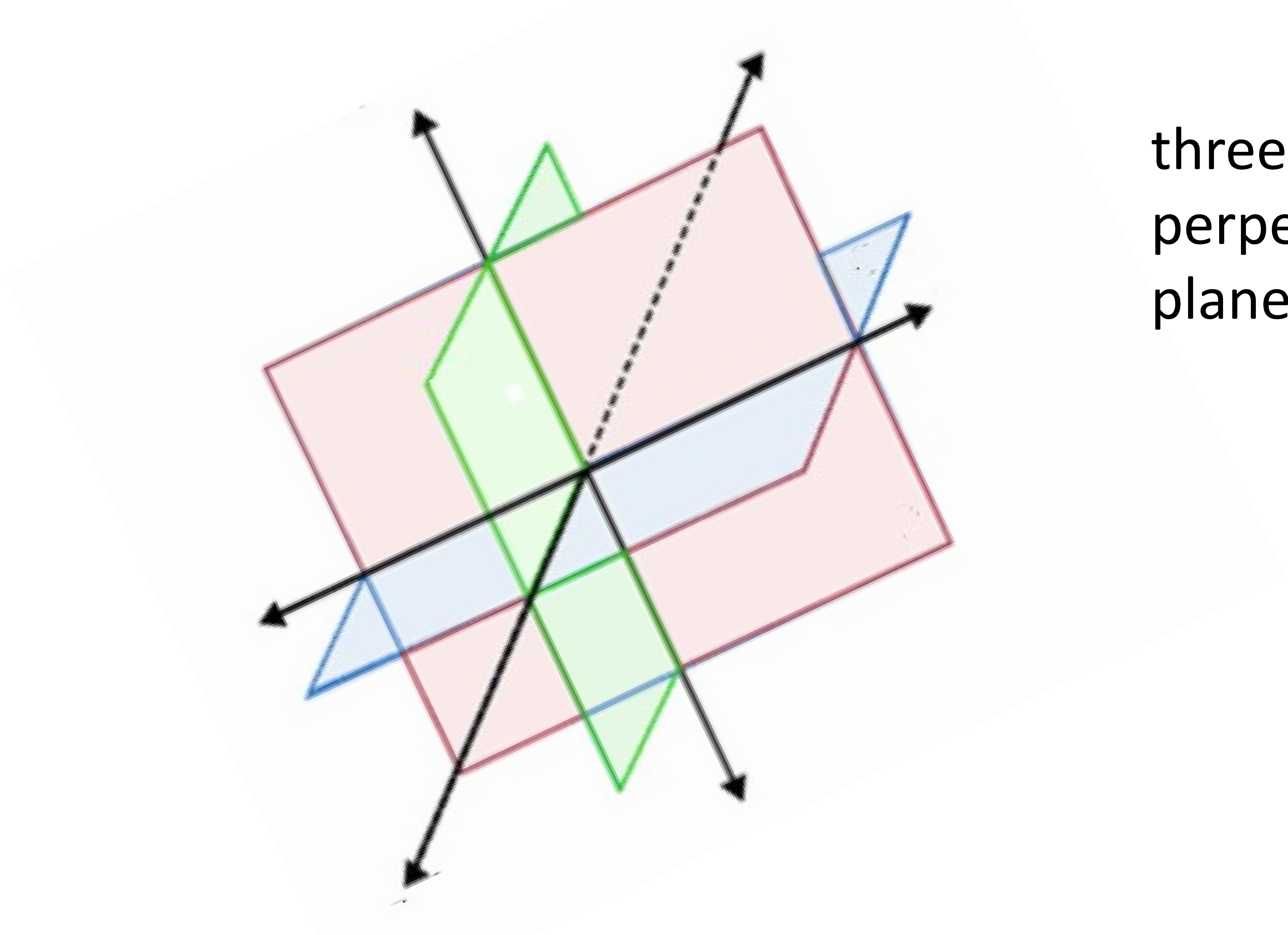
Solid Earth Dynamics

Bill Menke, Instructor

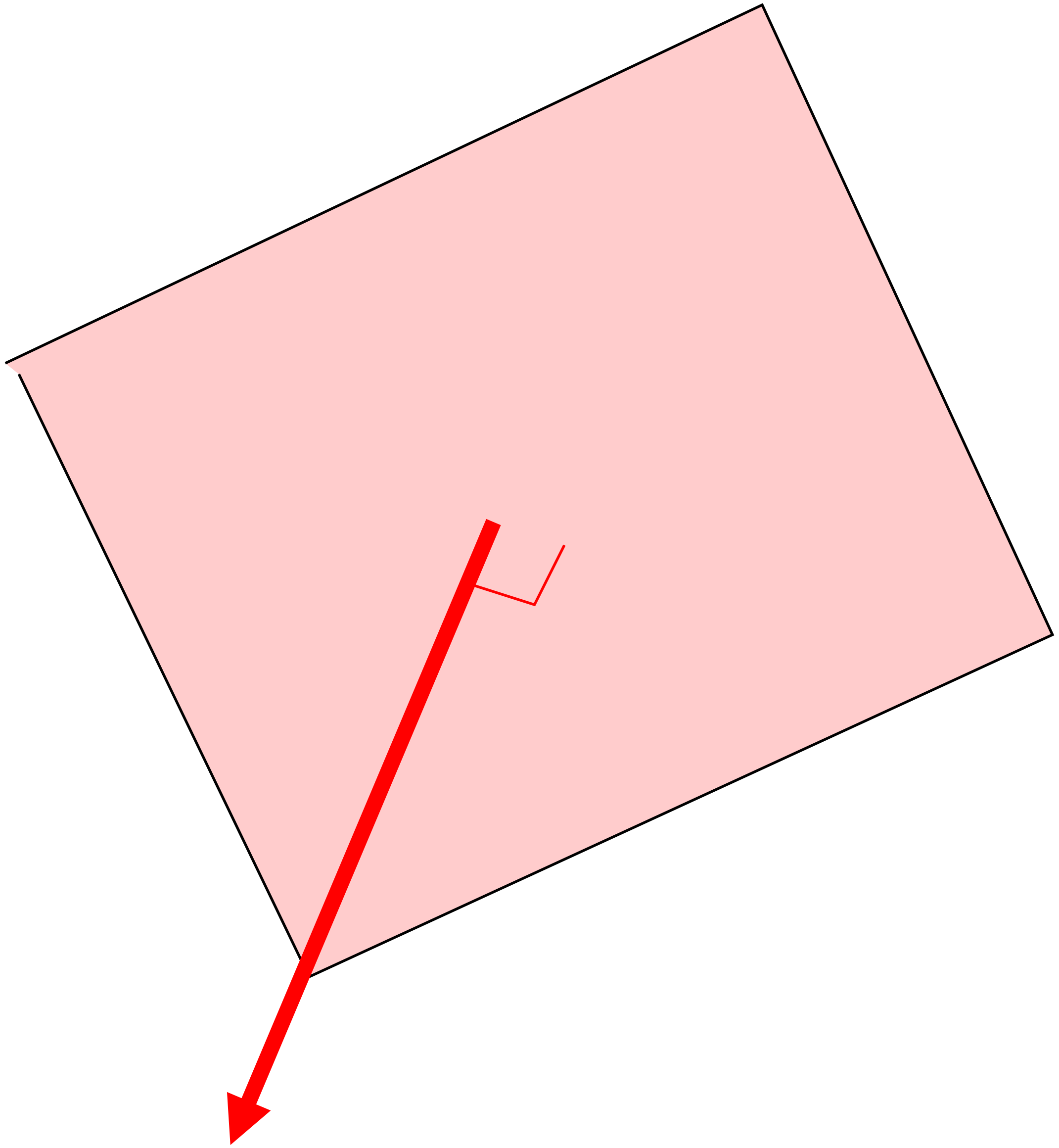
Lecture 19

Solid Earth Dynamics

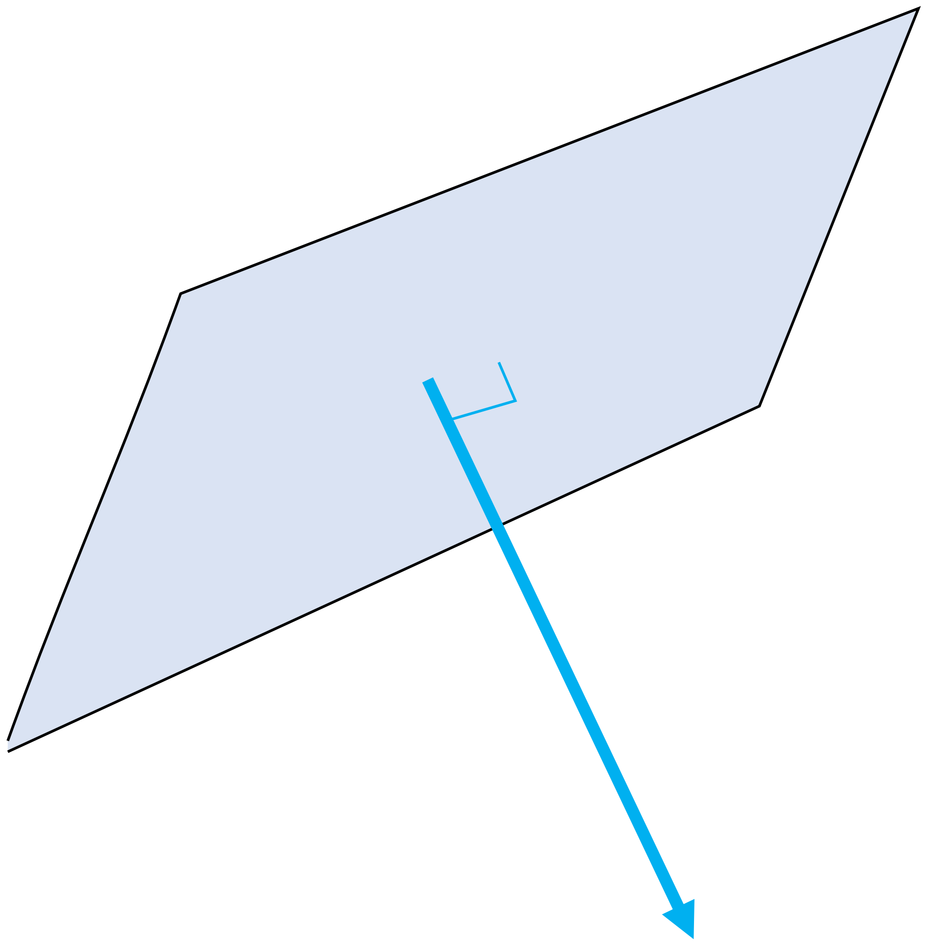
Faults and earthquakes (continued)



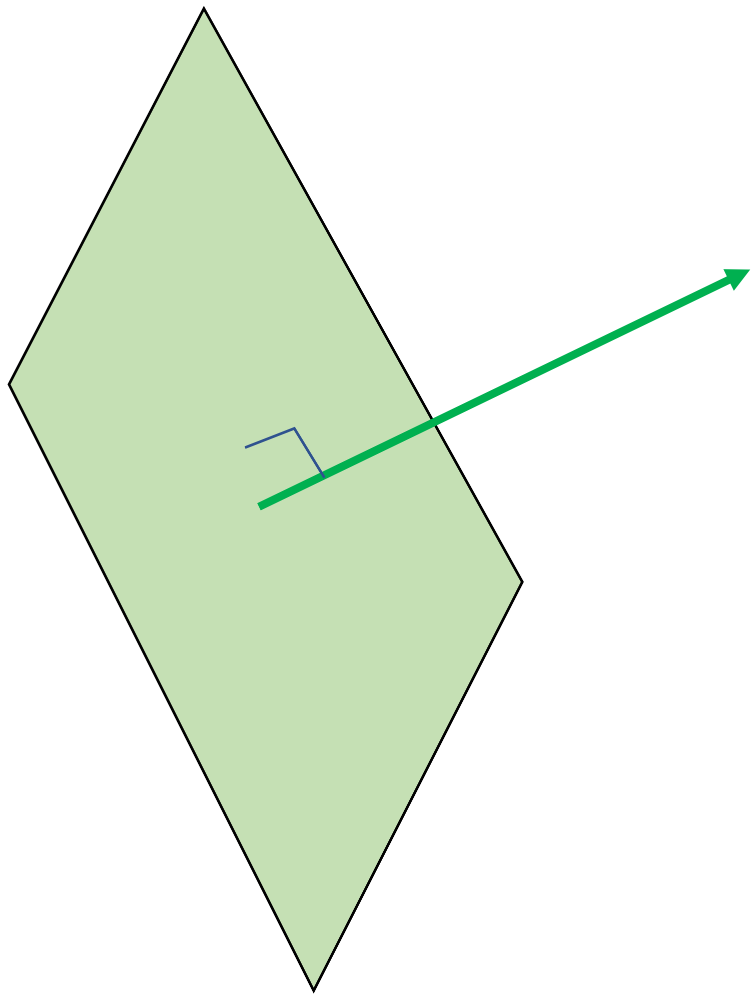
three mutually-perpendicular planes in space



