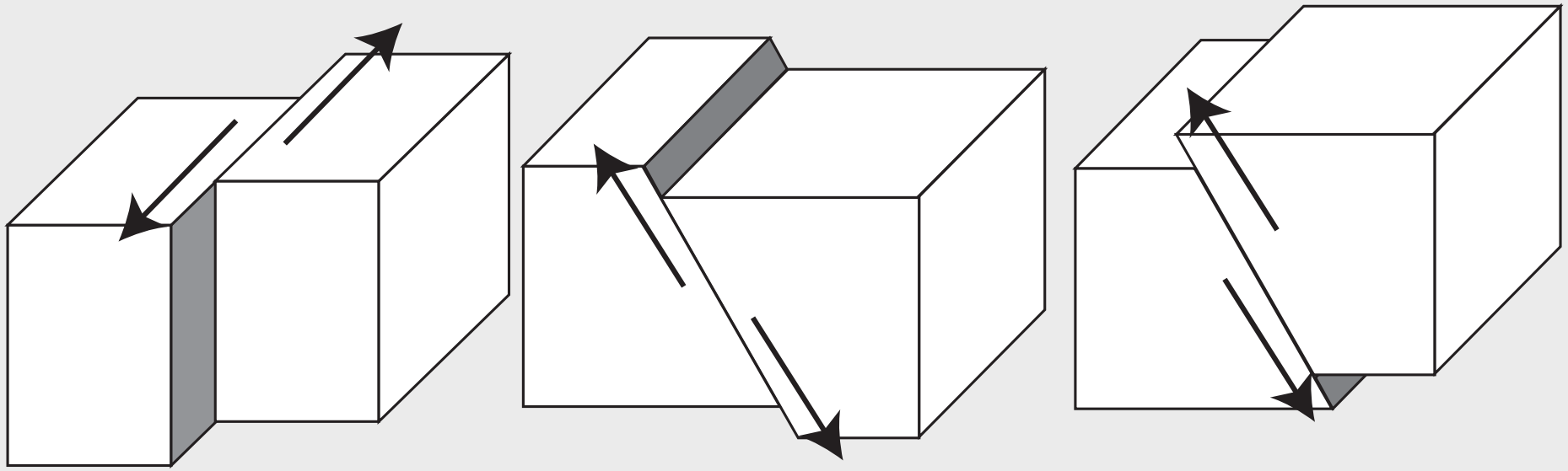
Focal mechanisms

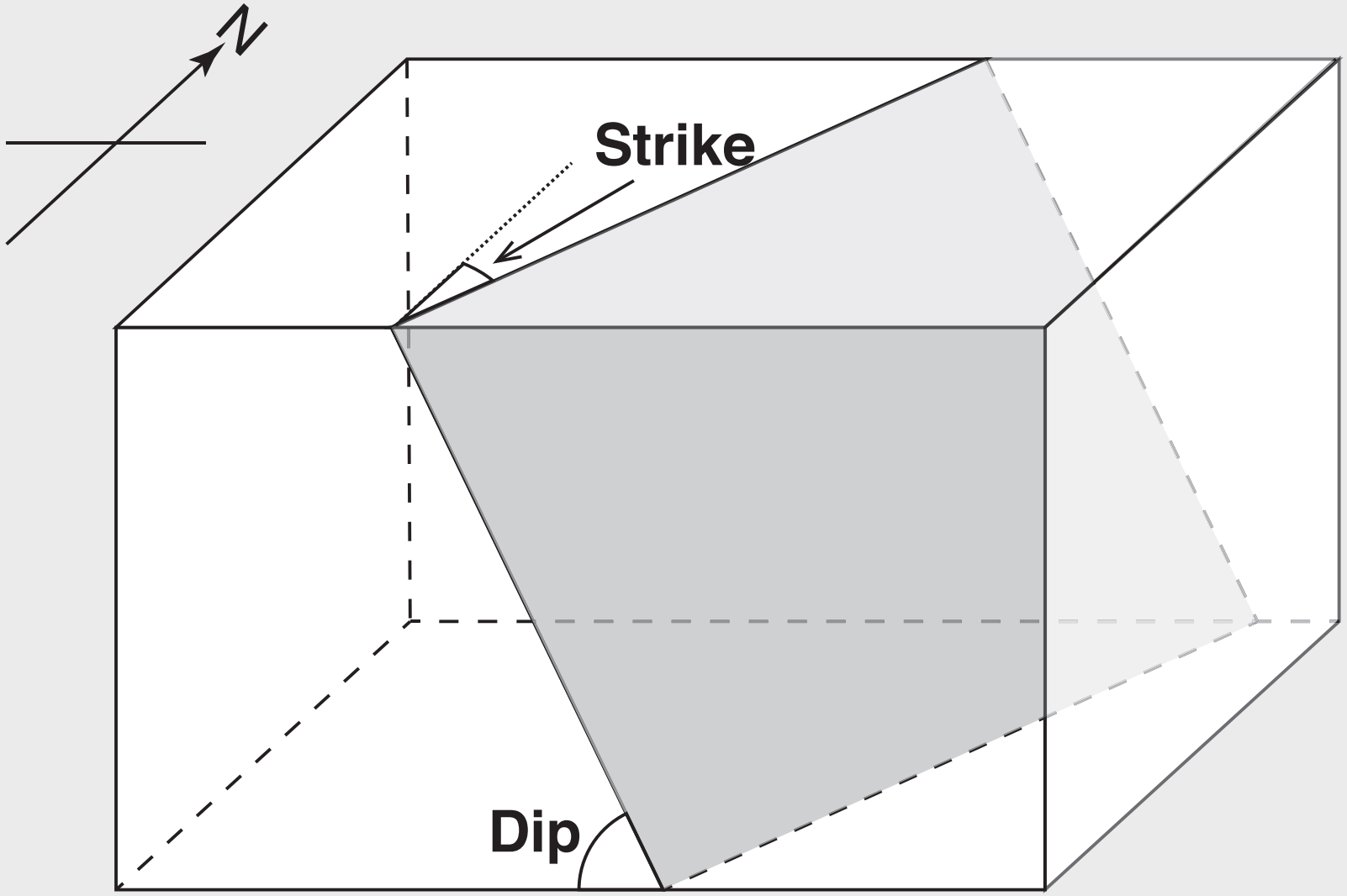
Nori Nakata

Stanford University

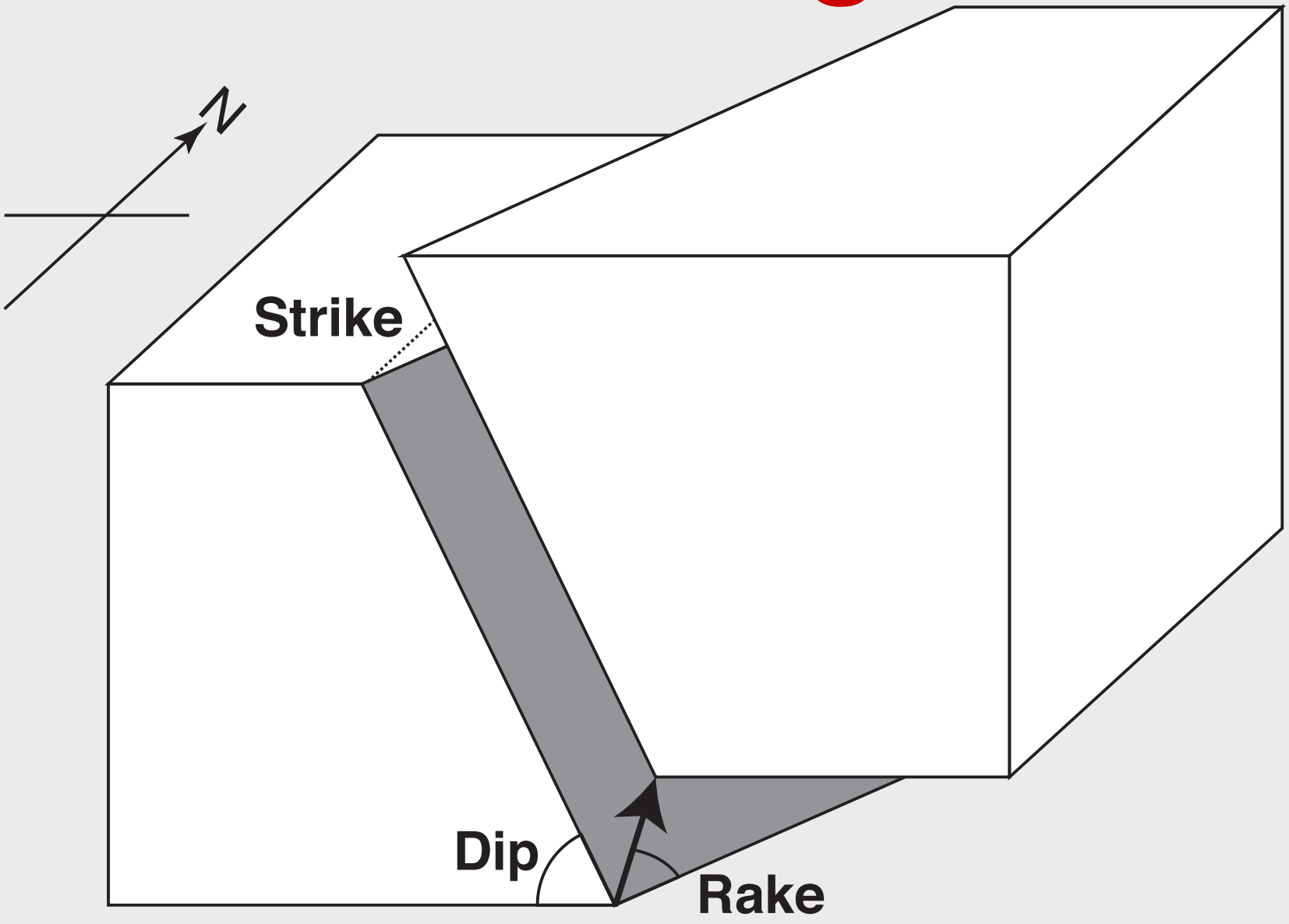
Faulting



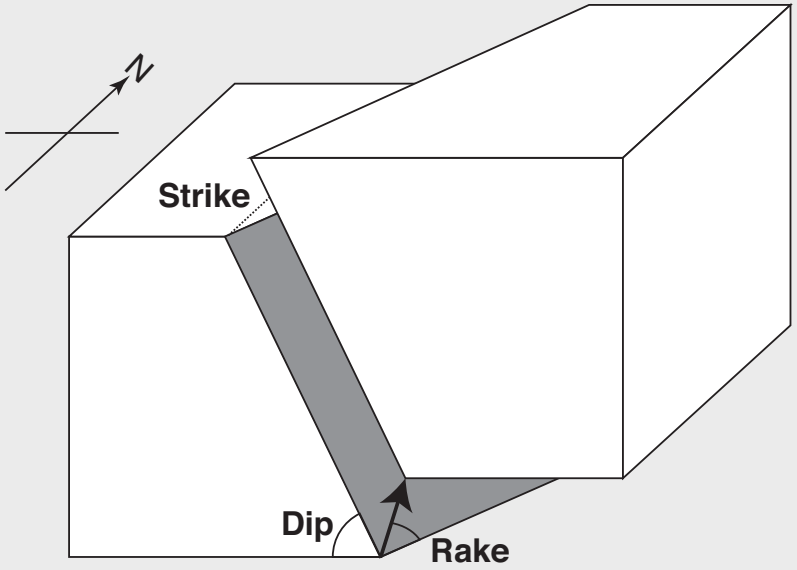
Faulting

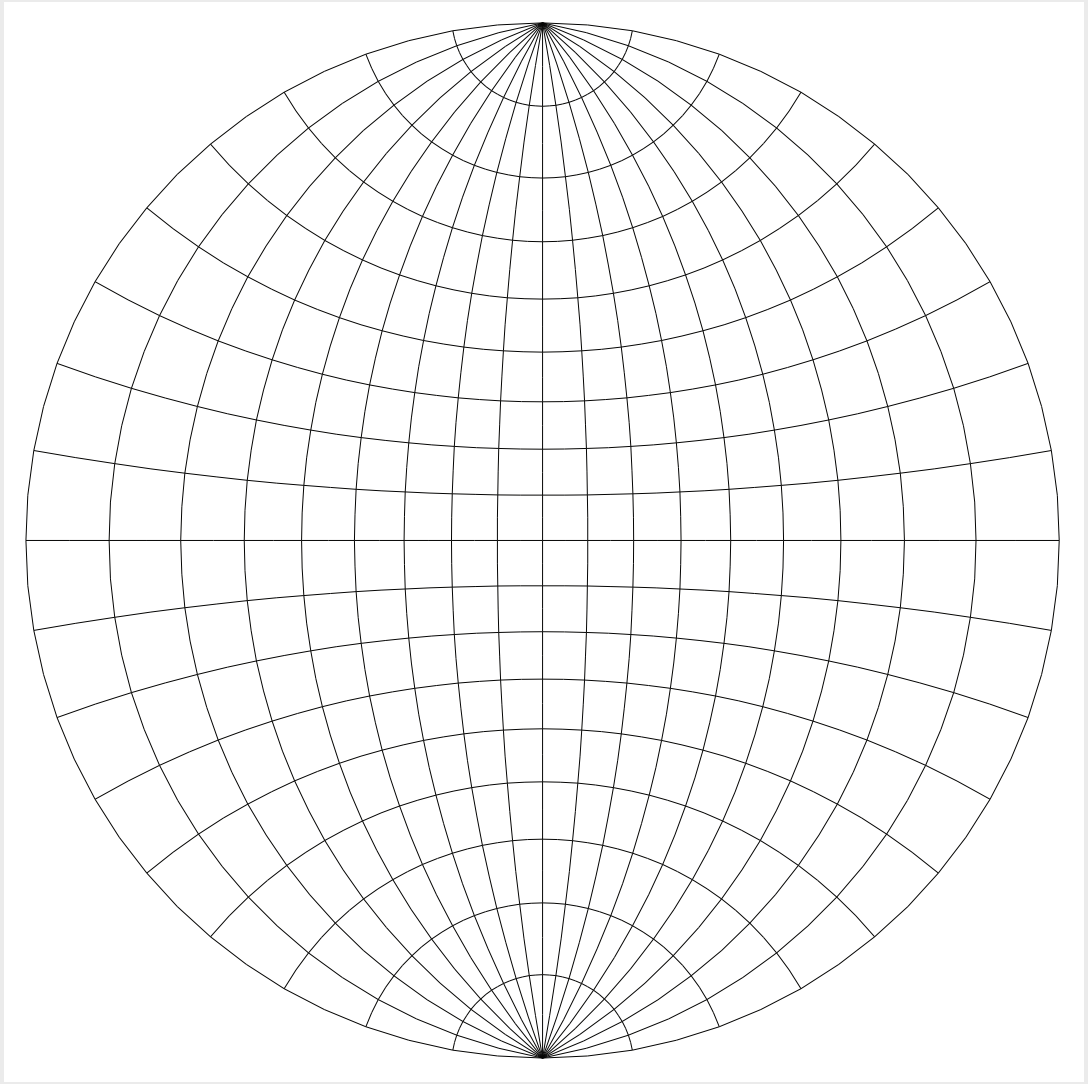


Faulting



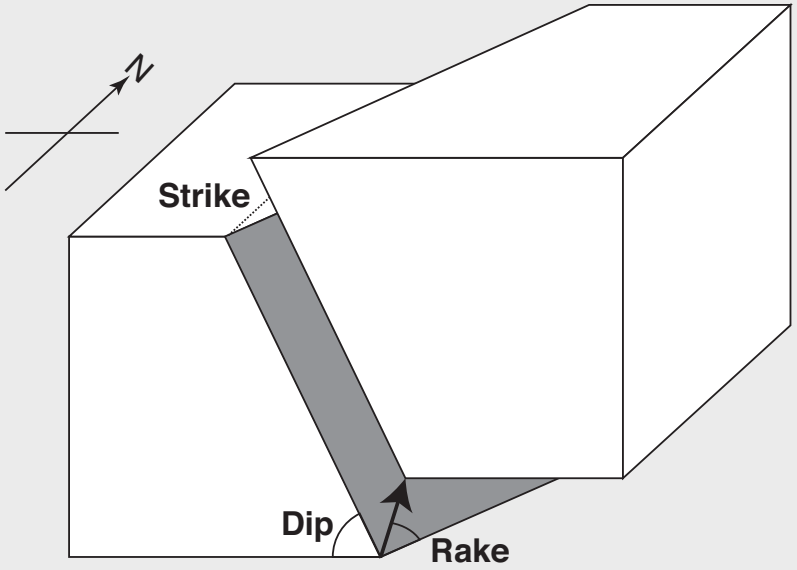
Focal mechanism

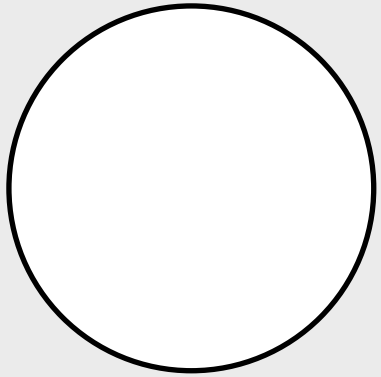




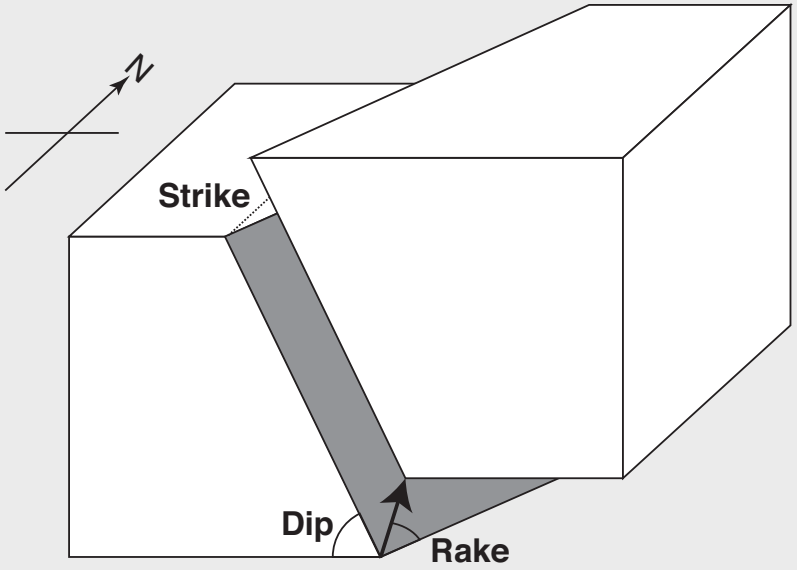
Strike: 0-360
Dip: 0-90
Rake: 0-360

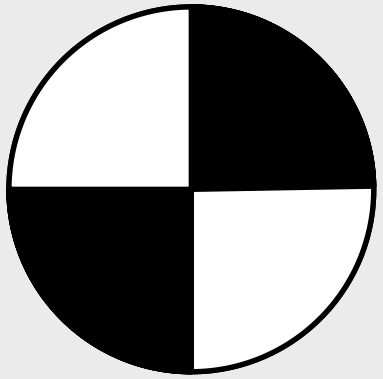
[s, d, r]=[0,90,0]



