Geol 600 Notable Historical Earthquakes

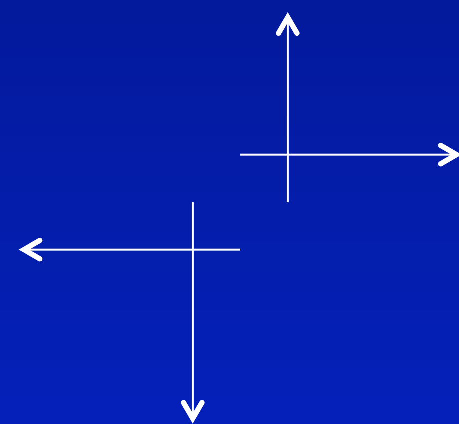
Source mechanisms and body wave radiation patterns

Force Couples:

Forces must occur in opposing directions to conserve momentum

no net torque

net torque



double couple:

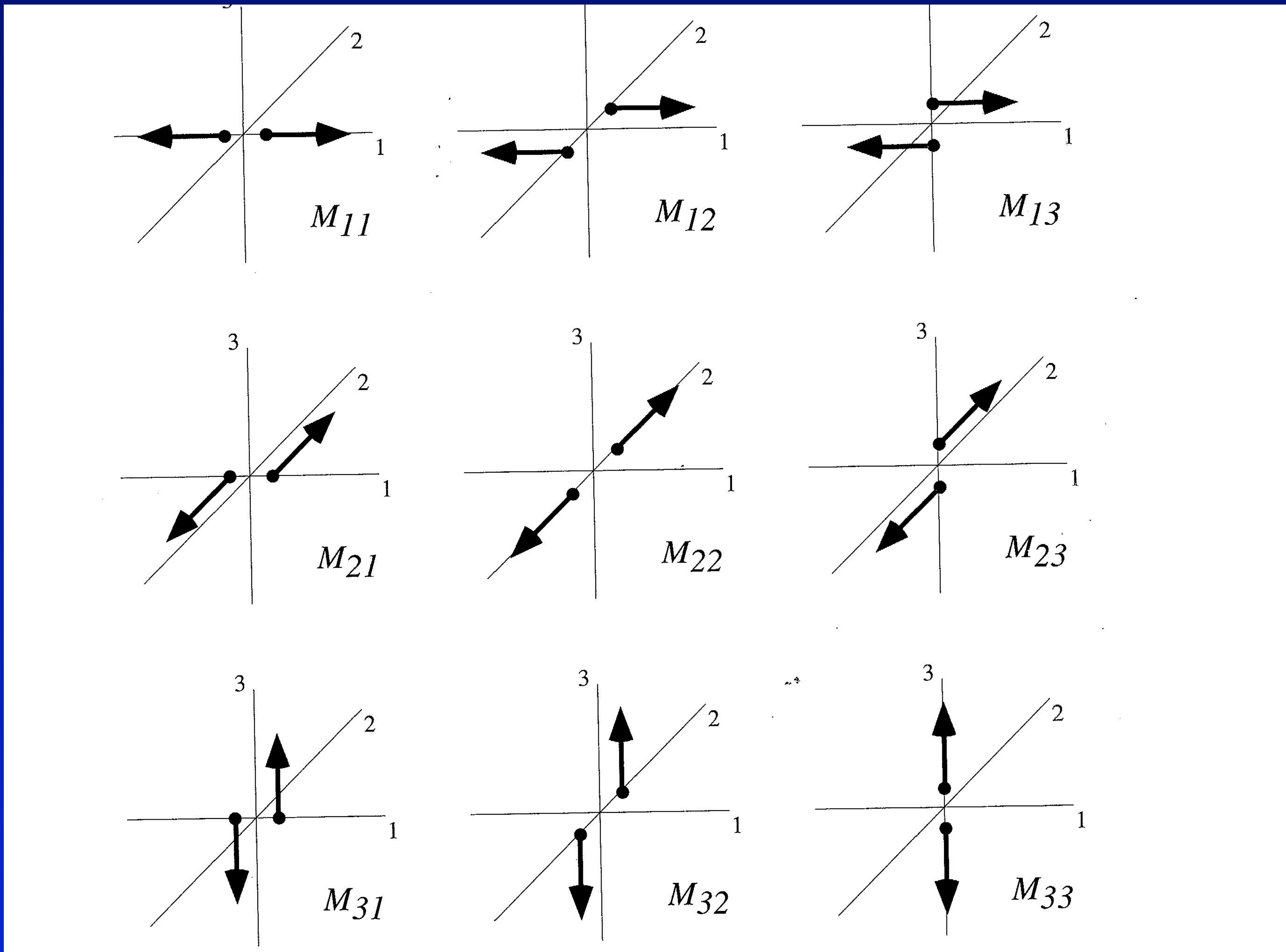
no net torque

9 Force Couples M_{ij} (the moment tensor), 6 different ($M_{ij}=M_{ji}$). $|M|=fd$

$$M=\begin{bmatrix} M_{11} & M_{12} & M_{13} \\ M_{21} & M_{22} & M_{23} \\ M_{31} & M_{32} & M_{33} \end{bmatrix}$$