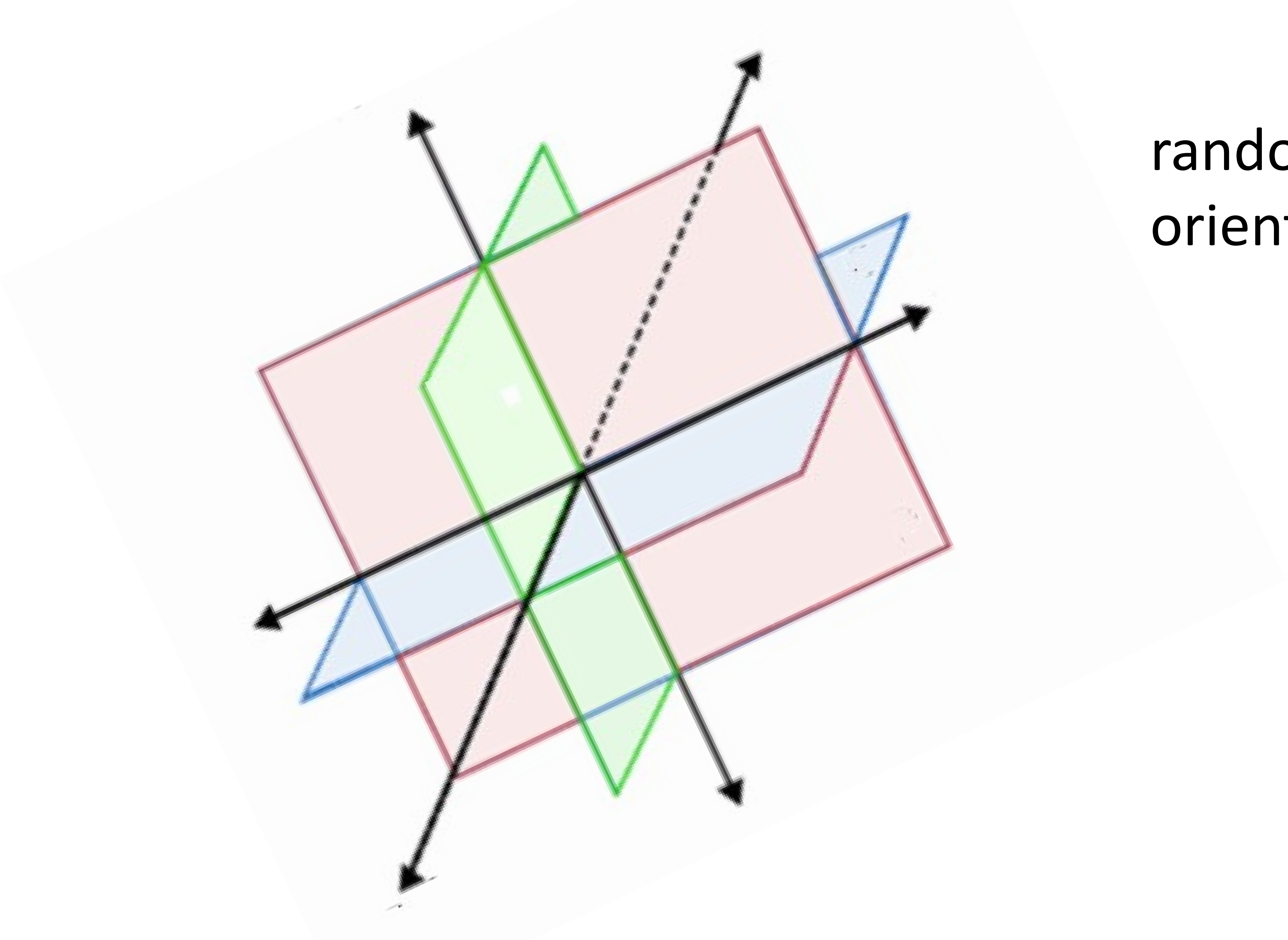
red plane
and its normal



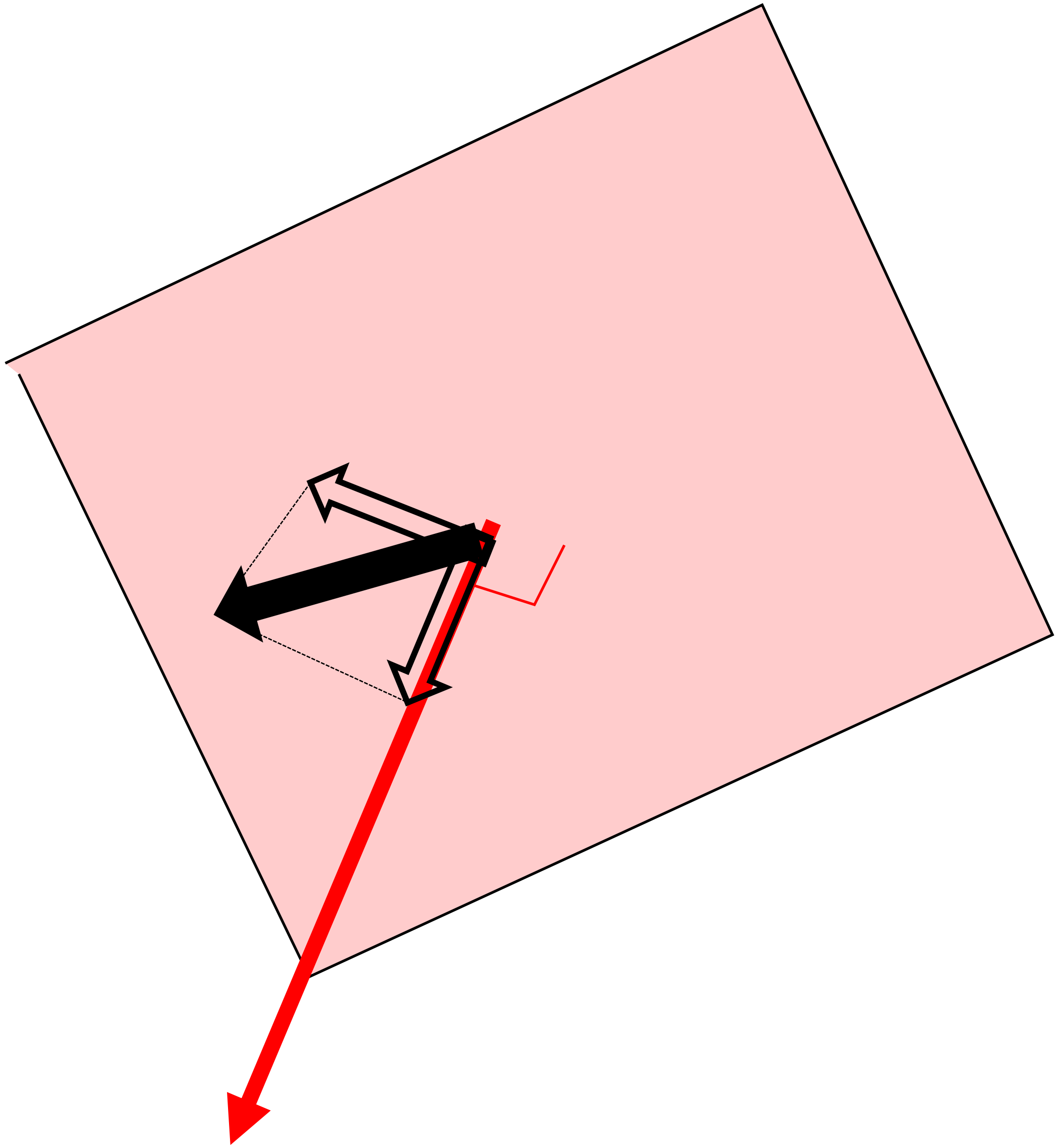
blue plane
and its normal



green plane
and its normal

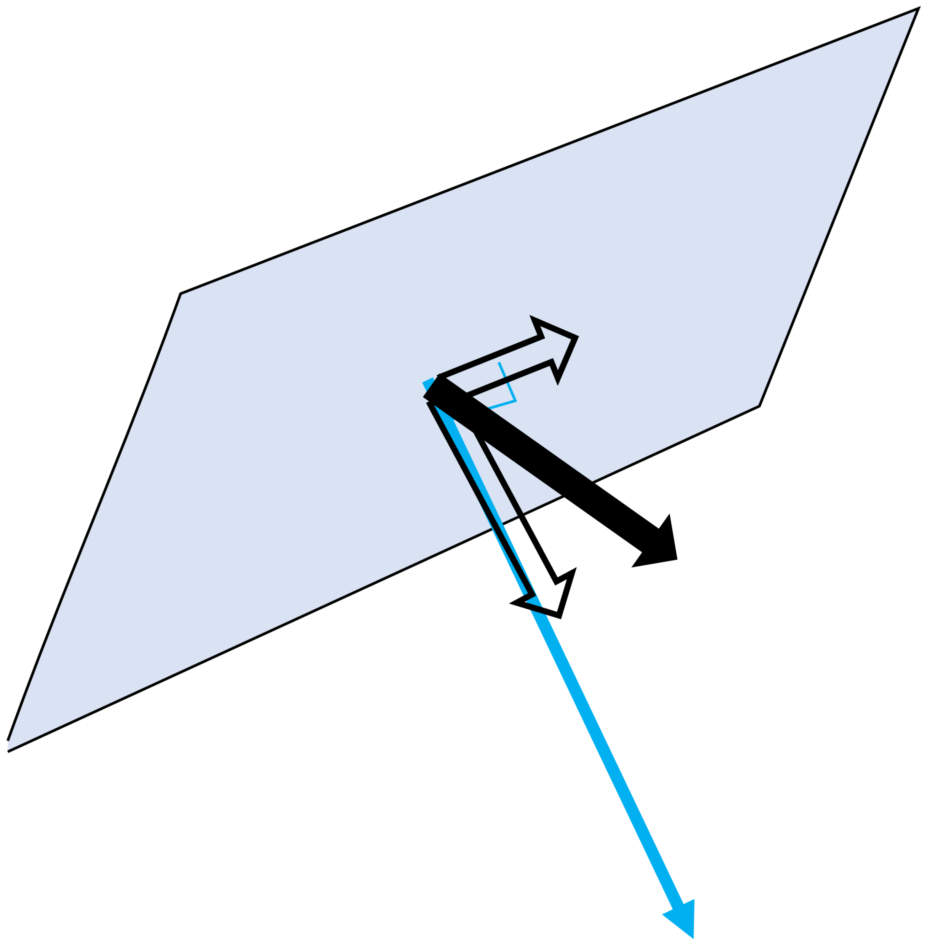


random
orientation



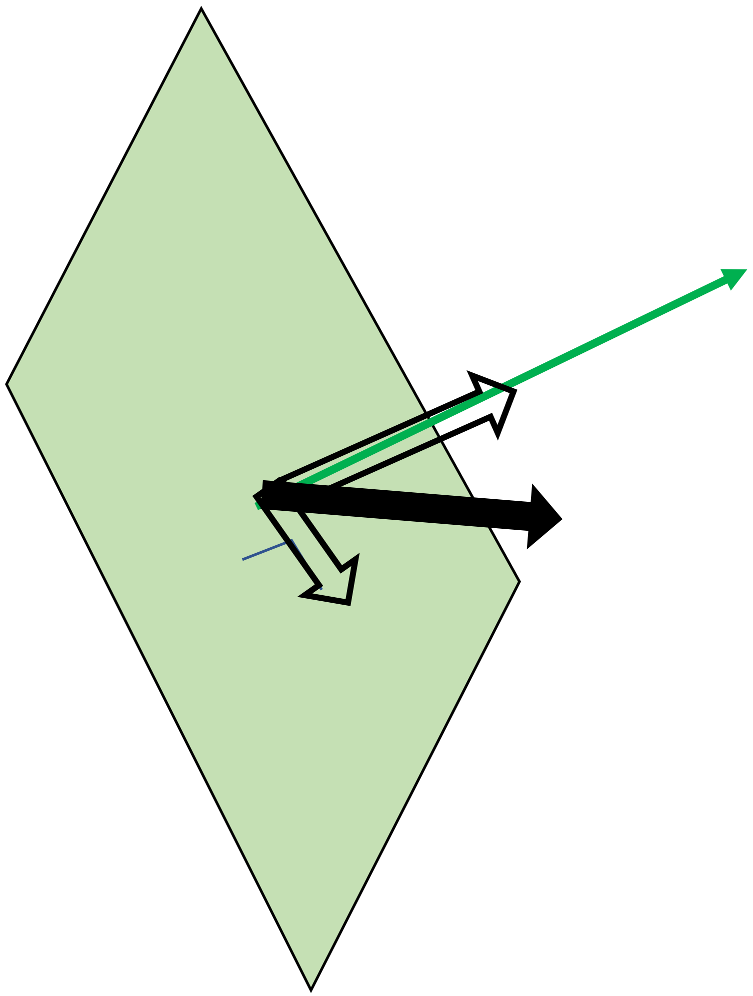
red plane
and its normal

oblique
traction
both normal
and
shear
components



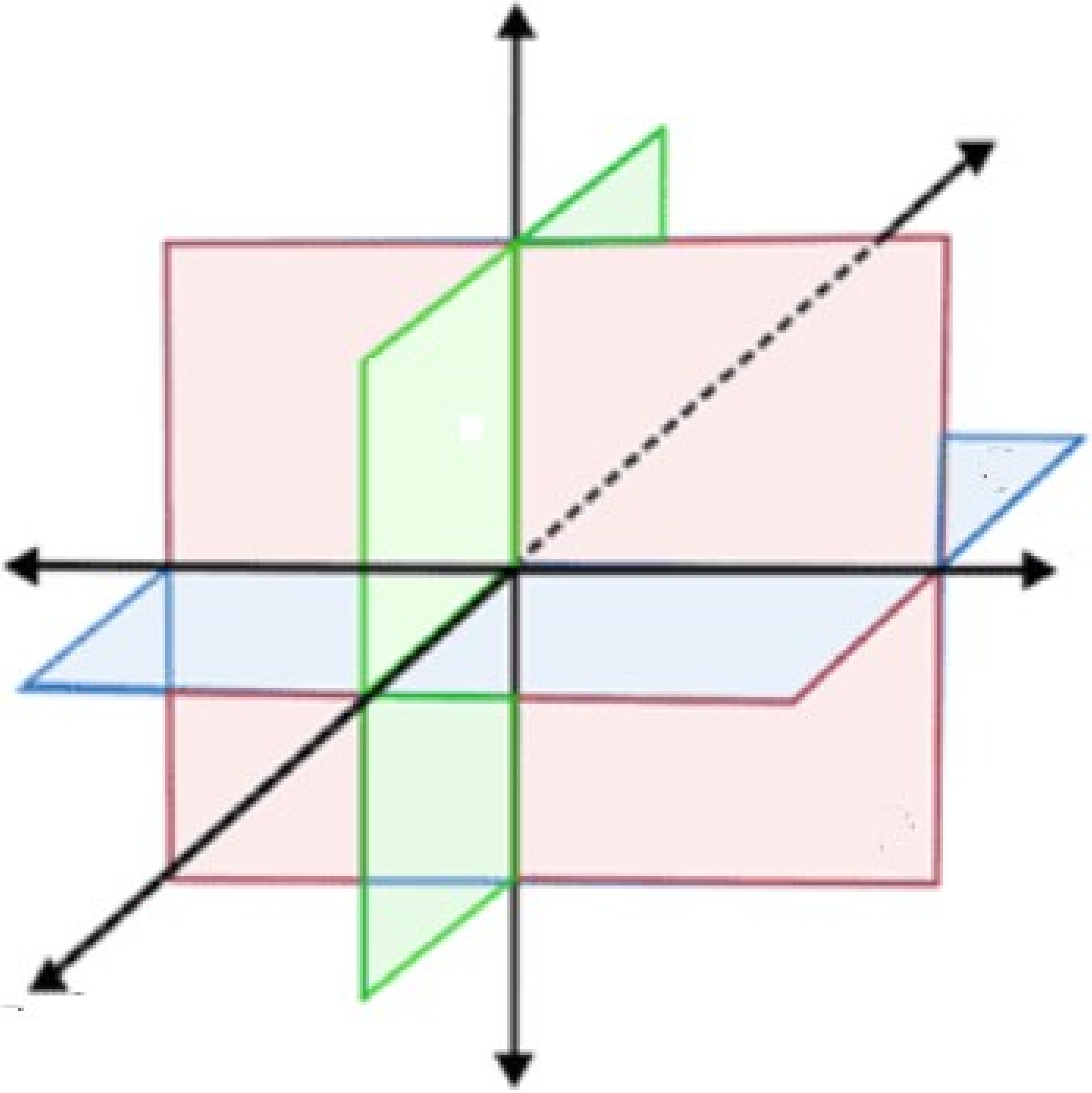
blue plane
and its normal

oblique
traction
both normal
and
shear
components

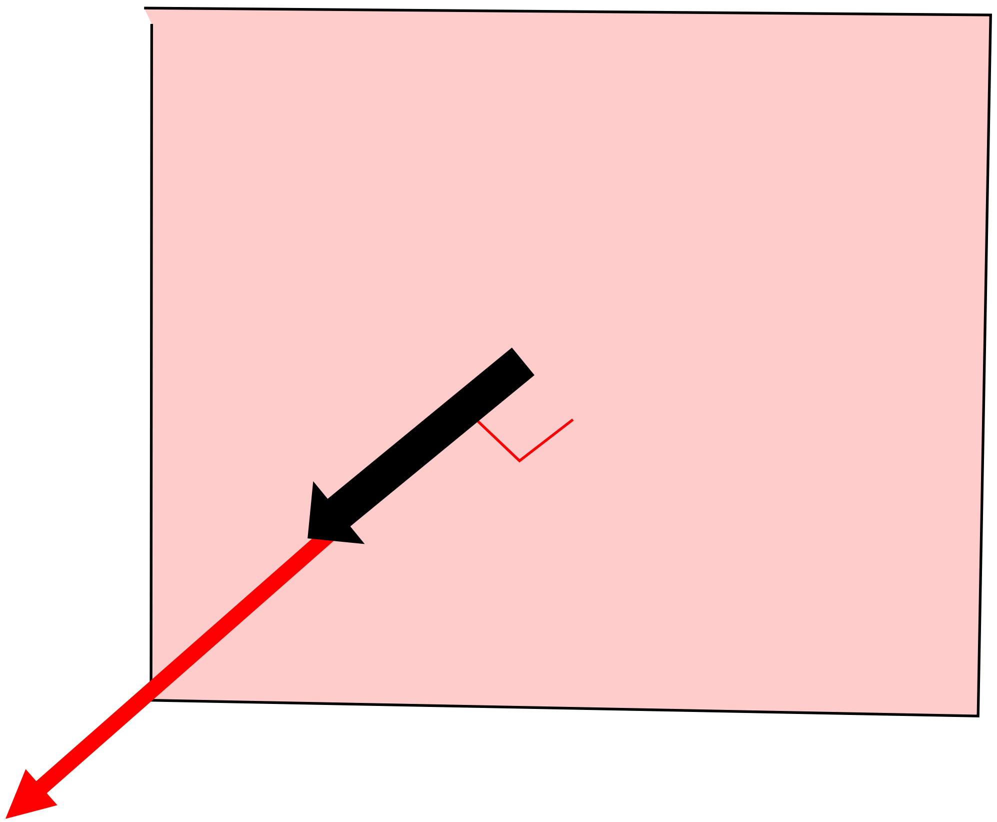


green plane
and its normal

oblique
traction
both normal
and
shear
components

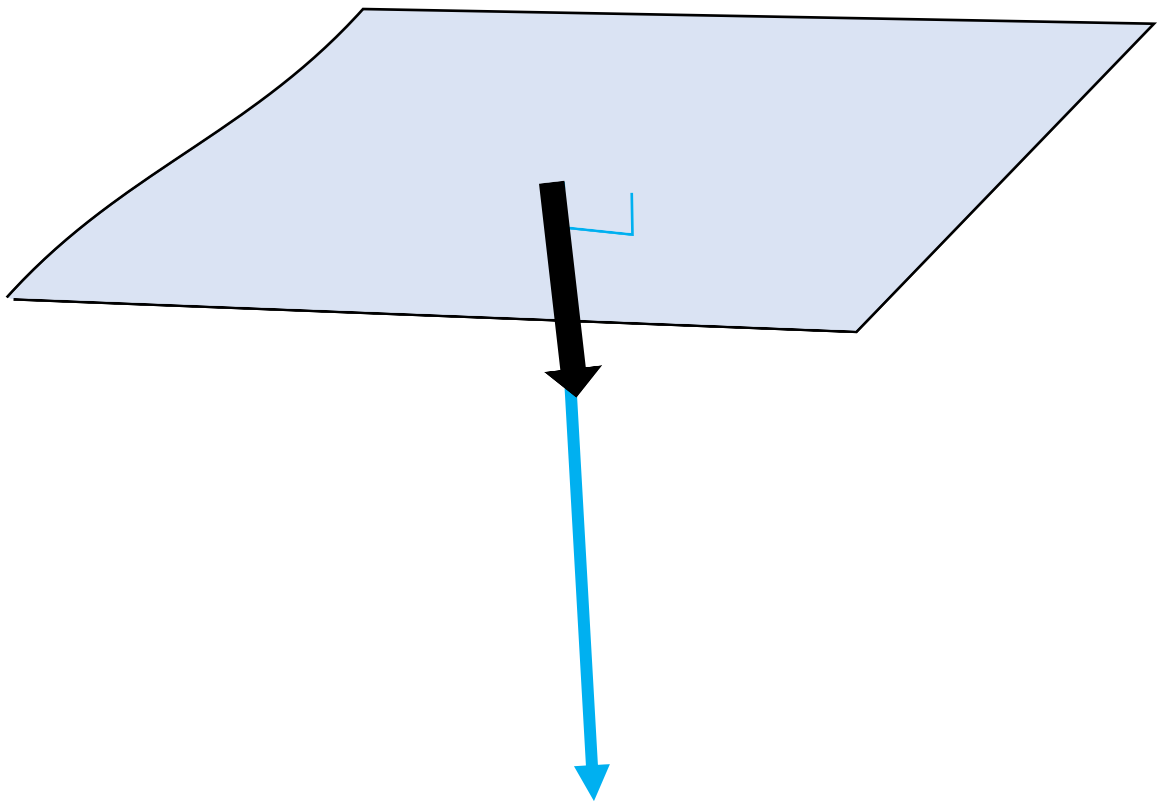