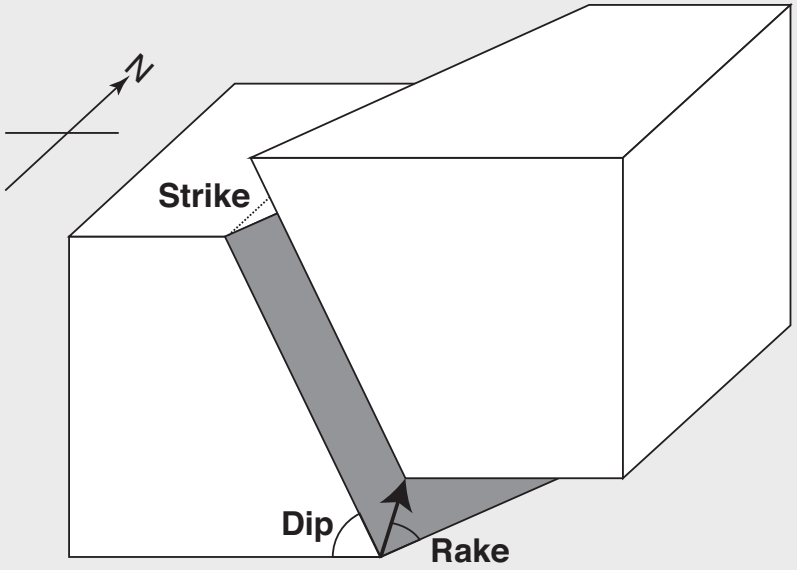


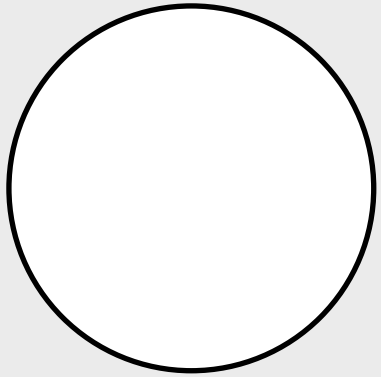
[s, d, r]=[0,90,0]



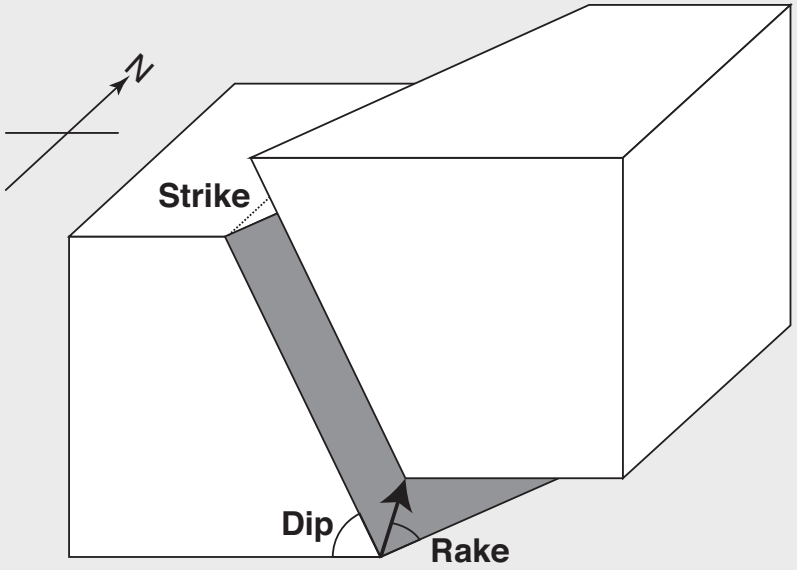


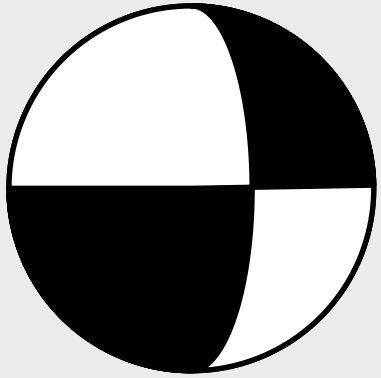
[s, d, r]=[0,60,0]





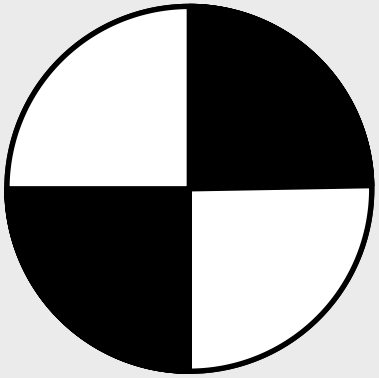
[s, d, r]=[0,60,0]





[s, d, r]=[0,90-0,0]

90



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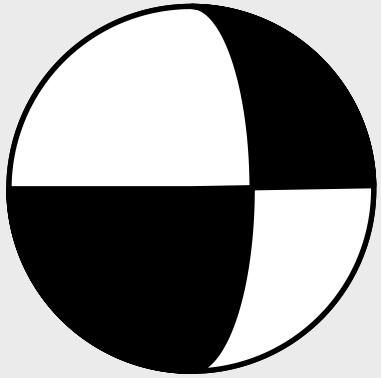

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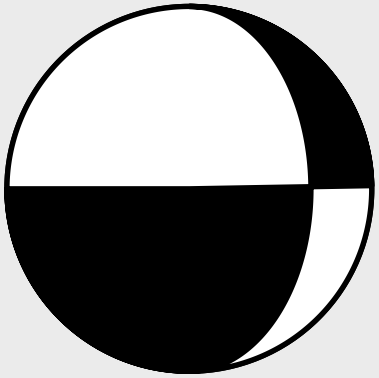

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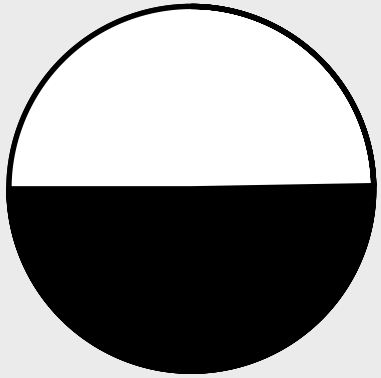

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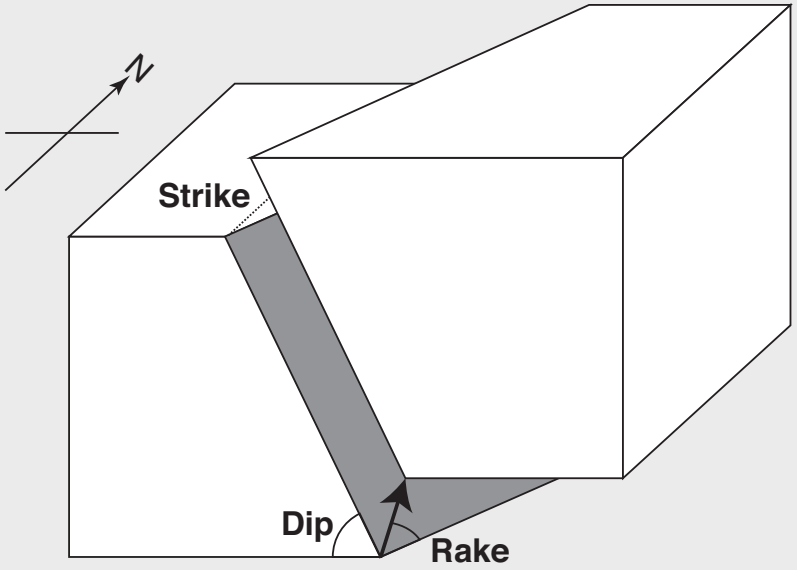

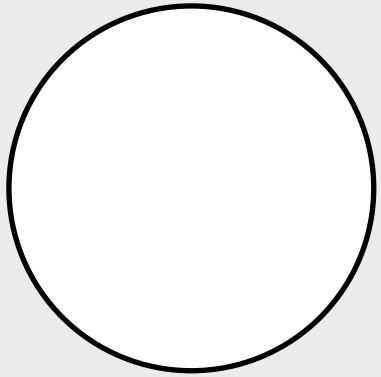

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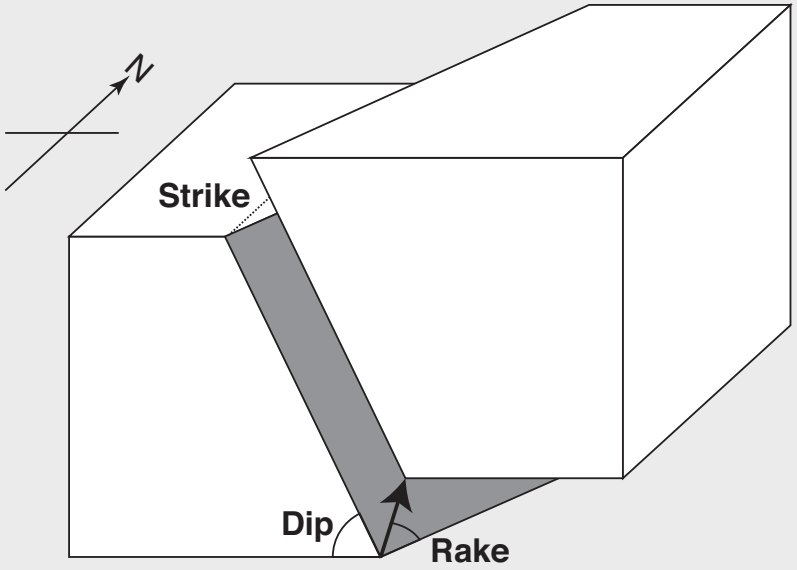

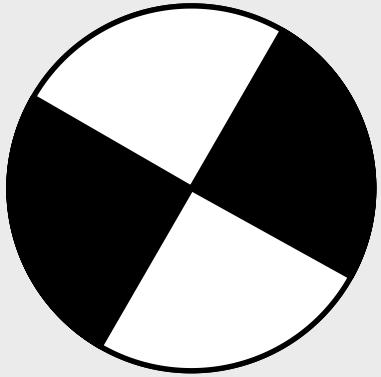

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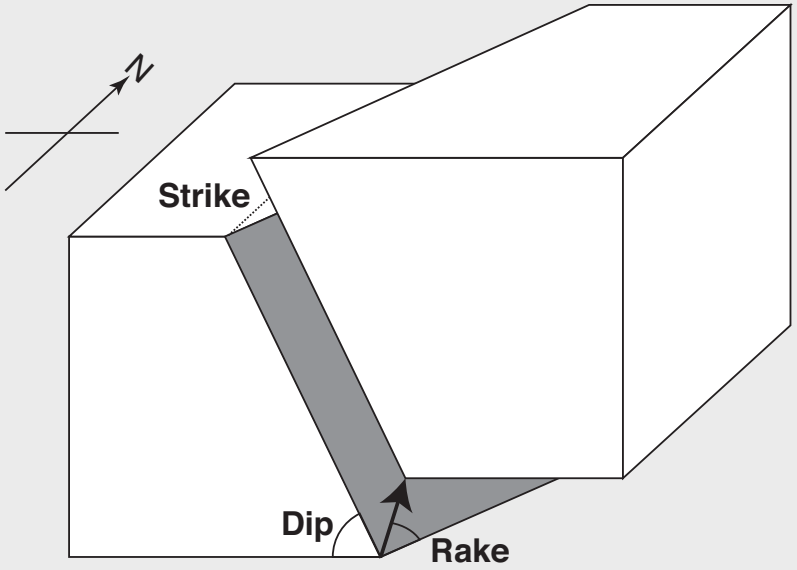

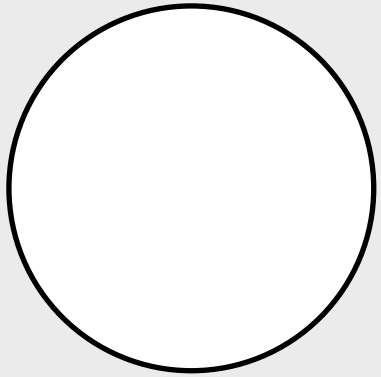

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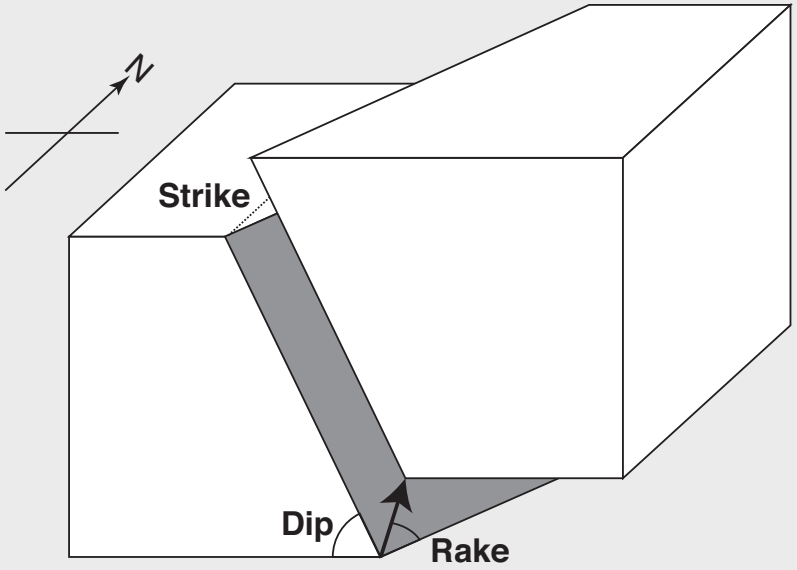

