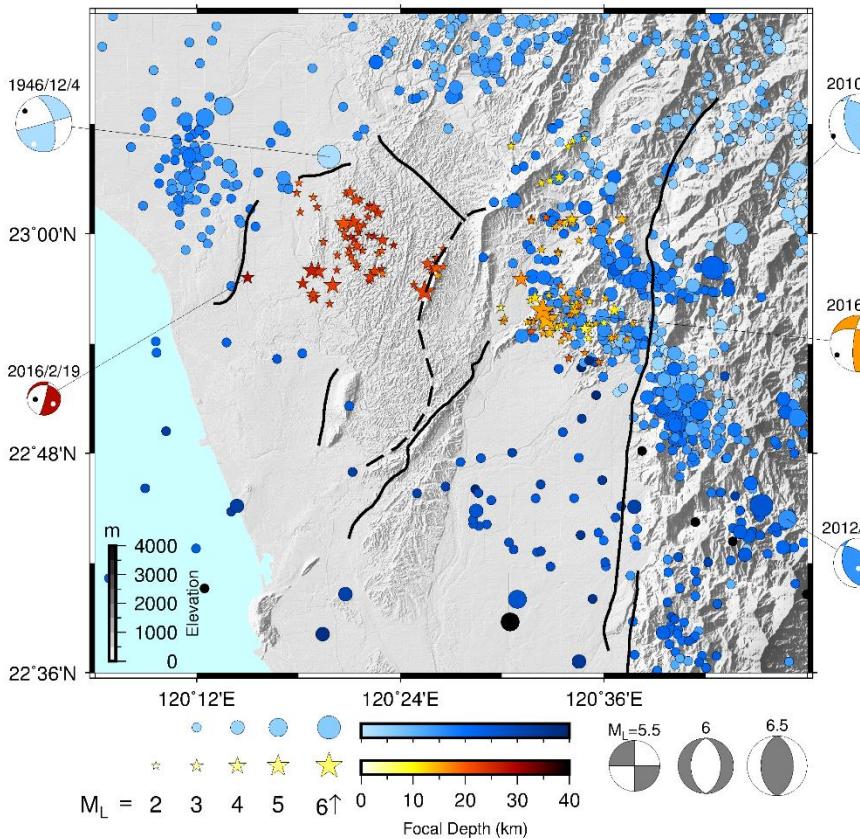
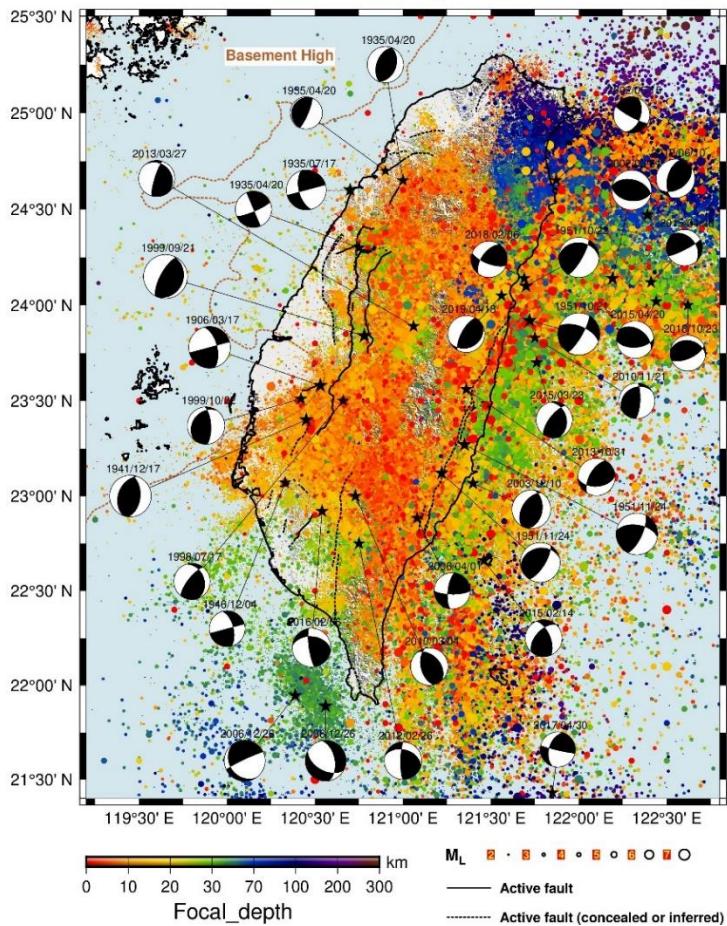