special
orientation



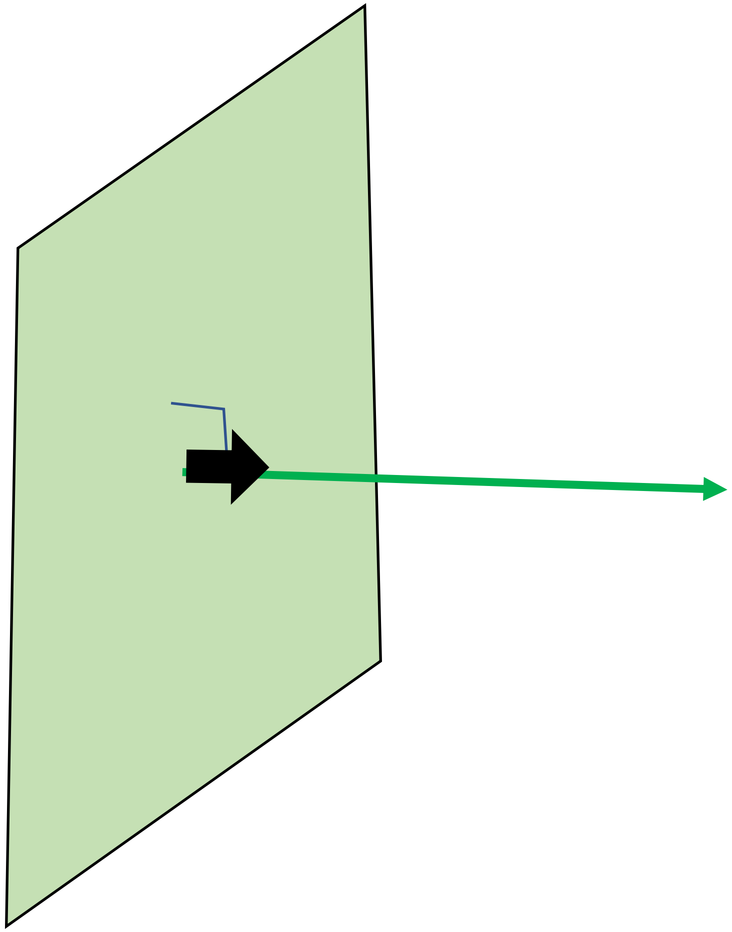
red plane
and its normal

only normal
component
of traction



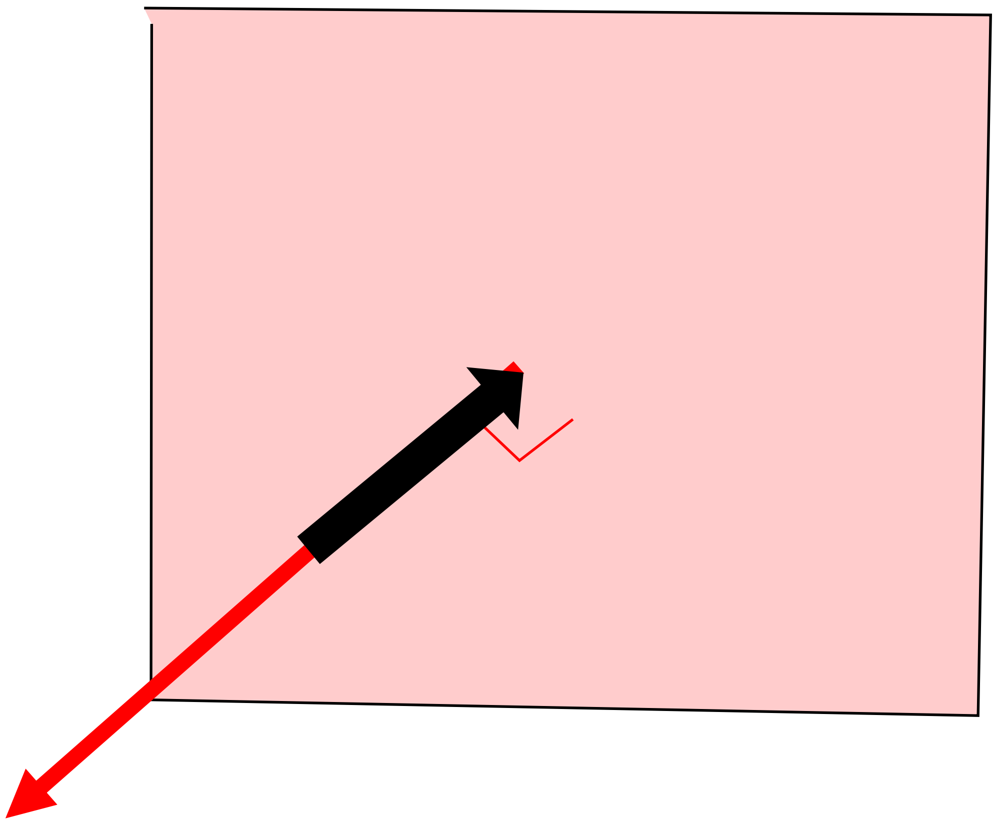
blue plane
and its normal

only normal
component
of traction



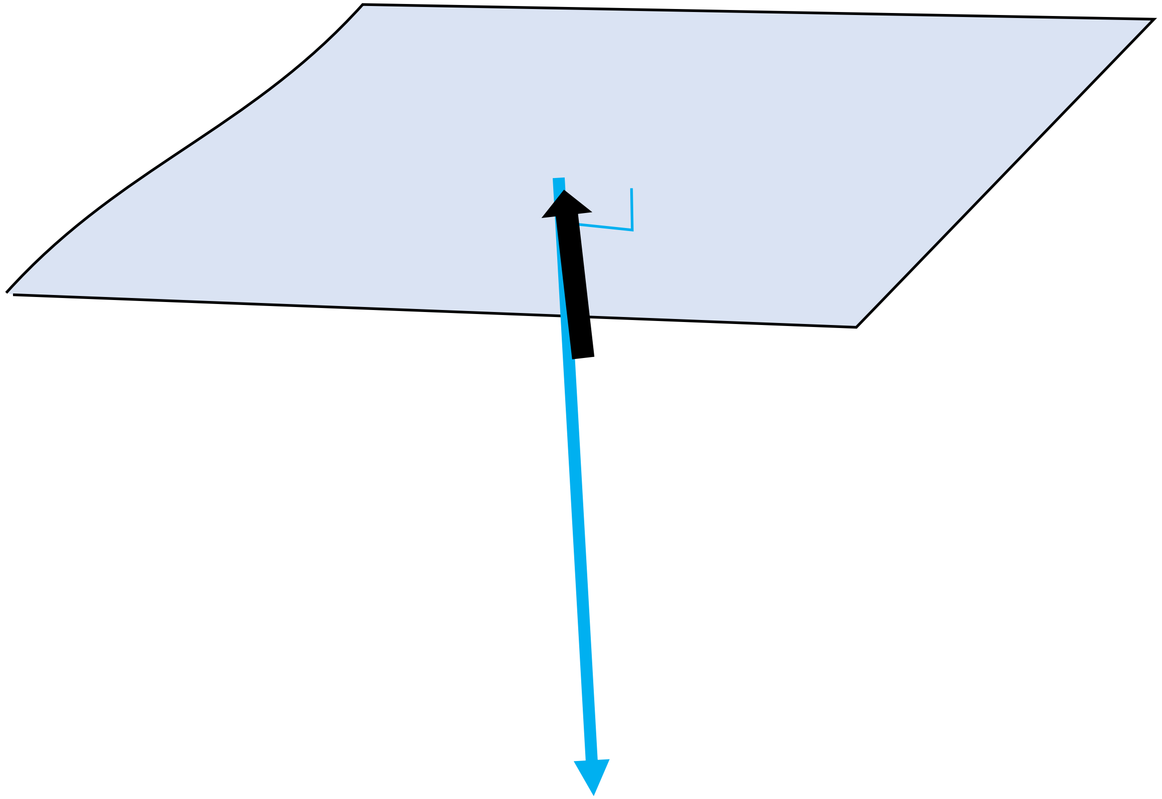
green plane
and its normal

only normal
component
of traction



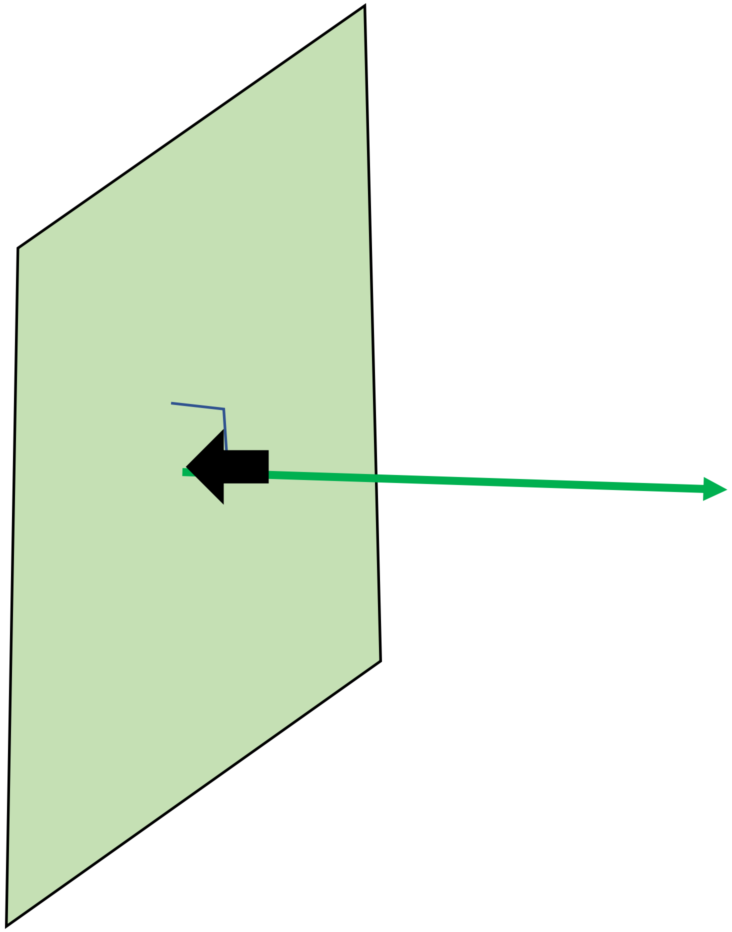
red plane
and its normal

direction of
maximum
compression



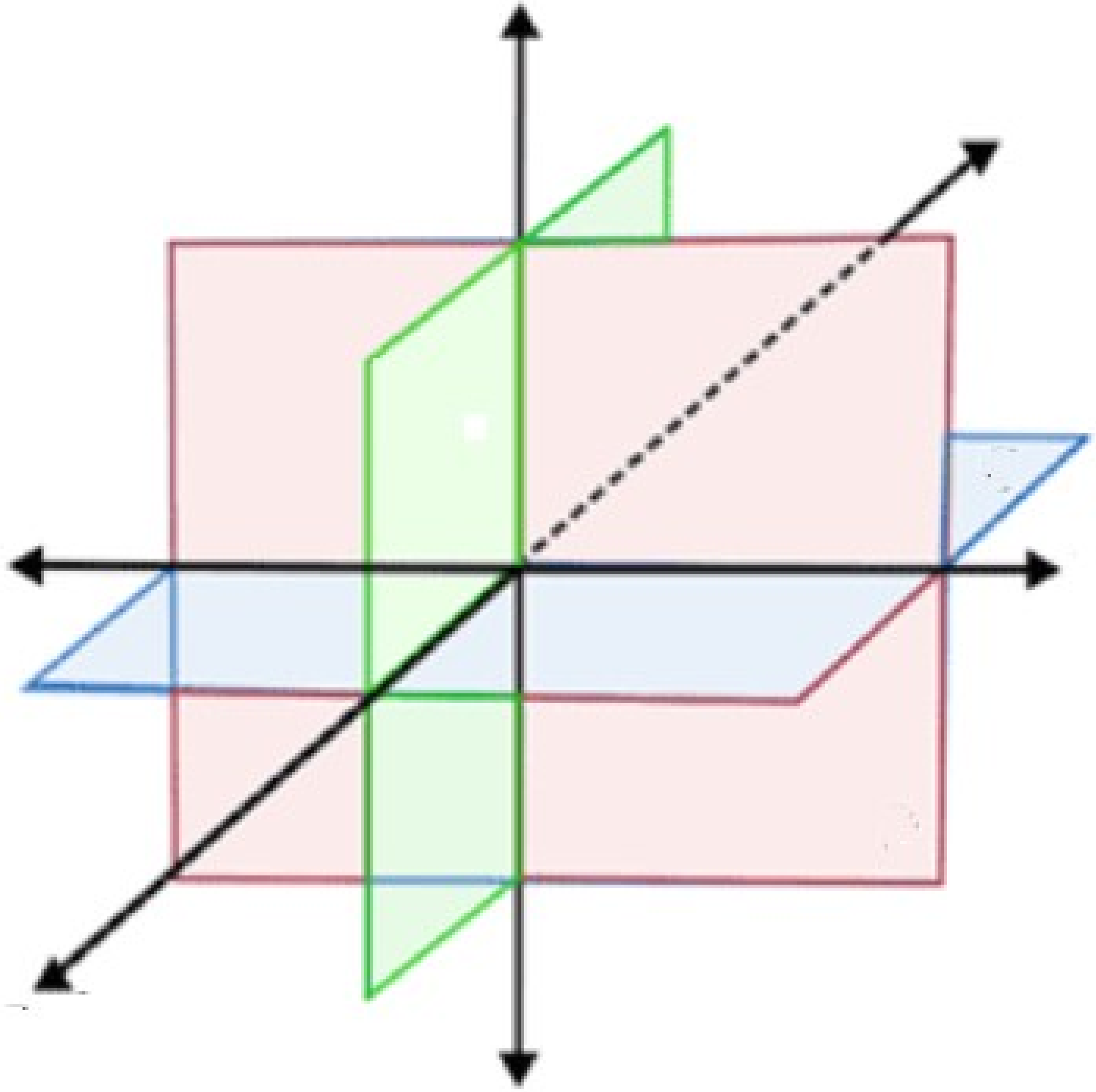
blue plane
and its normal

direction of
intermediate
compression



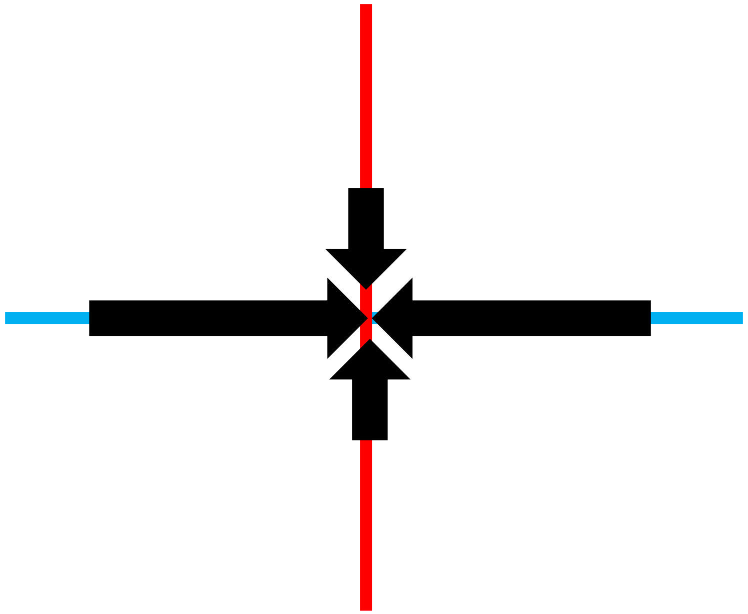
green plane
and its normal