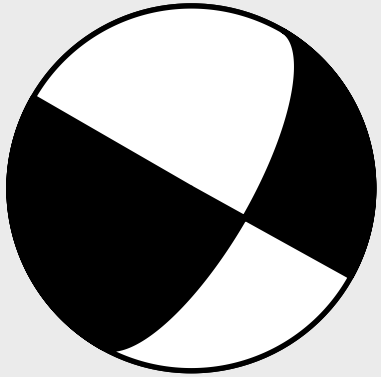

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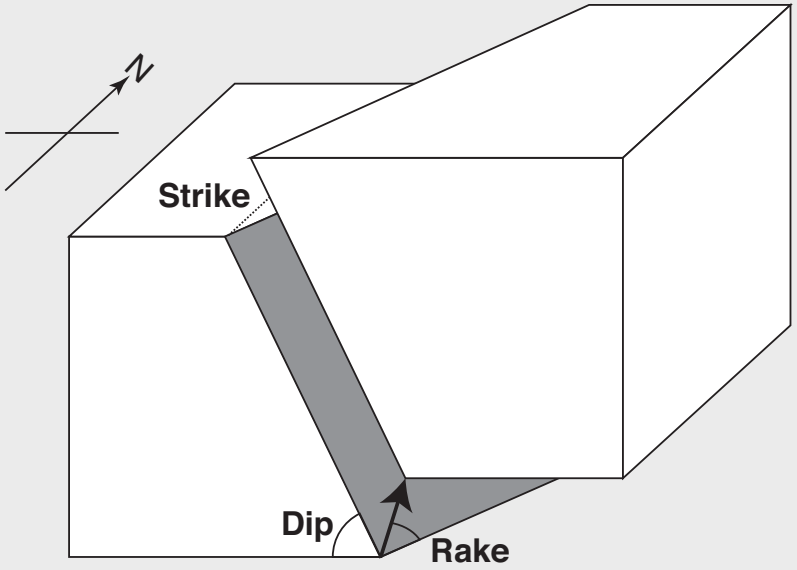

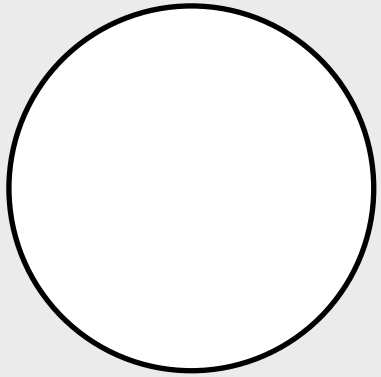

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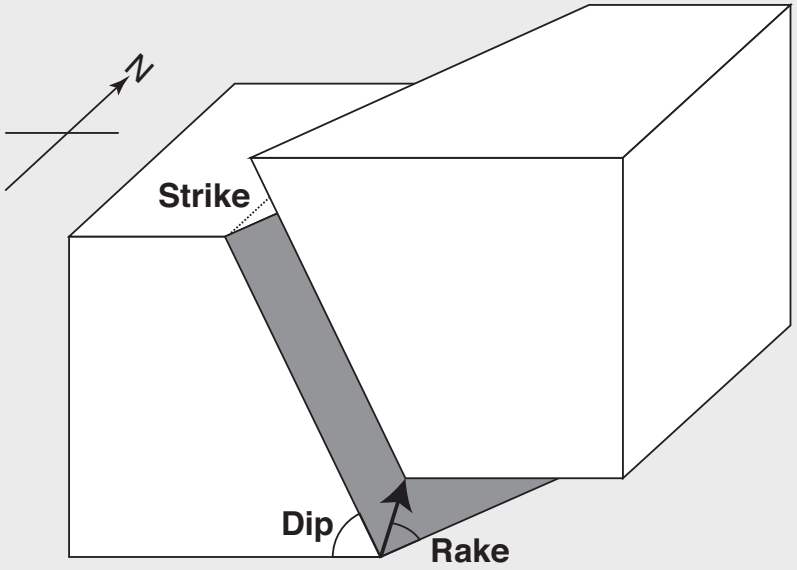

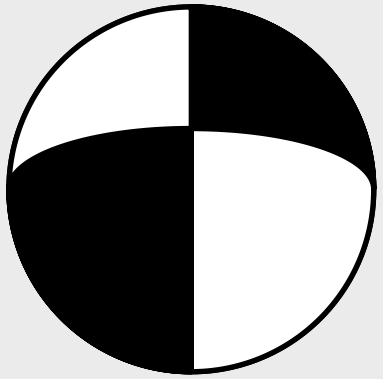

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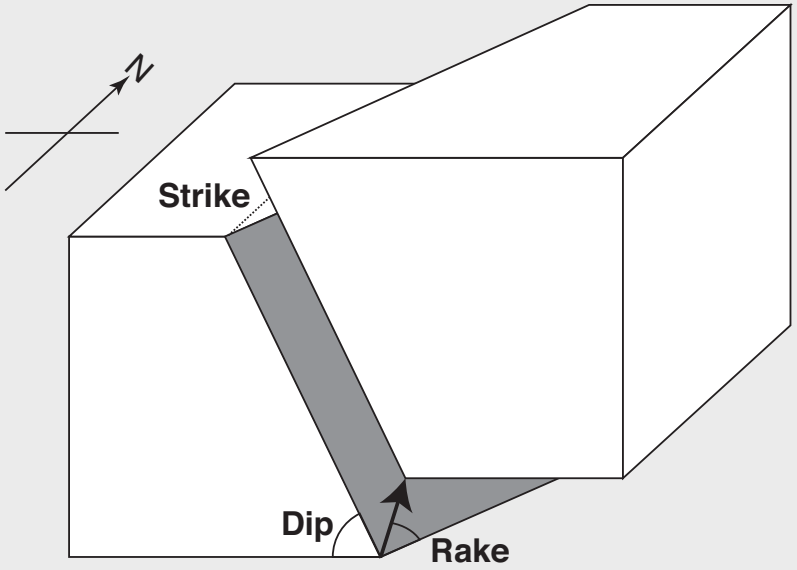

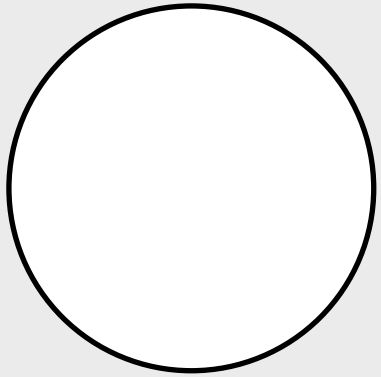

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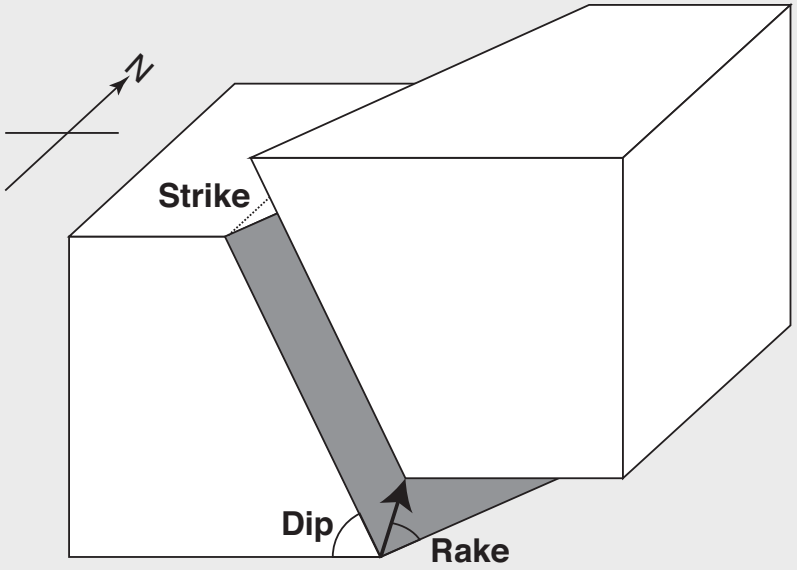
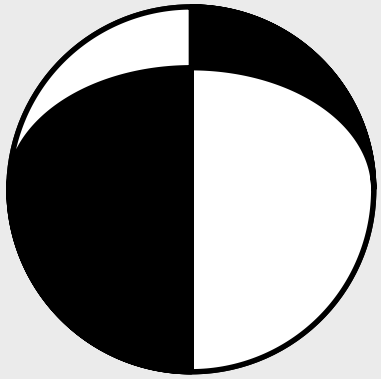
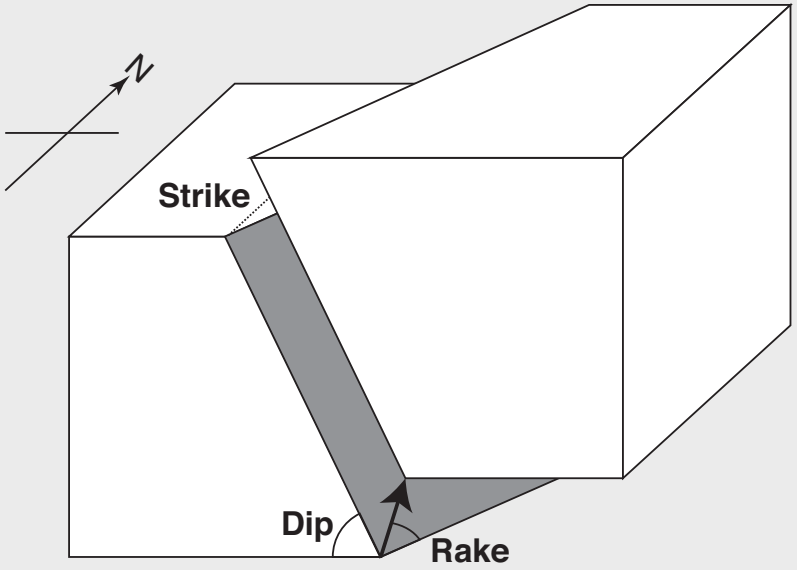
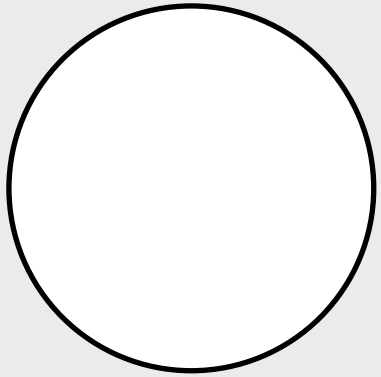


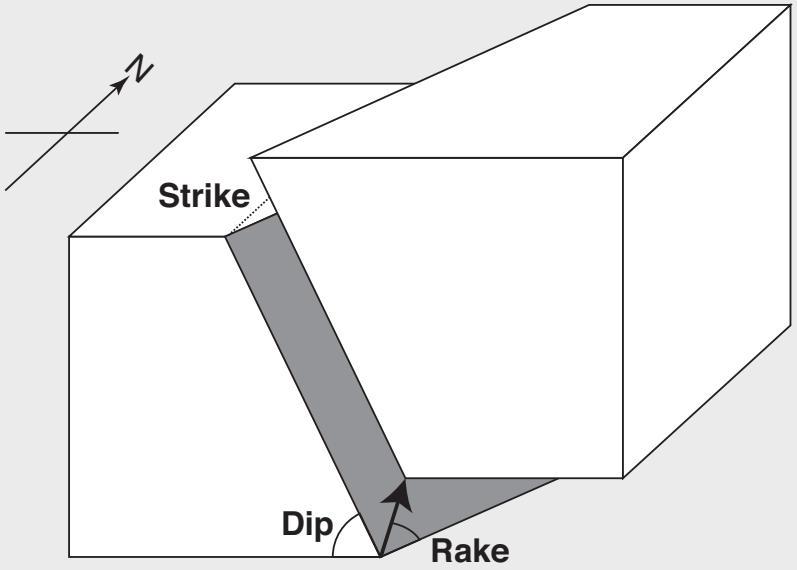


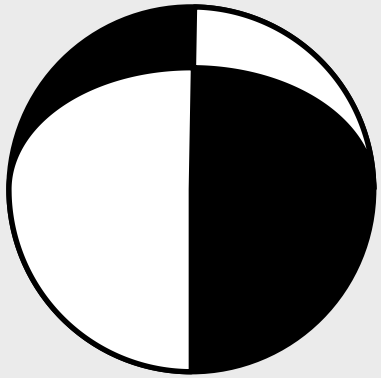
[s, d, r]=[270,30,0]





[s, d, r]=[270,30,0]





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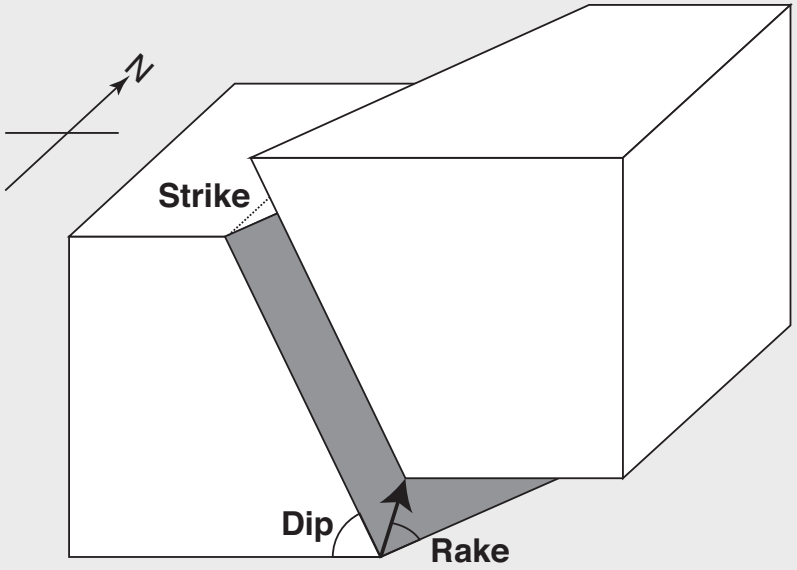
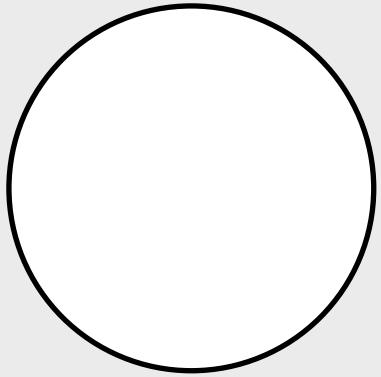
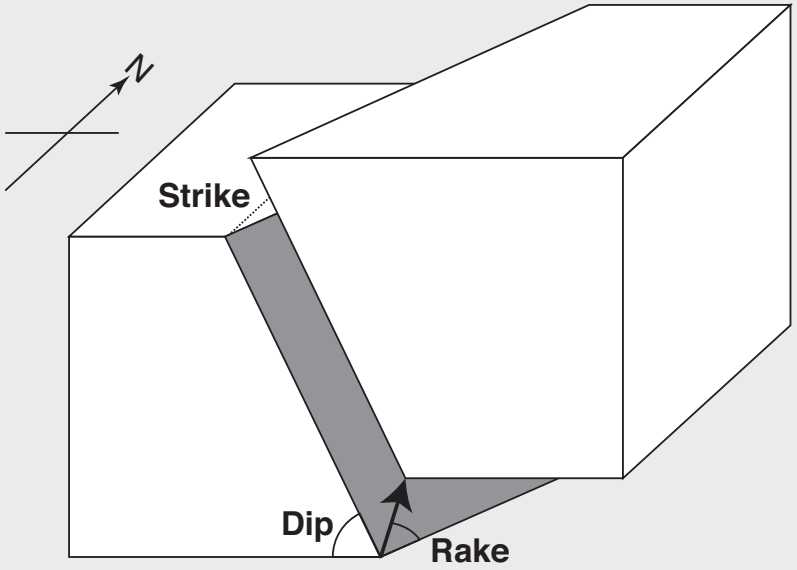
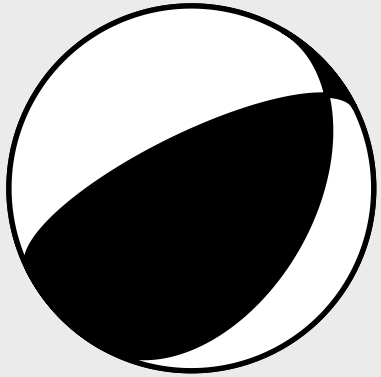


