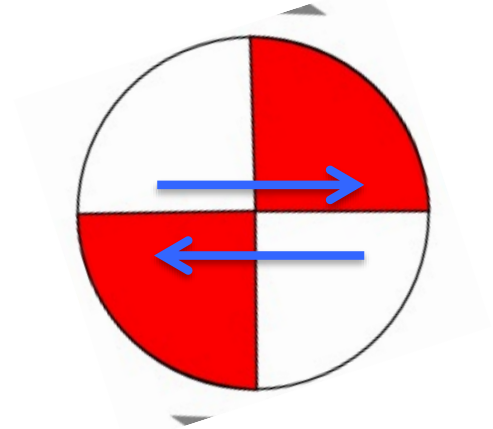
Comment caractériser une faille ?

Deux couples de forces possibles





ou

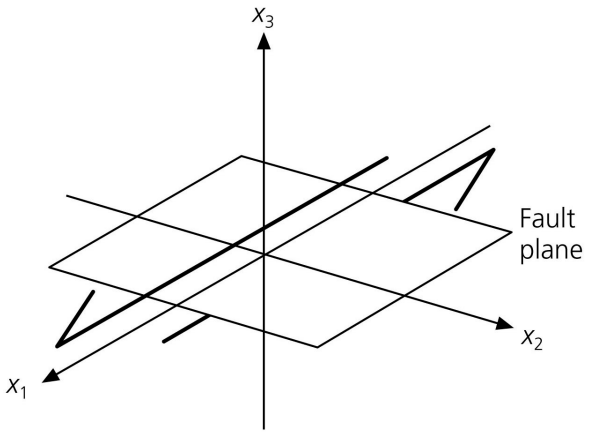


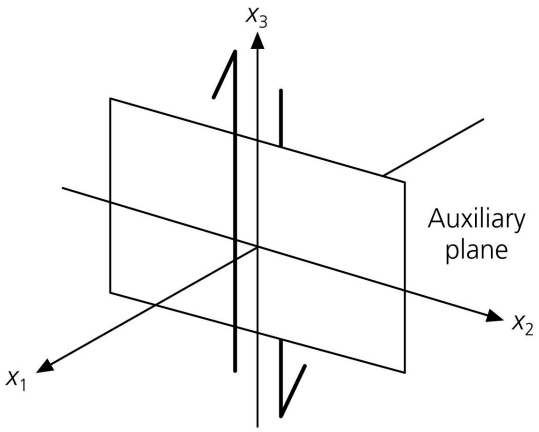
ONDES RADIÉES DEPUIS UNE FAILLE ÉQUIVALENTE À UN DOUBLE COUPLE?

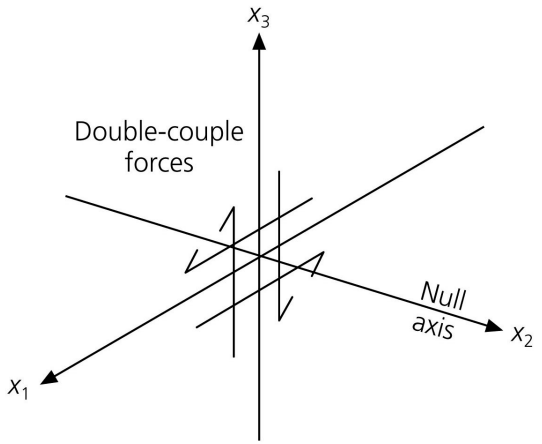
Les radiations sont dues à:

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

- un couple correspondant au plan auxiliaire







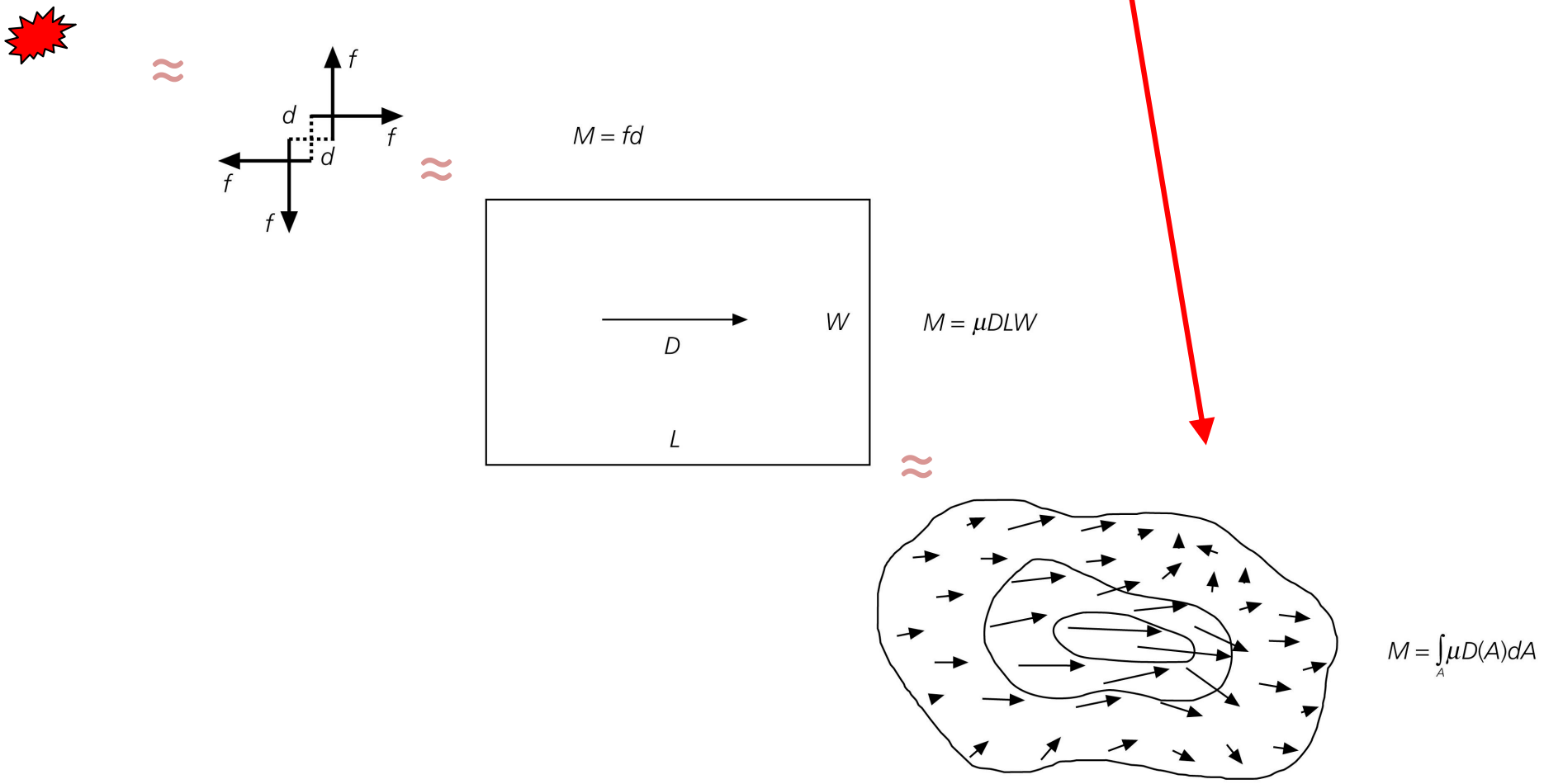
Pearce, 1977

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

(*)

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

Séisme = déplacement fini sur une faille étendue



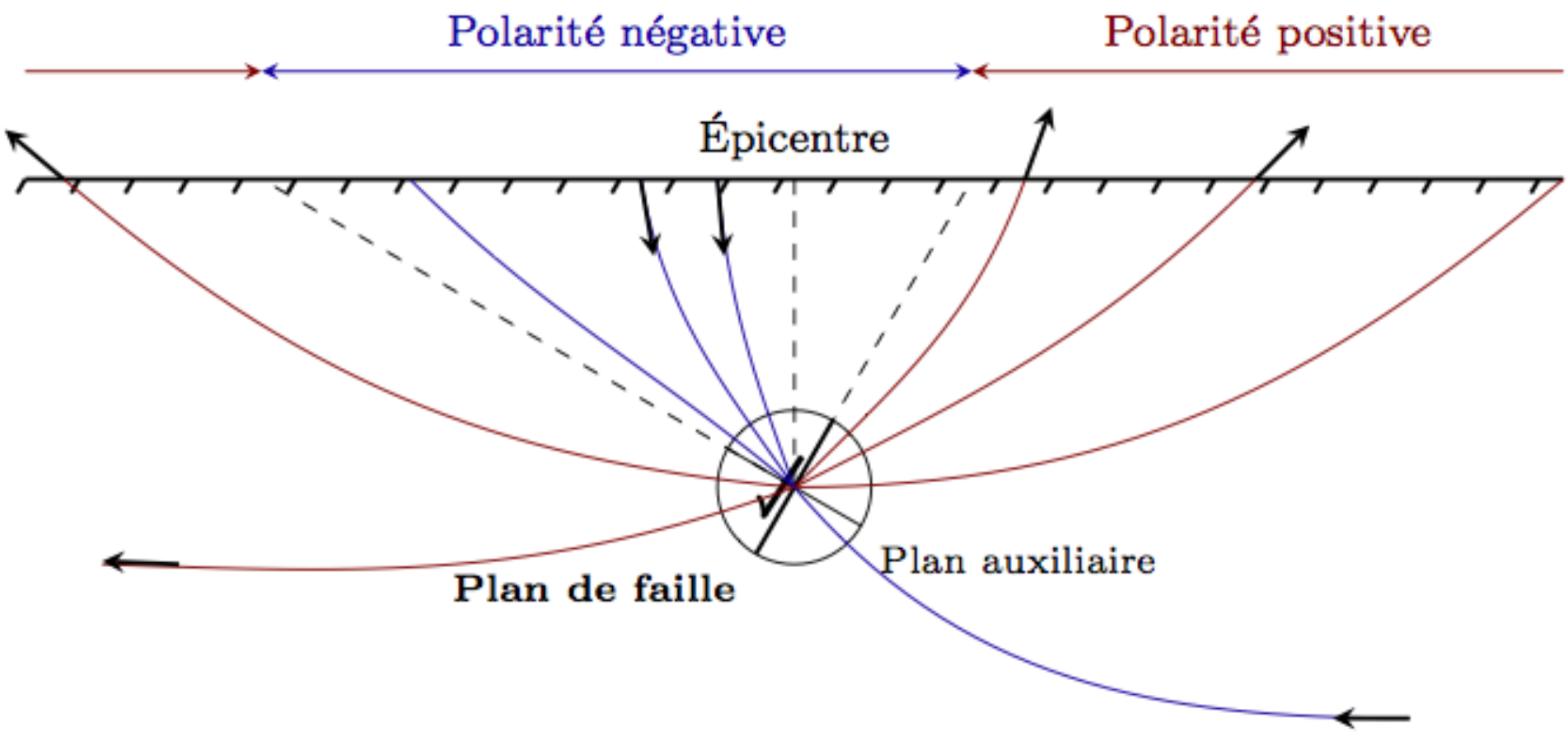
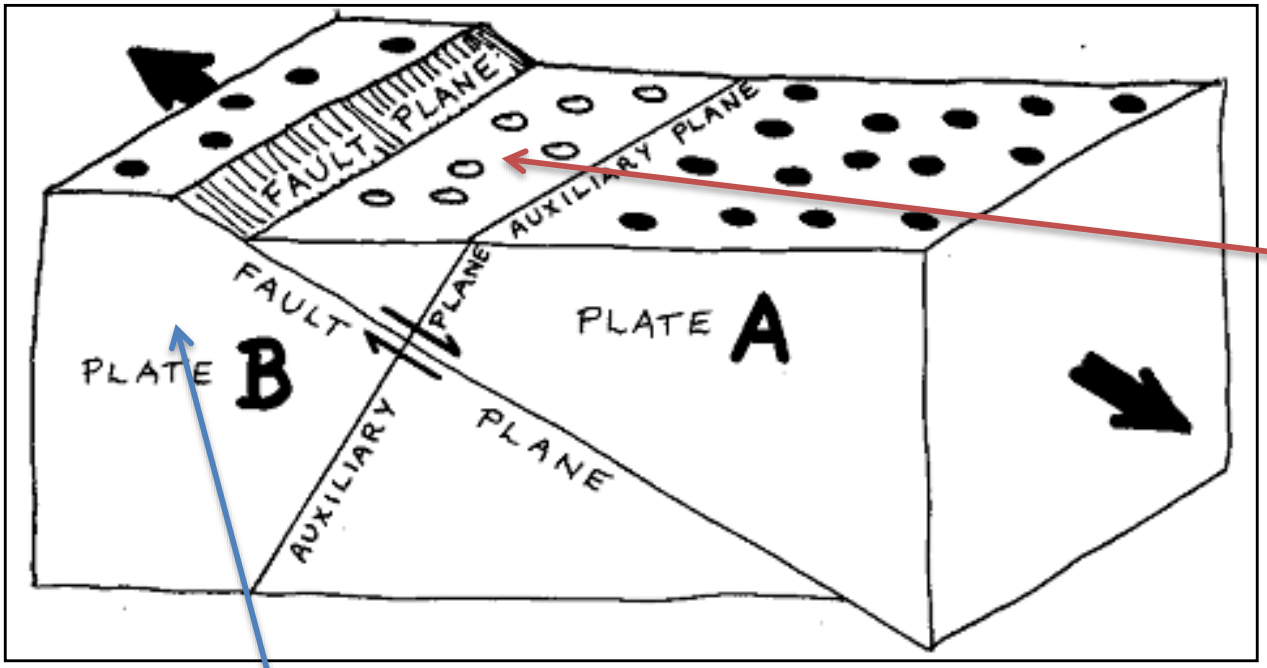