direction of
minimum
compression

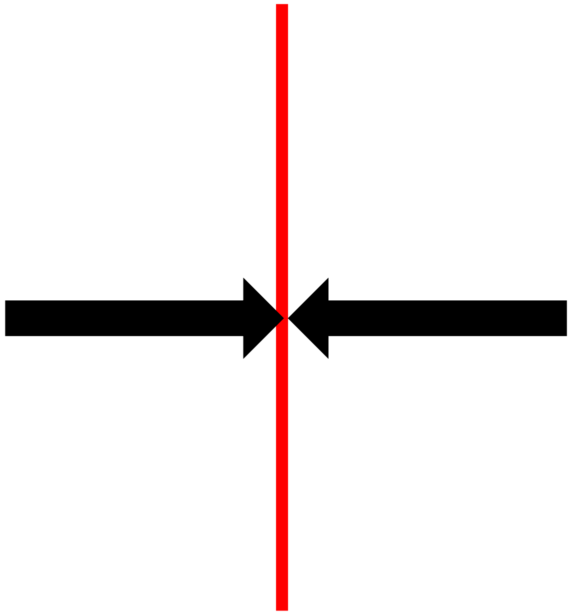


look at it edge on

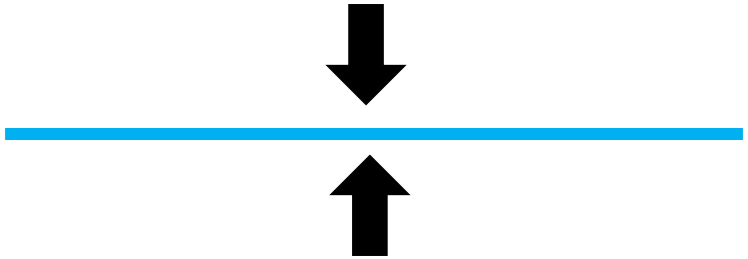
look at it edge on



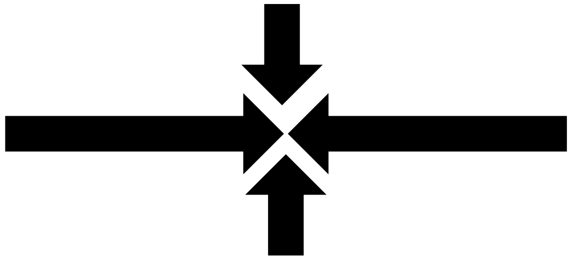
maximum
compression

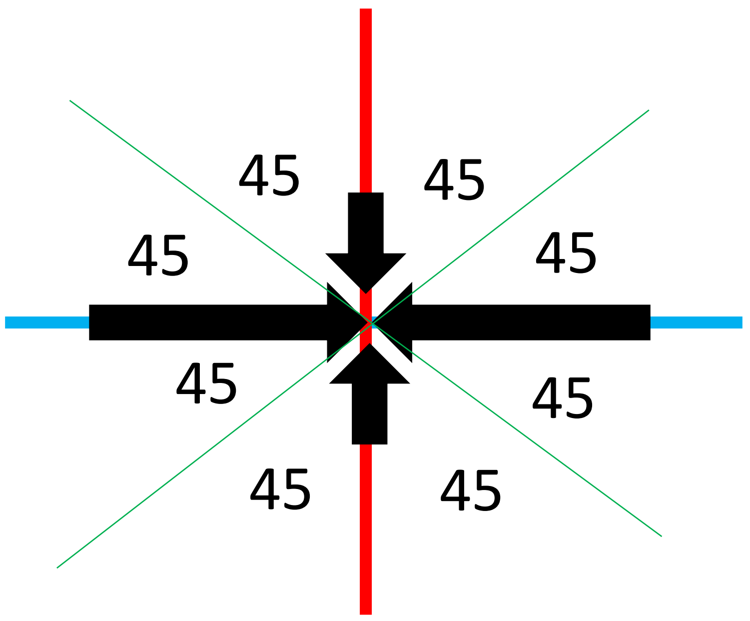


minimum
compression



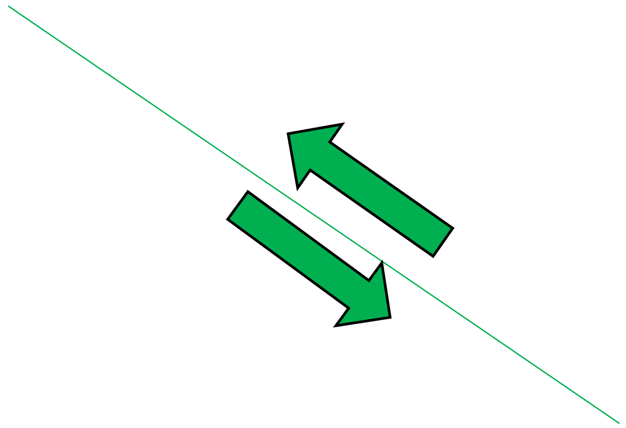
don’t show planes

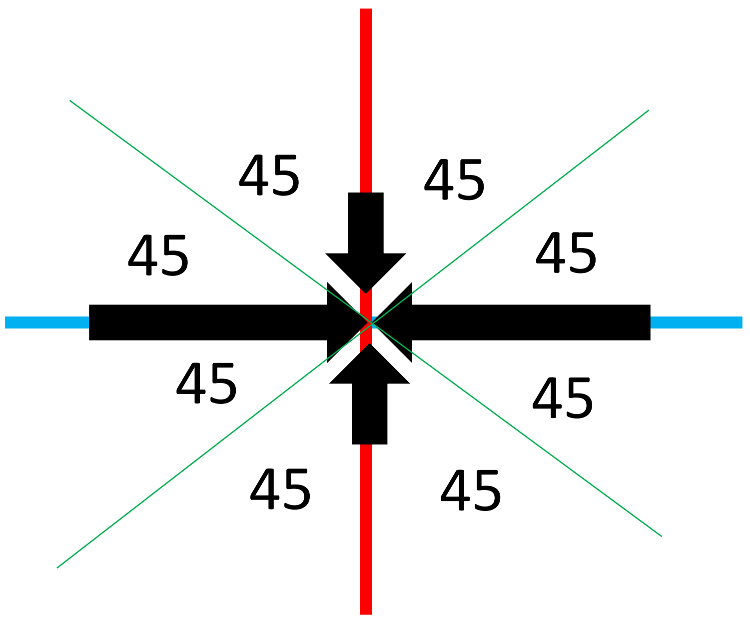




planes of maximum shear stress

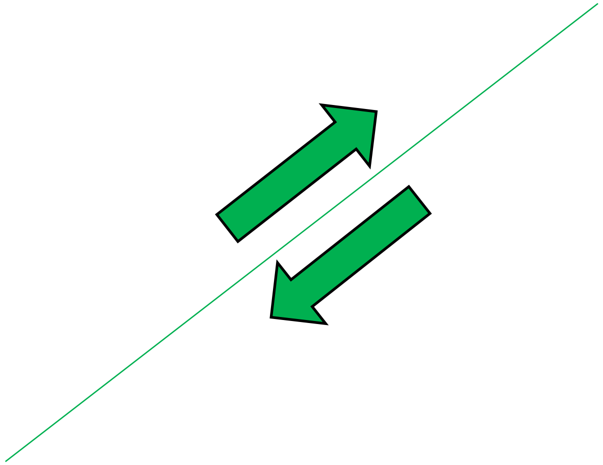
planes of
maximum
shear stress

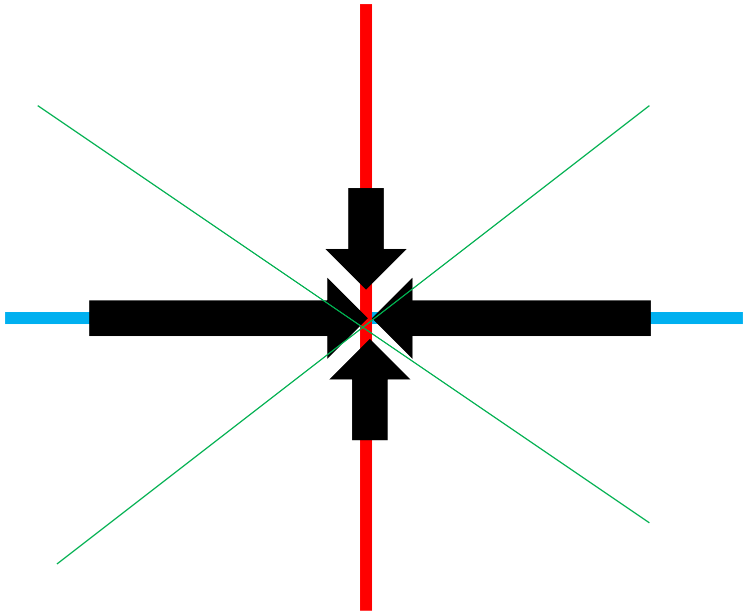




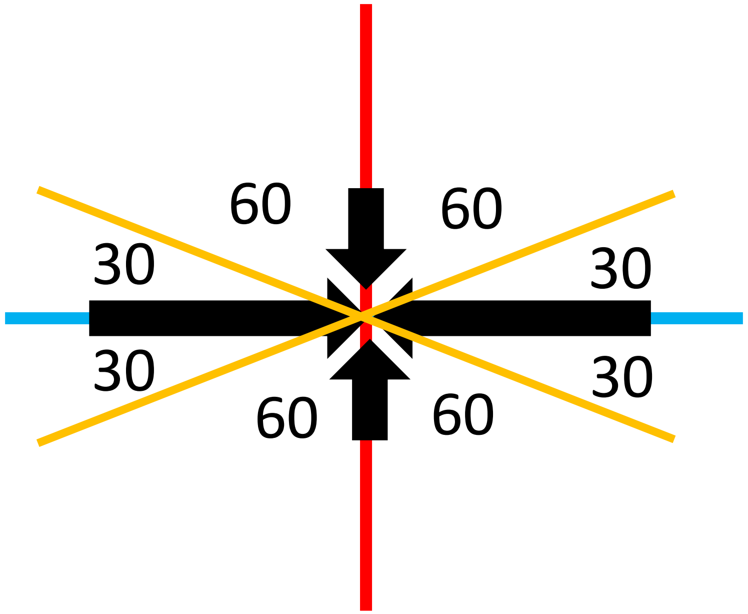
planes of maximum shear stress

planes of