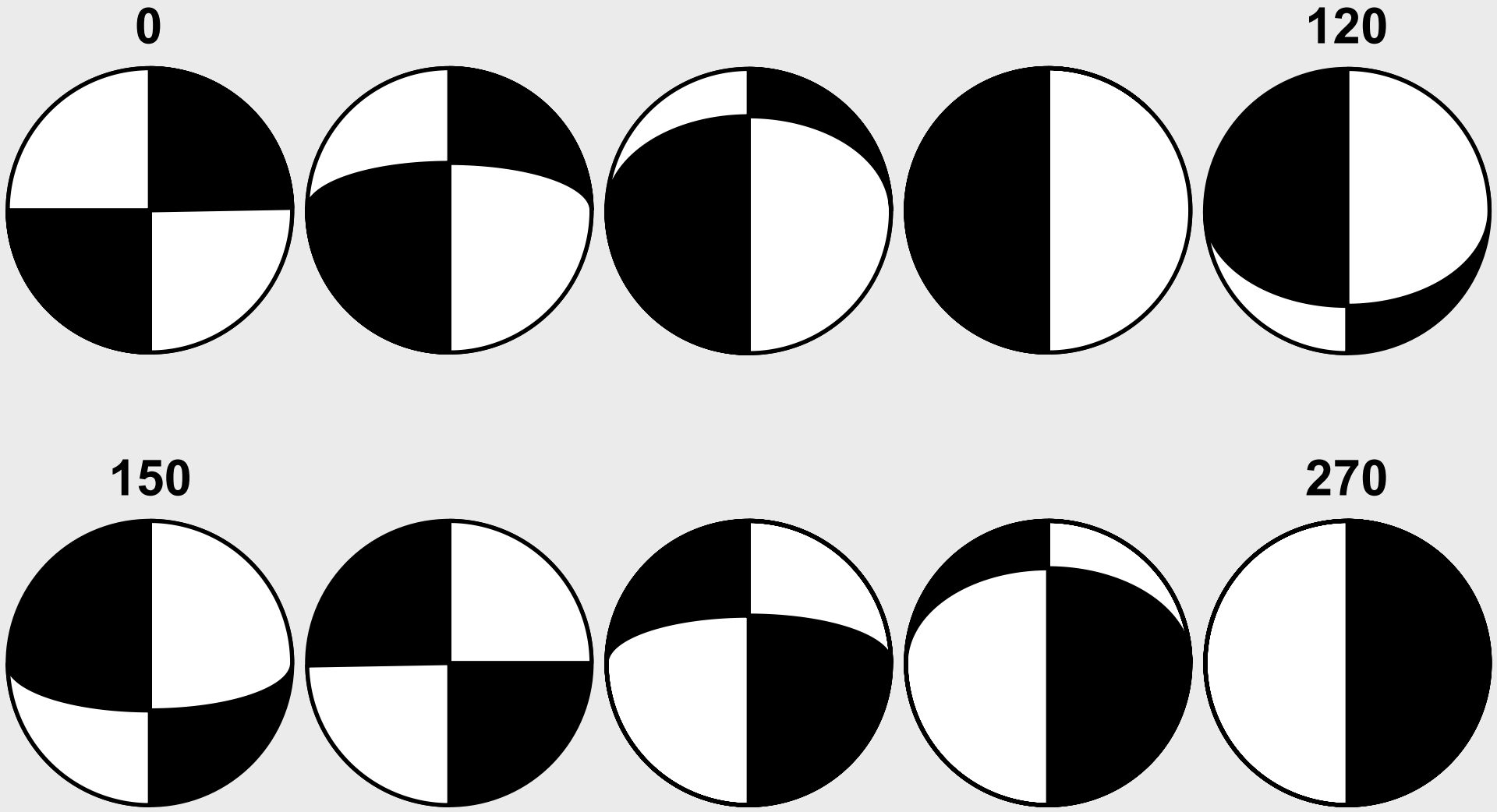


[s, d, r]=[30,30,60]

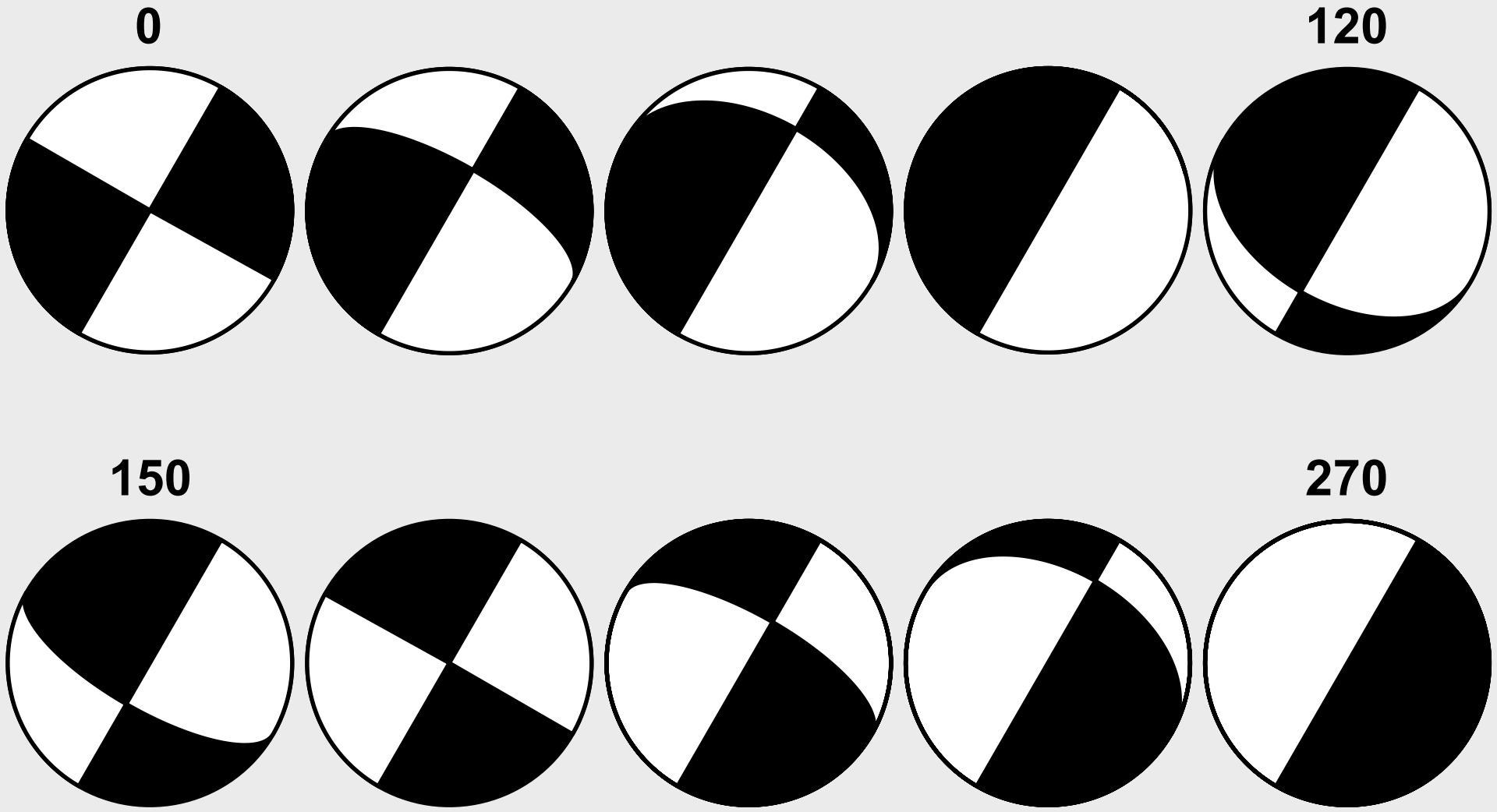




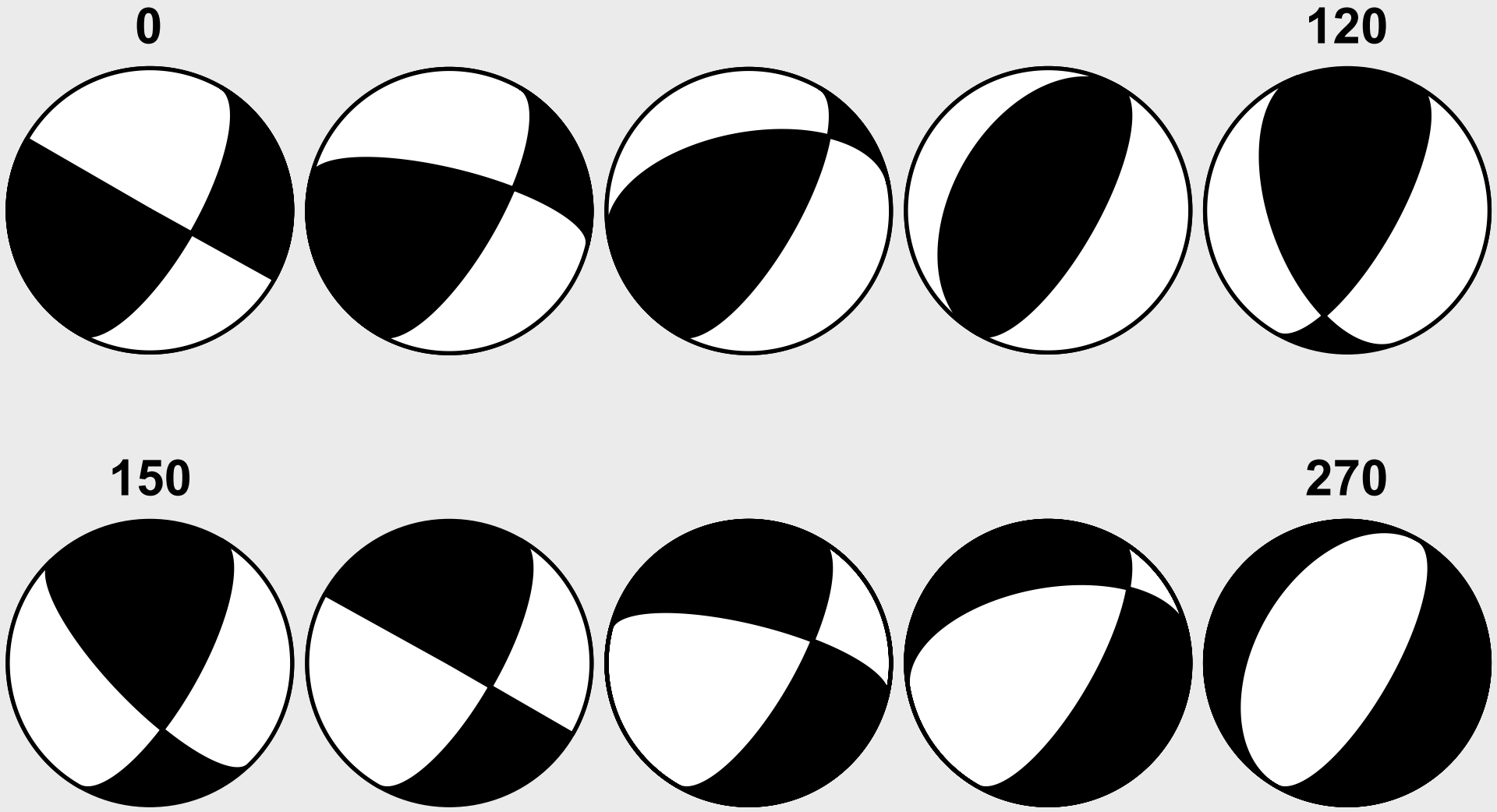
[s, d, r]=[0,90,0-270]



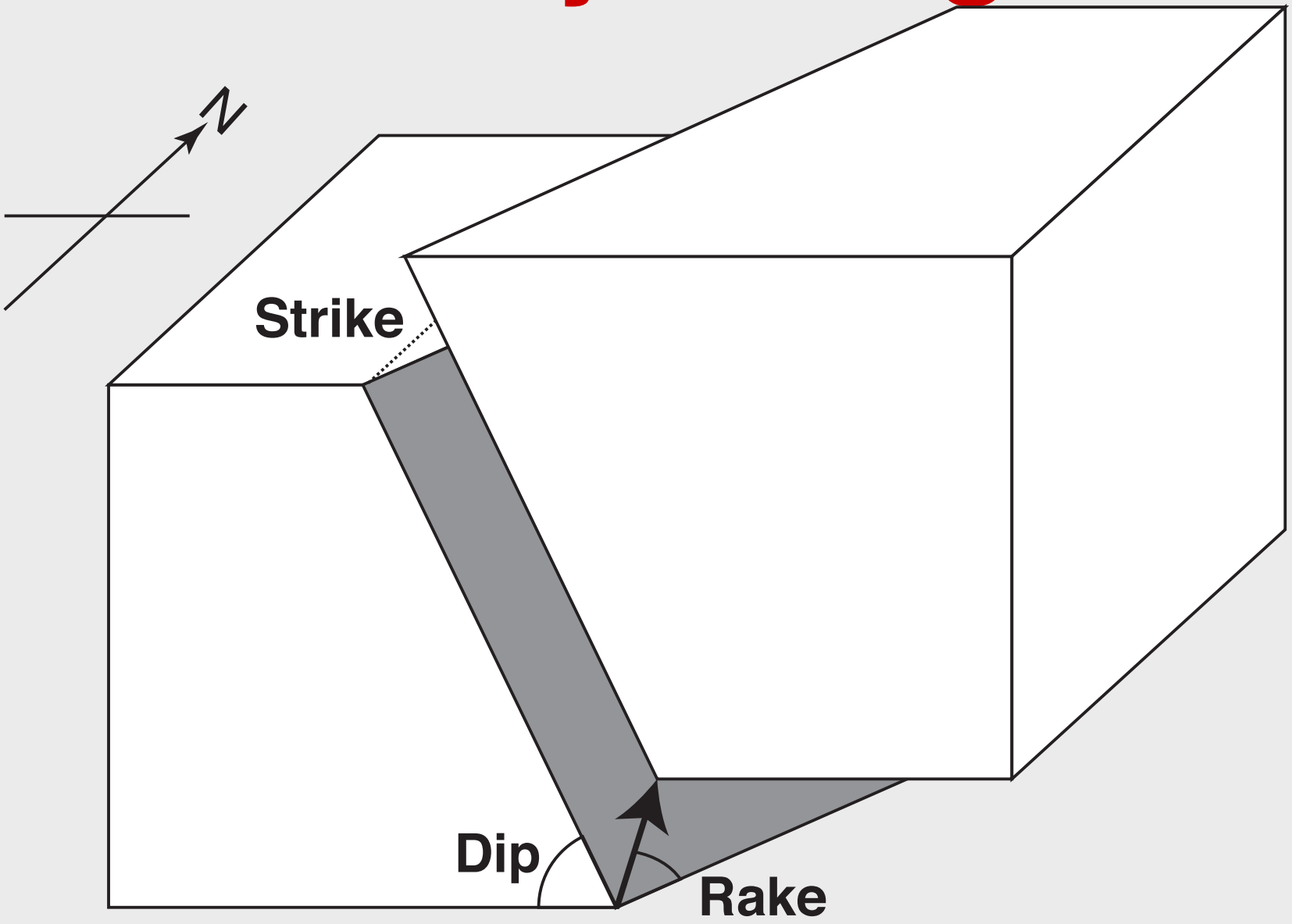
[s, d, r]=[30,90,0-270]



[s, d, r]=[30,60,0-270]

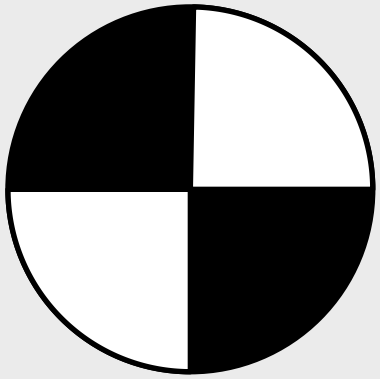


Are they enough?



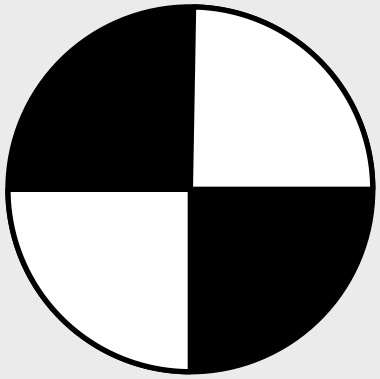
Are they enough?