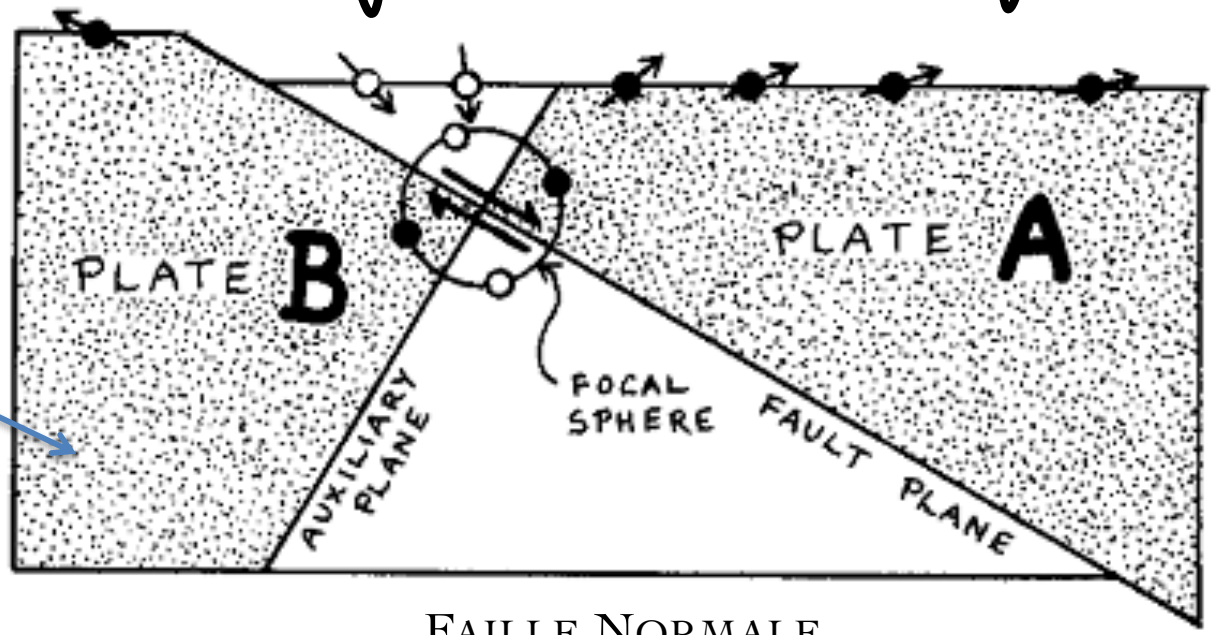
Schéma 2D du foyer sismique et des quadrants compressifs et extensifs.

(*)



Dilatation (-)

Compression (+)

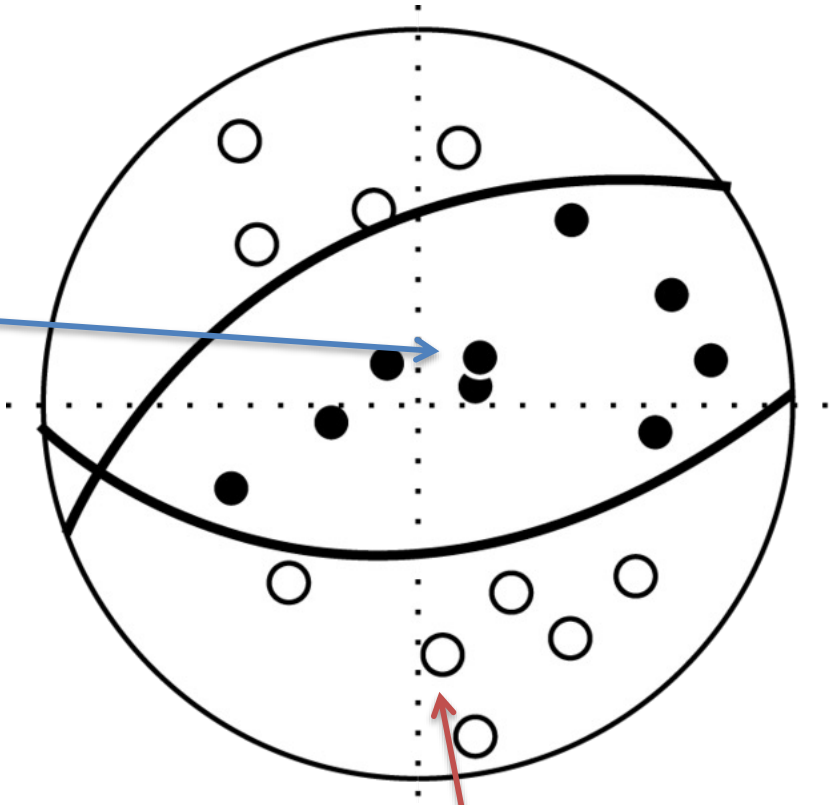


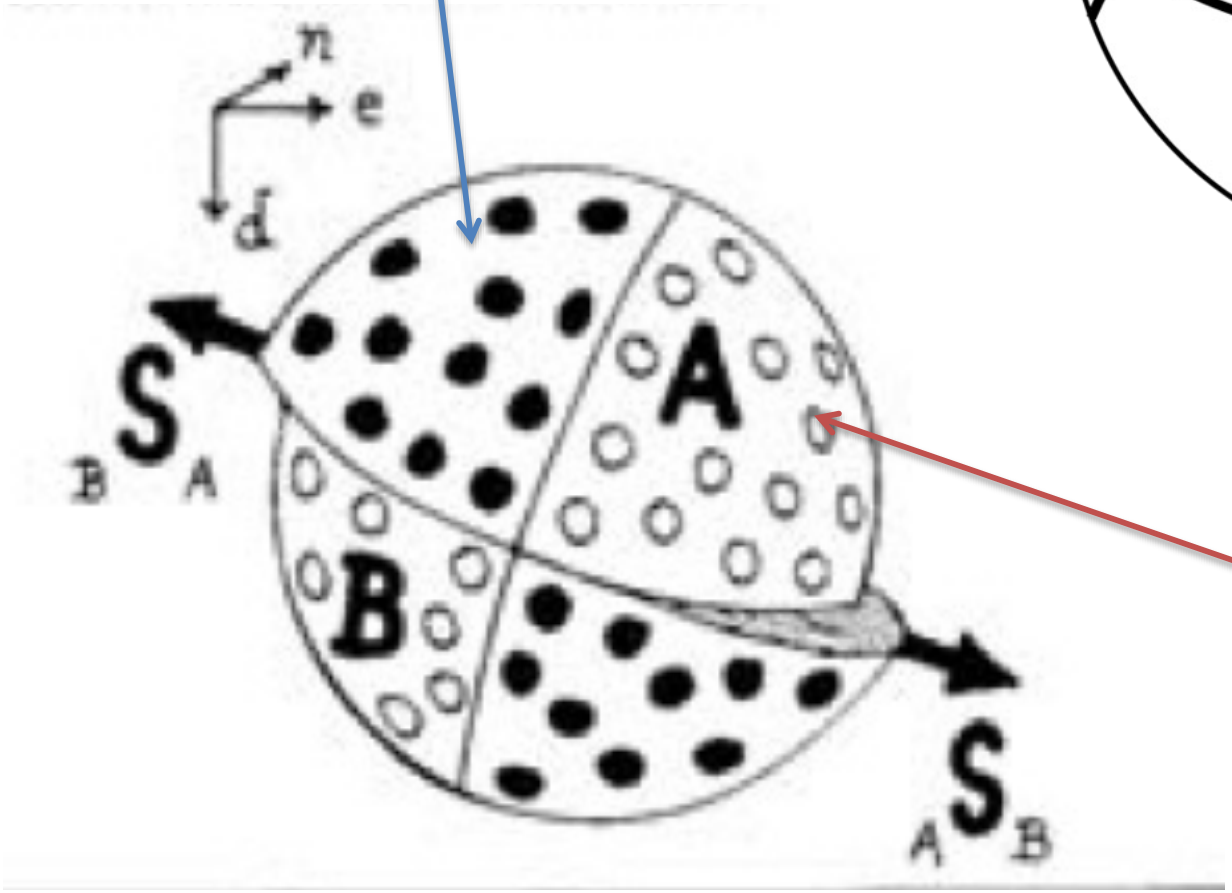
courtesy of Ian Hill, University of Leicester, UK

FAILLE NORMALE

Trouver les plans nodaux qui séparent les compressions des dilatations.

Compression (+)

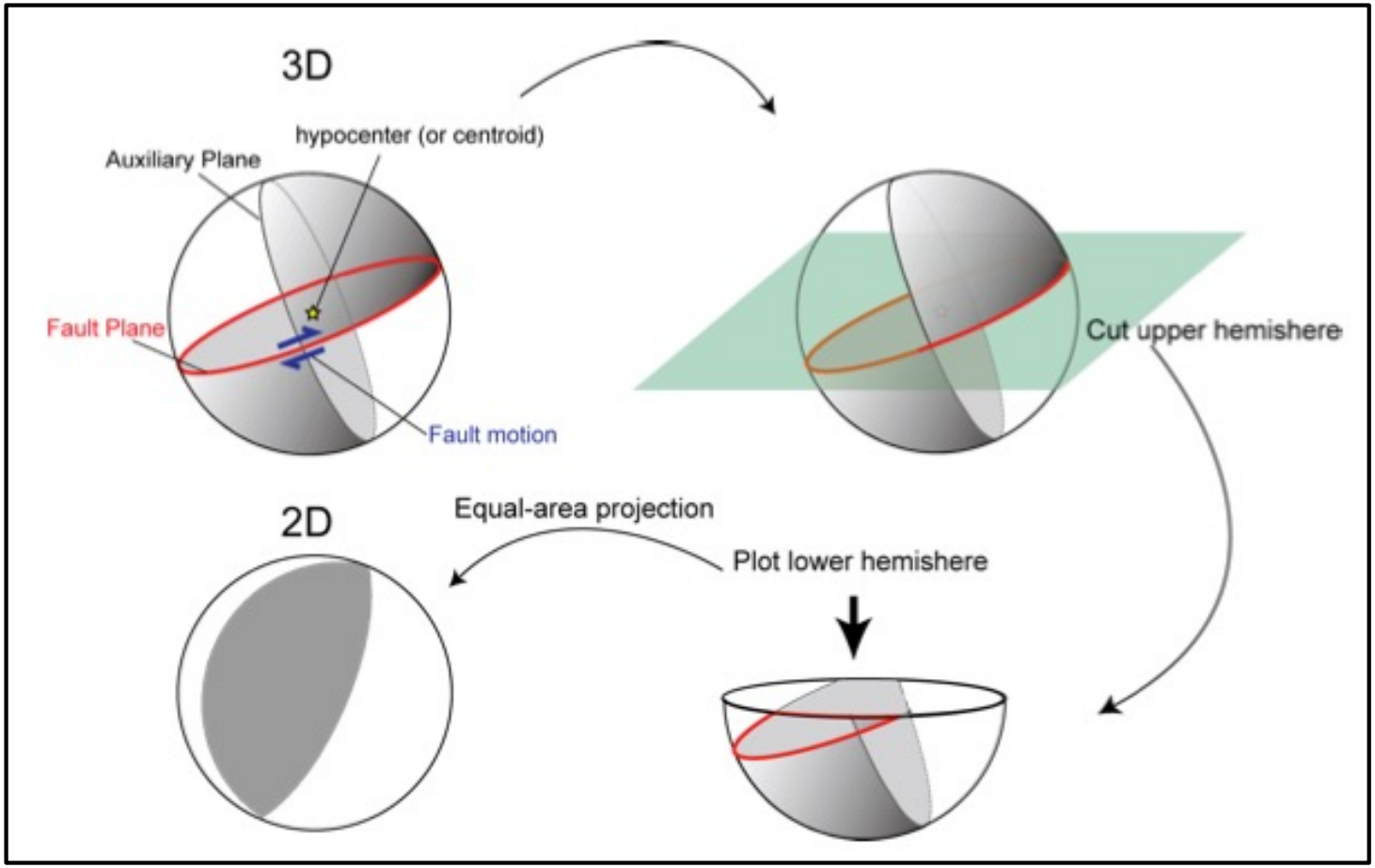




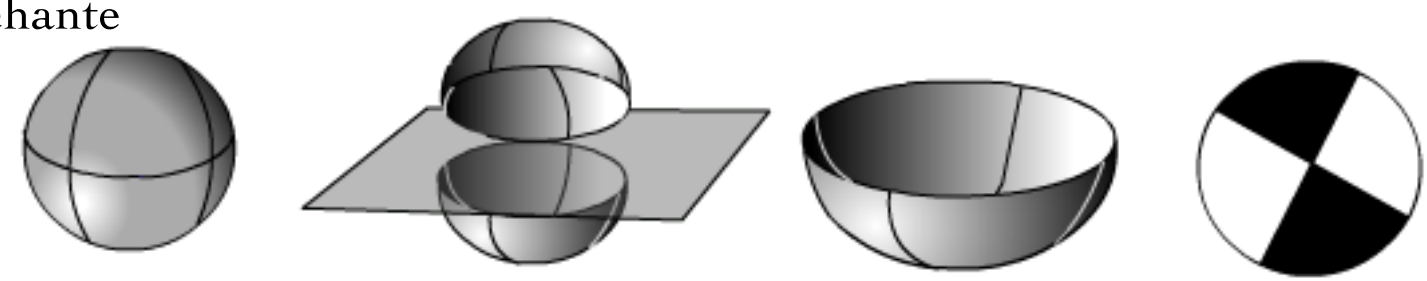
Dilatation (-)

FAILLE INVERSE

Comment représenter le mécanisme?