Good approximation for distant earthquakes due to a point source

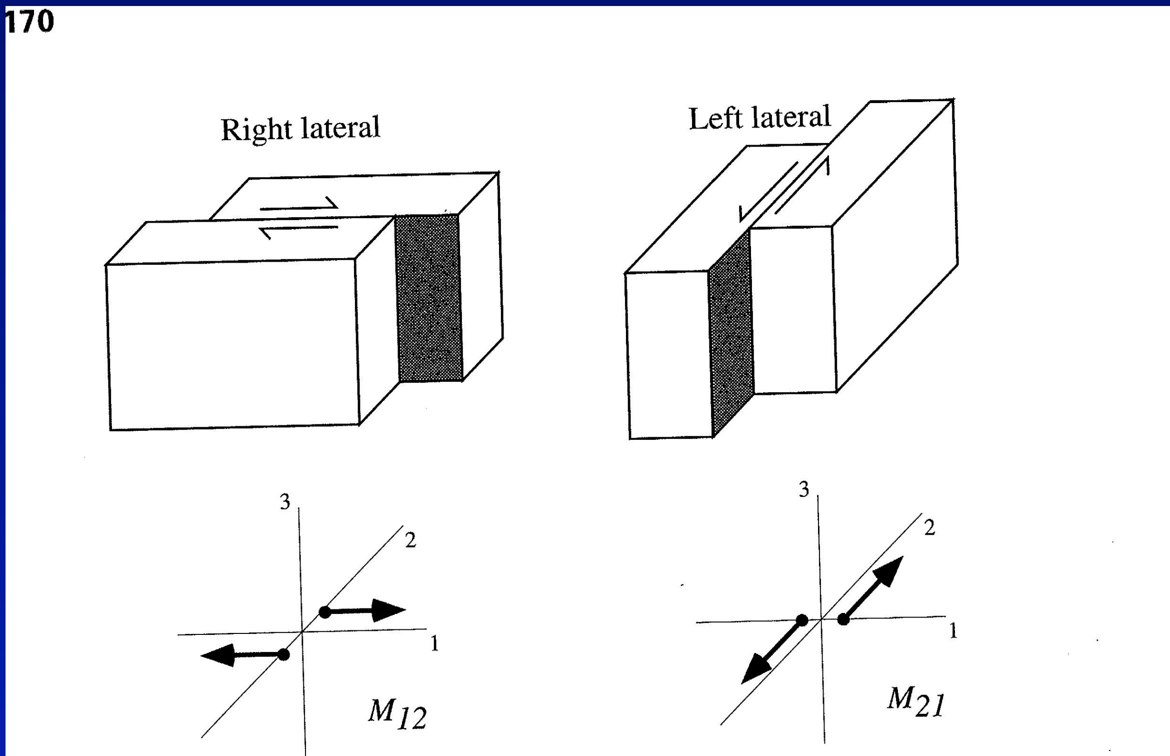
Larger earthquakes can be modeled as a sum of point sources



M11
M12
M13
M21
M22
M23
M31
M32
M33

Because of ambiguity $M_{ij}=M_{ji}$ two fault planes are consistent with a double-couple model: the primary fault plane, and the auxillary fault plane (model for both generates same far-field displacements).