Moment tensor



Moment tensor

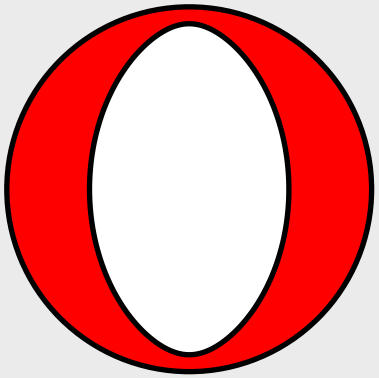
[s,d,r]=[0,90,0]



$$\frac{1}{\sqrt{2}}\begin{pmatrix} 0 & 1 & 0 \\ 1 & 0 & 0 \\ 0 & 0 & 0 \end{pmatrix}$$

Moment tensor

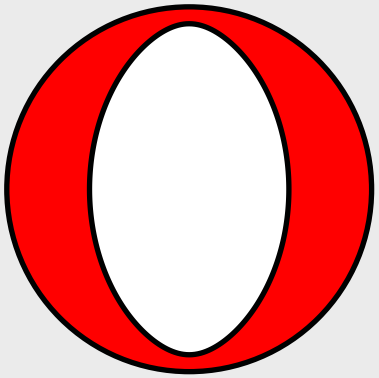
$$\begin{pmatrix} 0.0566 & 0 & 0 \\ 0 & 1.7015 & 0 \\ 0 & 0 & -1.758 \end{pmatrix}$$



Moment tensor

$$\begin{pmatrix} 0.0566 & 0 & 0 \\ 0 & 1.7015 & 0 \\ 0 & 0 & -1.758 \end{pmatrix}$$

$$\begin{pmatrix} 0 & 0 & 0 \\ 0 & 1.7298 & 0 \\ 0 & 0 & -1.7298 \end{pmatrix}$$



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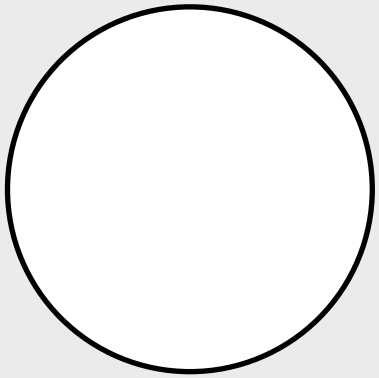
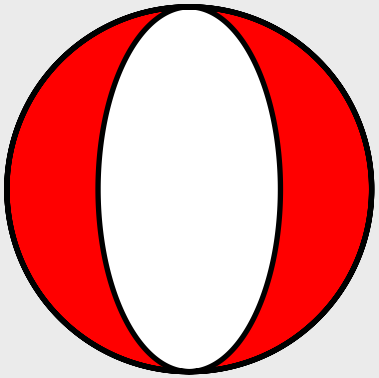


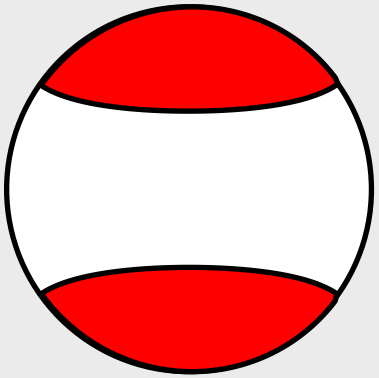
$$\begin{pmatrix} -7.4e-17 & 0 & 0 \\ 0 & -7.4e-17 & 0 \\ 0 & 0 & -7.4e-17 \end{pmatrix}$$

+

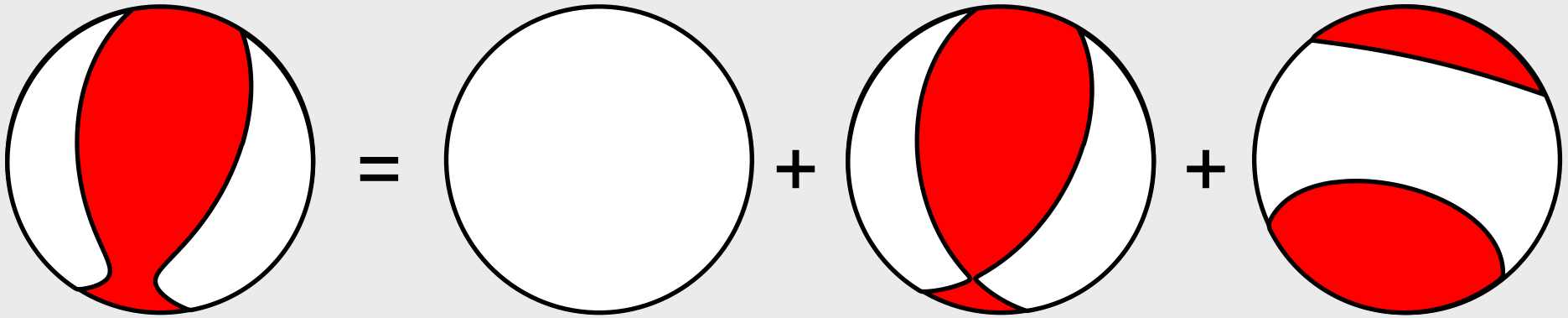


$$\begin{pmatrix} 0.0566 & 0 & 0 \\ 0 & -0.0283 & 0 \\ 0 & 0 & 0.0283 \end{pmatrix}$$

+



Moment tensor

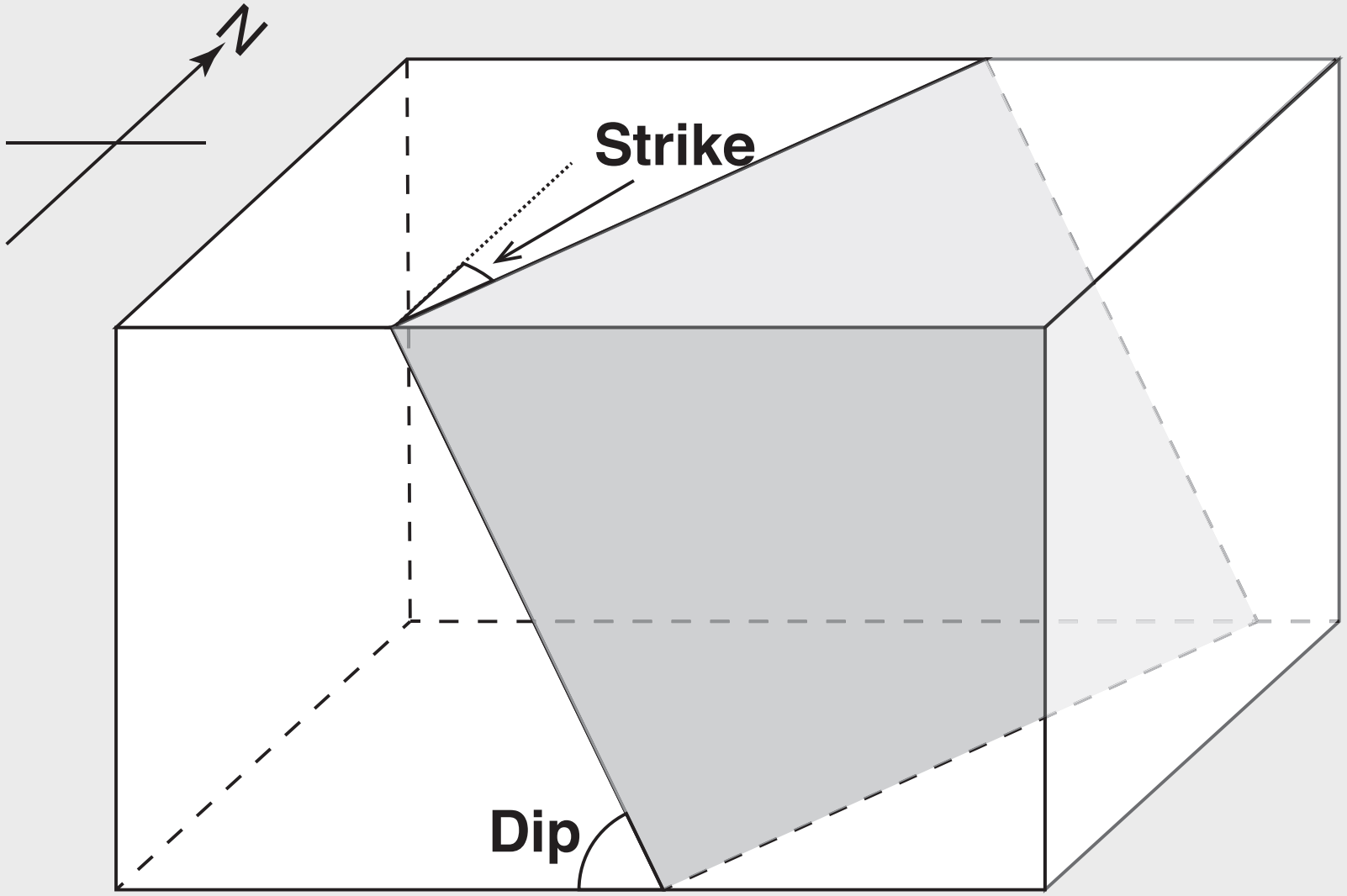


Moment magnitude

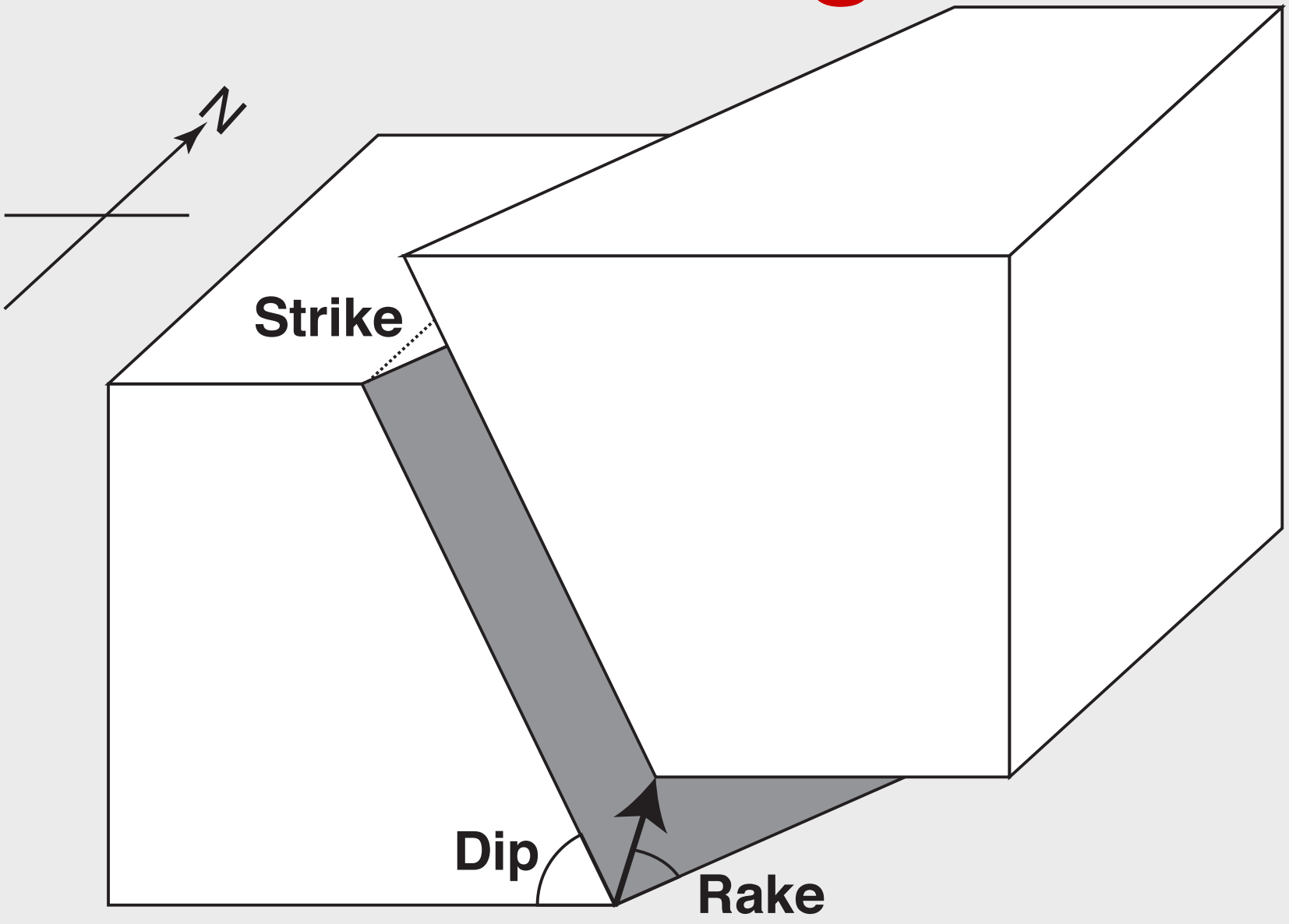
$$\mathbf{M}_0 = \frac{1}{\sqrt{2}} \left(\sum_{ij} \mathbf{M}_{ij}^2 \right)^{1/2}$$