maximum
shear stress



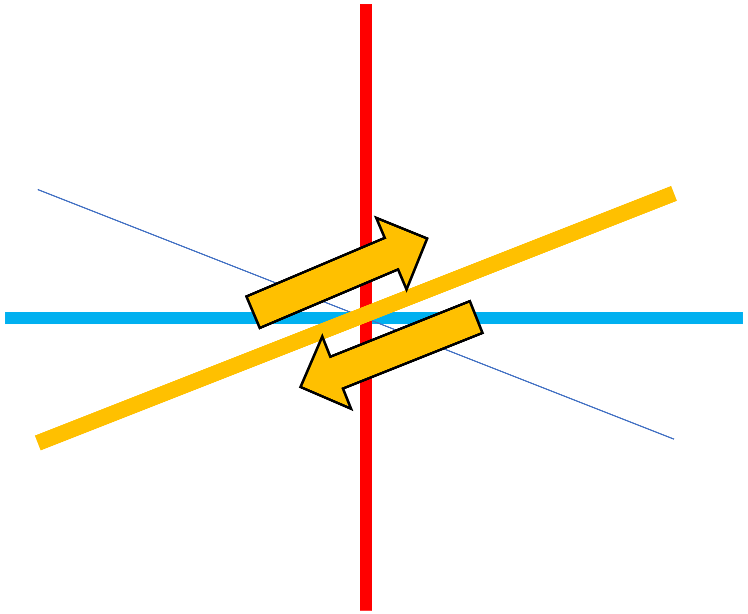


planes of maximum shear stress

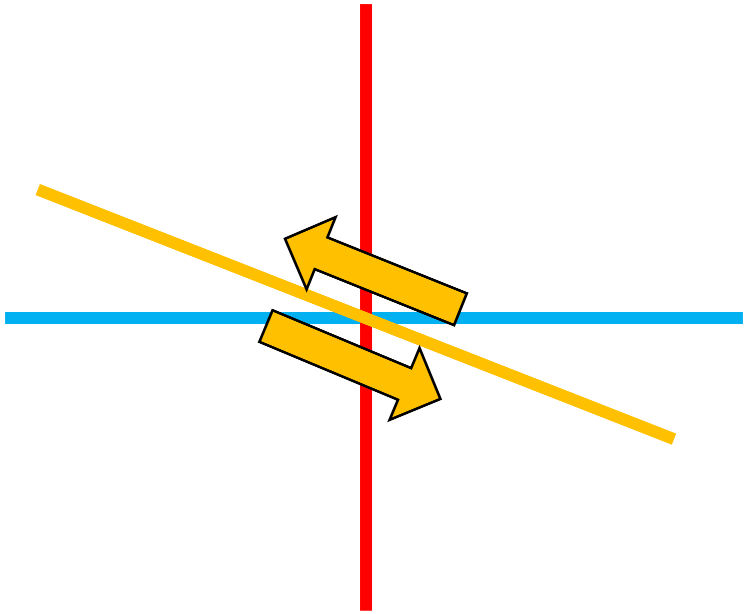


planes with
just a little less
shear stress
and a whole lot
less
normal stress

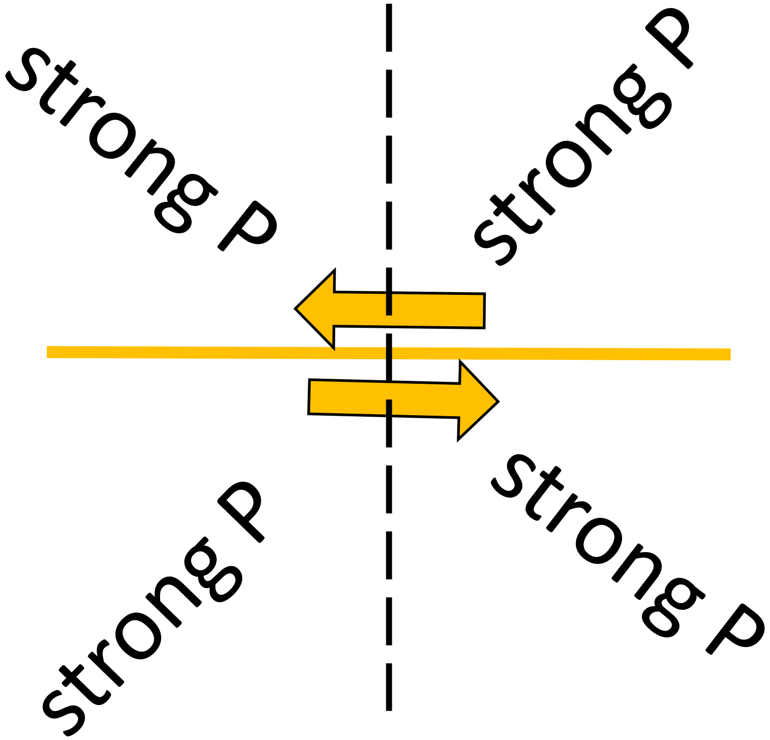
nascent
fault



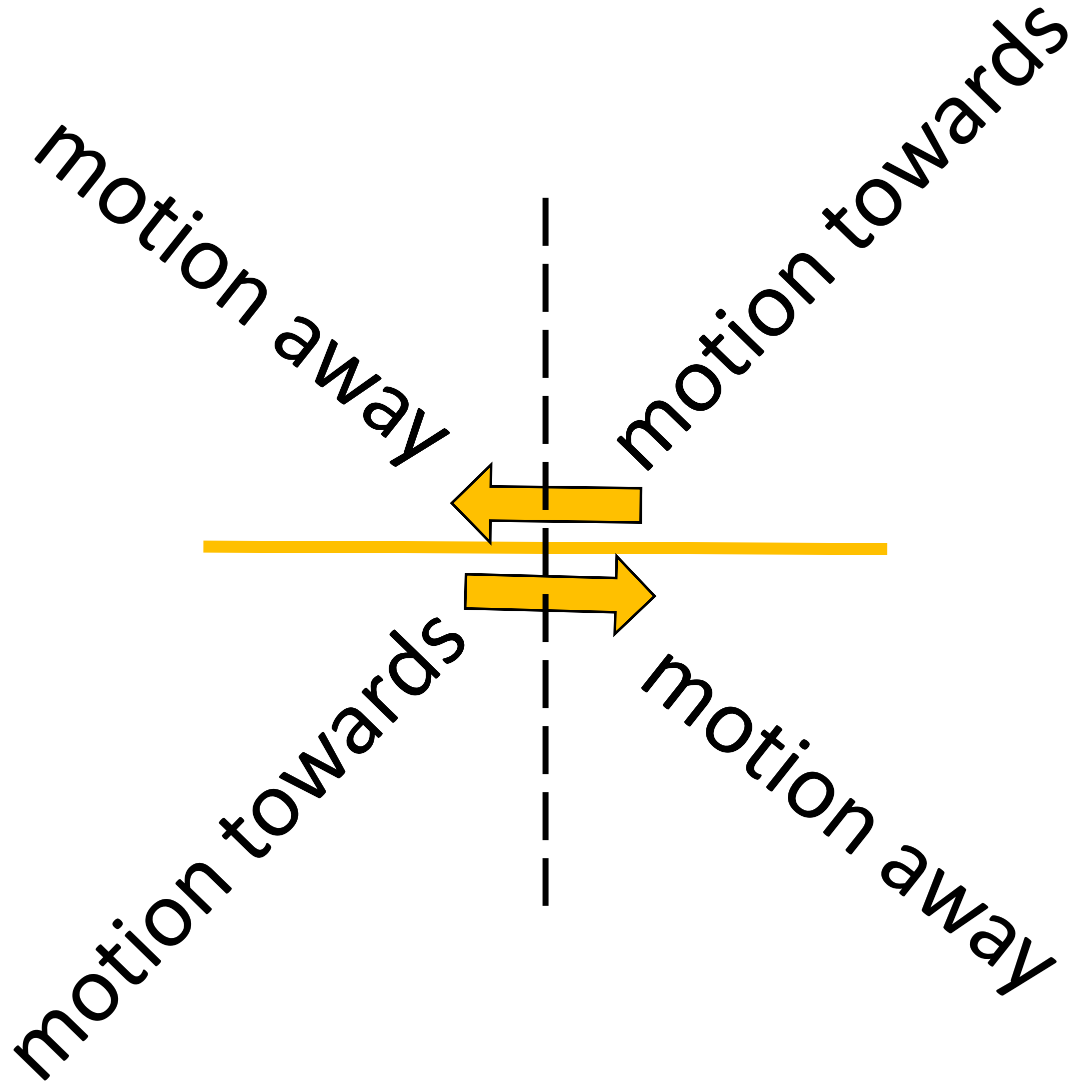
nascent
fault



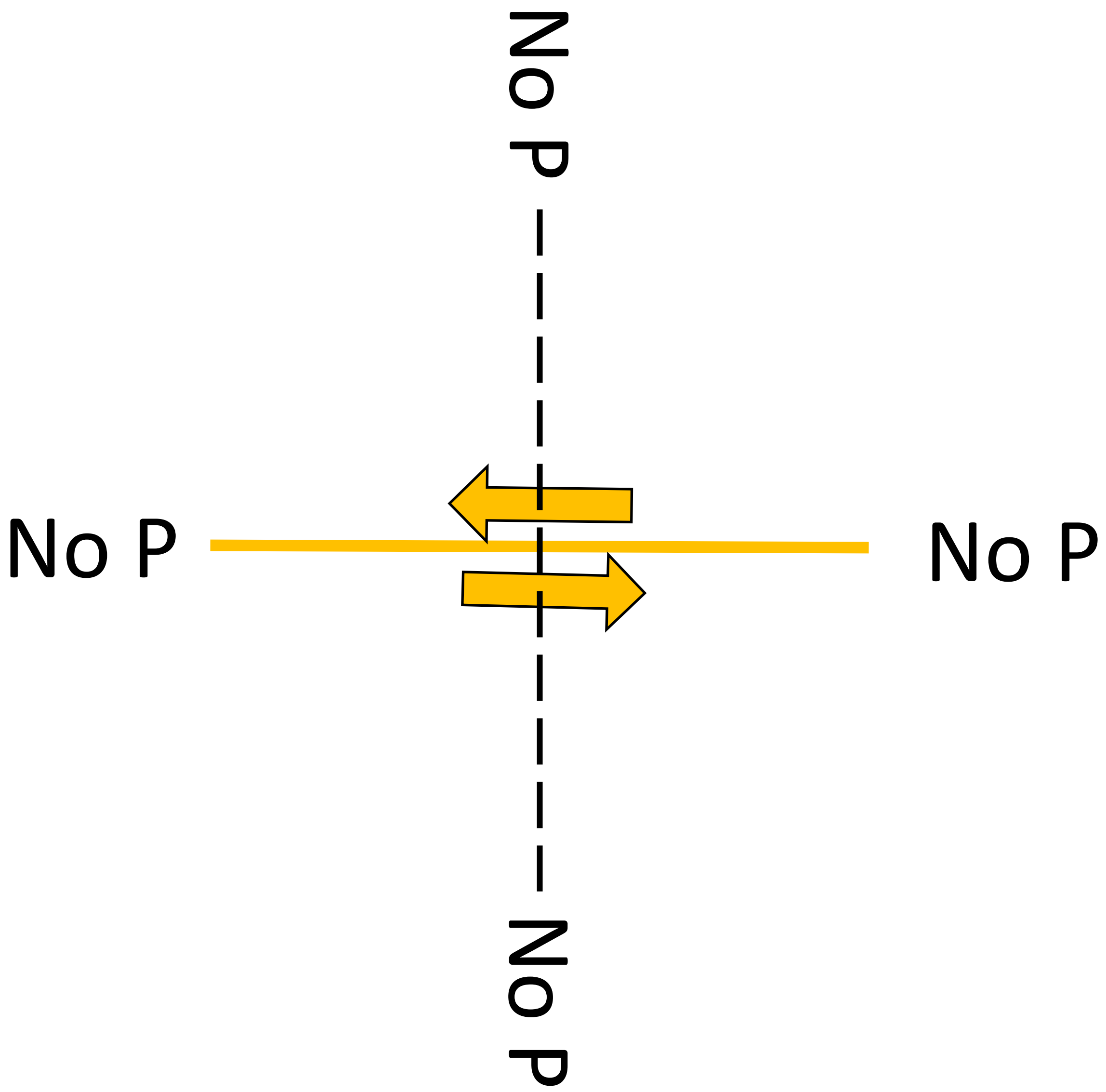
P wave amplitude

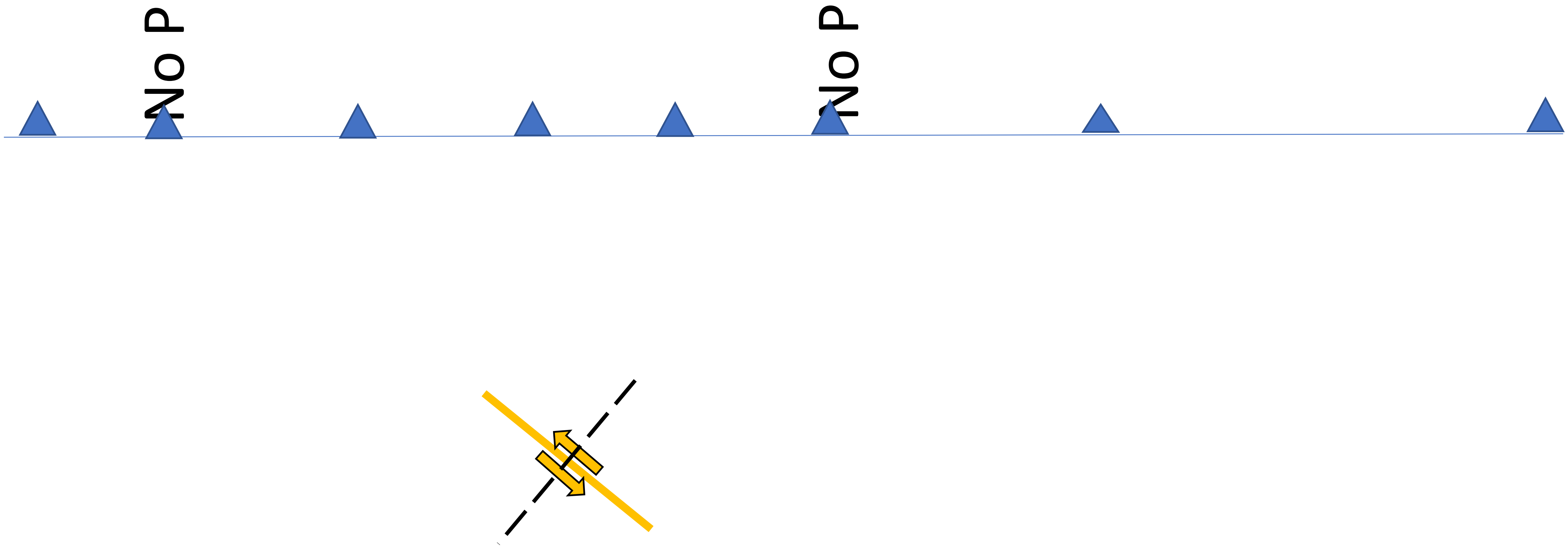


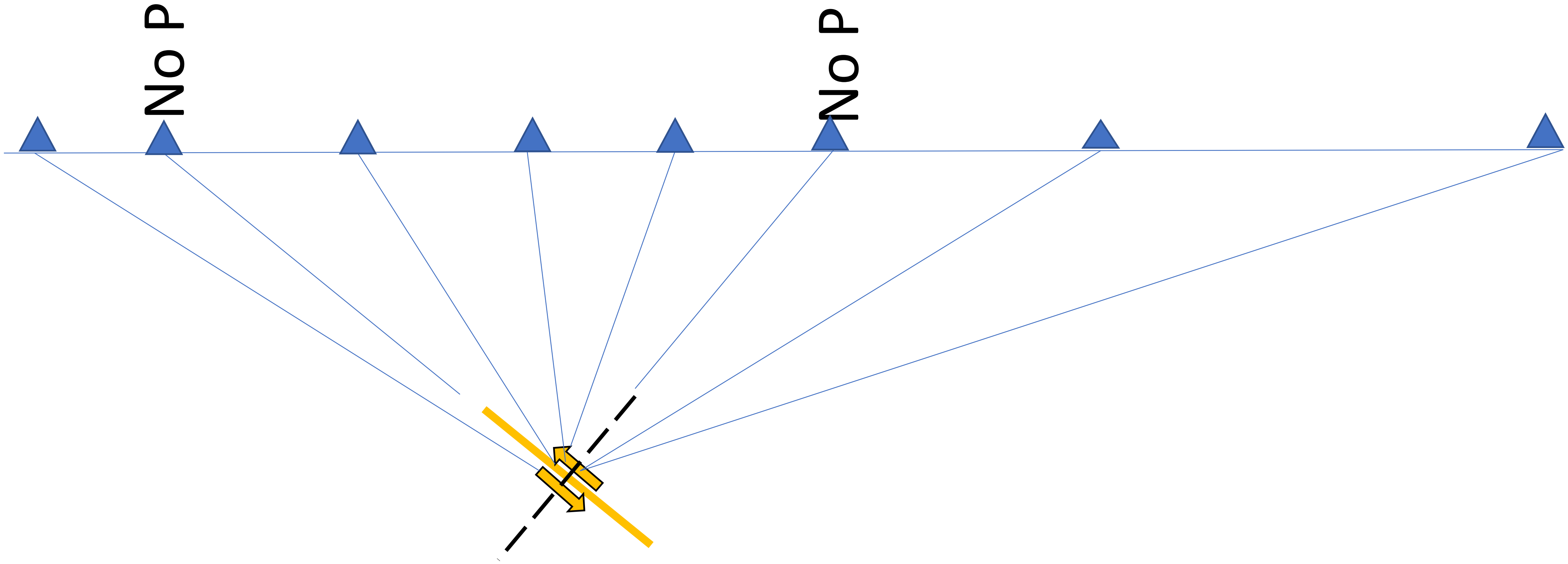
P wave amplitude



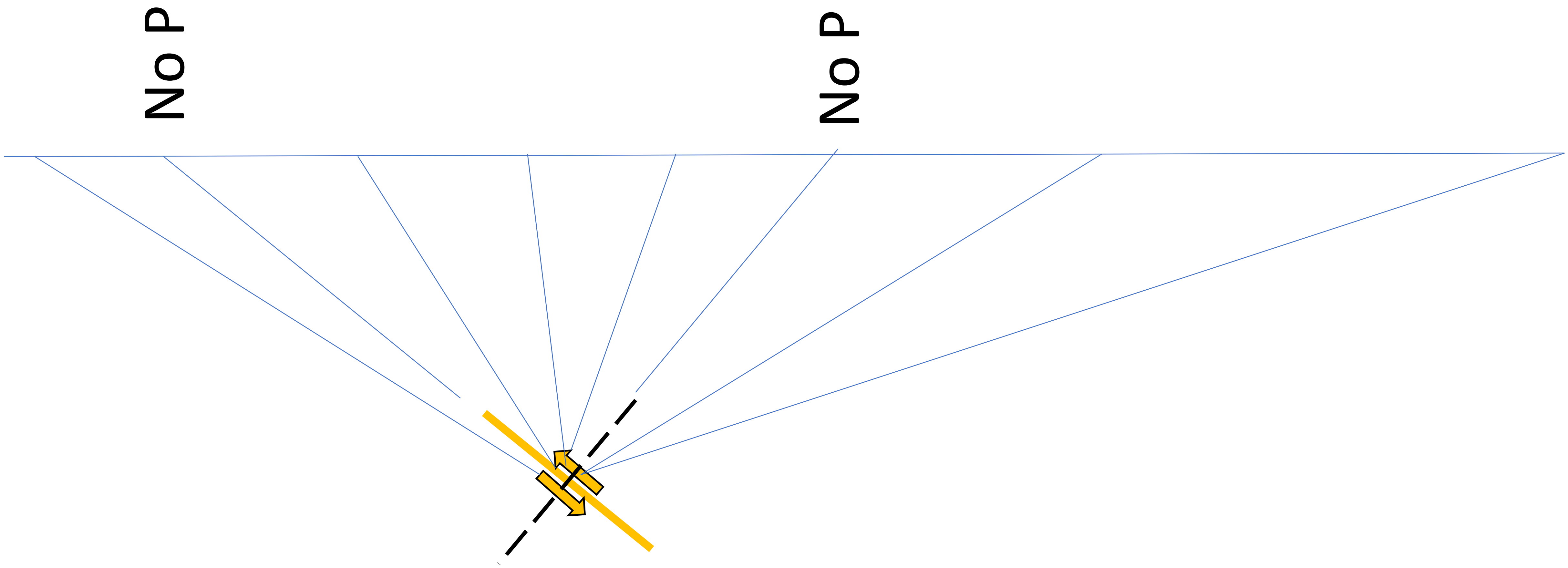
P wave amplitude

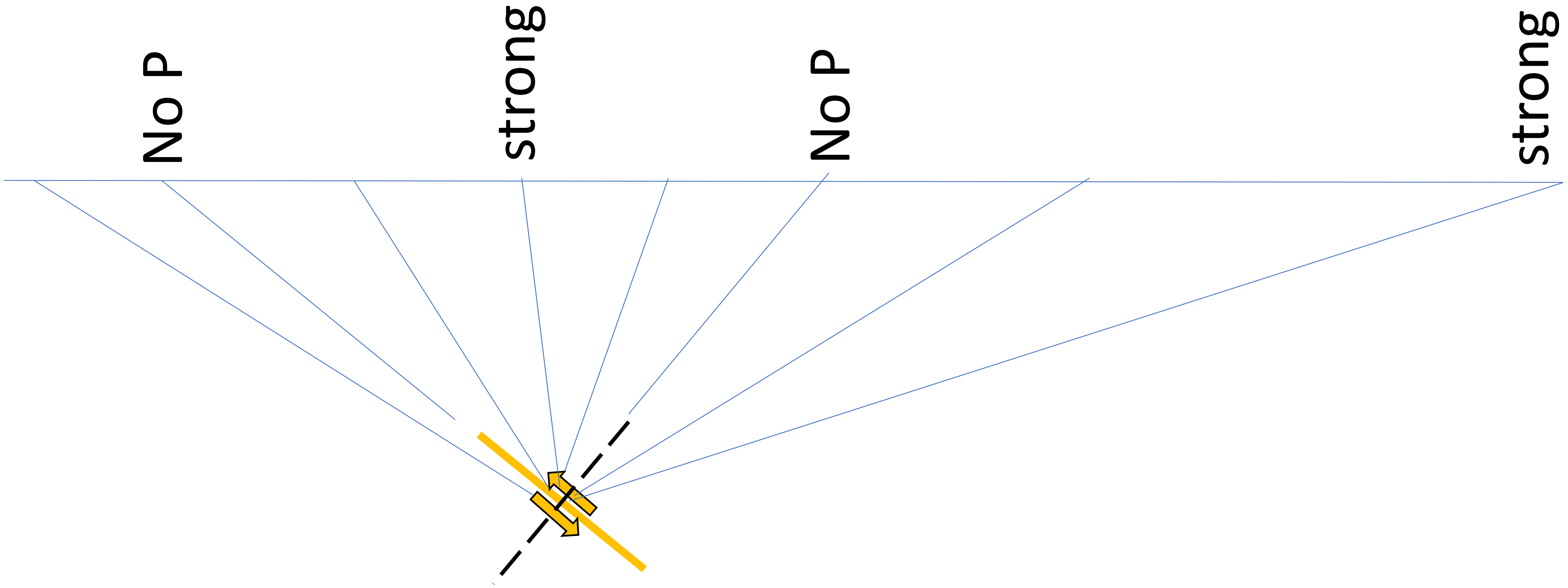


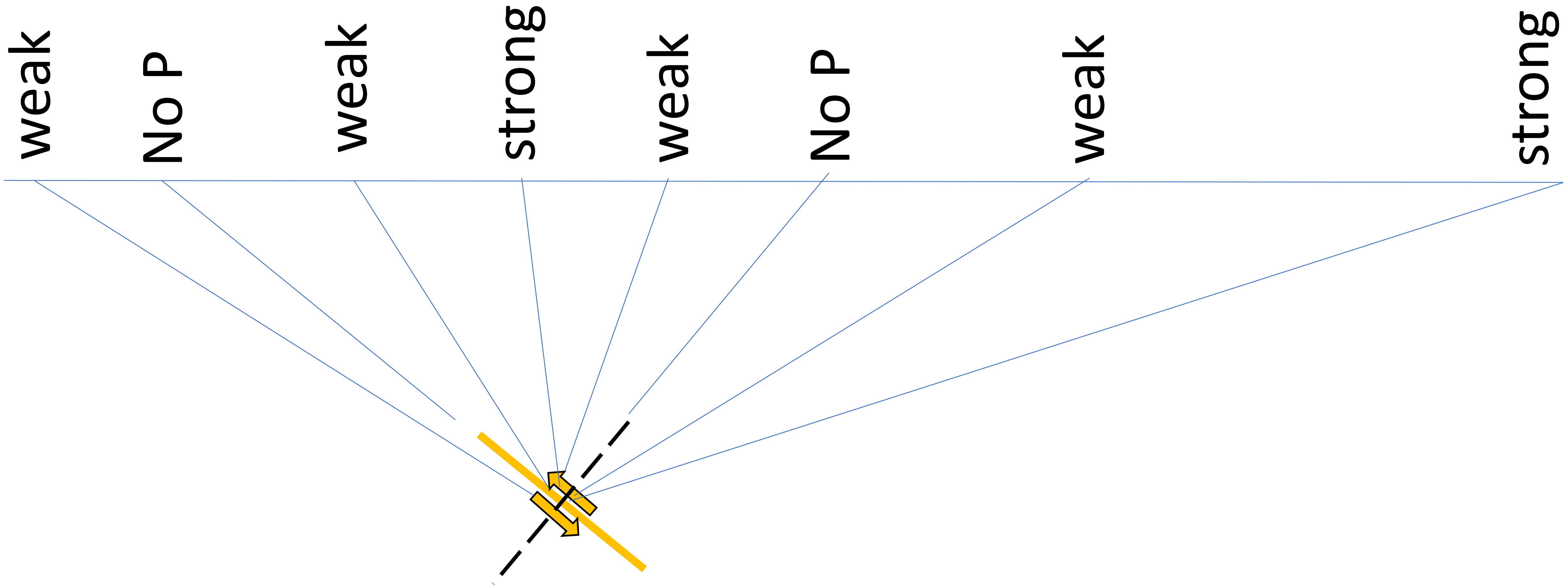