Distinguishing between the two requires further (geological) information



$$\mathbf{M}=\begin{bmatrix} 0 & M_0 & 0 \\ M_0 & 0 & 0 \\ 0 & 0 & 0 \end{bmatrix}$$

Example: vertical right-lateral along x

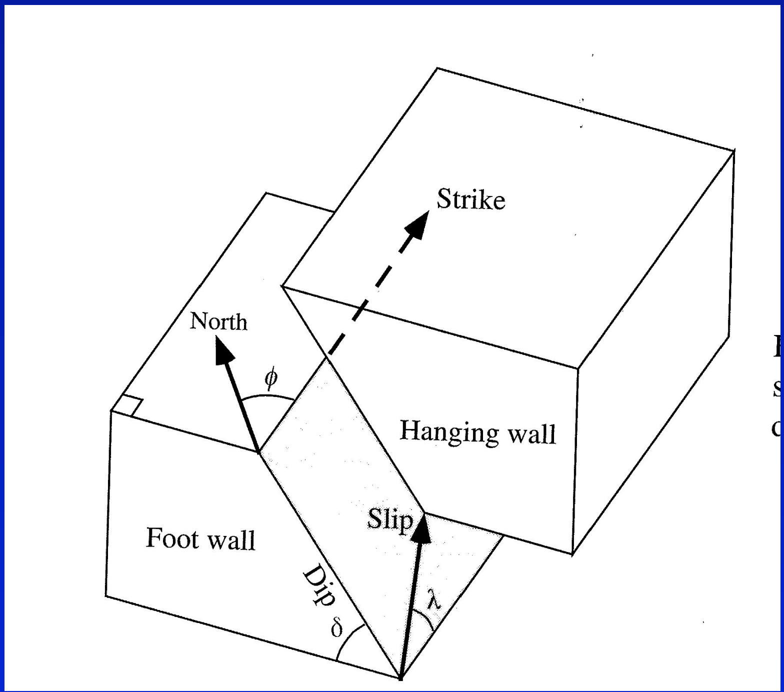
$M_0=\mu DA$ scalar seismic moment (Nm)

Description of earthquakes using moment tensors:

Parameters: strike ϕ, dip δ, rake λ

Right-lateral $\lambda=180^o$, left-lateral $\lambda=0^o$, $\lambda=90$ reverse, $\lambda=-90$ normal faulting

Strike, dip, rake, slip define the focal mechanism



Description of earthquakes using moment tensors:

M_{11}= $-M_0(\sin\delta \cos\lambda \sin 2\phi_s + \sin 2\delta \sin\lambda \sin^2\phi_s)$,

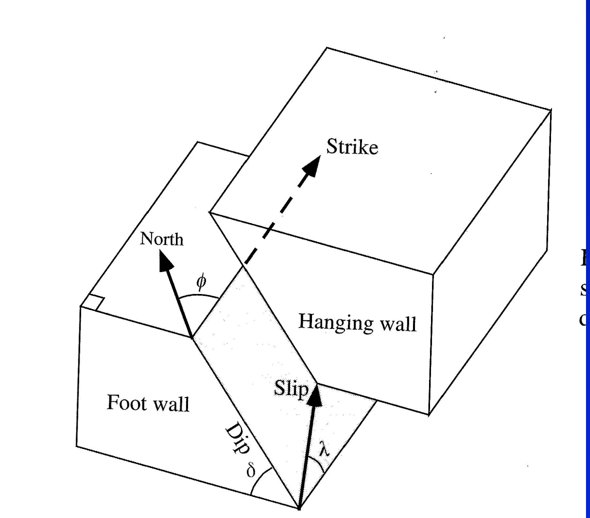
M_{12}= $M_0(\sin\delta \cos\lambda \cos 2\phi_s + 0.5 \sin 2\delta \sin\lambda \sin 2\phi_s)$,