$$\mathbf{M}_w = \frac{2}{3} (\log_{10} \mathbf{M}_0 - 9.1)$$

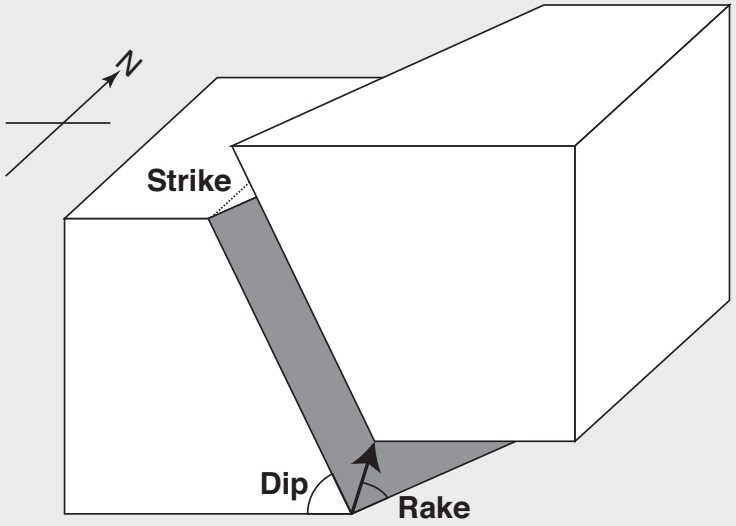
Faulting

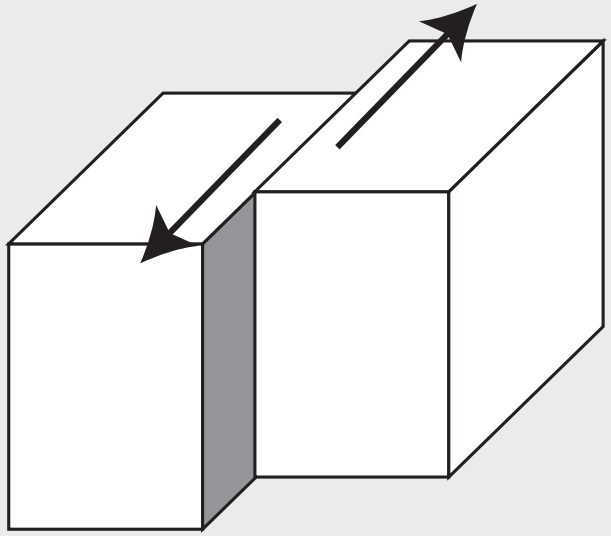


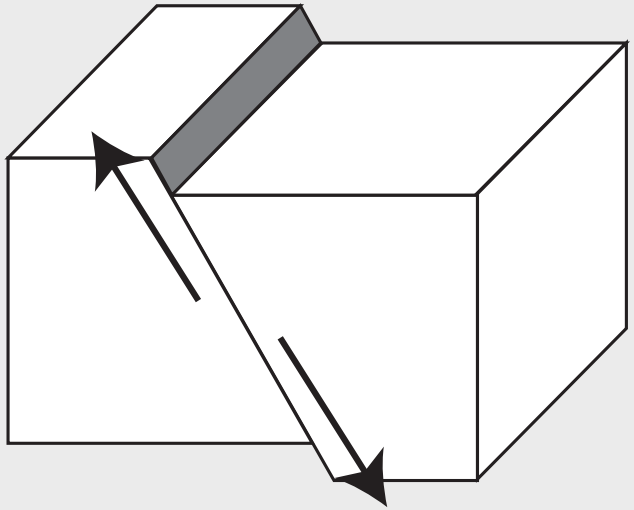
Faulting

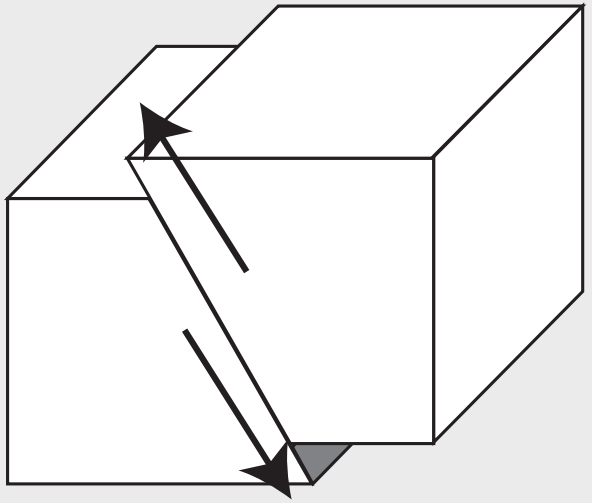


Faulting

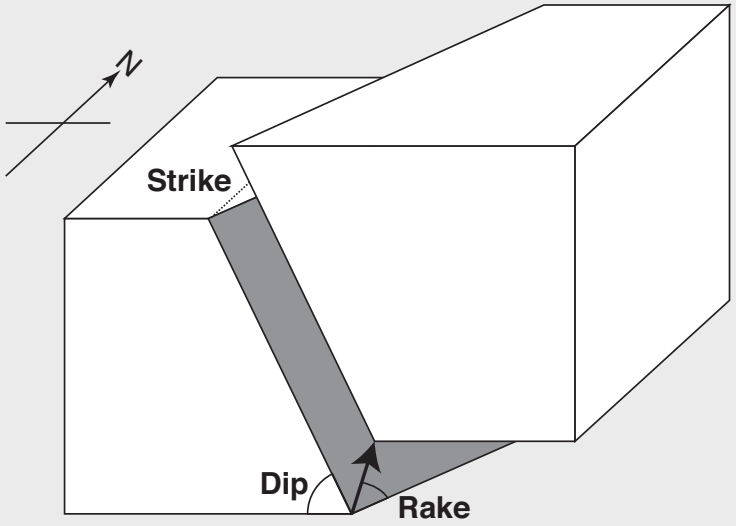




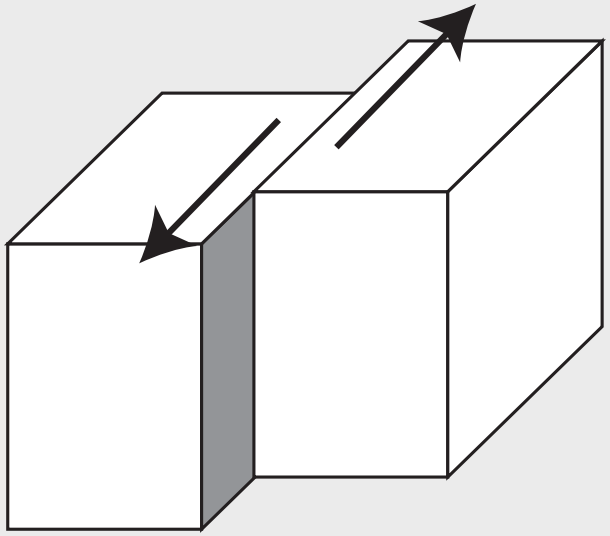




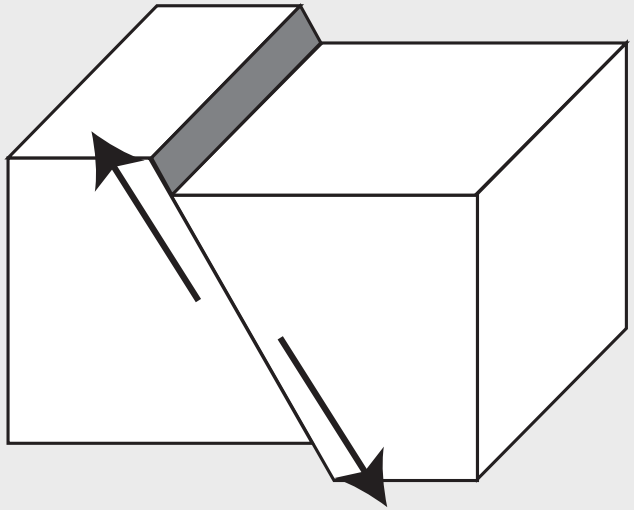
Faulting



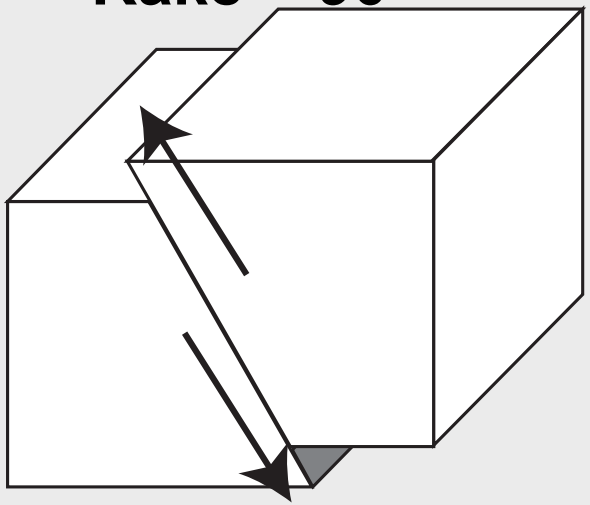
Rake = 0 (left)
180 (right)



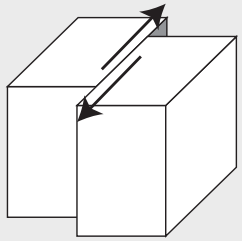
Rake = 270

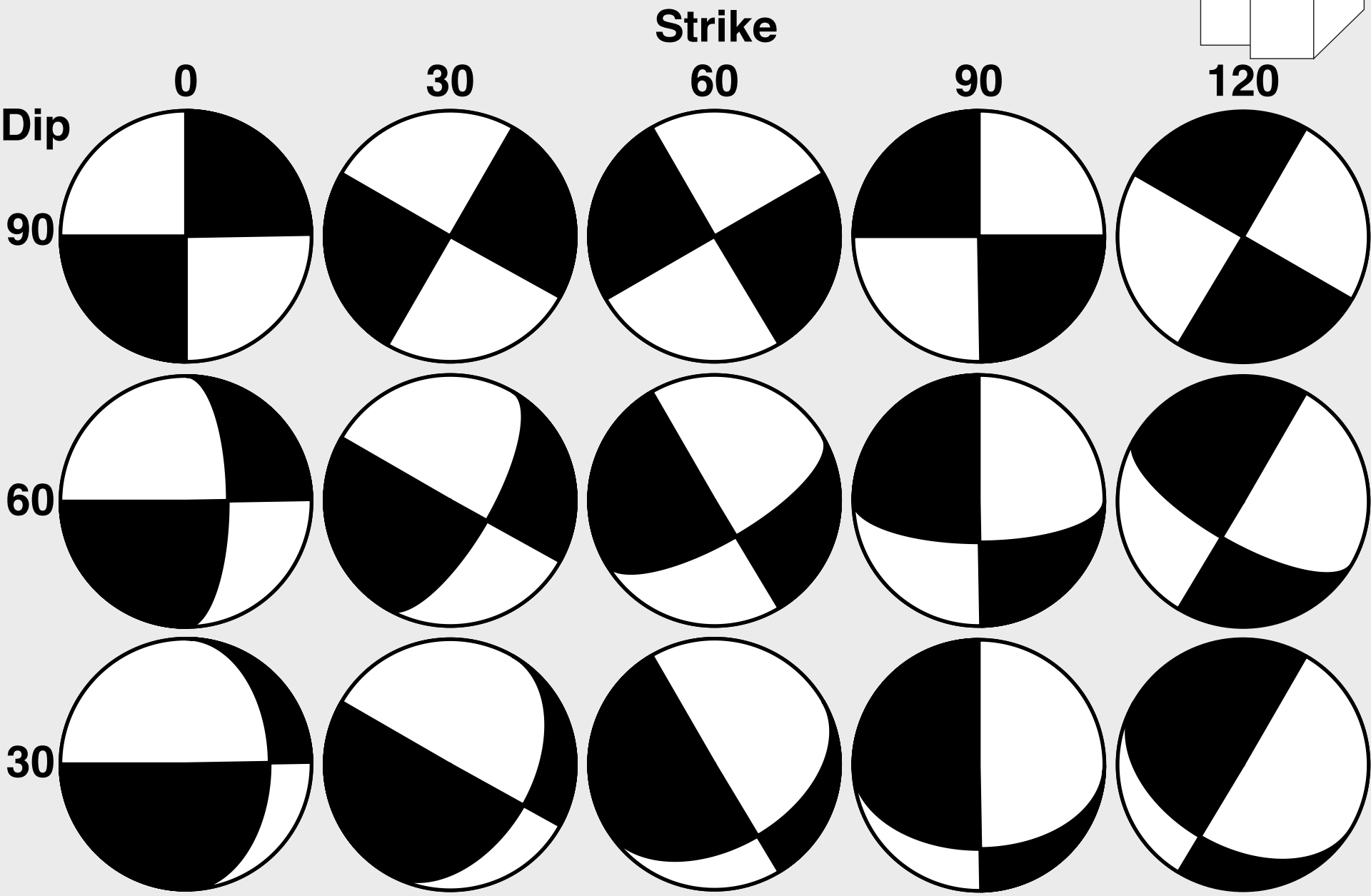


Rake = 90

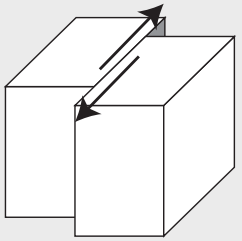


Left-lateral strike slip (rake=0)





Right-lateral strike slip (rake=180)