GMT Lecto6 : Focal Mechanism

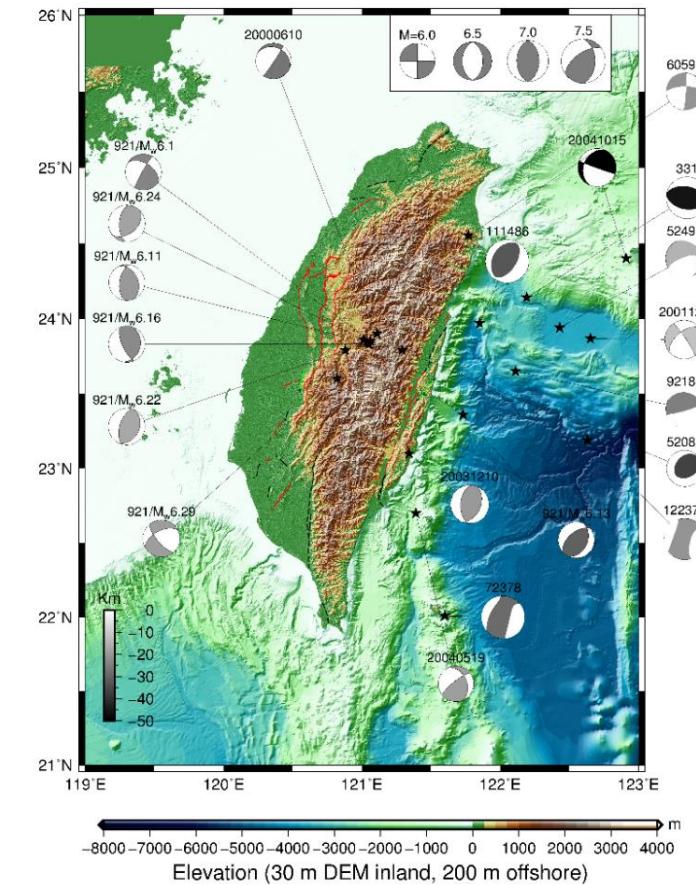
Meinong earthquake, aftershocks and seismicity



Historical earthquakes ($M_w > 6$) and seismicity



Focal Mechanisms with Sa and Sm conventions ($M_w > 6$)



胡植慶 國立臺灣大學地質科學系
Jyr-Ching HU, Dept. of Geosciences, NTU

GMT commands

meca - Plot focal mechanisms on maps (繪製下半球投影震源機制解)

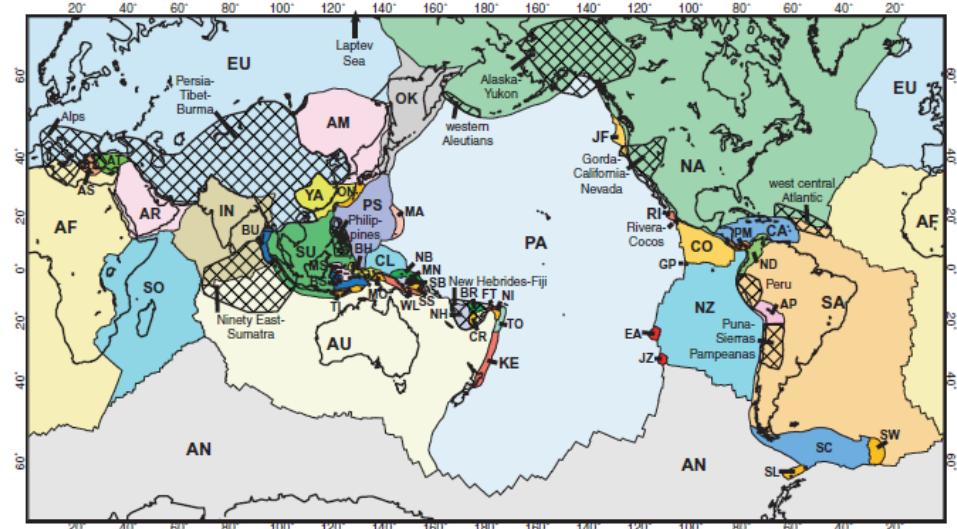
coupe - Plot cross-sections of focal mechanisms (繪製剖面震源機制解)