Exemple : Faille décrochante



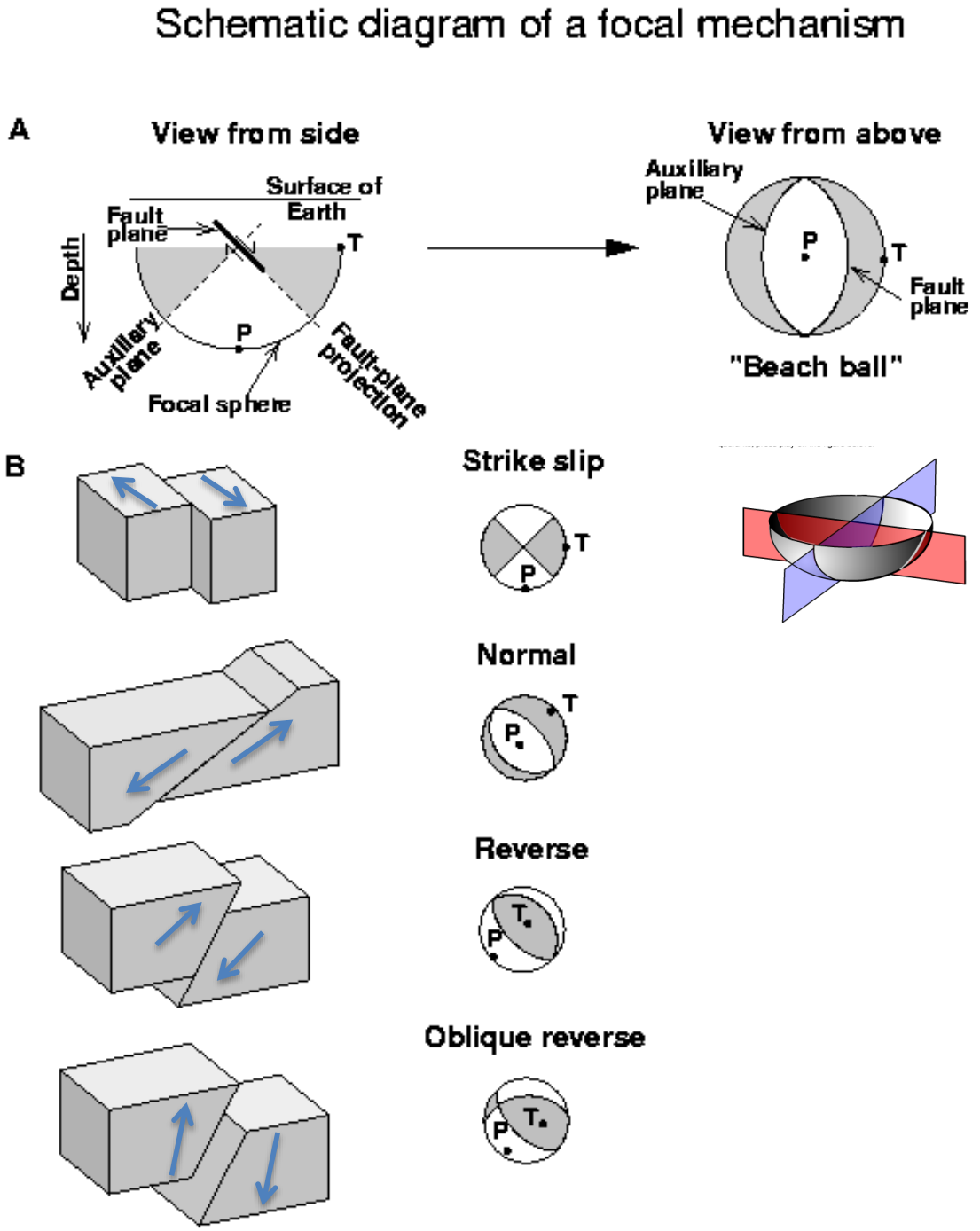
MÉCANISMES AU FOYER

FAILLE DECROCHANTES (TRANSFORMANTES)