No P
No P

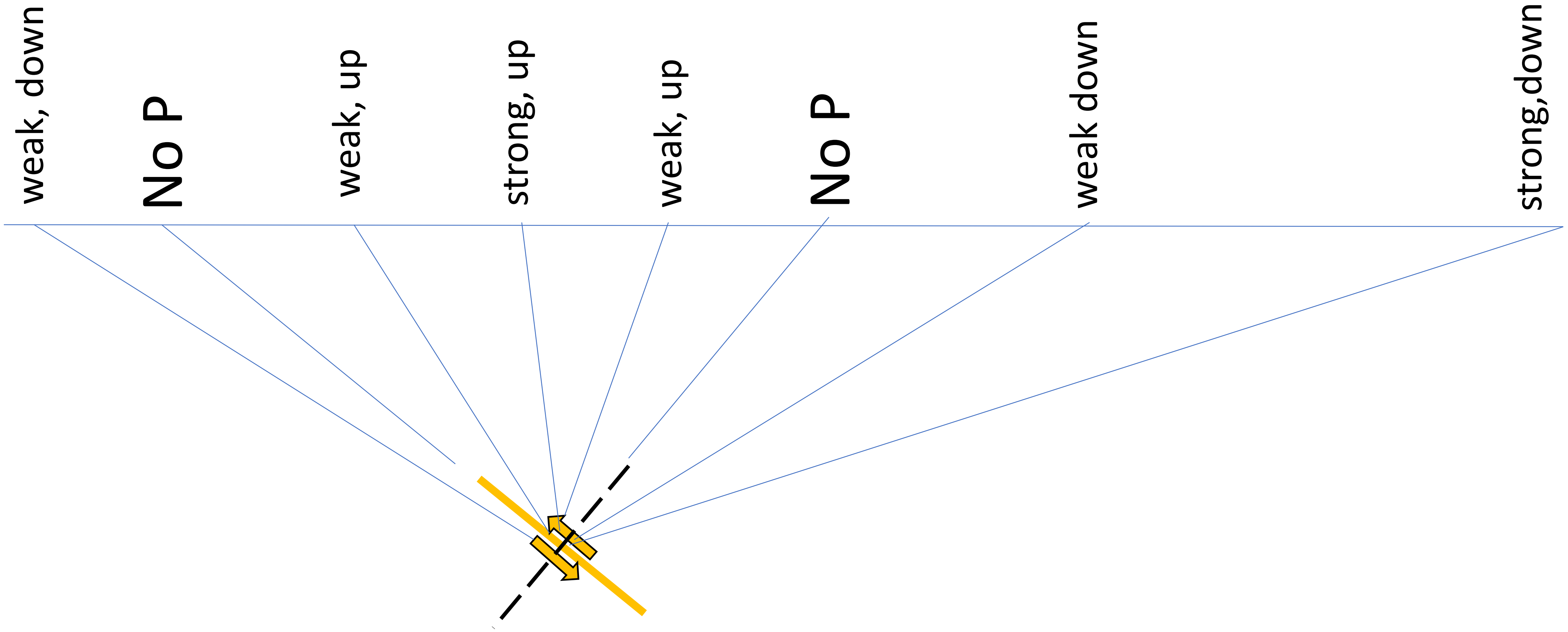


No P
No P

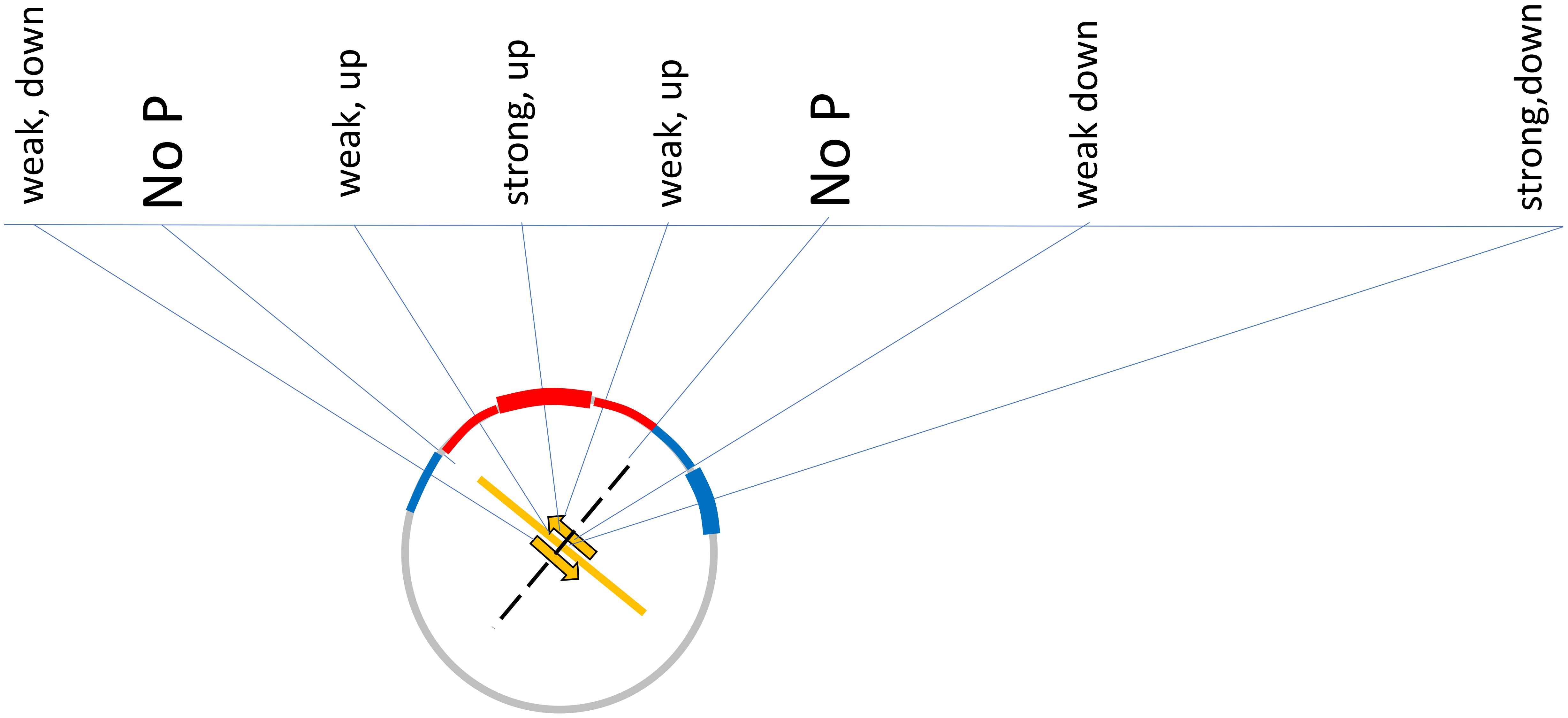

No P
No P

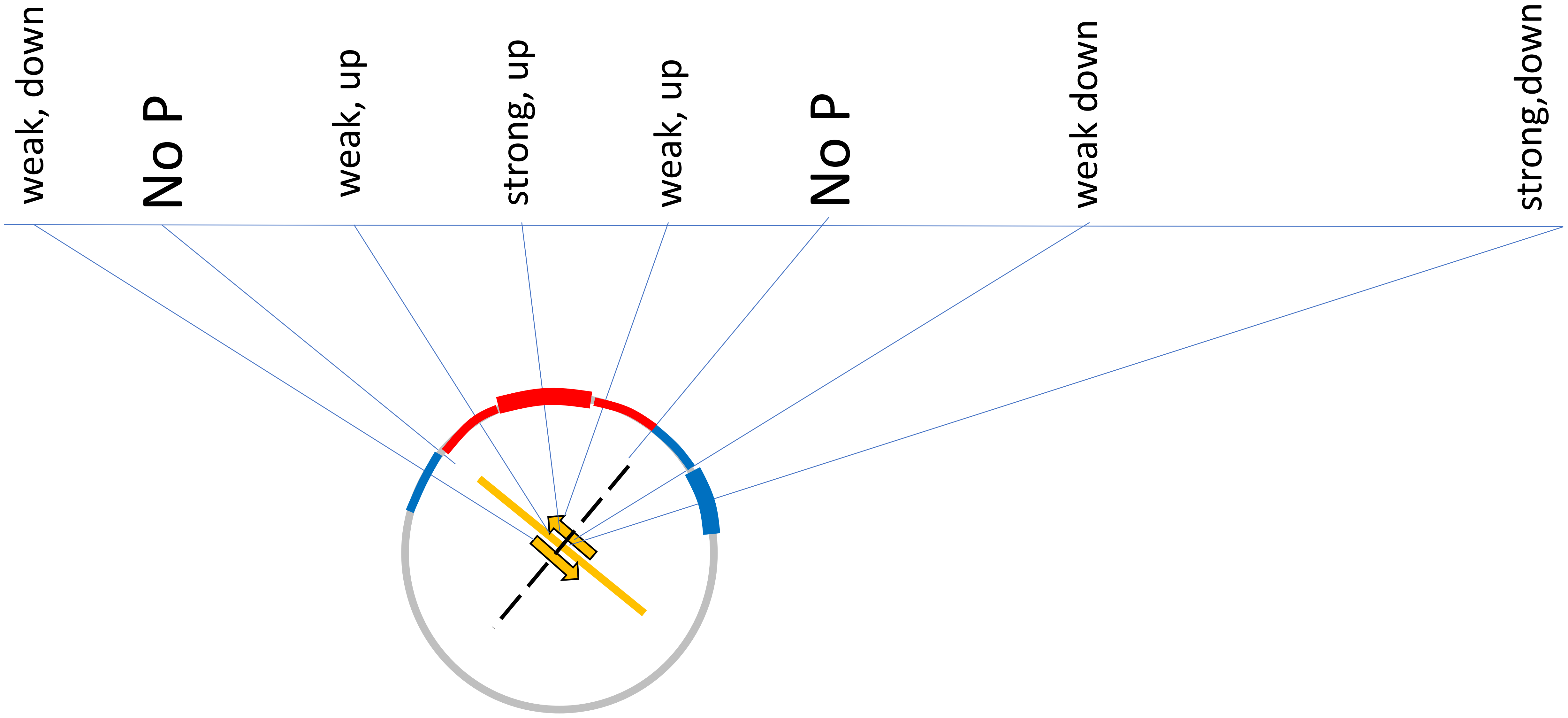

No P
strong
No P
strong


weak
No P
weak
strong
weak
No P
weak
strong

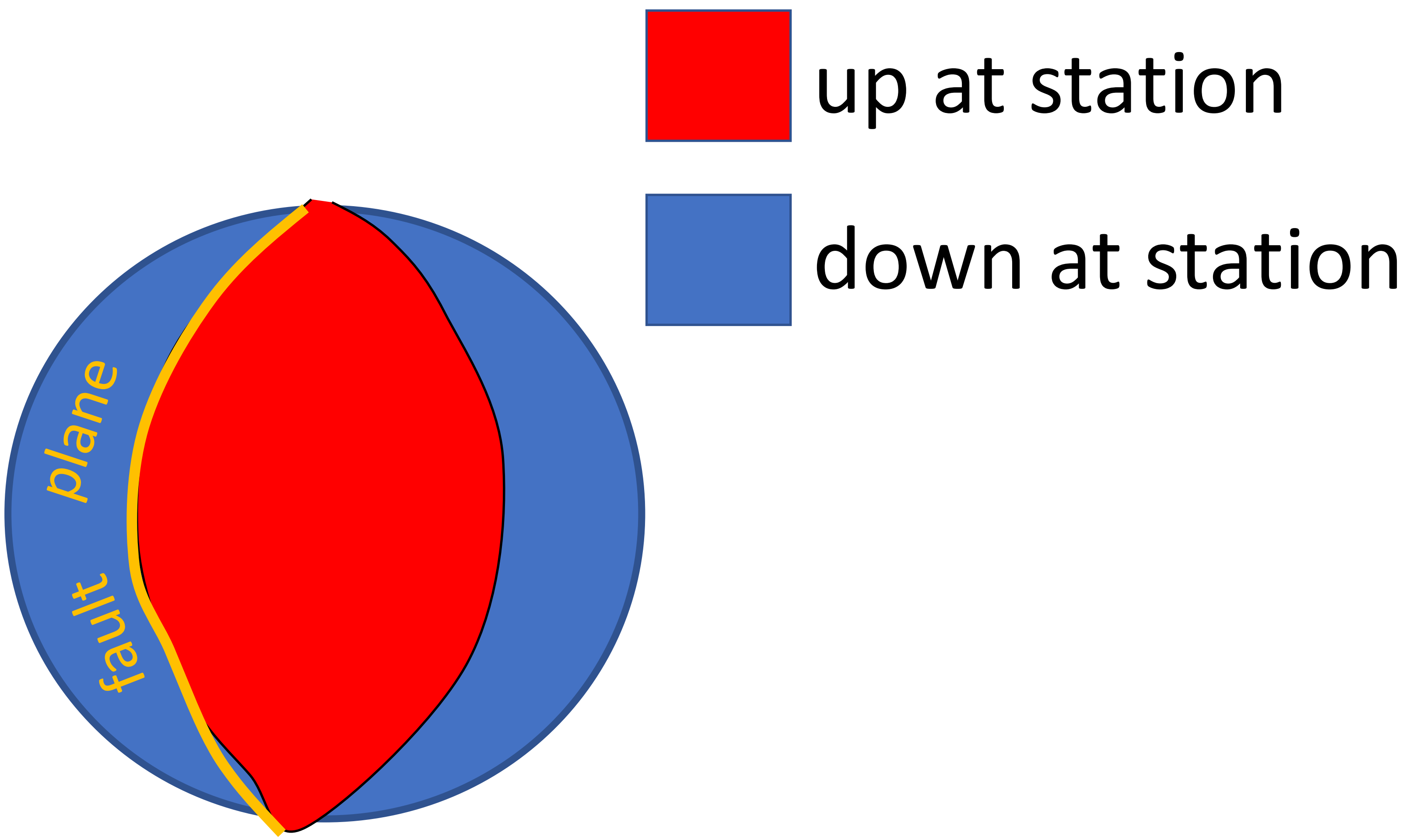


weak, down
No P
weak, up
strong, up
weak, up
No P
weak down
strong,down

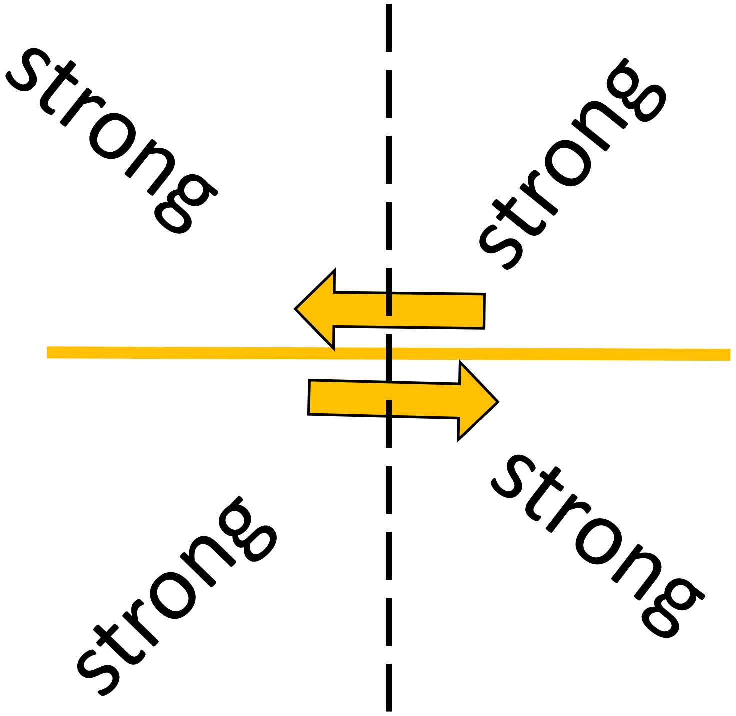

weak, down
No P
weak, up
strong, up
weak, up
No P
weak down
strong,down

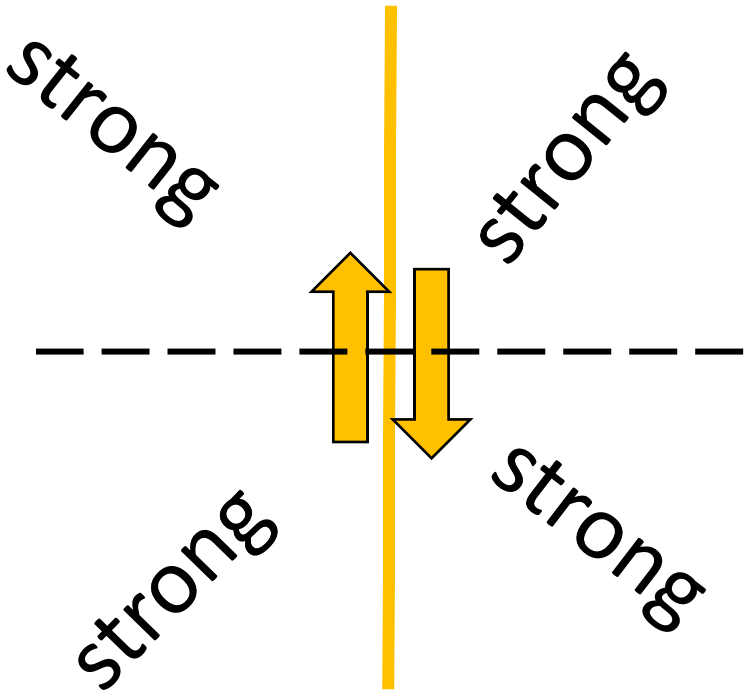


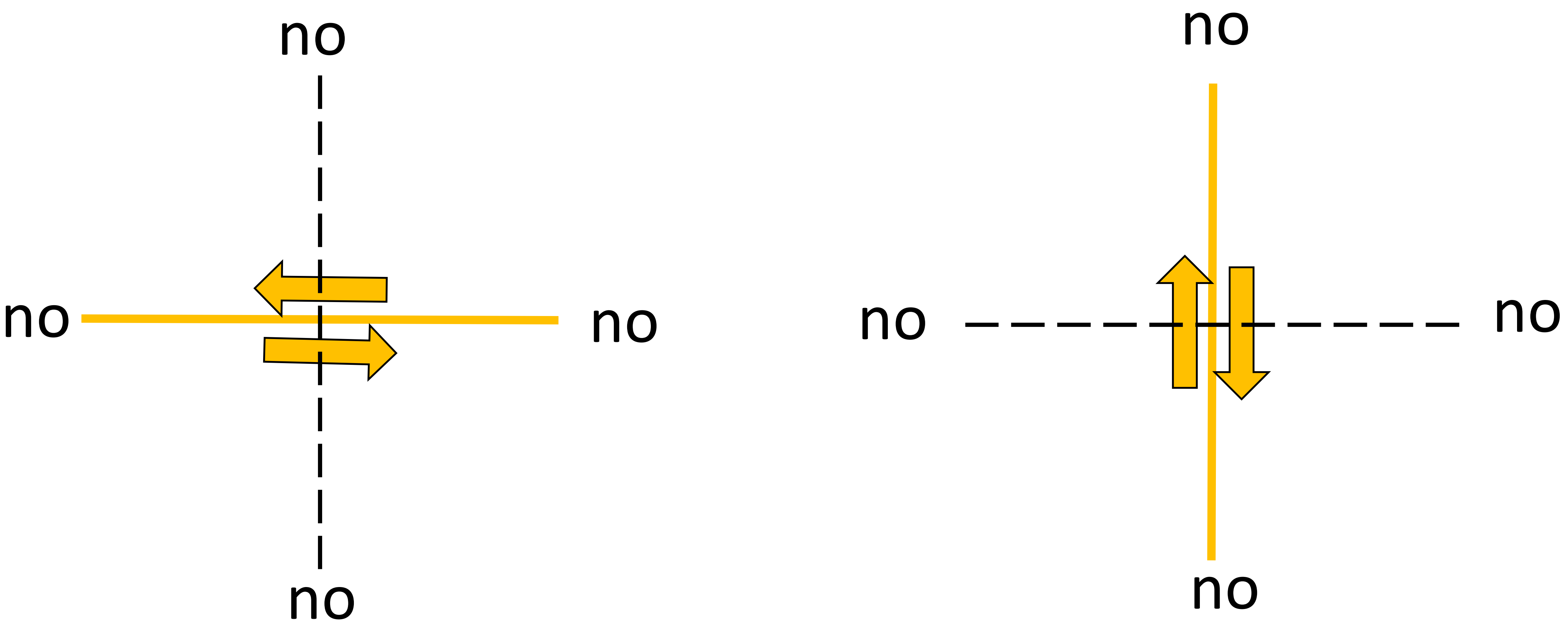
so what's it look like from the top?
looking down from an airplane?