Nota bene: [meca.html](#)和[coupe.html](#)檔案位於：

C:\programs\gmt6\share\doc\html\supplements\seis

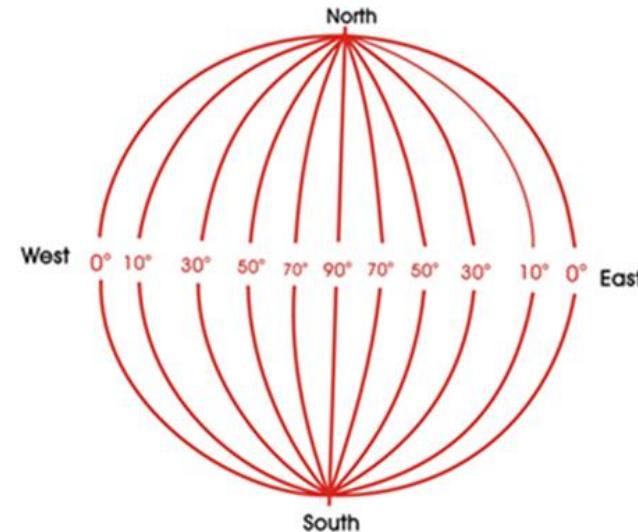
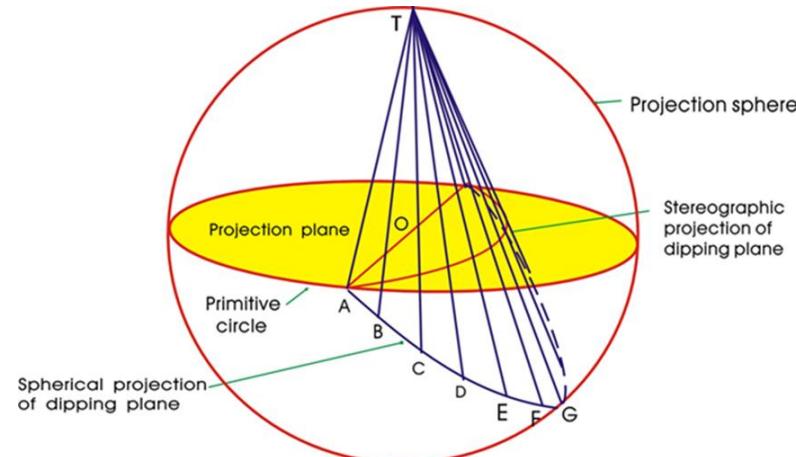
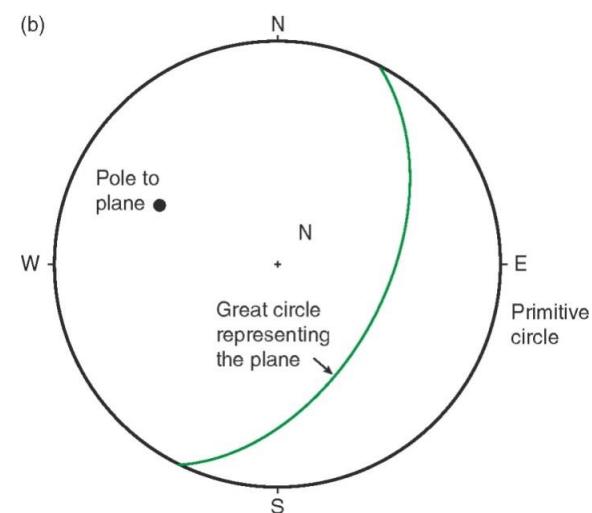
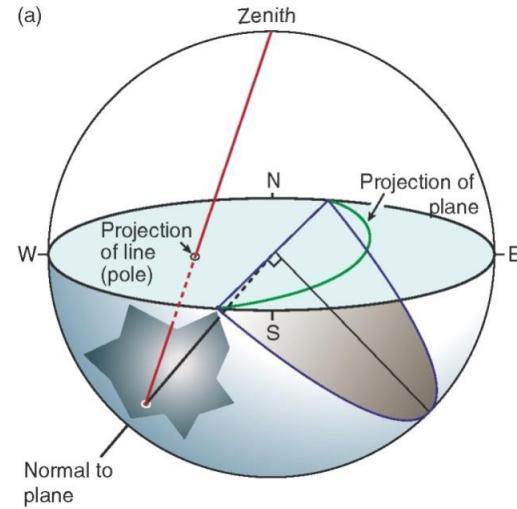
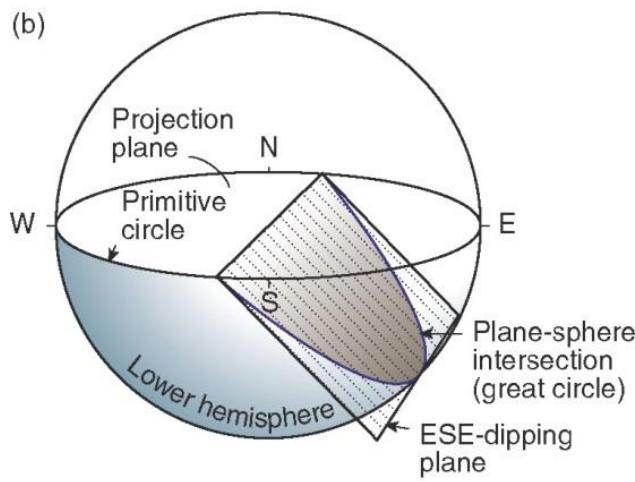
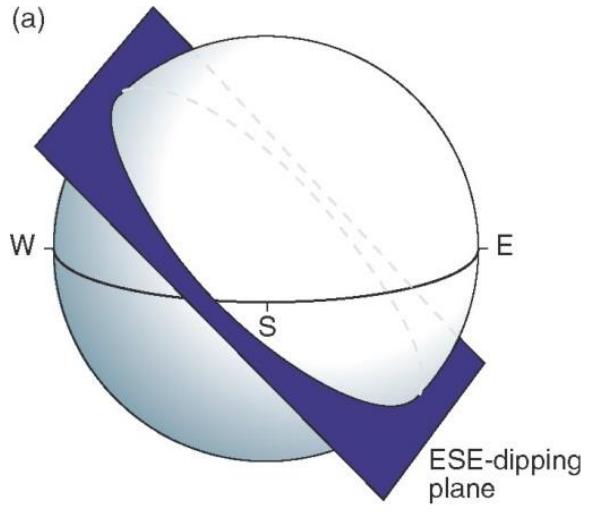
Data

1. 80 m DEM in Taiwan: [tw80m.nc](#)
2. Active faults in Taiwan (加上分段斷層名稱):
[ults_WGS84_CGS2012.gmt](#),
[Category_I_concealed_WGS84.gmt](#),
[Category_I_WGS84.gmt](#),
[Category_II_WGS84_CGS2012.gmt](#),
[Category_II_concealed_WGS84.gmt](#)
2. Plate boundaries: [ridge.gmt](#) (中洋脊), [transform.gmt](#) (轉形斷層), [trench.gmt](#) (海溝)
3. Plate boundaries: PB2002, an updated digital model of plate boundaries.