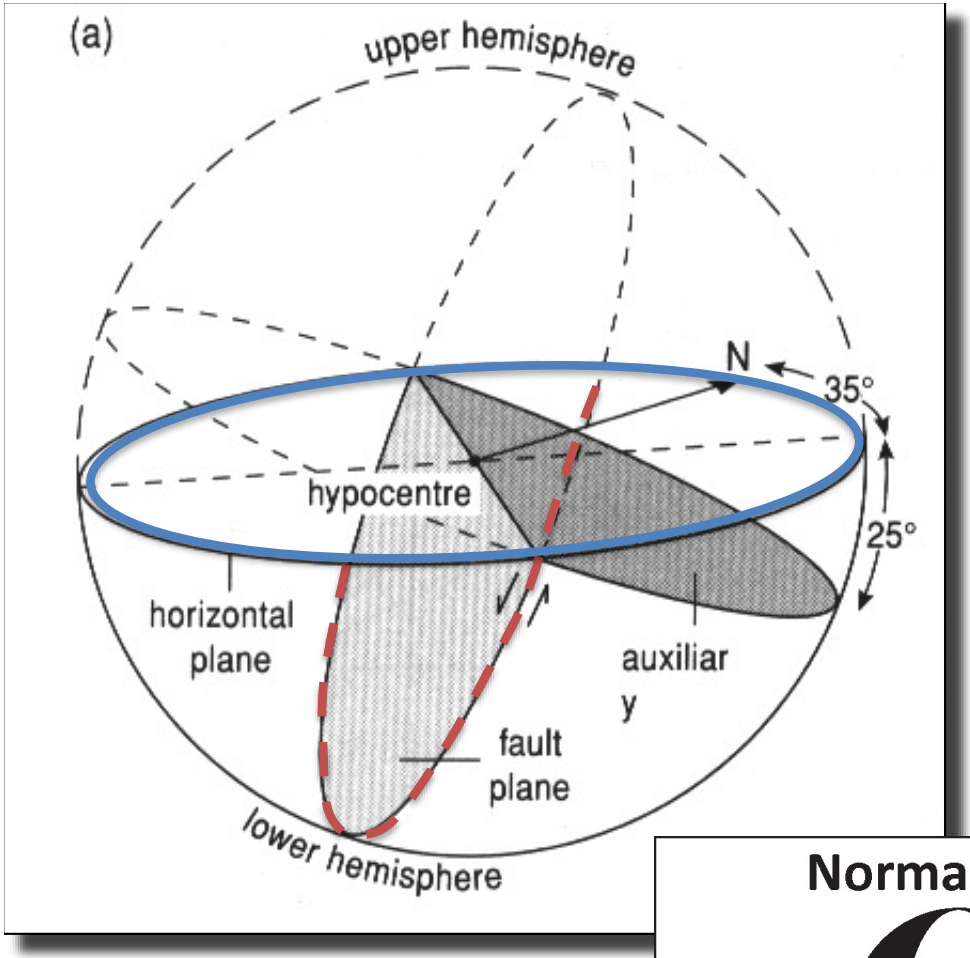
FAILLE NORMALE

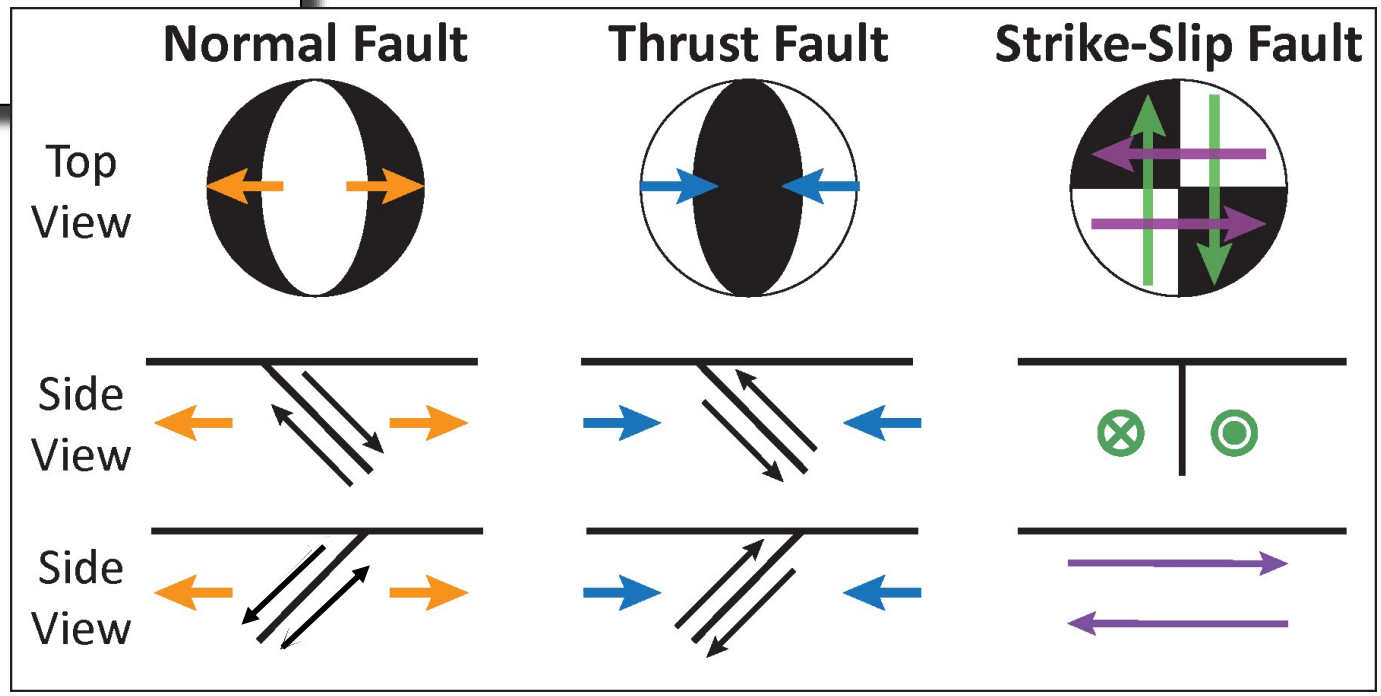
FAILLE INVERSE

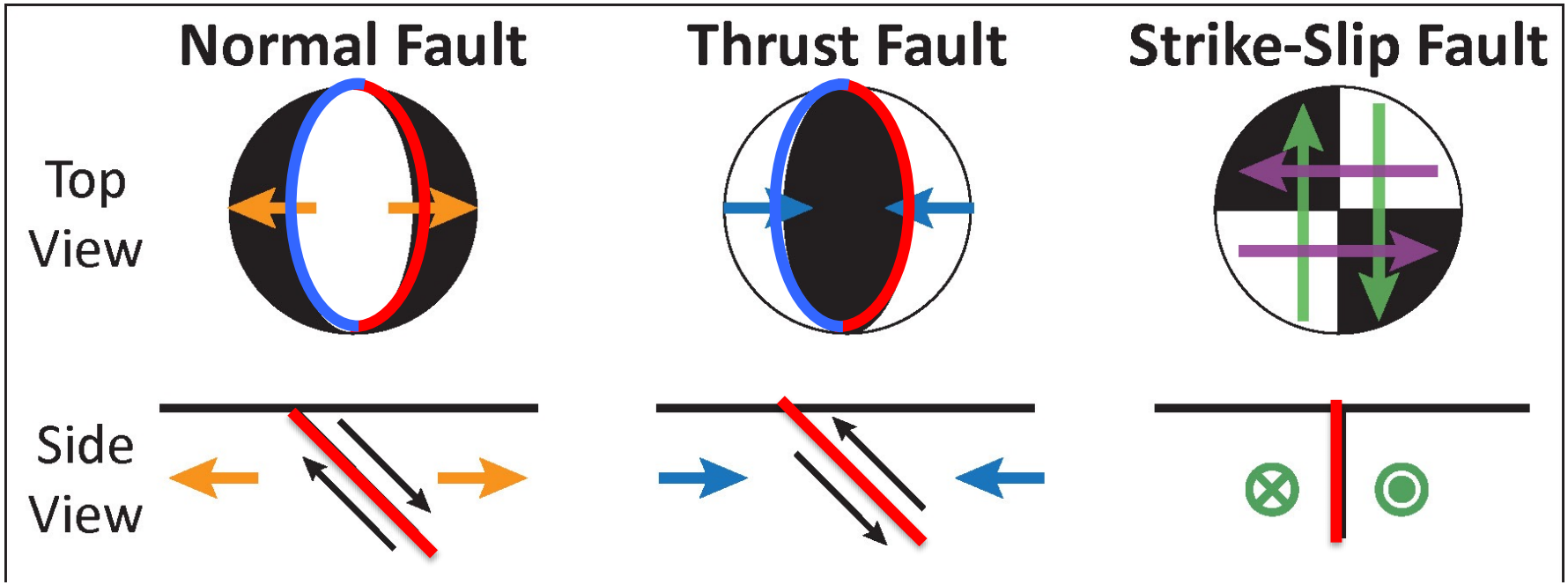
FAILLE OBLIQUE



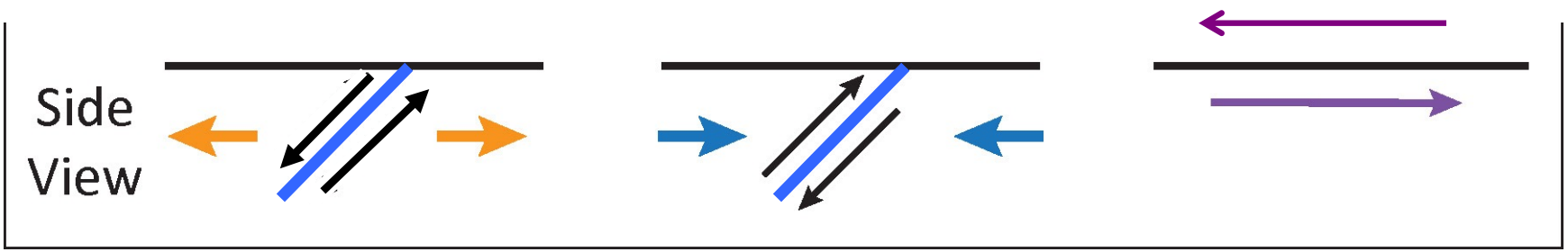
USGS, 1996

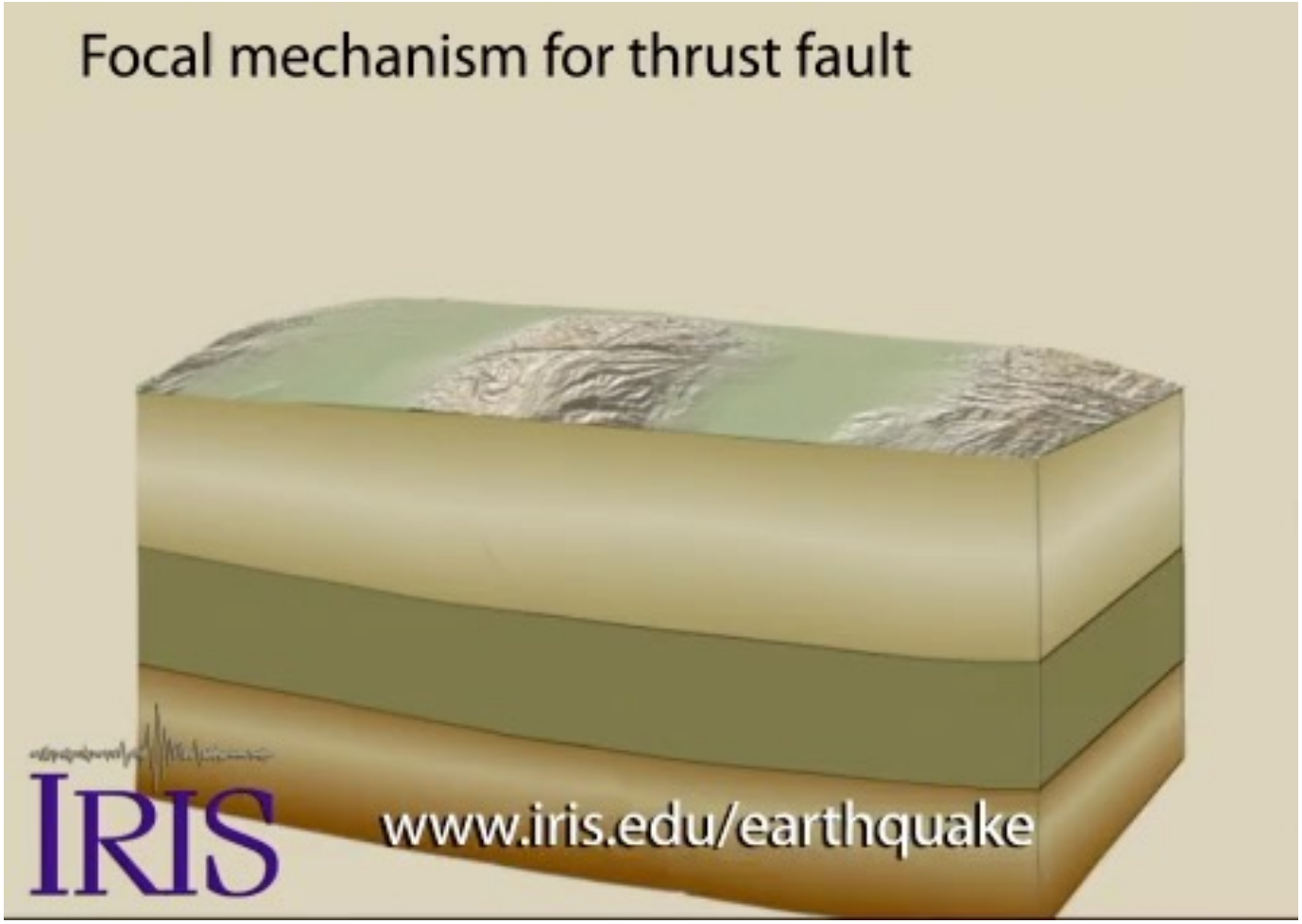

(a)
upper hemisphere
N
35°
25°
hypocentre
horizontal plane
auxiliary
fault plane
lower hemisphere


Normal Fault
Thrust Fault
Strike-Slip Fault
Top View
Side View
Side View


Normal Fault
Thrust Fault
Strike-Slip Fault
Top View
Side View

Ou bien :


Side View


Focal mechanism for thrust fault
IRIS
www.iris.edu/earthquake

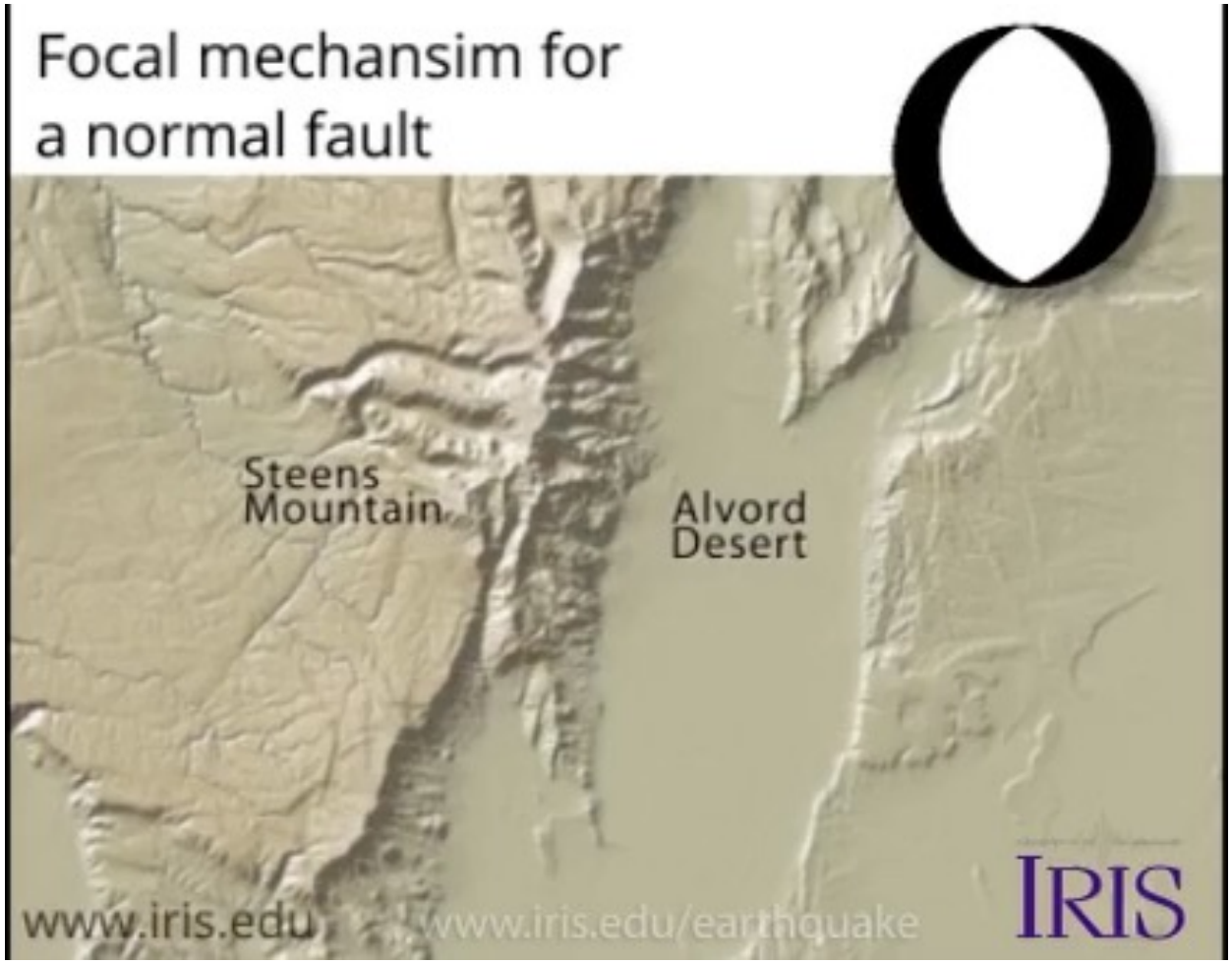
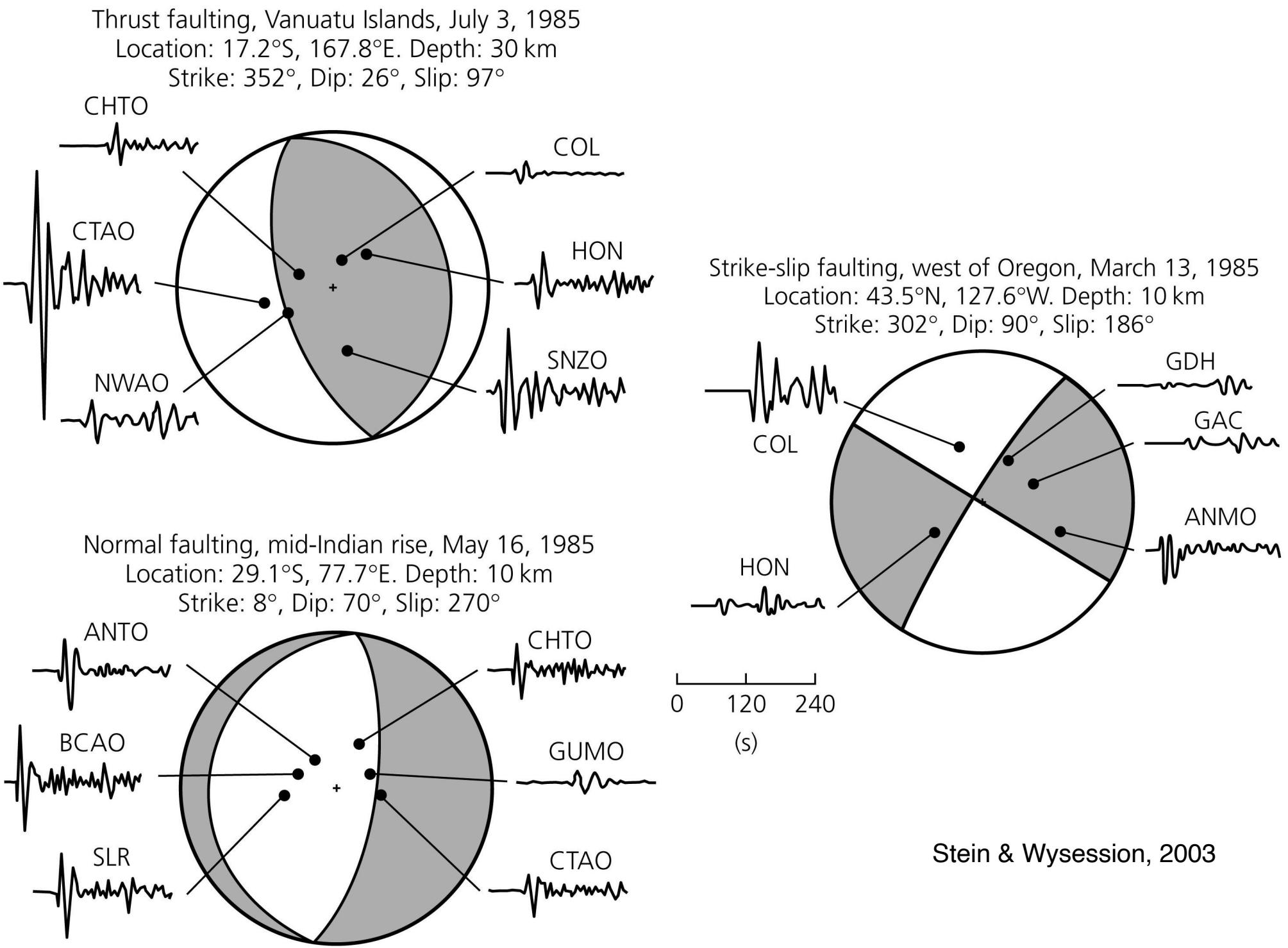
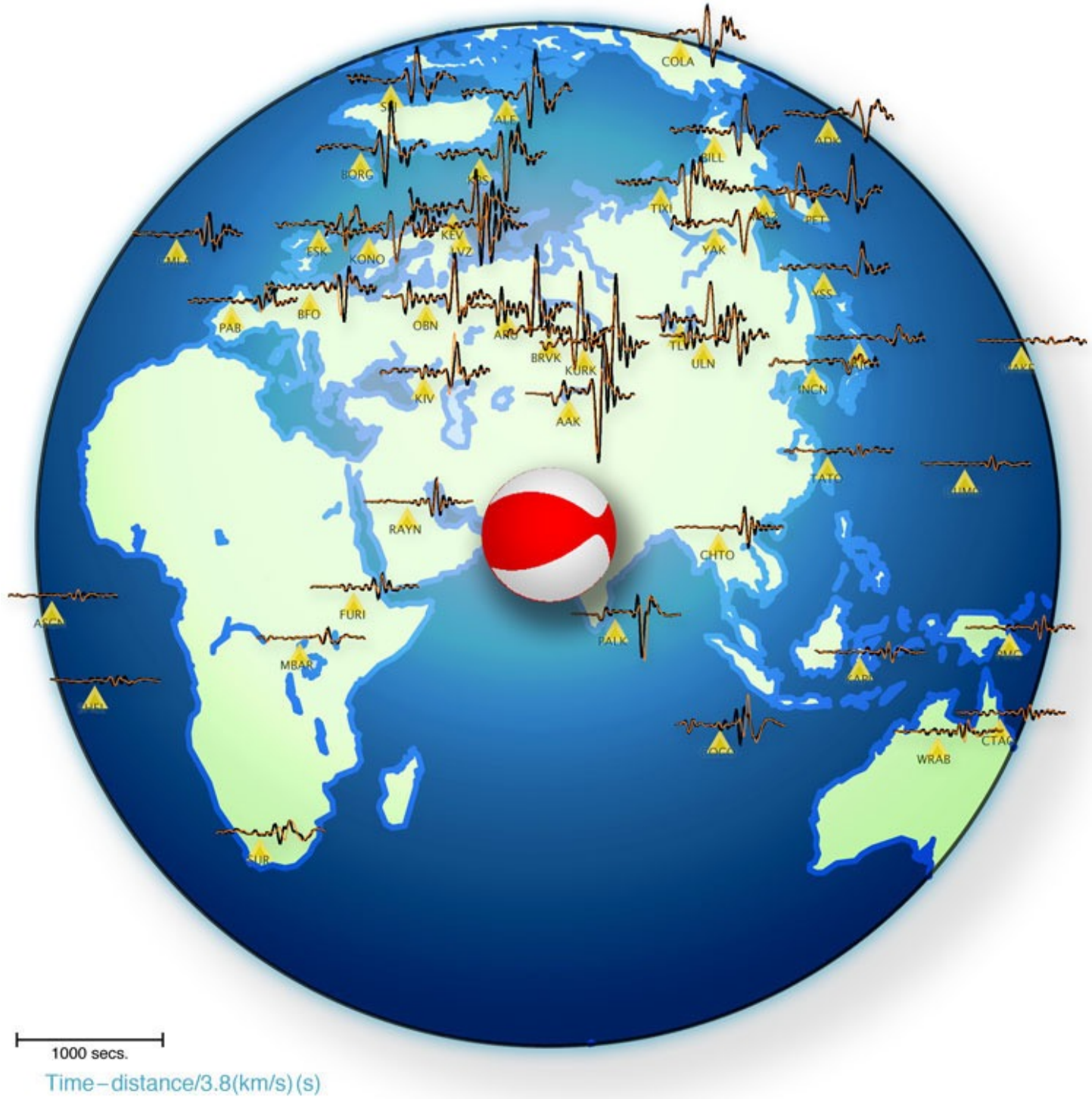