M_{13}= $-M_0(\cos\delta \cos\lambda \cos\phi_s + \cos 2\delta \sin\lambda \sin\phi_s)$,

M_{22}= $M_0(\sin\delta \cos\lambda \sin 2\phi_s - \sin 2\delta \sin\lambda \cos^2\phi_s)$,

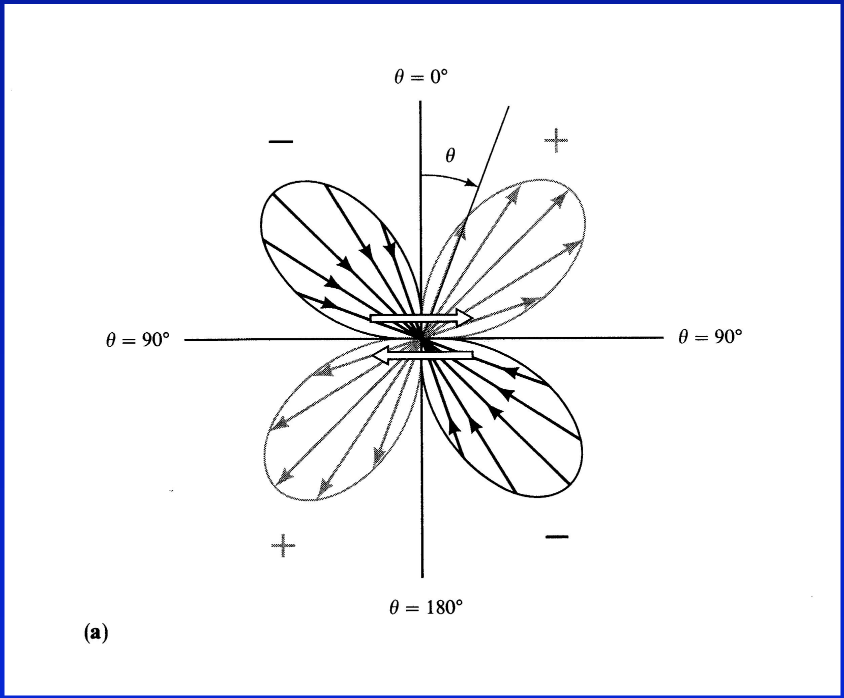
M_{23}= $-M_0(\cos\delta \cos\lambda \sin\phi_s - \cos 2\delta \sin\lambda \cos\phi_s)$,

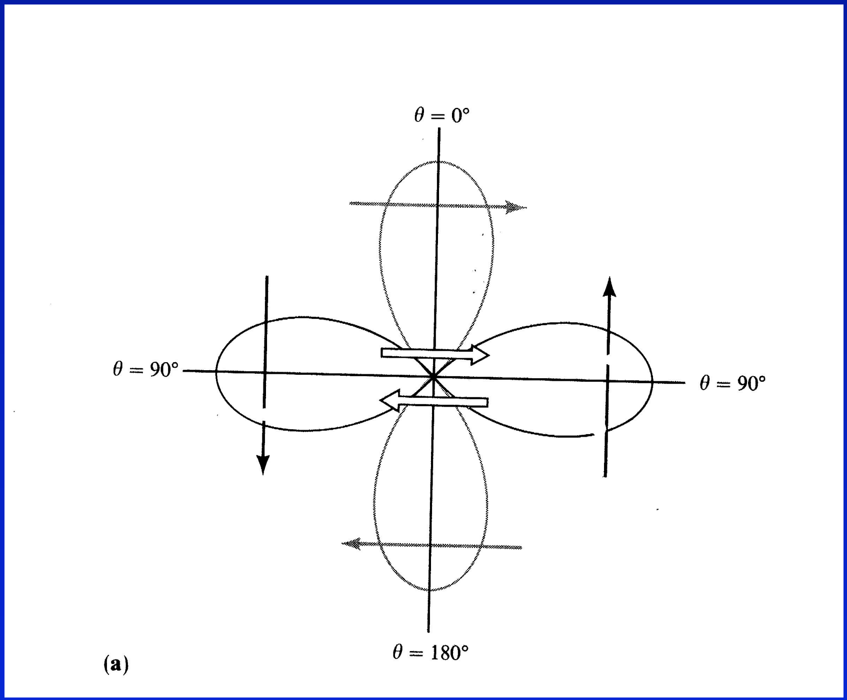
M_{33}= $M_0 \sin 2\delta \sin\lambda$.