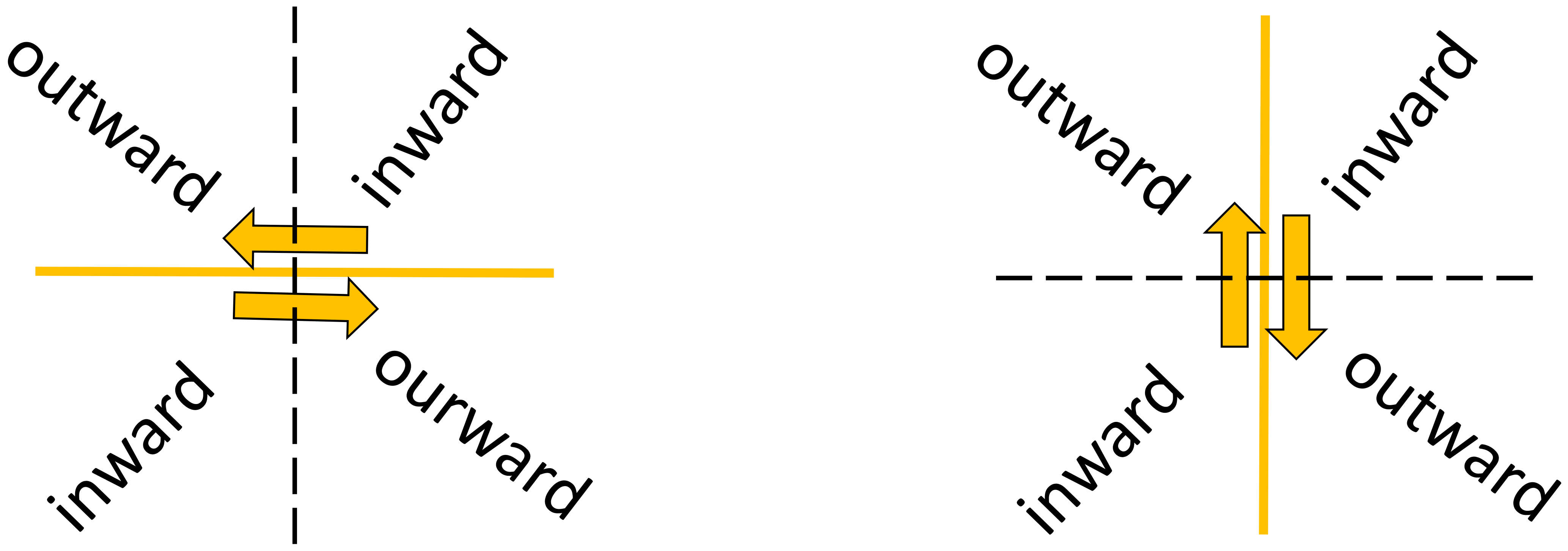


focal mechanism

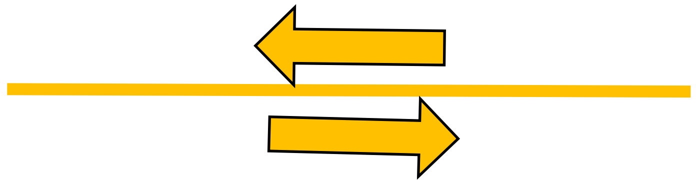

strong
strong
strong
strong

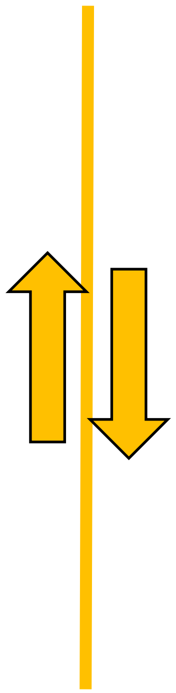

strong
strong
strong
strong

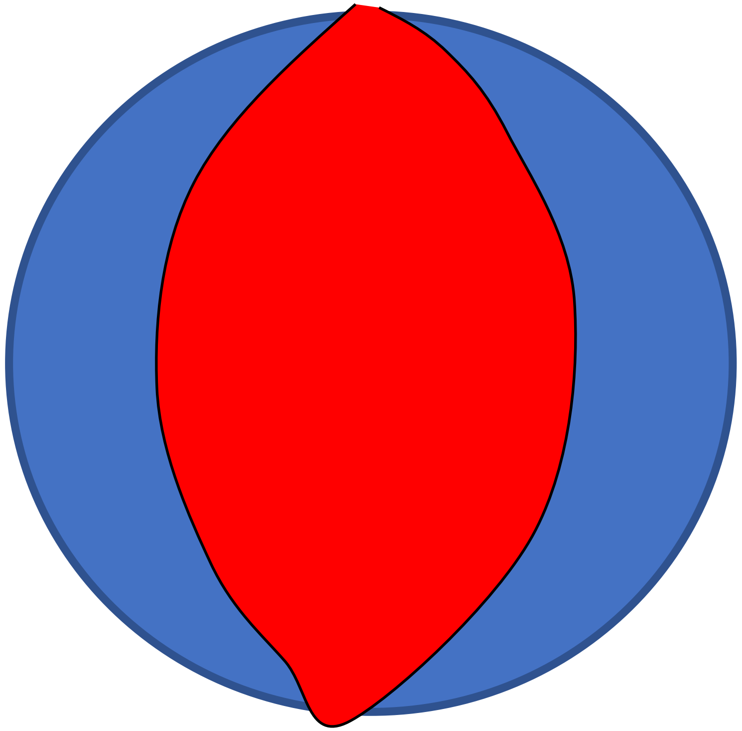

no
no
no
no
no
no
no
no


outward
inward
inward
ourward
outward
inward
inward
outward

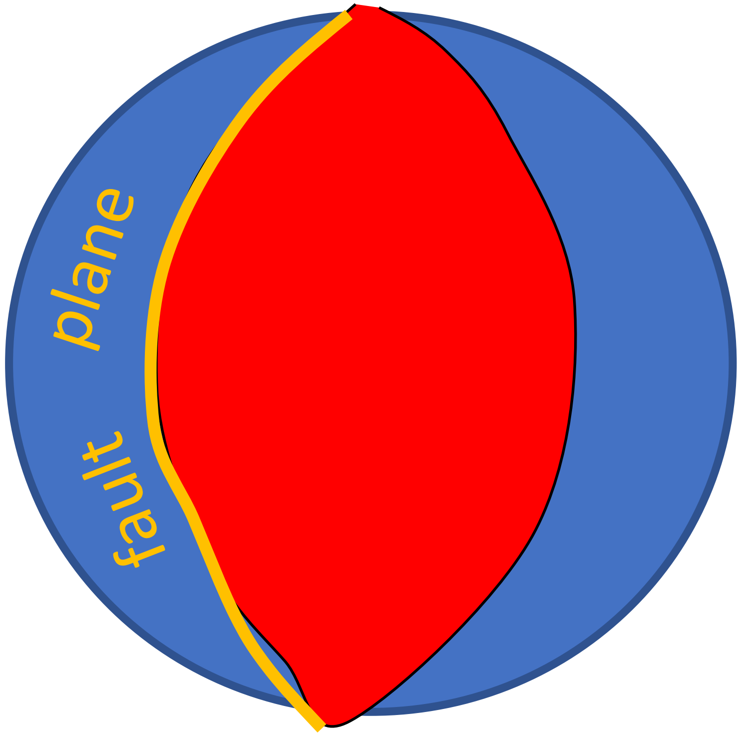
these two faults cannot be distinguished



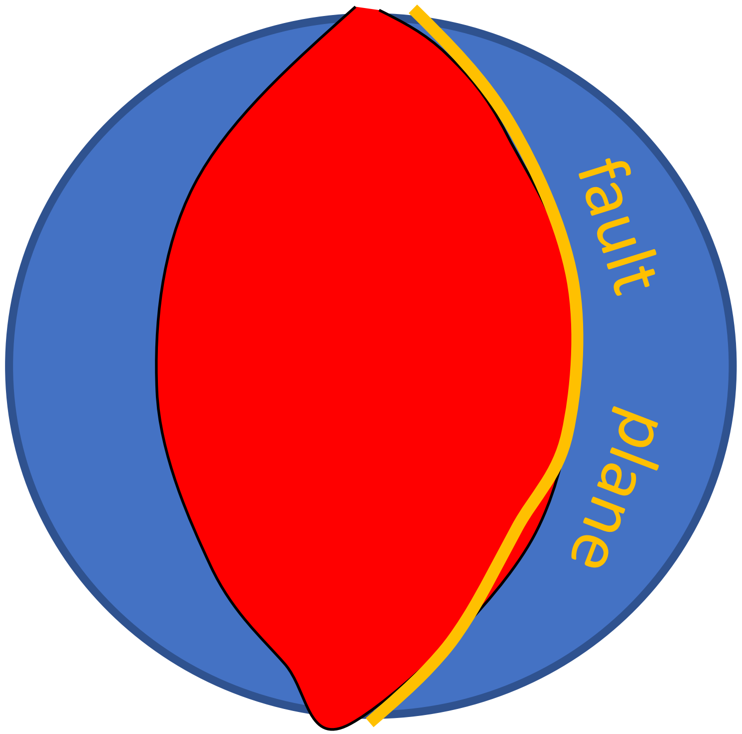




focal mechanism



is this the fault plane?



OR is this the fault plane?

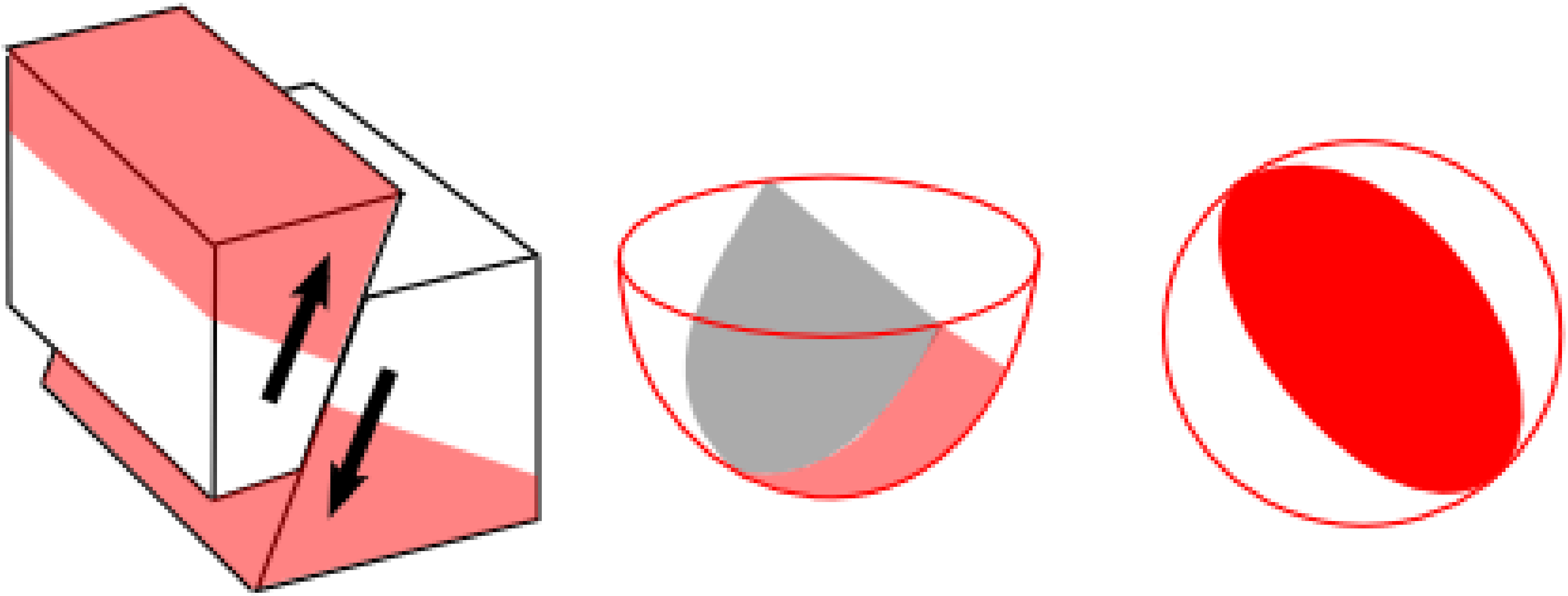
Putting it together

Angular behavior of P wave: Focal mechanism,
fault is one of two possible
planes

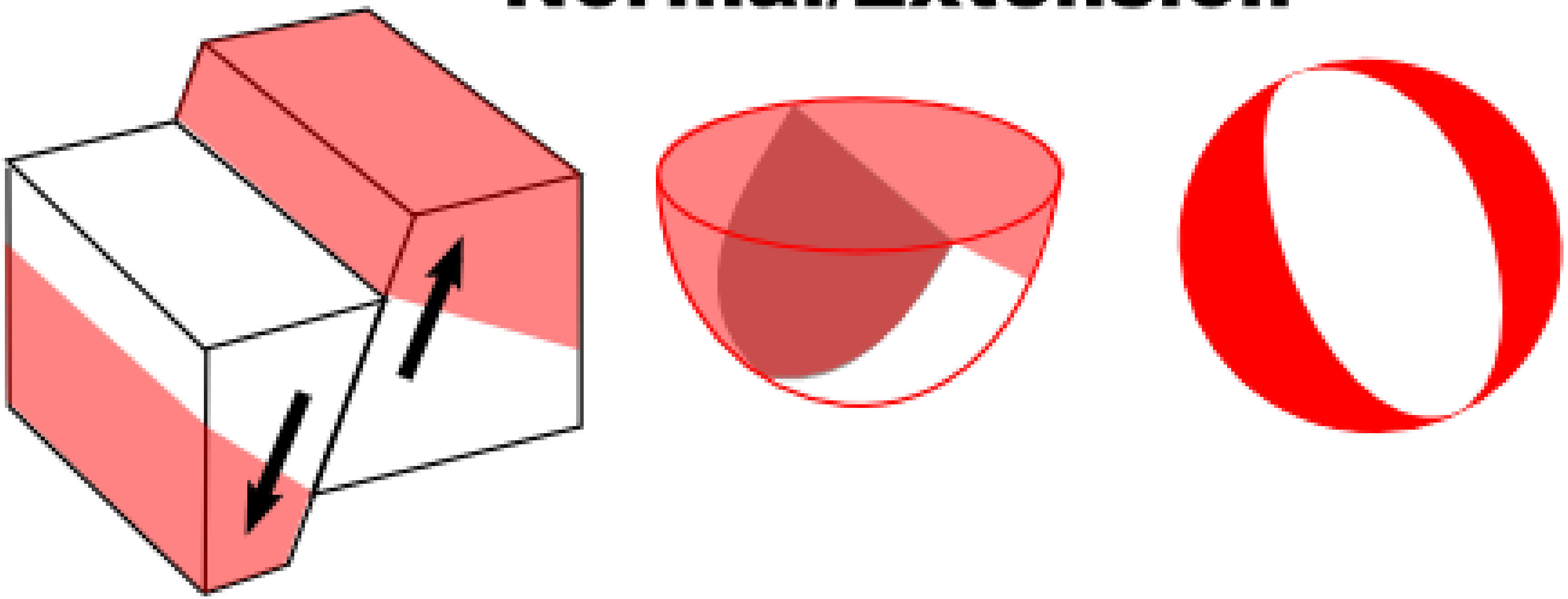
Area under the P wave
(after correcting for distance & focal mechasm):
Moment = slip x area x rigidity