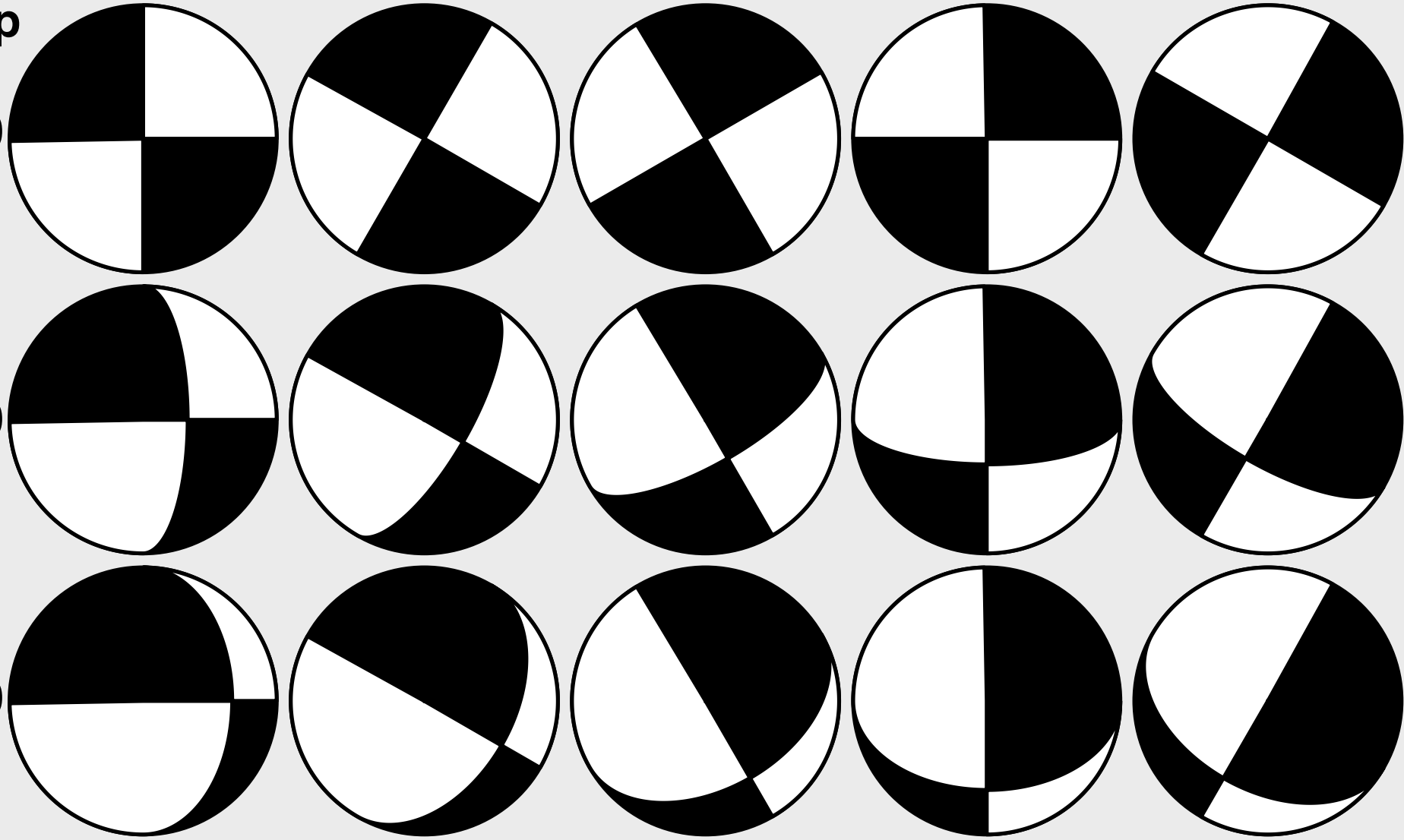


Strike

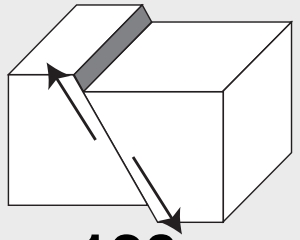
0 30 60 90 120

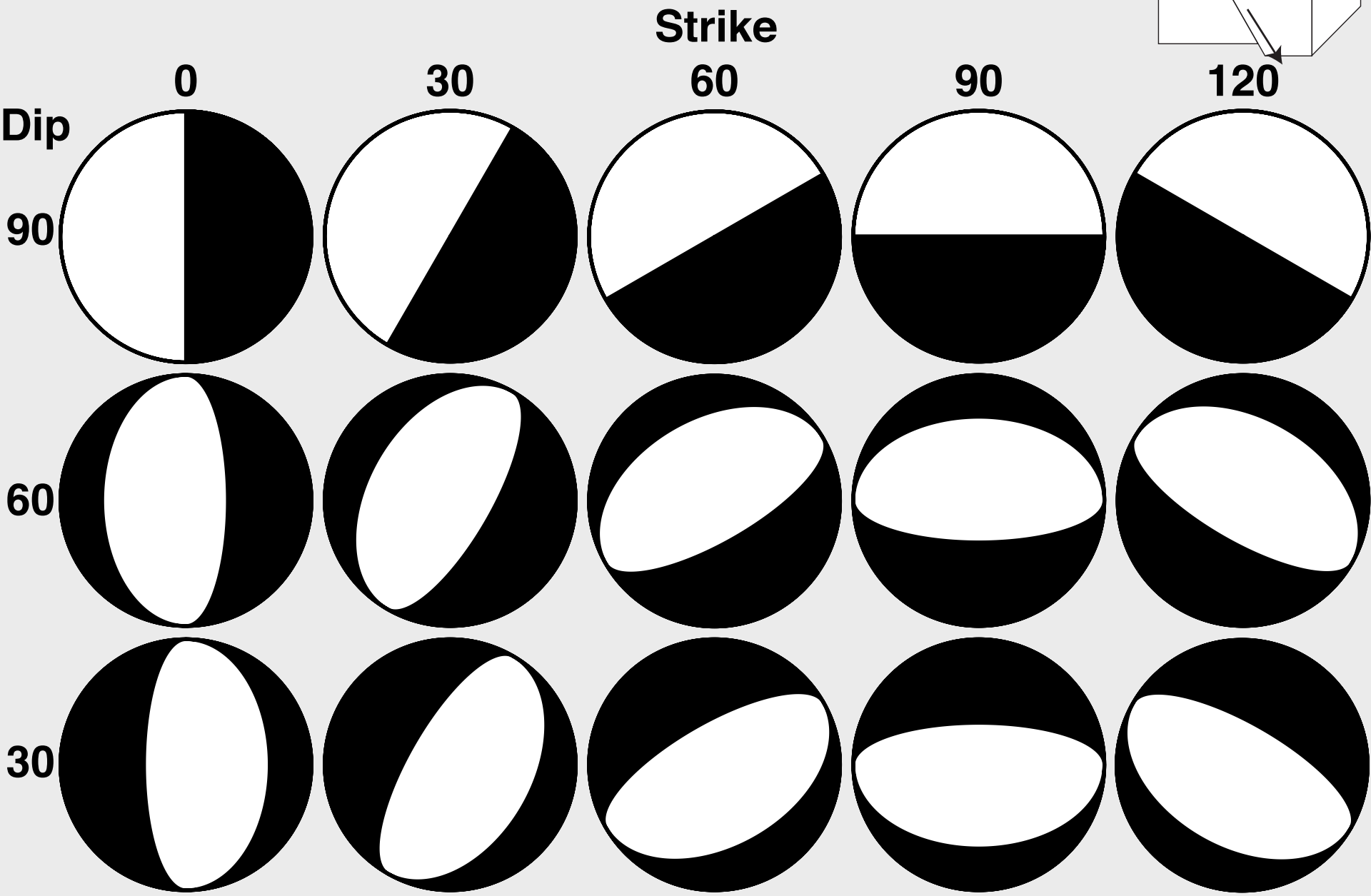
Dip

90 60 30

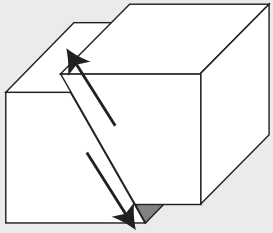


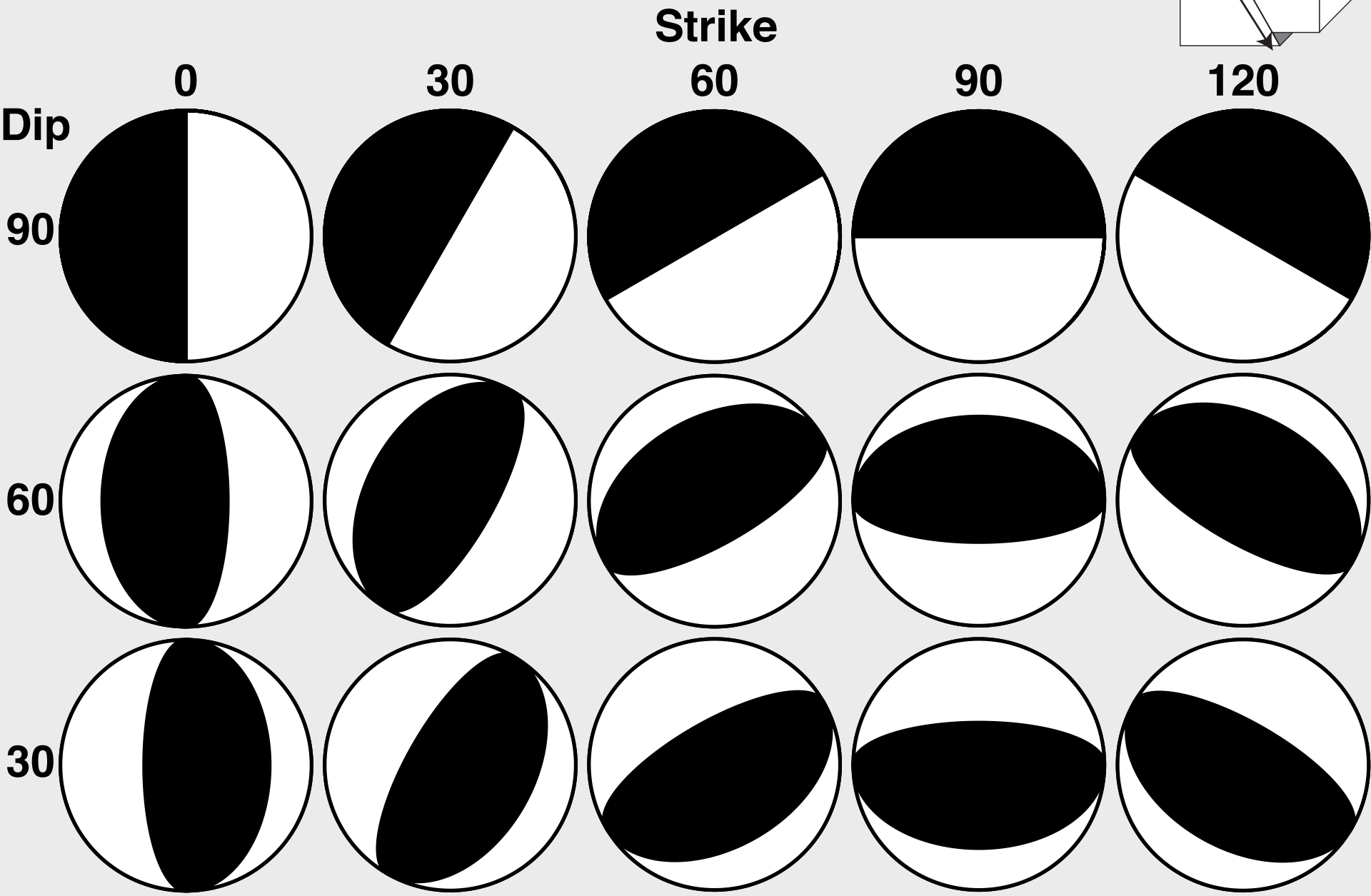
Normap-dip slip (rake=270)



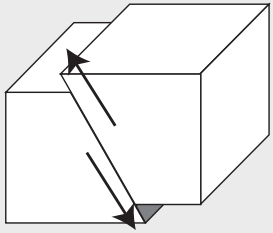


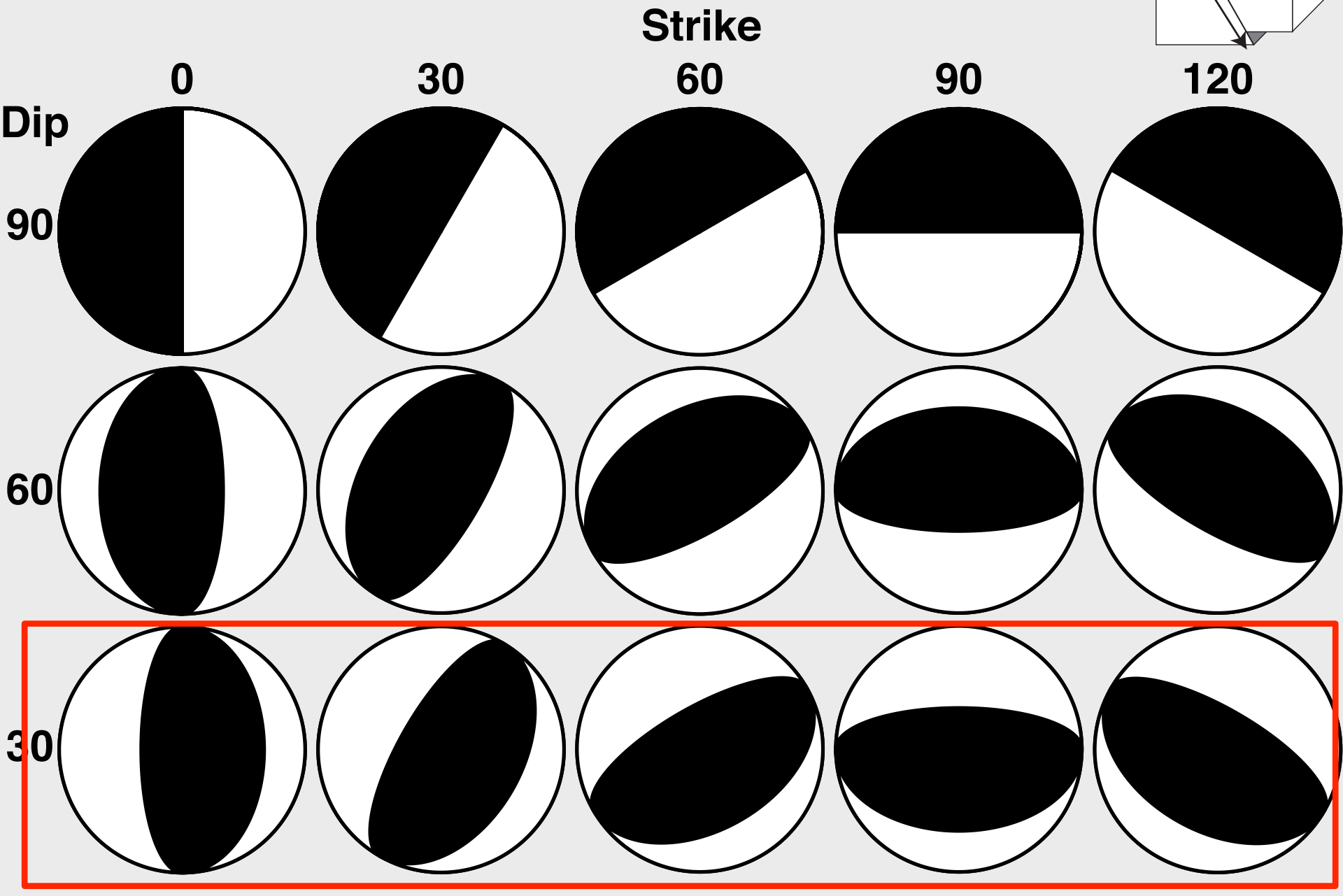
Reverse-dip slip (rake=90)





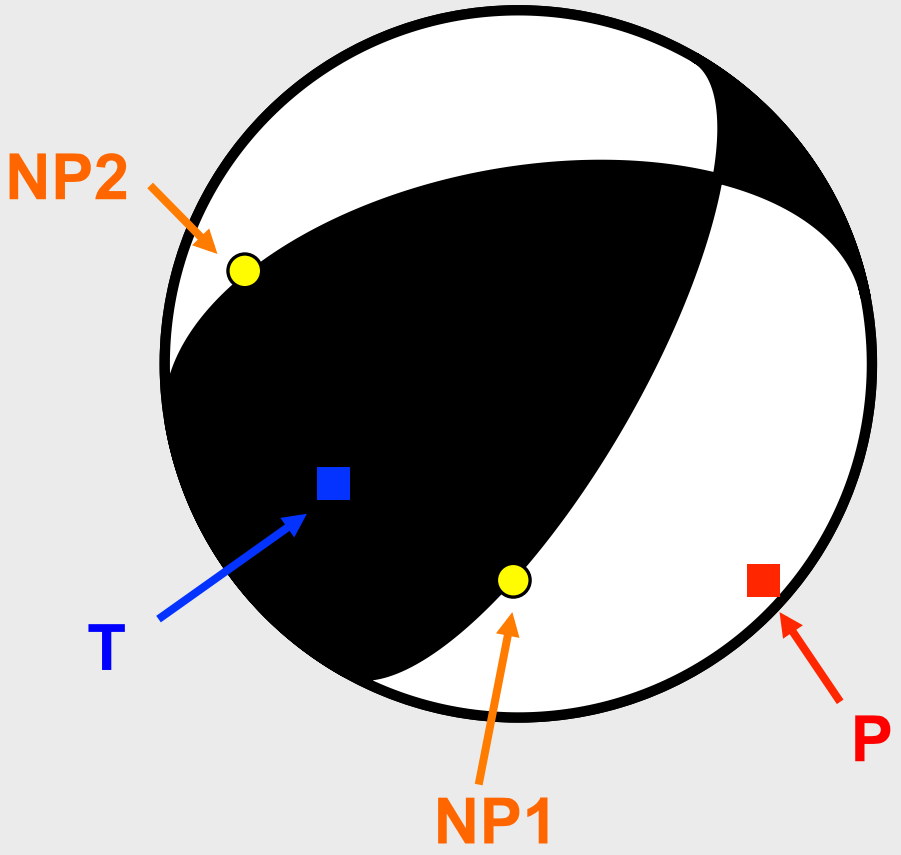
Reverse-dip slip (rake=90)



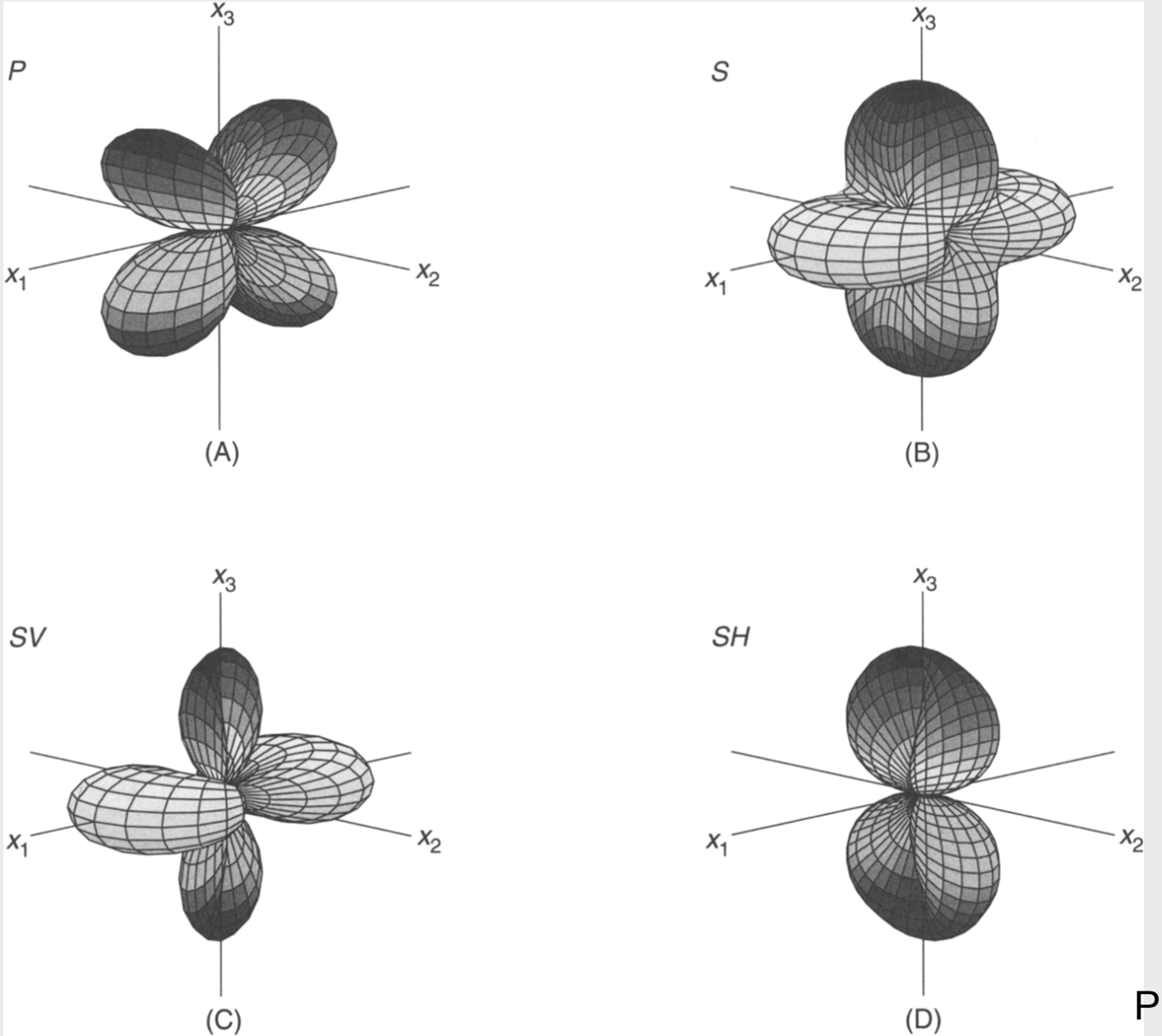


P and T axes

P: maximum compressive principal stress
T: minimum compressive principal stress

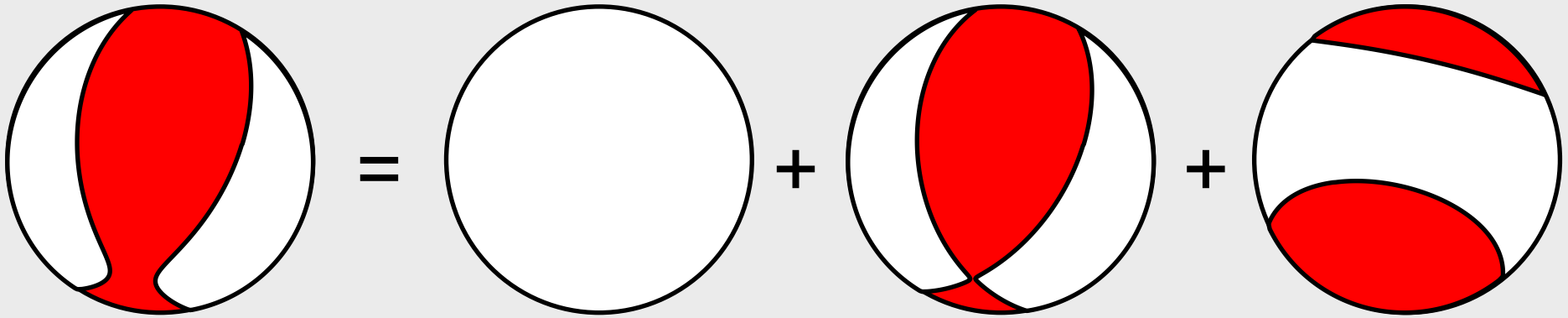


Radiation pattern



Pujol (2003)

Moment tensor



Characterize earthquake

What kind of faulting?

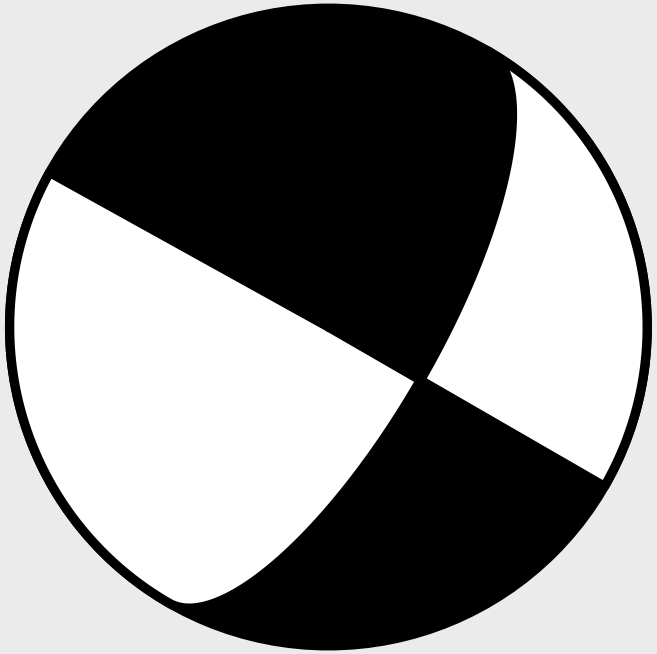
Is the dip shallow or steep?

Is the mechanism deviatoric?

…

Characterize earthquake

[s,d,r]=[30,60,180]



What kind of faulting?