Focal mechansim for
a normal fault
Steens
Mountain
Alvord
Desert
www.iris.edu
www.iris.edu/earthquake
IRIS

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

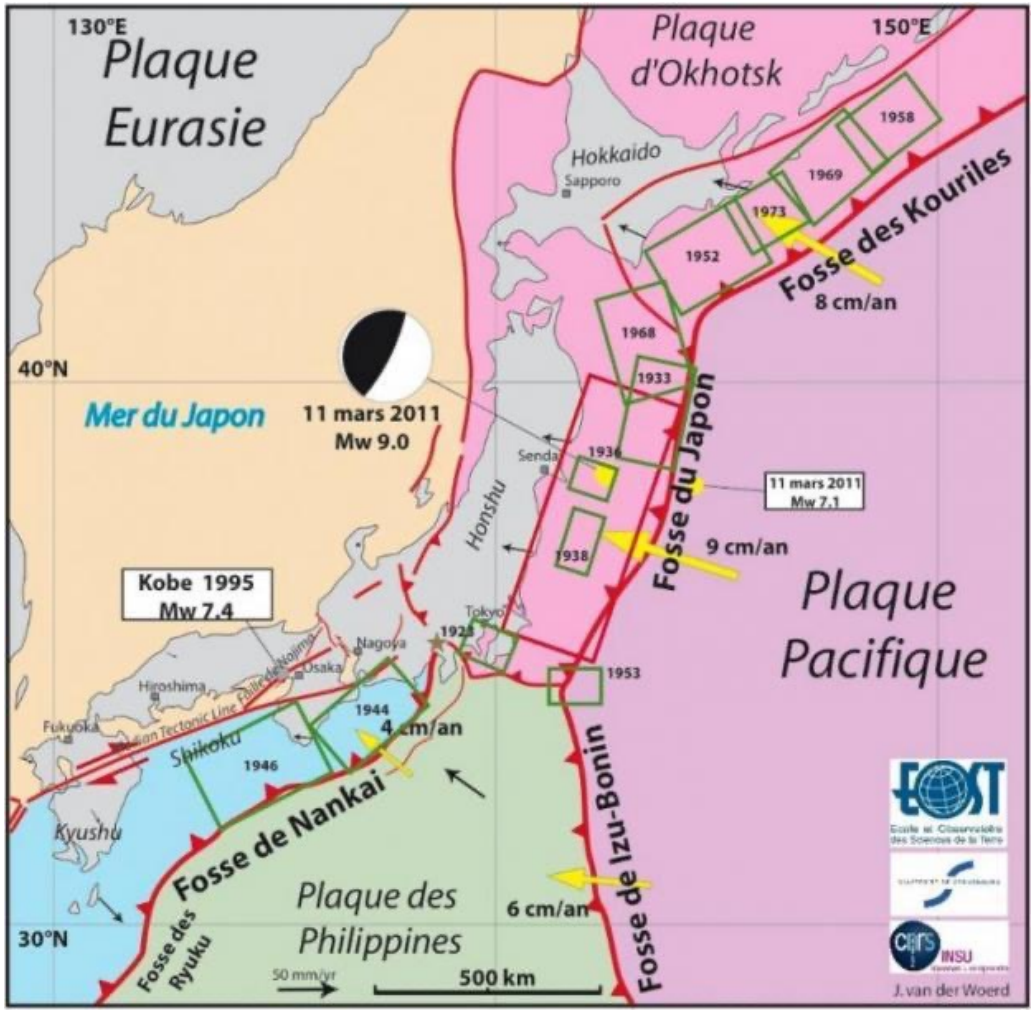


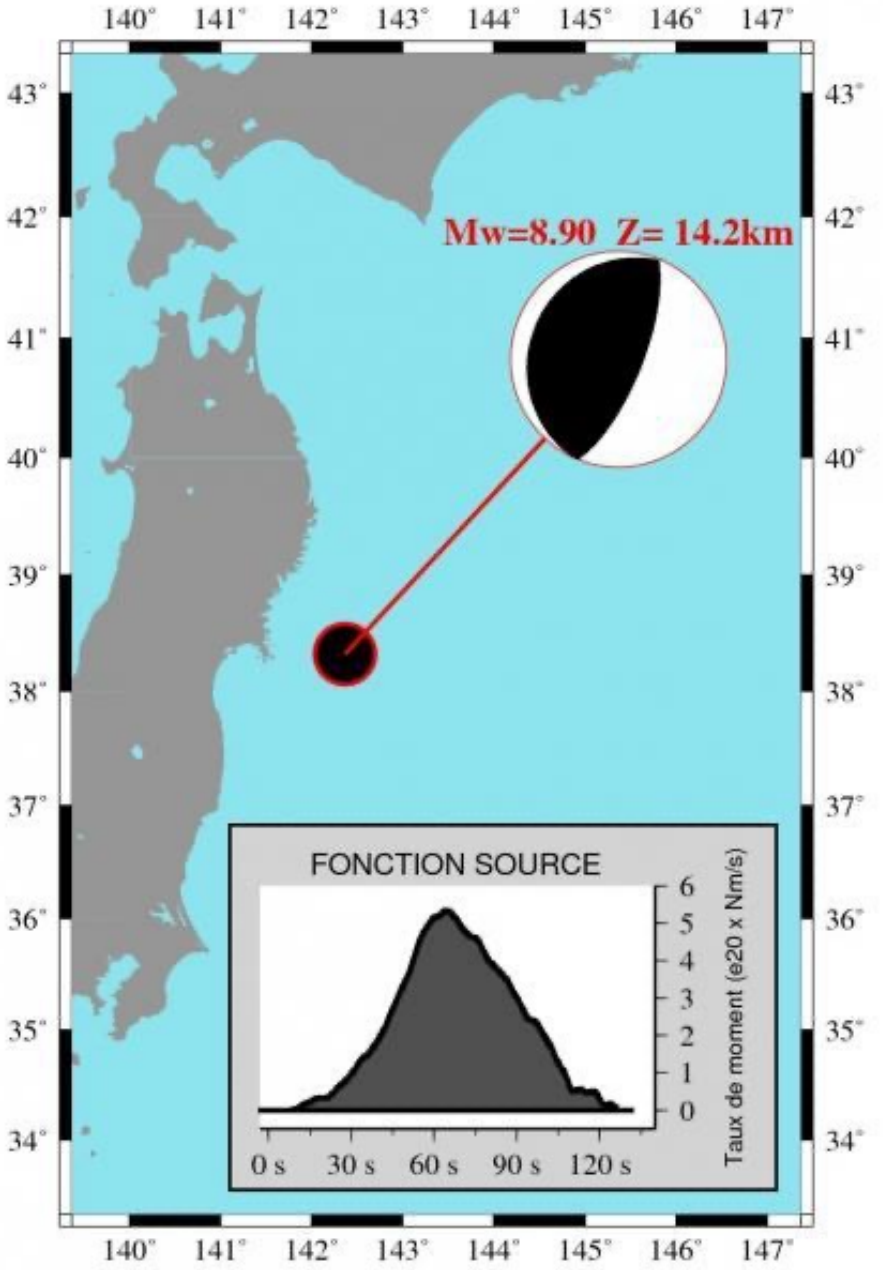
Stein & Wysession, 2003

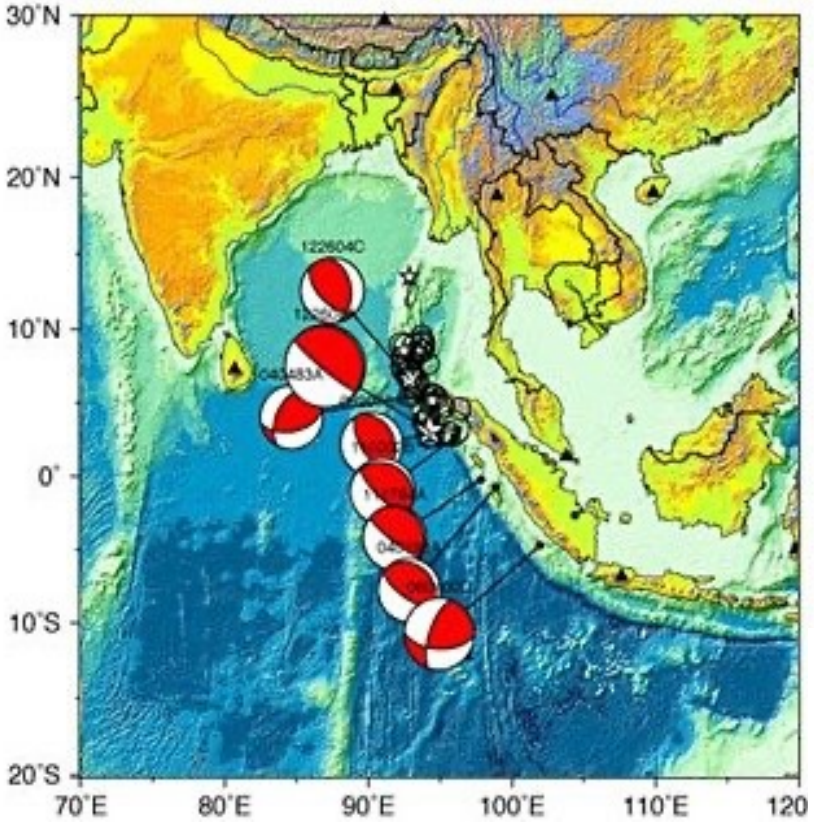


2001 Séisme de Bhuj, Inde (Mw 7.7) , inverse - oblique

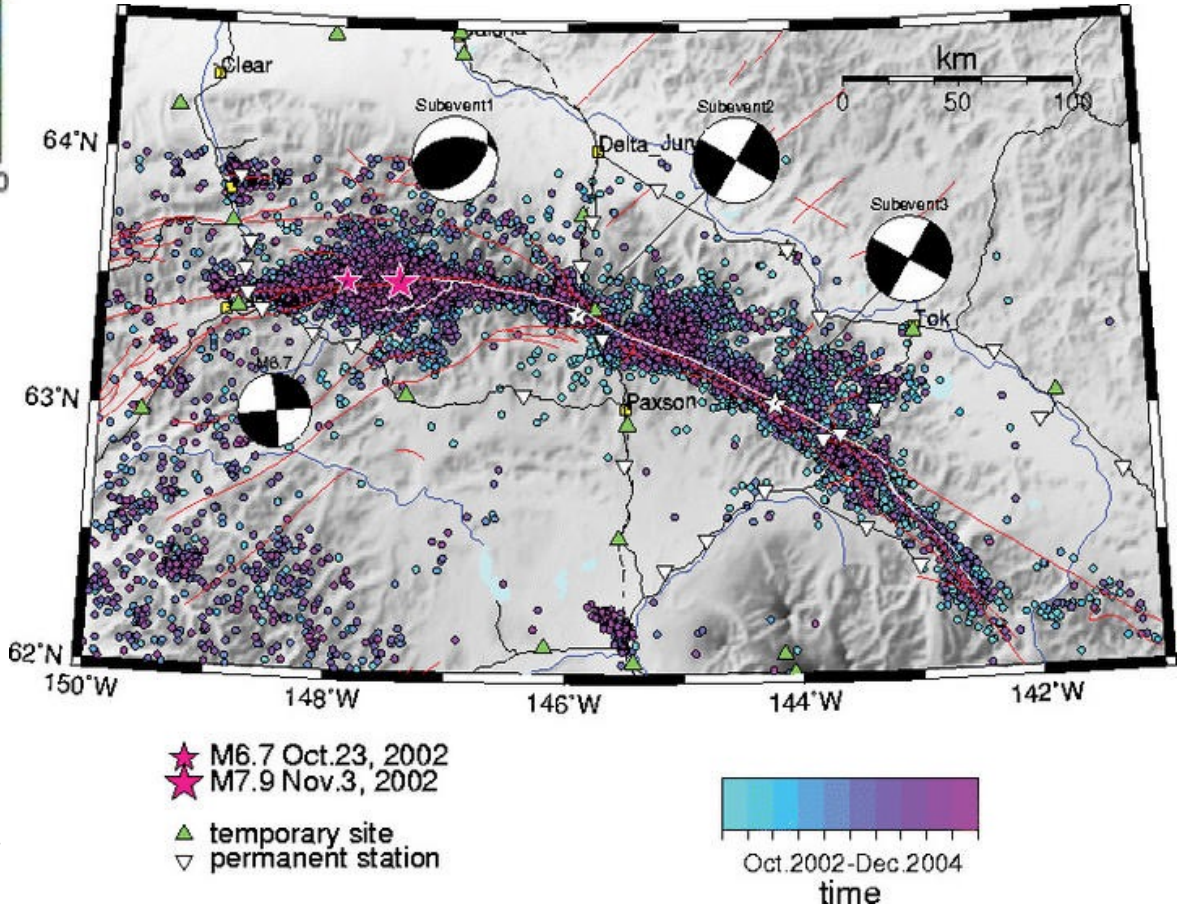
Exemple du Séisme de Tohoku
Mw 9.1, 2011