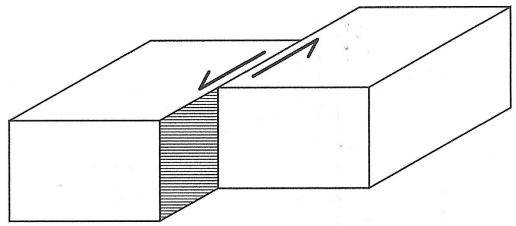
P-waves

S-waves

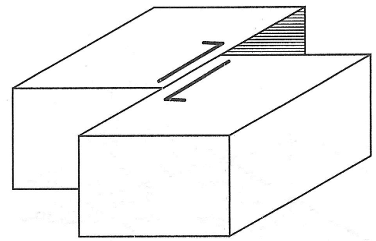




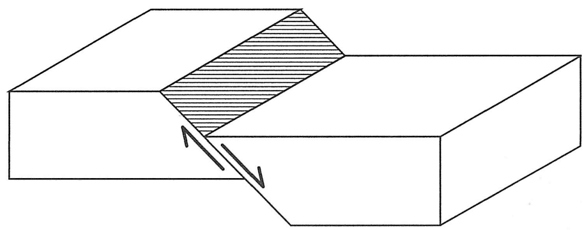
Determining an earthquake’s mechanism from first P motions



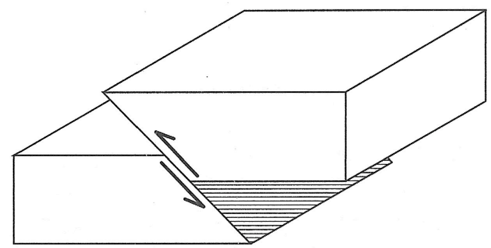
Left-lateral strike-slip fault
($\lambda = 0°$)



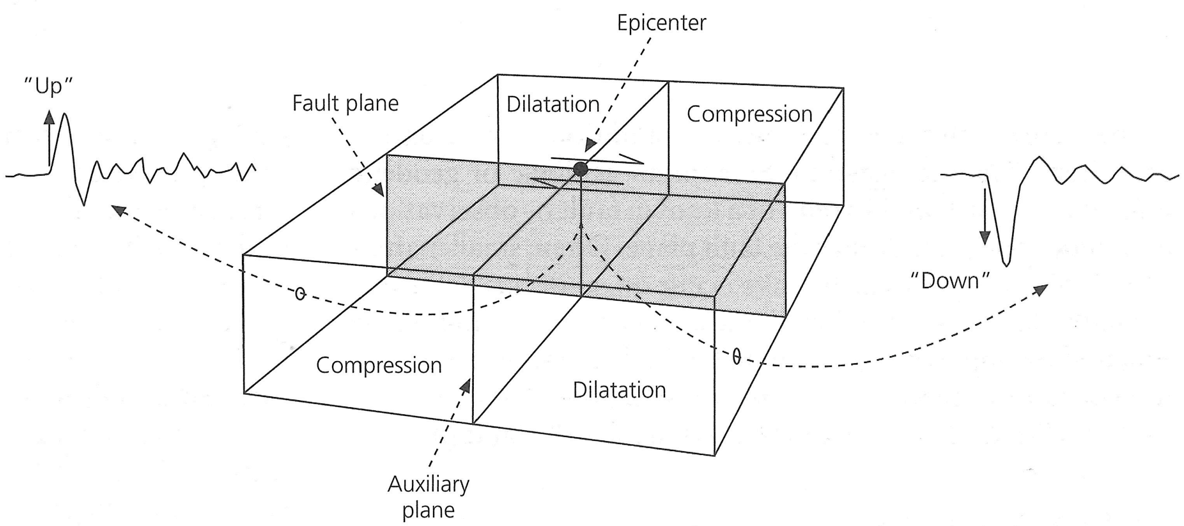
Right-lateral strike-slip fault
($\lambda = 180°$)