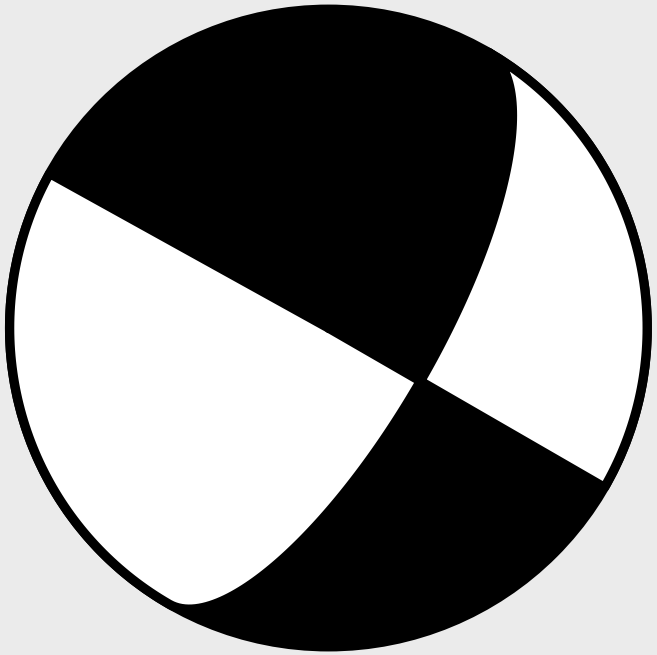
Is the dip shallow or steep?

Is the mechanism deviatoric?

What is the horizontal direction of faulting?

Characterize earthquake

[s,d,r]=[30,60,180]



What kind of faulting?

Right lateral strike slip

Is the dip shallow or steep?

Steep

Is the mechanism deviatoric?

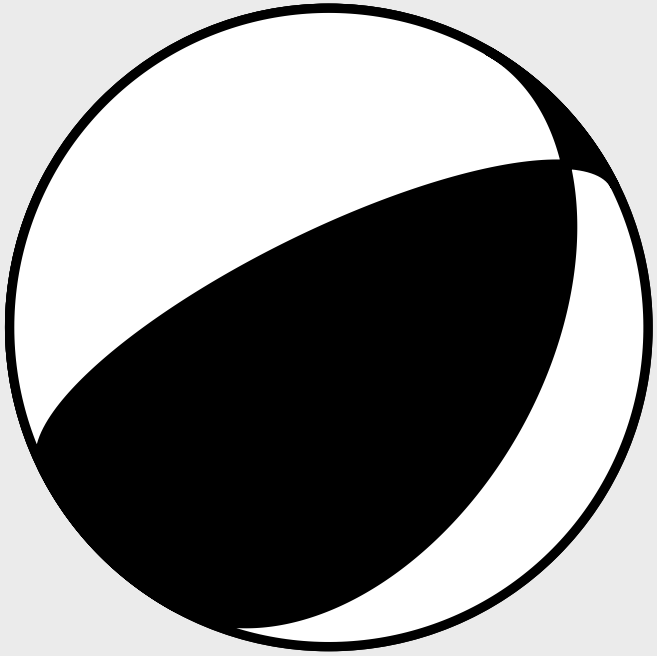
Yes

What is the horizontal direction of faulting?

30 degrees from North

Characterize earthquake

[s,d,r]=[30,30,60]



What kind of faulting?

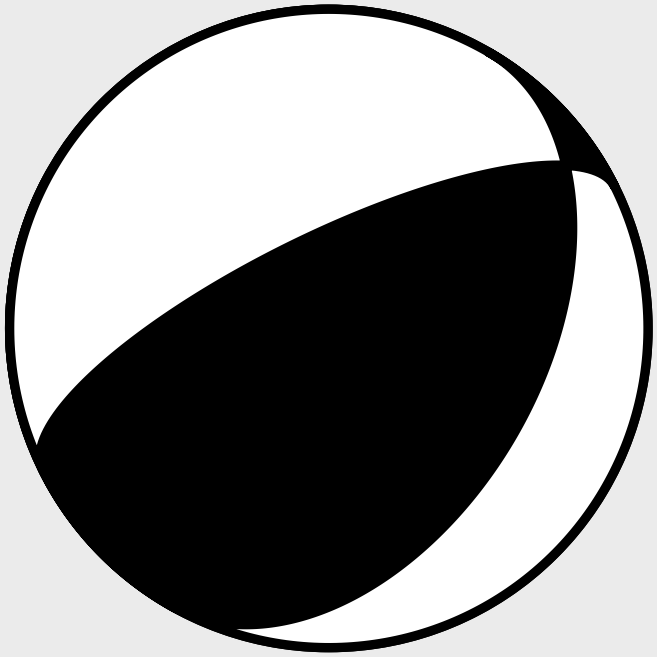
Is the dip shallow or steep?

Is the mechanism deviatoric?

What is the horizontal direction of faulting?

Characterize earthquake

[s,d,r]=[30,30,60]



What kind of faulting?

Mostly reverse-dip slip with some left-lateral strike slip

Is the dip shallow or steep?

Shallow

Is the mechanism deviatoric?

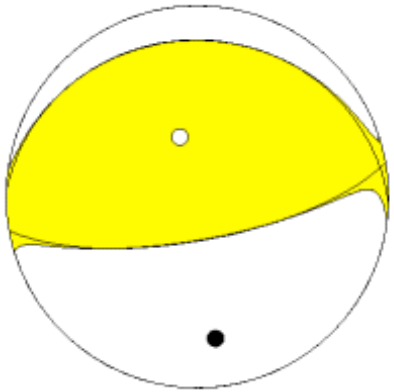
Yes

What is the horizontal direction of faulting?

30 degrees from North

EASTERN TURKEY

```
11/10/23 10:41:21.73

Epicenter:  38.710   43.446
MW 7.3

USGS CENTROID MOMENT TENSOR
11/10/23 10:41:44.50
Centroid:  39.451   43.354
Depth  16          No. of sta: 159
Moment Tensor;   Scale 10**19 Nm
  Mrr= 5.89        Mtt=-6.13
  Mpp= 0.24        Mrt= 7.73
  Mrp= 1.60        Mtp=-0.51
 Principal axes:
  T  Val=  9.83  Plg=63  Azm=344
  N        0.22       4       81
  P      -10.05      26      173

Best Double Couple:Mo=9.9*10**19
 NP1:Strike= 80 Dip=71 Slip=  86
 NP2:       272     19       101
```



http://earthquake.usgs.gov/earthquakes/

What kind of faulting?

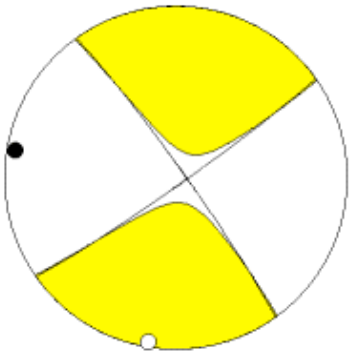
Is the dip shallow or steep (closer to 0 or 90 degrees)?

Is the mechanism deviatoric?

What is meant by “centroid”?

OKLAHOMA

```
11/11/06 03:53:10.53

Epicenter:  35.537  -96.747
MW 5.6

USGS/SLU REGIONAL MOMENT TENSOR
Depth   7          No. of sta: 32
Moment Tensor;   Scale 10**17 Nm
  Mrr=-0.17        Mtt= 3.22
  Mpp=-3.05        Mrt=-0.07
  Mrp=-0.28        Mtp=-1.09
 Principal axes:
  T  Val=  3.40  Plg= 0  Azm=190
  N       -0.14      85       95
  P       -3.26       5      280

Best Double Couple:Mo=3.3*10**17
 NP1:Strike= 55 Dip=87 Slip=-176
 NP2:       324     86        -3
```



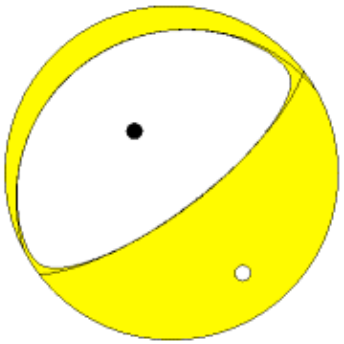
What kind of faulting?

What is the strike?

Is the mechanism deviatoric?

SOUTHERN TEXAS

```
11/10/20 12:24:40.58

Epicenter:  28.803  -98.154
MW 4.8

USGS/SLU REGIONAL MOMENT TENSOR
Depth    5          No. of sta: 22
Moment Tensor;    Scale 10**16 Nm
  Mrr=-1.05         Mtt= 0.73
  Mpp= 0.32         Mrt=-1.14
  Mrp=-0.91         Mtp= 0.46
 Principal axes:
  T  Val=  1.78  Plg=27  Azm=145
  N         0.03       3       53
  P        -1.80      63      318

Best Double Couple:Mo=1.8*10**16
 NP1:Strike= 53 Dip=72 Slip= -93
 NP2:        241     18       -82
```



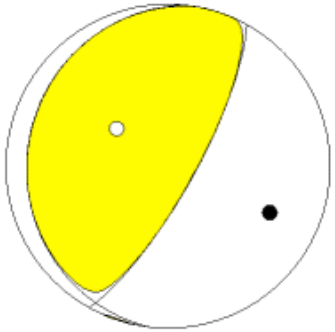
What kind of faulting?

What is the dip?

Is the mechanism deviatoric?

NEAR EAST COAST OF HONSHU, JAPAN

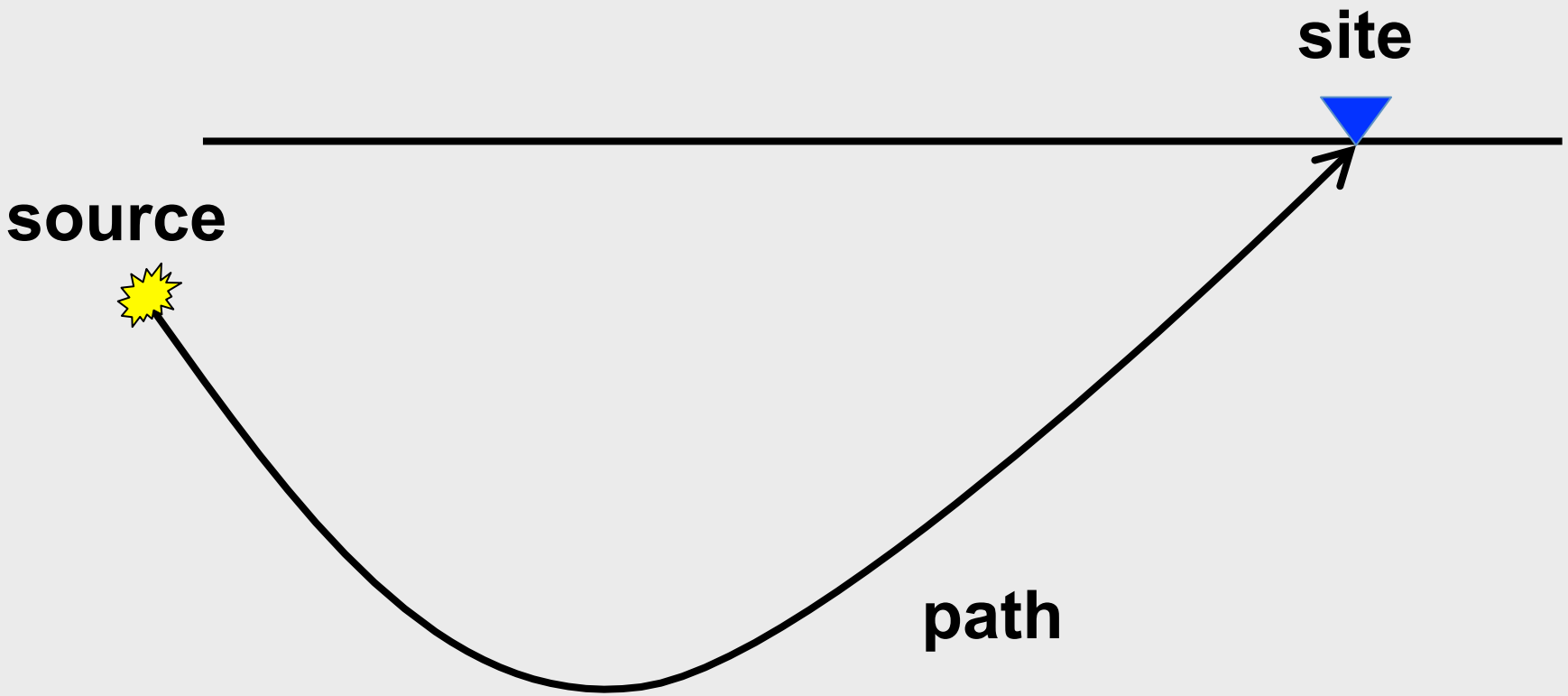
```
11/03/11 05:46:23.82

Epicenter:  38.308  142.383
MW 9.0

USGS CENTROID MOMENT TENSOR
11/03/11 05:47:47.20
Centroid:  38.486  142.597
Depth  10          No. of sta: 151
Moment Tensor;   Scale 10**22 Nm
  Mrr= 2.03        Mtt=-0.16
  Mpp=-1.87        Mrt= 2.06
  Mrp= 3.49        Mtp=-0.60
 Principal axes:
  T  Val=  4.57  Plg=58  Azm=306
  N       -0.05       5      208
  P       -4.52      32      115

Best Double Couple:Mo=4.5*10**22
 NP1:Strike= 29 Dip=77 Slip=  95
 NP2:       187     14         68
```



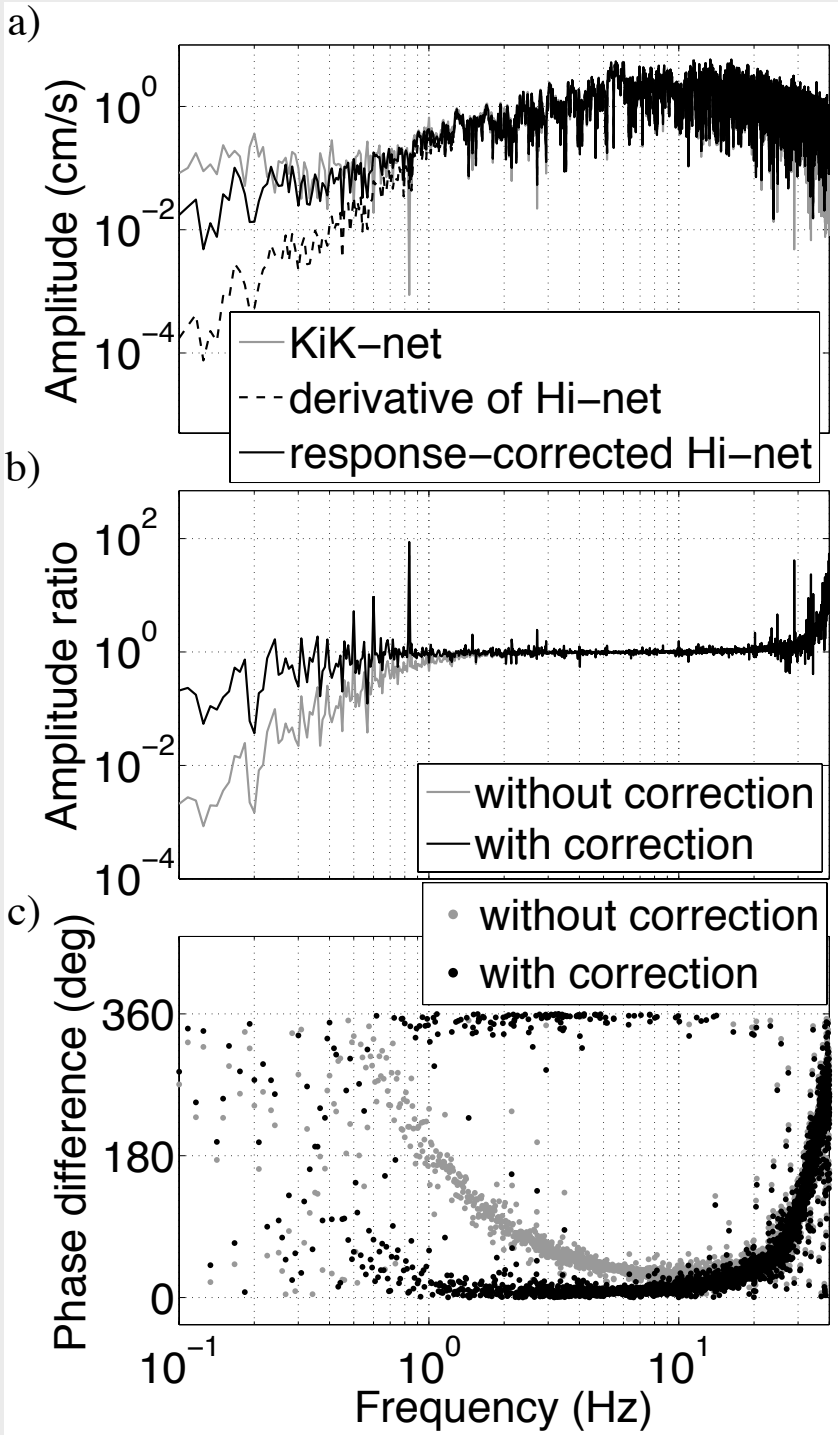
What kind of faulting?

Which is the fault plane?

Records



Instrument response



Nakata (2013)