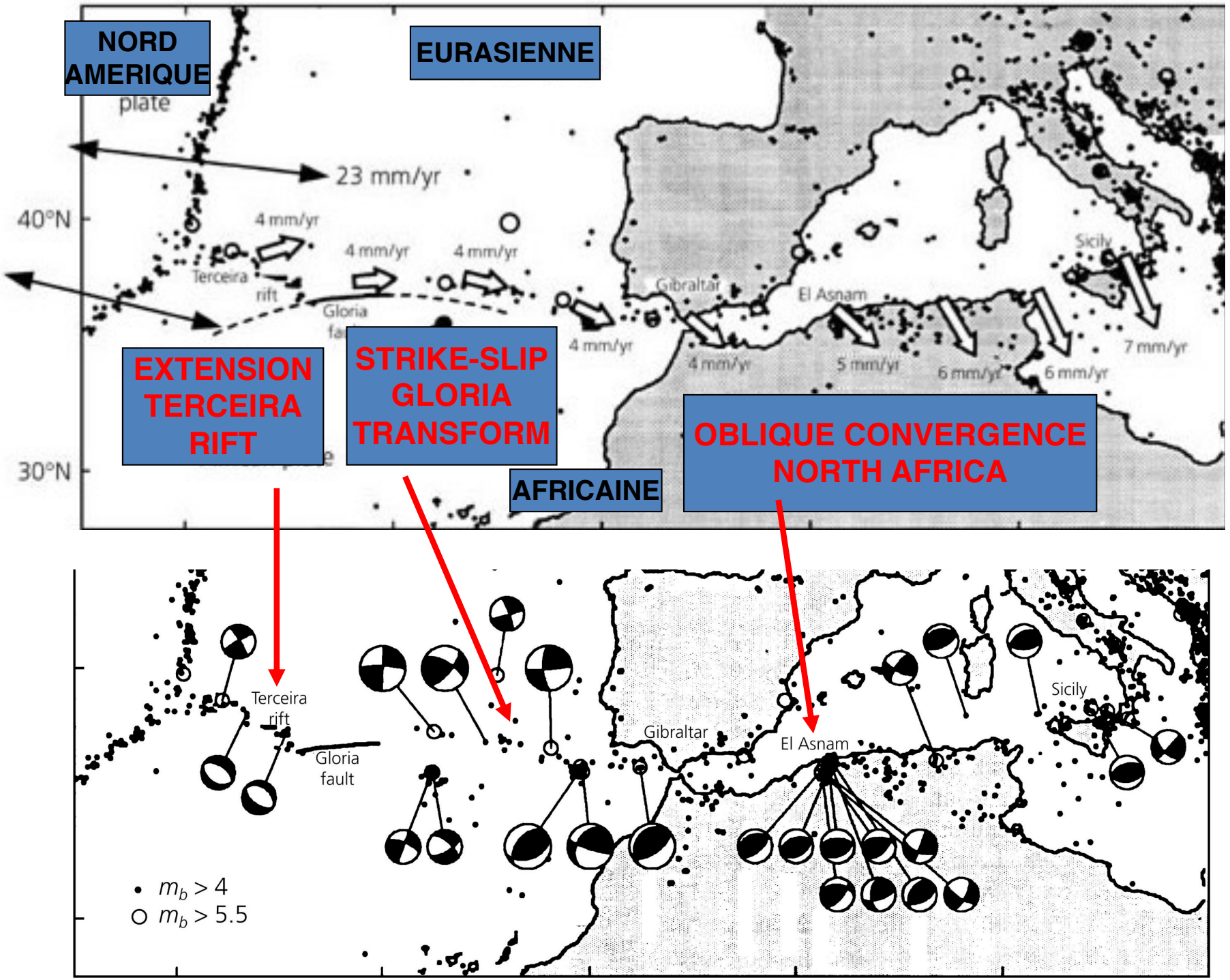




Sumatra 2004



Denali 2002

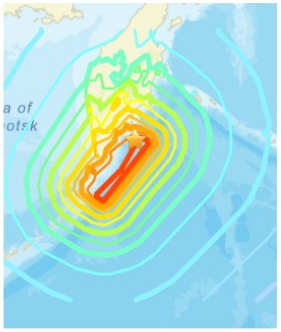


Limites de plaques Divergentes / Transformantes / Convergentes

M 8.8 – 2025 Kamchatka Peninsula, Russia Earthquake

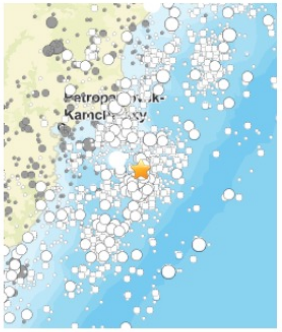
2025-07-29 23:24:52 (UTC) | 52.495°N 160.240°E | 35.0 km depth

Interactive Map



Contributed by US

Regional Information



Contributed by US

Felt Report - Tell Us!

0 0 0 1 2 4

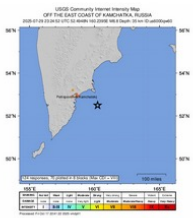
Responses

Contribute to citizen science. Please tell us about your experience.

Citizen Scientist Contributions

Did You Feel It?

IX

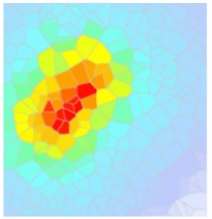


Community Internet Intensity Map

Contributed by US

ShakeMap

IX

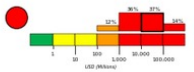


Estimated Intensity Map

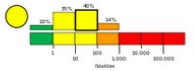
Contributed by US

PAGER

RED



Estimated Economic Losses



Estimated Fatalities

Contributed by US

Ground Failure

Landslide Estimate

Extensive area affected

Significant population exposed

Liquefaction Estimate

Significant area affected

Limited population exposed

Contributed by US

Aftershock Forecast

According to our forecast, the chance of at least one aftershock within the next **month**:

M 8+	< 1%
M 7+	12%
M 6+	79%
M 5+	> 99%
M 4+	> 99%
M 3+	> 99%

Contributed by US

Origin

Review Status
REVIEWED

Magnitude
8.8 mww

Depth
35.0 km

Time
2025-07-29 23:24:52 UTC

Contributed by US

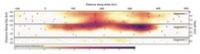
Moment Tensor



Fault Plane Solution

Contributed by US

Finite Fault



Cross-section of slip distribution.

Contributed by US

Tsunami

U.S. Tsunami Warning System

To view any current tsunami advisories for this and other events please visit https://www.tsunami.gov.

NOAA

View Nearby Seismicity

Time Range
± Three Weeks

Search Radius
250.0 km

Magnitude Range
≥ 5.0

ANSS Comcat

Contributors

US

USGS science for a changing world

USGS National Earthquake Information Center, PDE

Authoritative Network

https://earthquake.usgs.gov/earthquakes/eventpage/us6000qw60/executive

M 8.8 - 2025 Kamchatka Peninsula, Russia Earthquake

2025-07-29 23:24:52 (UTC) | 52.495°N 160.240°E | 35.0 km depth

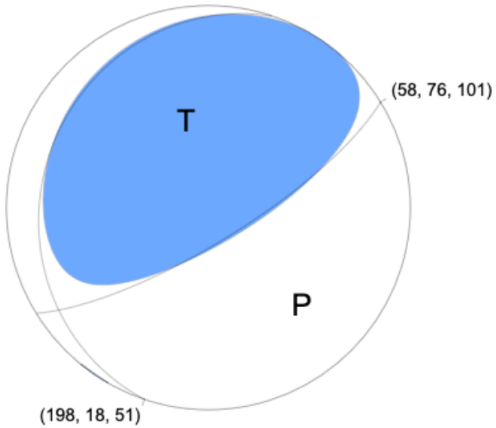
Moment Tensor

View all moment-tensor products (1 total)

Contributed by US last updated 2025-10-11 20:57:35 (UTC)

✓ The data below are the most preferred data available
✓ The data below have been reviewed by a scientist

W-phase Moment Tensor (Mww)



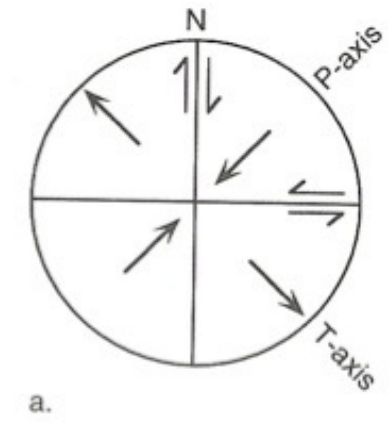
Moment	2.221e+22 N-m
Magnitude	8.83 Mww
Depth	21.5 km
Percent DC	84%
Half Duration	112.50 s
Catalog	US
Data Source	US
Contributor	US

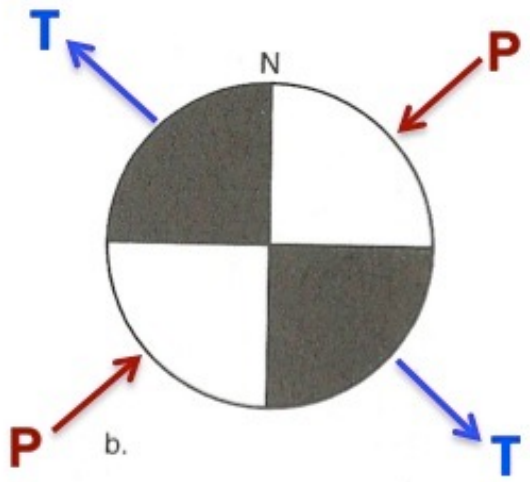
Nodal Planes

Plane	Strike	Dip	Rake
NP1	198°	18°	51°
NP2	58°	76°	101°

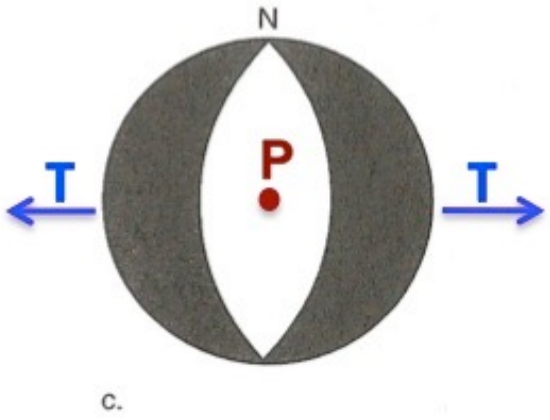
Principal Axes

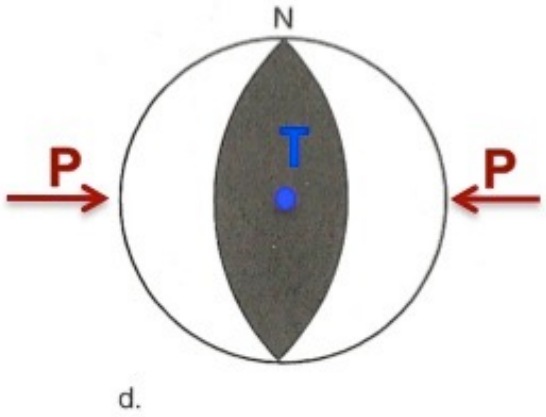
Axis	Value	Plunge	Azimuth
T	2.308e+22	58°	344°
N	-0.186e+22	11°	236°
P	-2.122e+22	30°	139°





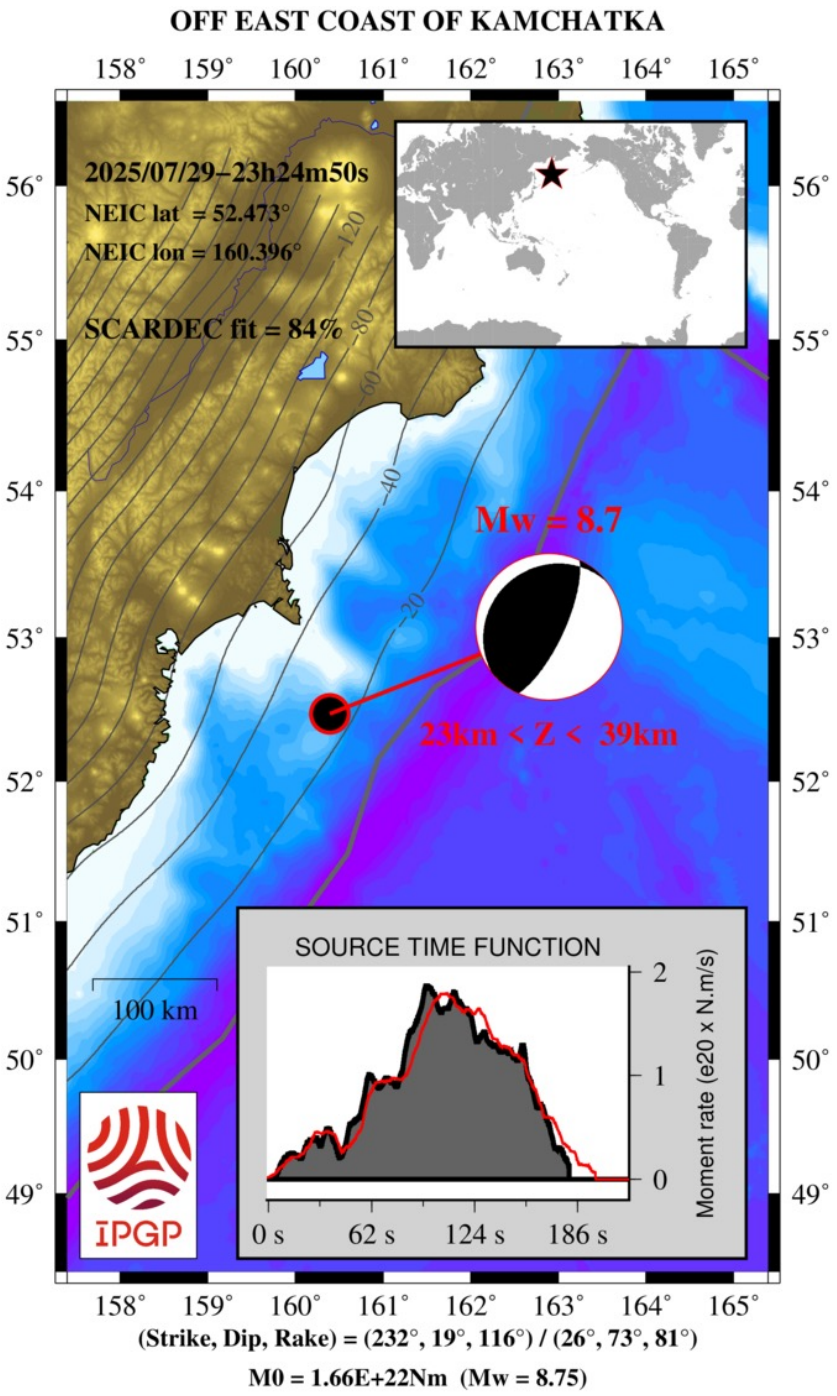
$$\sigma = \begin{pmatrix} \sigma_1 & 0 & 0 \\ 0 & \sigma_2 & 0 \\ 0 & 0 & \sigma_3 \end{pmatrix}$$