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



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



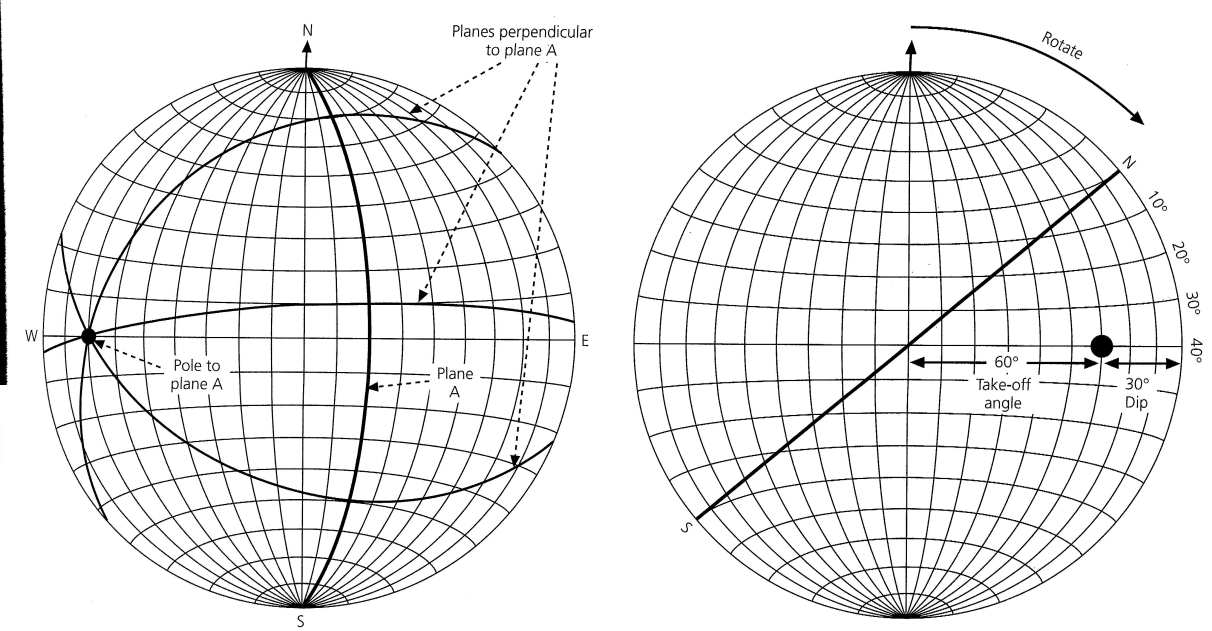
Take-off angle:

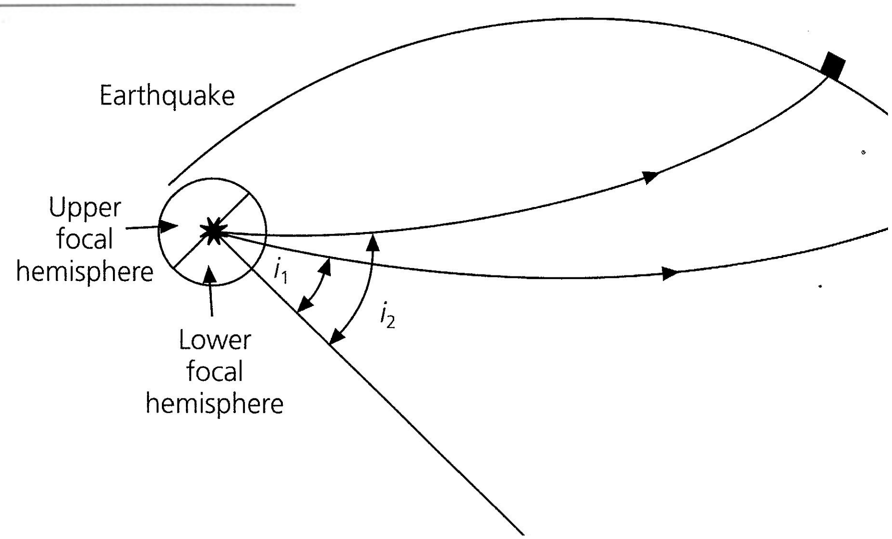
$$\frac{\sin i}{v} = \frac{dT}{d\Delta}$$

Table 4.2-1 *P*-wave take-off angles for a surface-focus earthquake.

Distance (°)	Take-off angle (°)	Distance (°)	Take-off angle (°)	Distance (°)	Take-off angle (°)
21	36	47	25	73	19
23	32	49	24	75	18
25	30	51	24	77	18
27	29	53	23	79	17
29	29	55	23	81	17
31	29	57	23	83	16
33	28	59	22	85	16
35	28	61	22	87	15
37	27	63	21	89	15
39	27	65	21	91	15
41	26	67	20	93	14
43	26	69	20	95	14
45	25	71	19	97	14

Source: After Pho and Behe (1972).





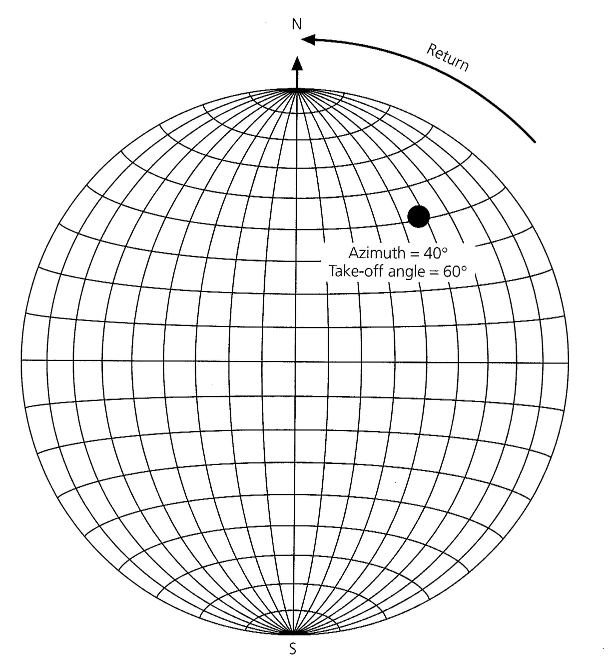
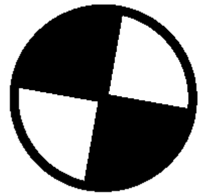
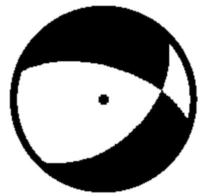


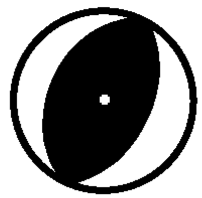
Fig. 4.2-8 The angle of incidence at the earthquake source is the a



Type of faults:

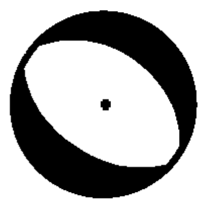


Type of faults:

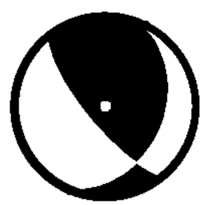


Type of faults:

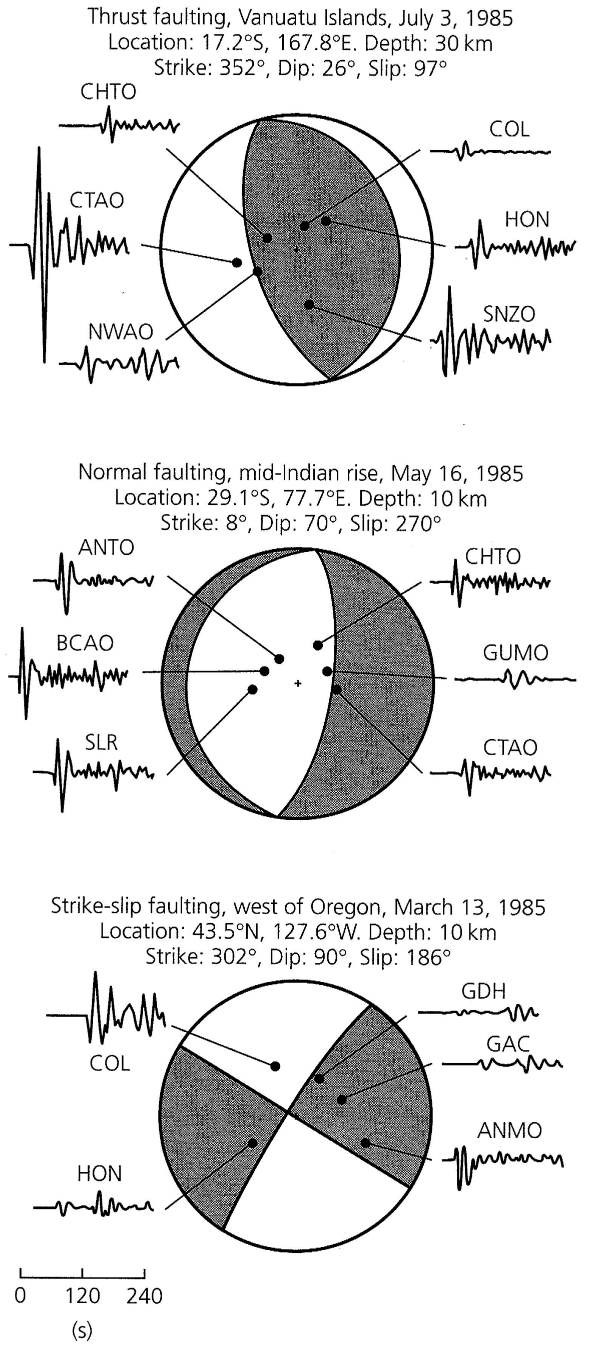
Type of faults:



Type of faults:



Type of faults:


Thrust faulting, Vanuatu Islands, July 3, 1985
Location: 17.2°S, 167.8°E. Depth: 30 km
Strike: 352°, Dip: 26°, Slip: 97°
CHTO
CTAO
NWAO
COL
HON
SNZO
Normal faulting, mid-Indian rise, May 16, 1985
Location: 29.1°S, 77.7°E. Depth: 10 km
Strike: 8°, Dip: 70°, Slip: 270°
ANTO
BCAO
SLR
CHTO
GUMO
CTAO
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°
COL
HON
GDH
GAC
ANMO
0
120
240
(s)

Earthquake focal mechanism determination from first P motion (assuming double-couple model):

- Only vertical component instruments needed
- No amplitude calibration needed
- Initial P motion easily determined (up or down)
- Up: ray left the source in compressional quadrant
- Down: ray left source in dilatational quadrant
- Plotted on focal sphere (lower hemisphere)
- Allows division of focal sphere into compressional/ dilatational quadrants
- Focal mechanism is then found from two orthogonal planes (projections on the focal sphere)

Earthquake focal mechanism determination from first P motion (assuming double-couple model):

- Focal sphere is shaded in compressional quadrants, generating ‘beach ball’
- Normal faulting: white with black edges
- Reverse faulting: black with white edges
- Strike-slip: cross pattern