Duration of the P wave: Duration of rupture

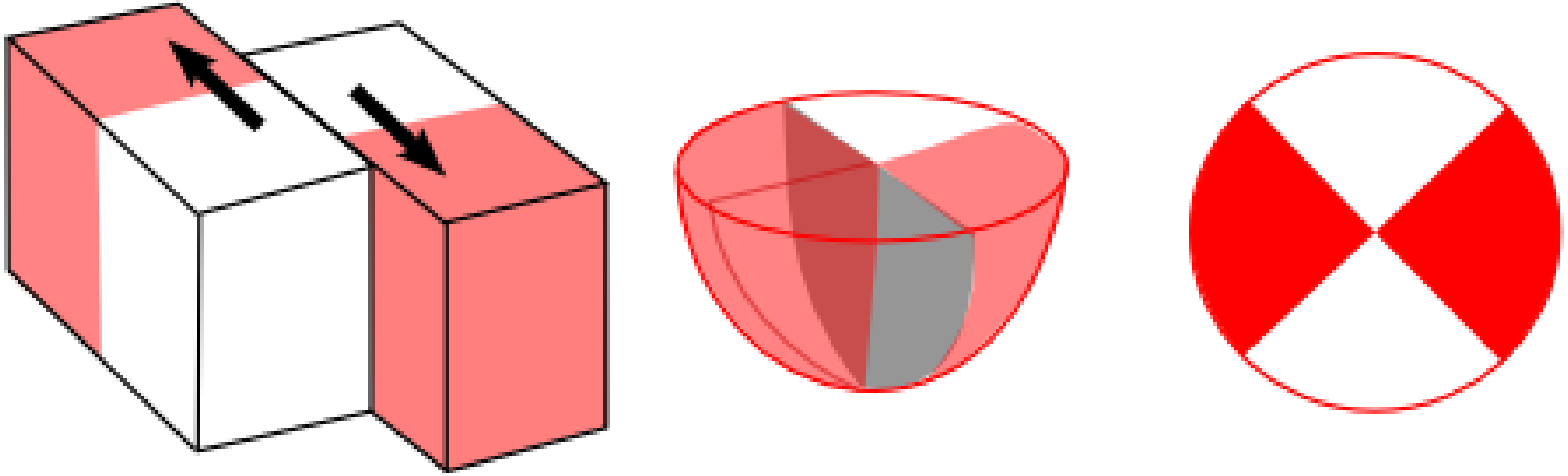
Reverse/Thrust/Compression



Normal/Extension



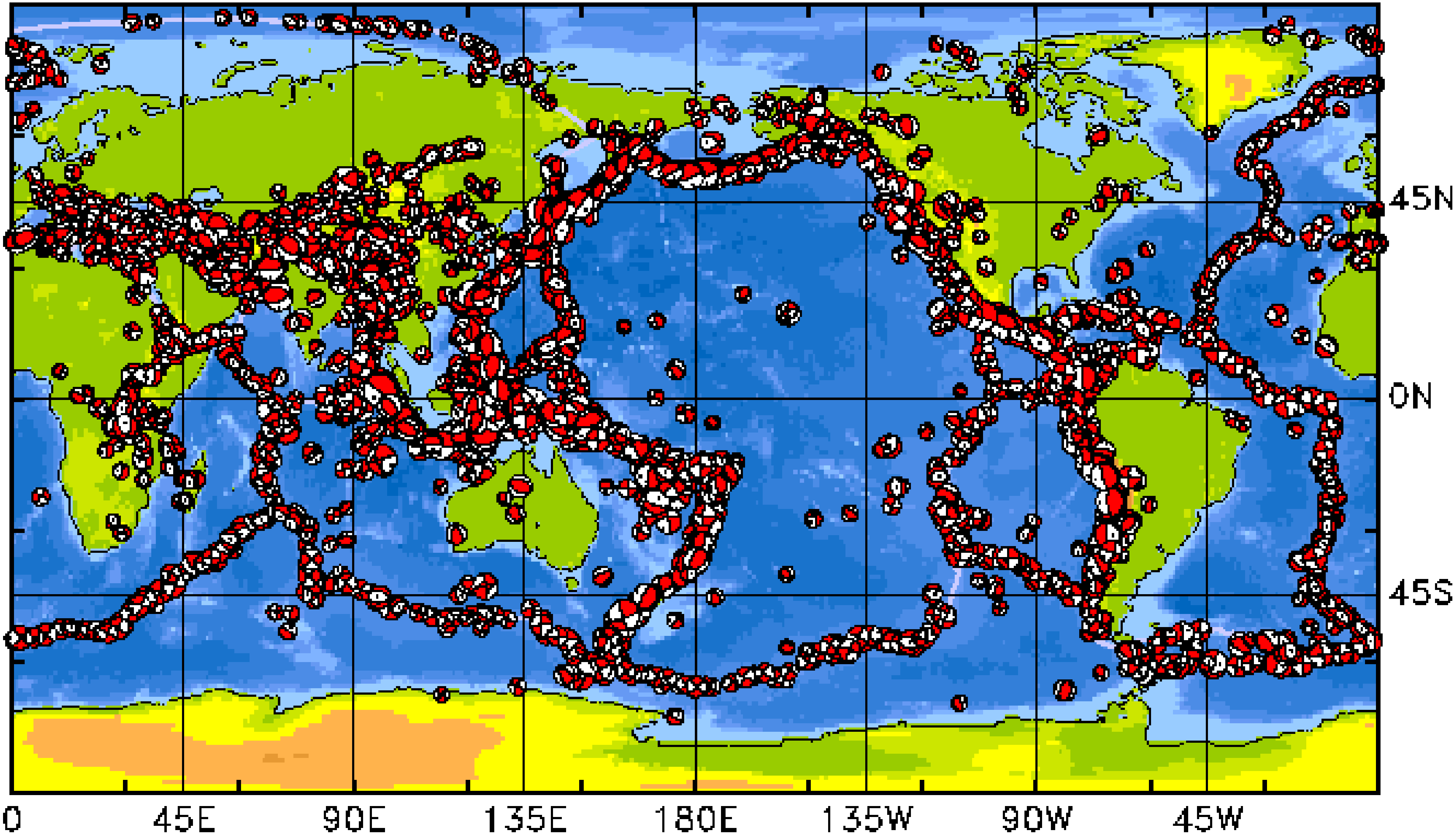
Strike-Slip/Shear

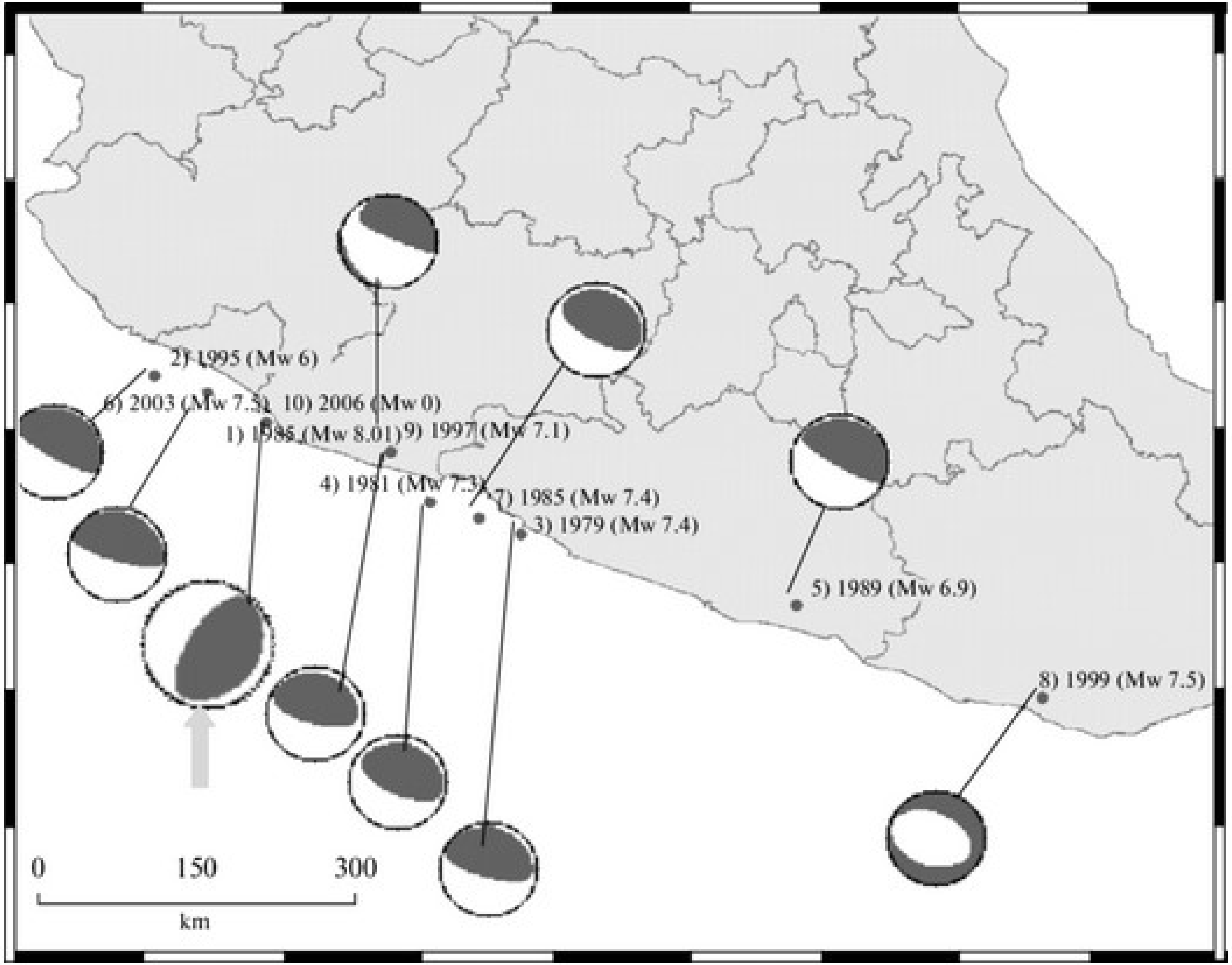


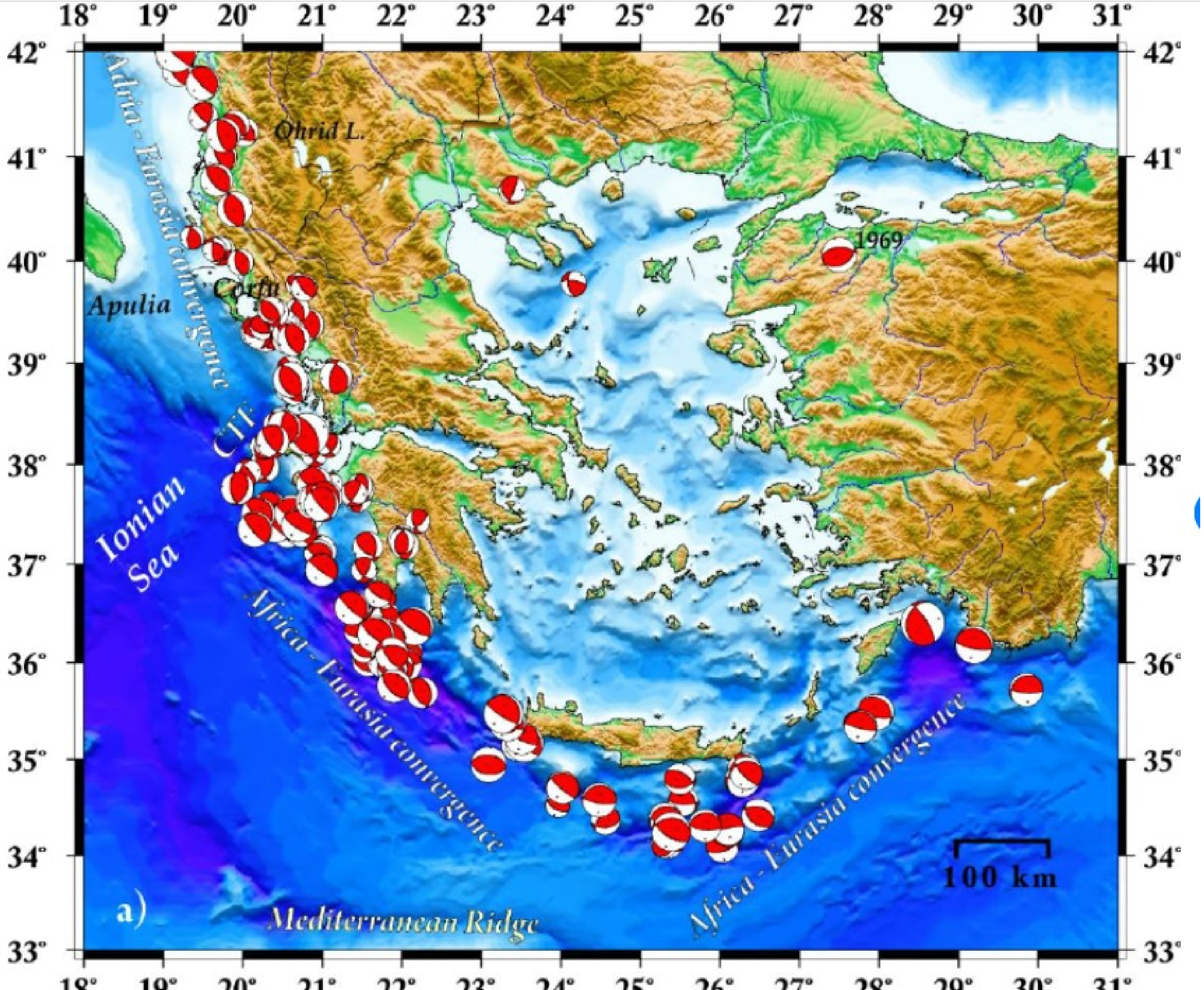
Block model

Focal Sphere

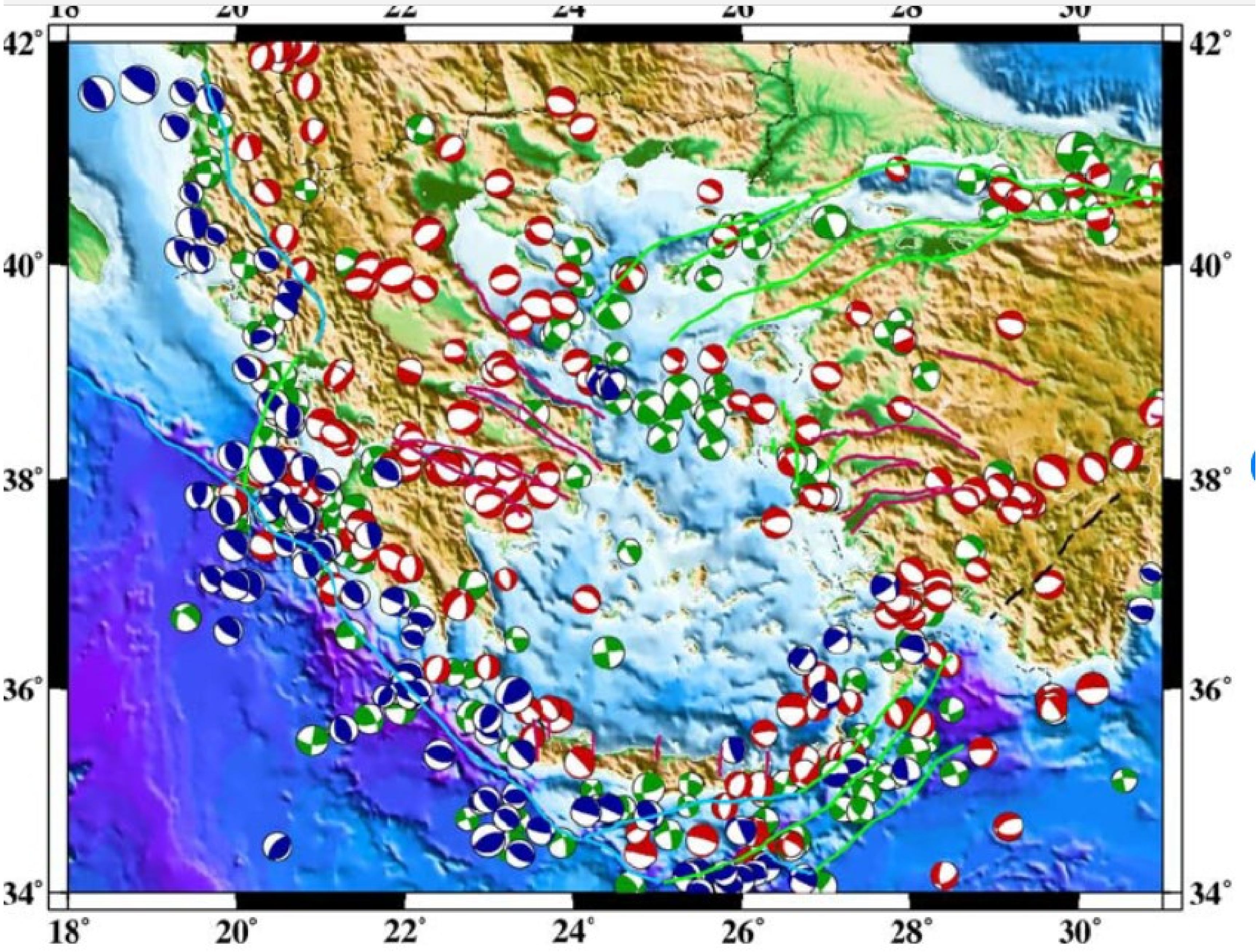
2D Projection of Focal Sphere


45N
0N
45S
0
45E
90E
135E
180E
135W
90W
45W


2) 1995 (Mw 6)
6) 2003 (Mw 7.3)
10) 2006 (Mw 0)
1) 1985 (Mw 8.01)
9) 1997 (Mw 7.1)
4) 1981 (Mw 7.3)
7) 1985 (Mw 7.4)
3) 1979 (Mw 7.4)
5) 1989 (Mw 6.9)
8) 1999 (Mw 7.5)
0
150
300
km



Ohrid L.
Adria - Eurasia convergence
1969
Corfu
Apulia
CTF
Ionian Sea
Africa - Eurasia convergence
Africa - Eurasia convergence
100 km
a)
Mediterranean Ridge


18° 20° 22° 24° 26° 28° 30°
42° 40° 38° 36° 34°

Moment of a very large earthquake

Rigidity x slip x length x width

$3 \times 10^{10}\ pa$ $1\ m$ $10^5 m$ $10^5 m$

$3 \times 10^{20}\ pa\ m^3$

$$\frac{N}{m^2} m^3$$

$M_0 = 3 \times 10^{20}\ N\ m$ (annoyingly big number)

Moment of a very large earthquake

Rigidity x slip x length x width

$3 \times 10^{10}\, pa$ $1\, m$ $10^5 m$ $10^5 m$

typical ratio 1:10^5

$3 \times 10^{20}\, pa\, m^3$

$\frac{N}{m^2} m^3$

$M_0 = 3 \times 10^{20}\, N\, m$ (annoyingly big number)

$$M_0 = 3 \times 10^{20}\ N\ m$$

$$M = (\log_{10} M_0 - 9.05)/1.5$$

$M = 7.6$ Moment magnitude

or colloquially, the magnitude of the earthquake

$$M_0 = 3 \times 10^{21}\ N\ m$$

$$M = (\log_{10} M_0 - 9.05)/1.5$$

$M = 8.3$ Moment magnitude

or colloquially, the magnitude of the earthquake

Tiny earthquake
1 millimeter of slip
on a fault 100 m long
magnitude 1.5

Moderate earthquake
1 meter of slip
on a fault 10 km long
magnitude 4.8

Huge earthquake

100 m of slip

on a fault 1000 km long

magnitude 9.7