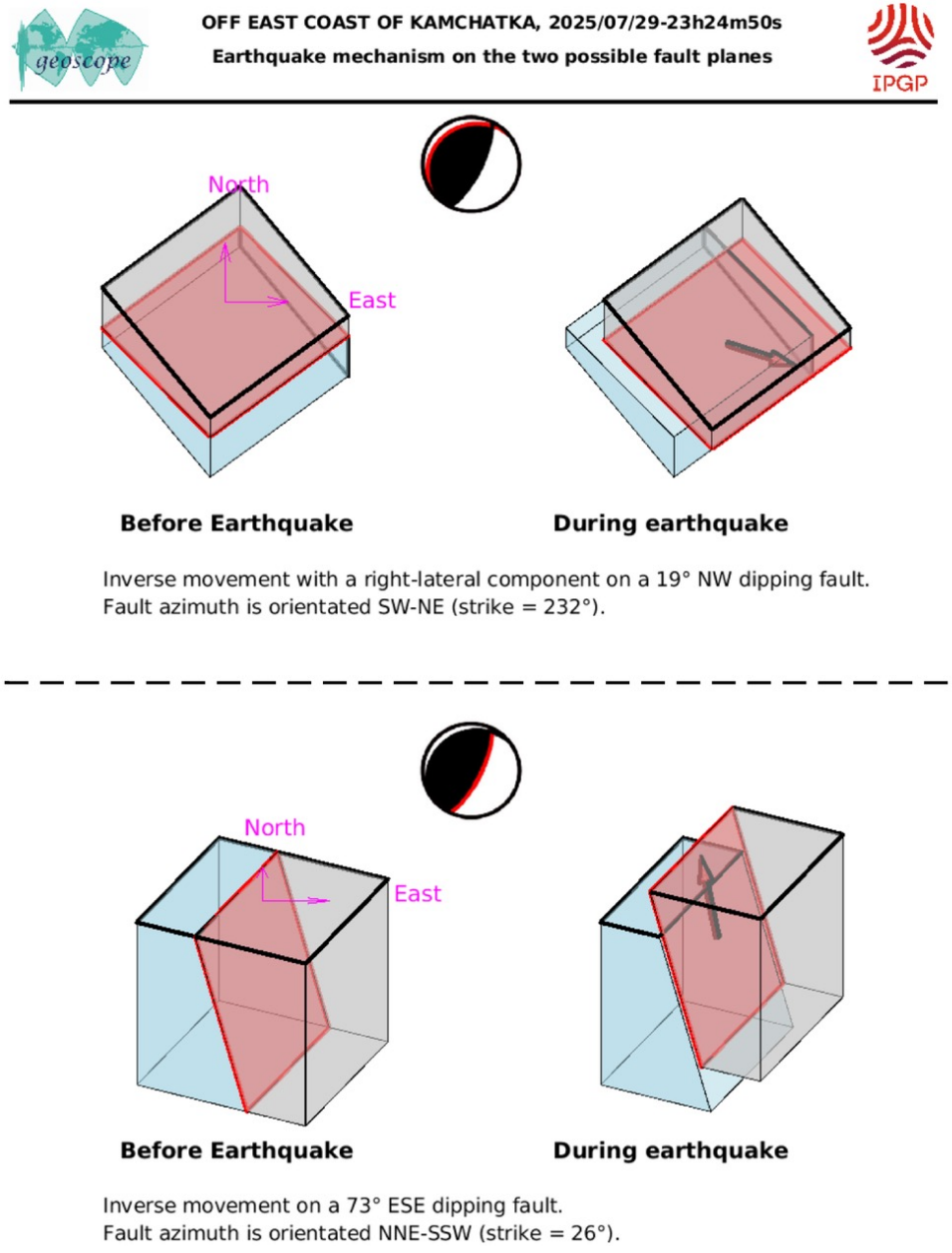




$$\sigma_1 \geq \sigma_2 \geq \sigma_3$$

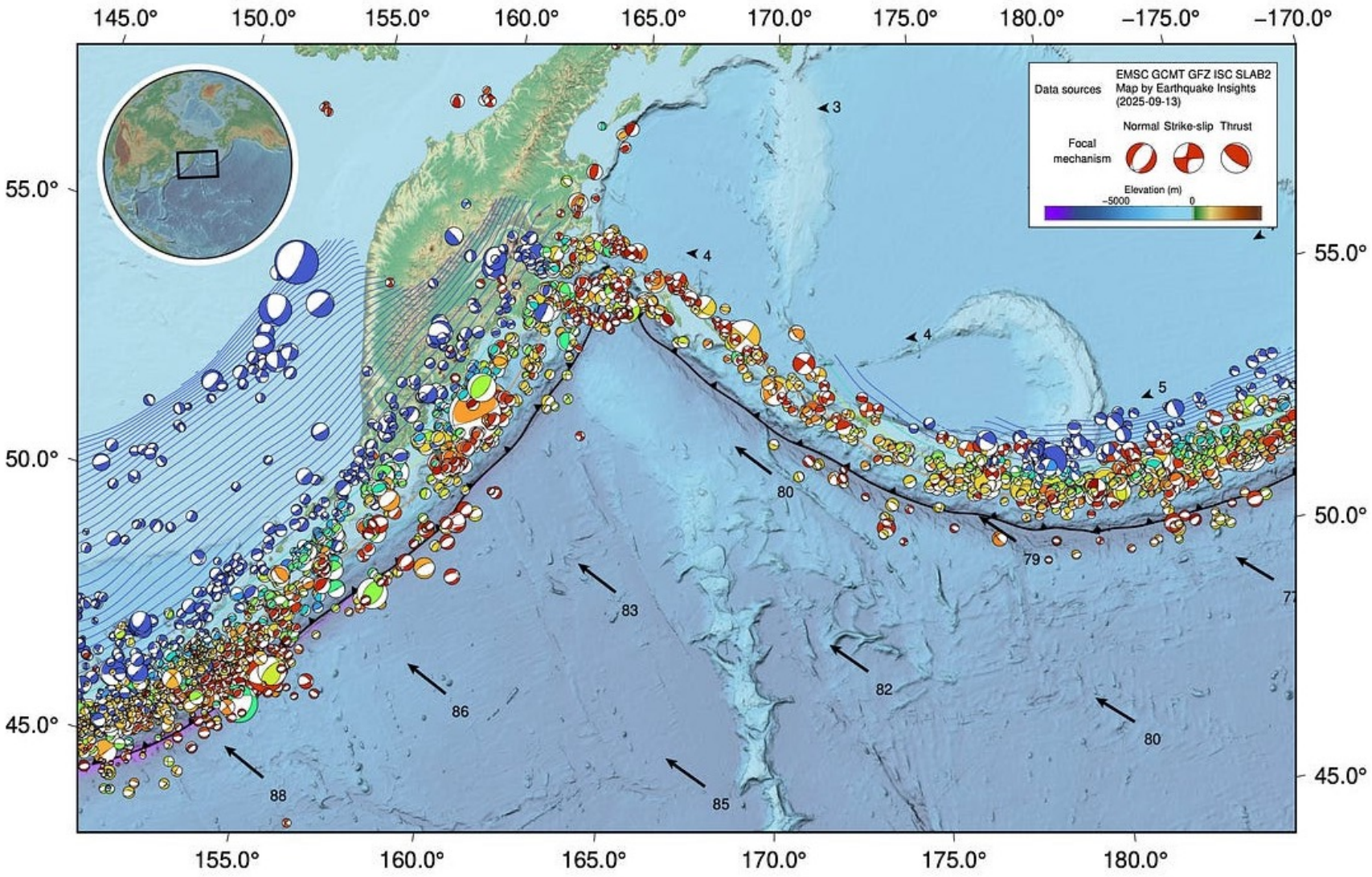
P axe de pression σ_1 (compression)
T axe de tension σ_3 (extension)
N axe nul σ_2





http://geoscope.ipgp.fr/index.php/en/catalog/earthquake-description?seis=us6000qw60

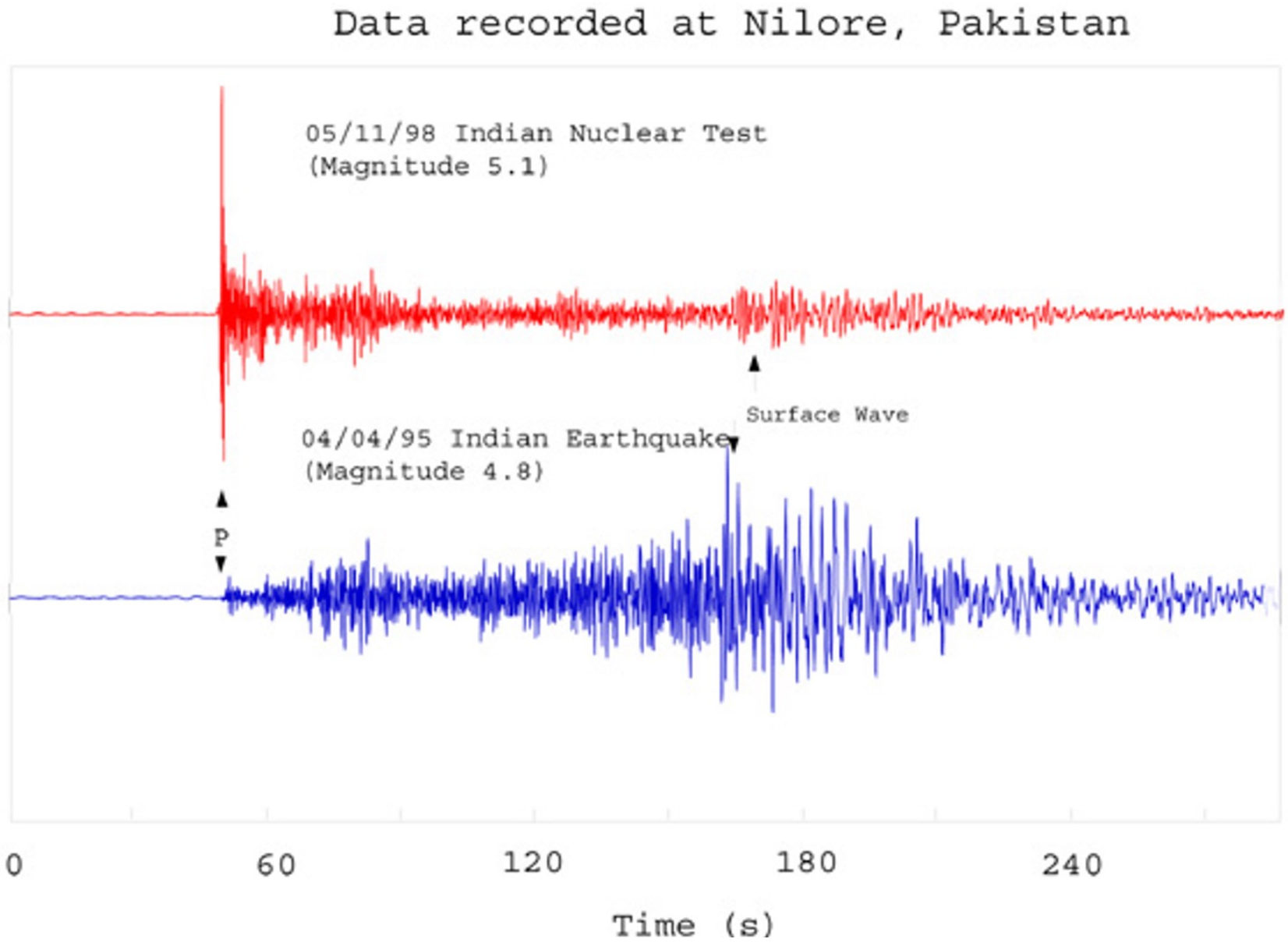
Contexte géodynamique



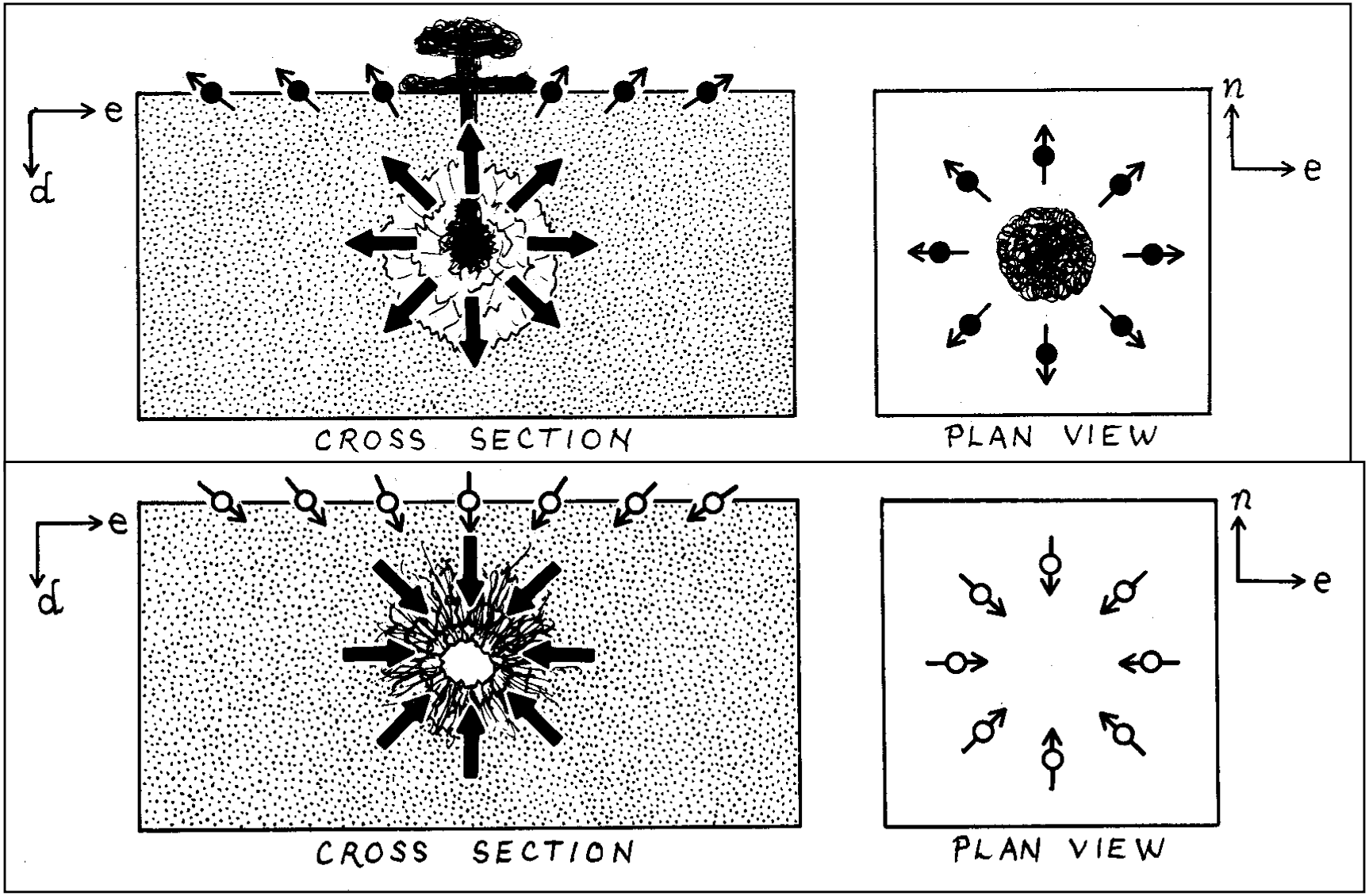
Jonction Kuril-Kamchatka / Aleutians

Flèches noires: mouvement de la plaque Pacifique en fonction

De la Plaque Nord Américaine (Kamchatka) Modèle MORVEL (mm/an)

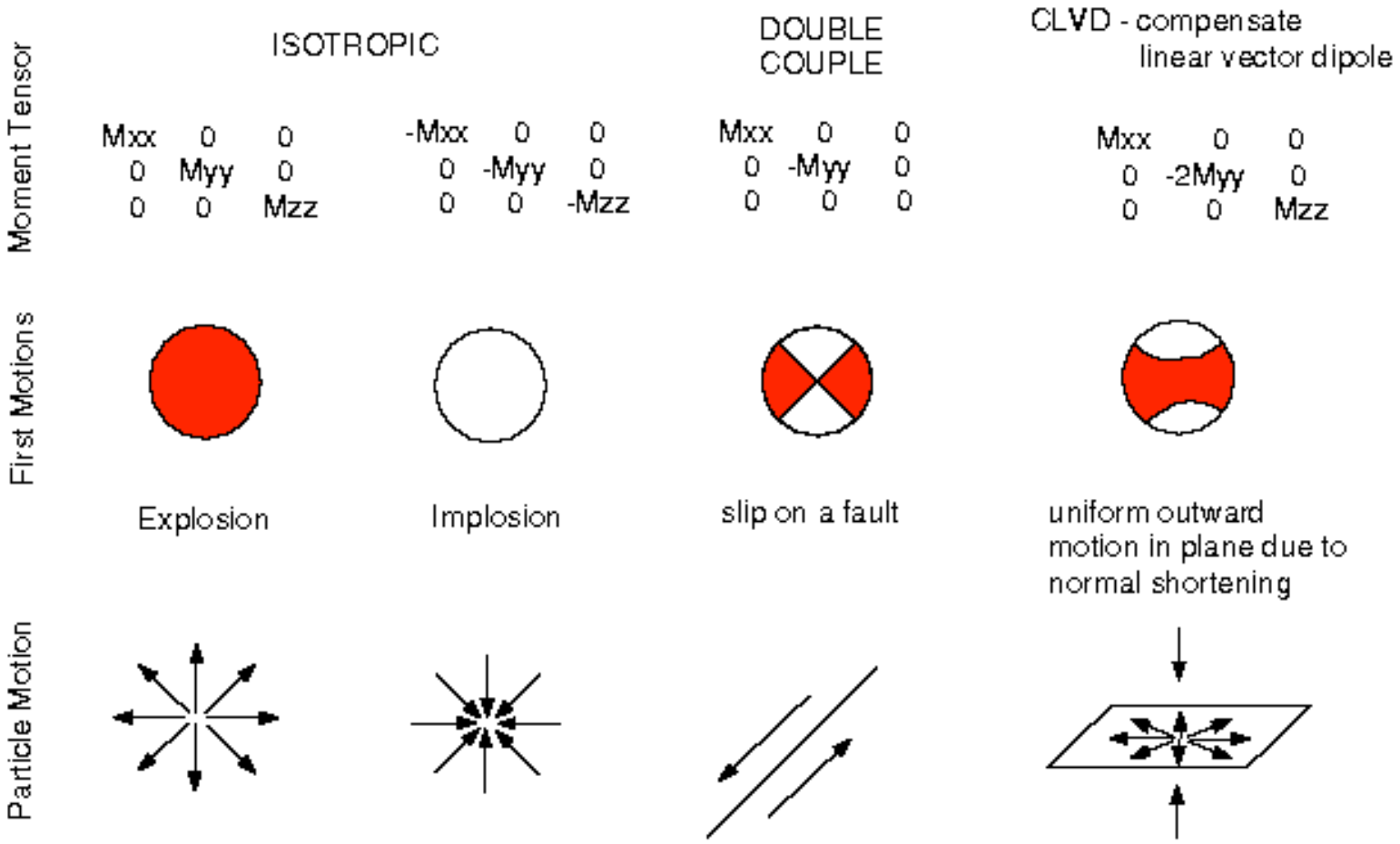

Data recorded at Nilore, Pakistan
05/11/98 Indian Nuclear Test
(Magnitude 5.1)
Surface Wave
04/04/95 Indian Earthquake
(Magnitude 4.8)
P
0
60
120
180
240
Time (s)

Premier mouvement



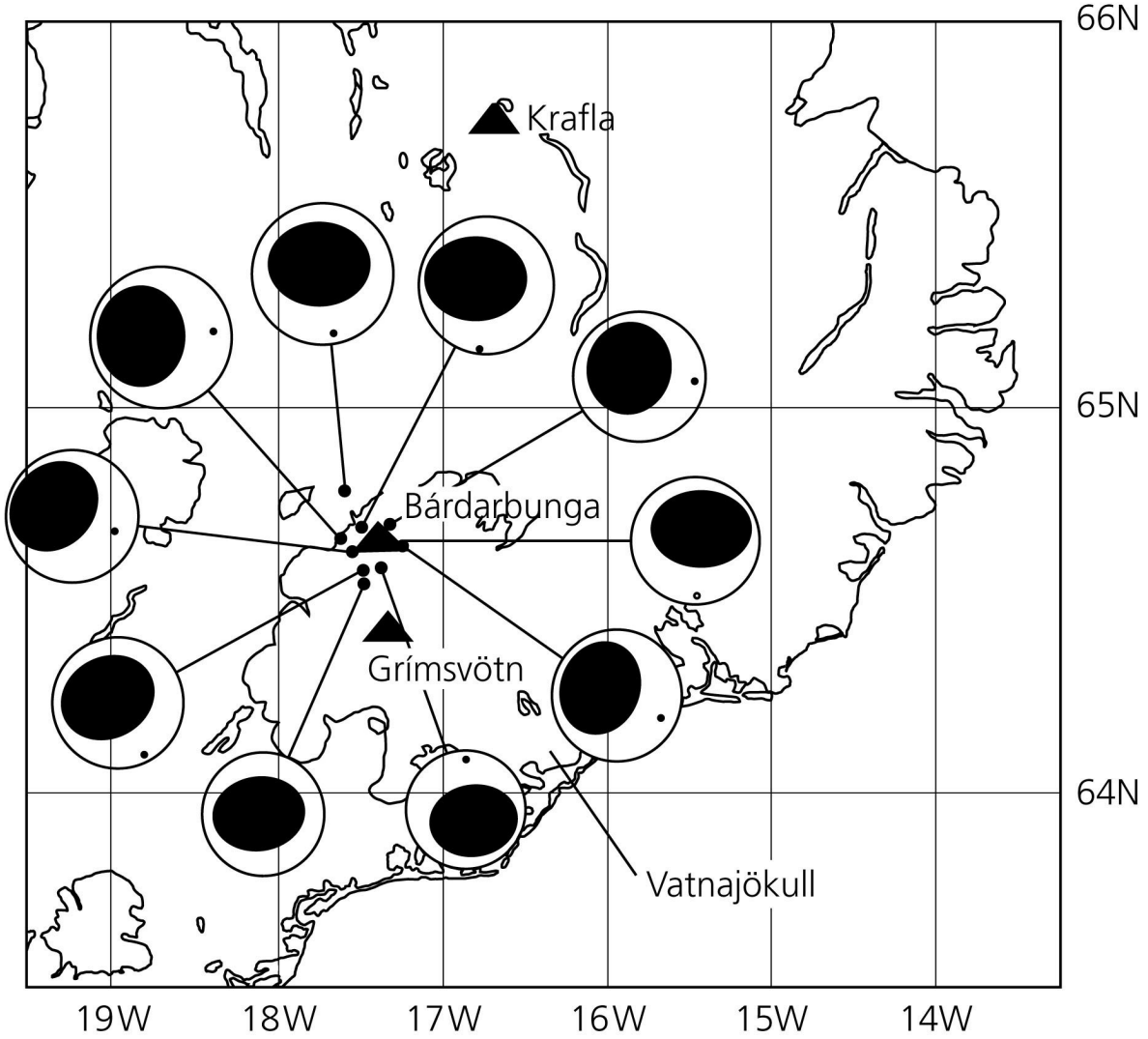
SOURCES QUI ONT UNE COMPOSANTE NON - DOUBLE COUPLE:

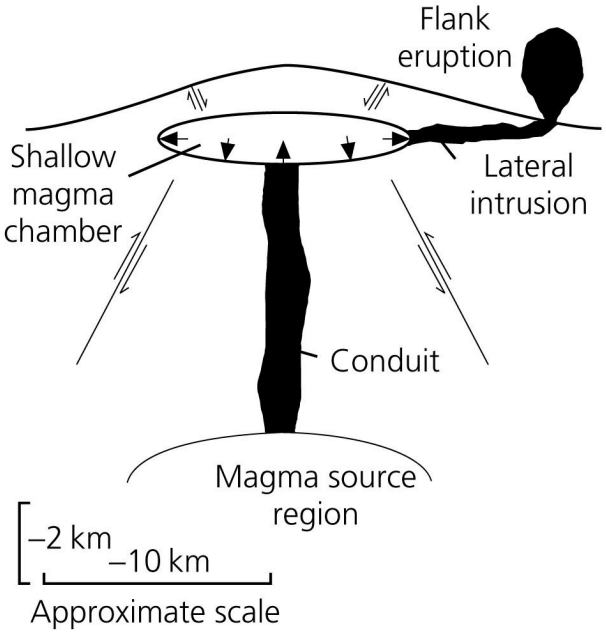
- Isotropes: Explosions – Implosions
- Compensated Linear Vector Dipoles (CLVD's) (double couple + 1 composante volumétrique), souvent le cas pour les très gros séismes.

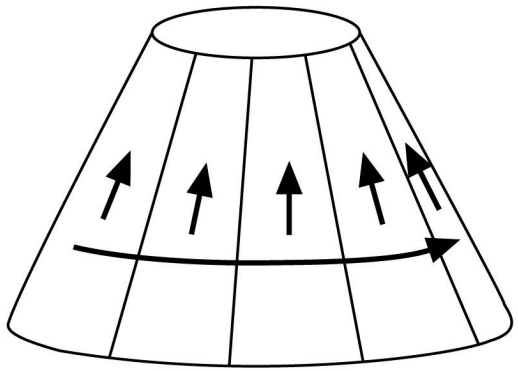


FAILLES INVERSES EN FORME DE CÔNE ET DIKES (CRACKS) QUI S'OUVRENT AVEC LE MAGMA

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







TENSEUR DES MOMENTS SISMIQUES

Pour décrire tous les doubles couples

$$\mathbf{M} = \begin{pmatrix} M_{xx} & M_{xy} & M_{xz} \\ M_{yx} & M_{yy} & M_{yz} \\ M_{zx} & M_{zy} & M_{zz} \end{pmatrix}$$

Le tenseur est symétrique $M_{ij}=M_{ji}$

Figure 4.4-4: Nine force couples which compose the seismic moment tensor.