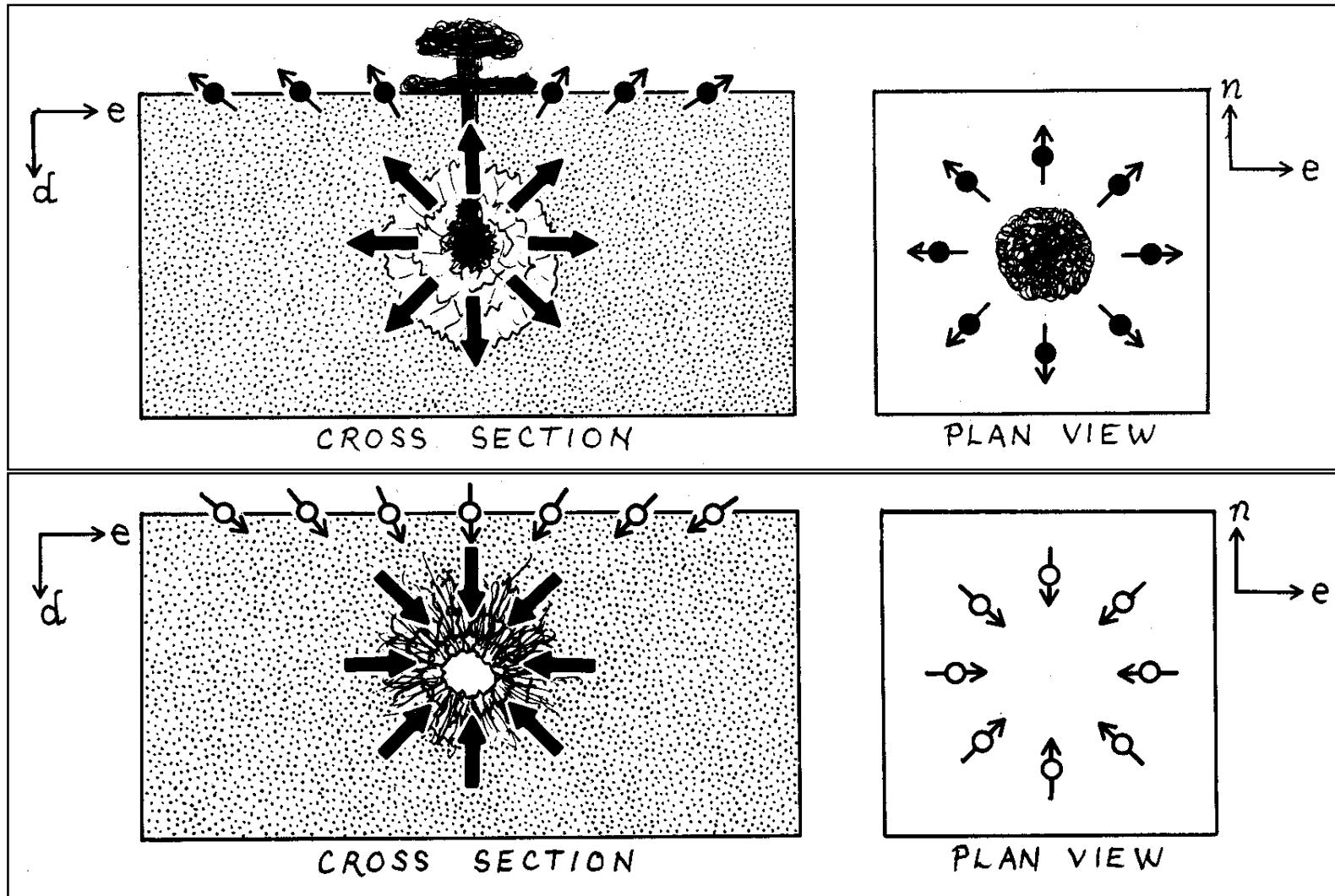


Stereographic projection (極射赤平投影)

Primitive circle (基準圓), Great circle (大圓), Lower hemisphere (下半球)
 Pole to plane (面的極點)

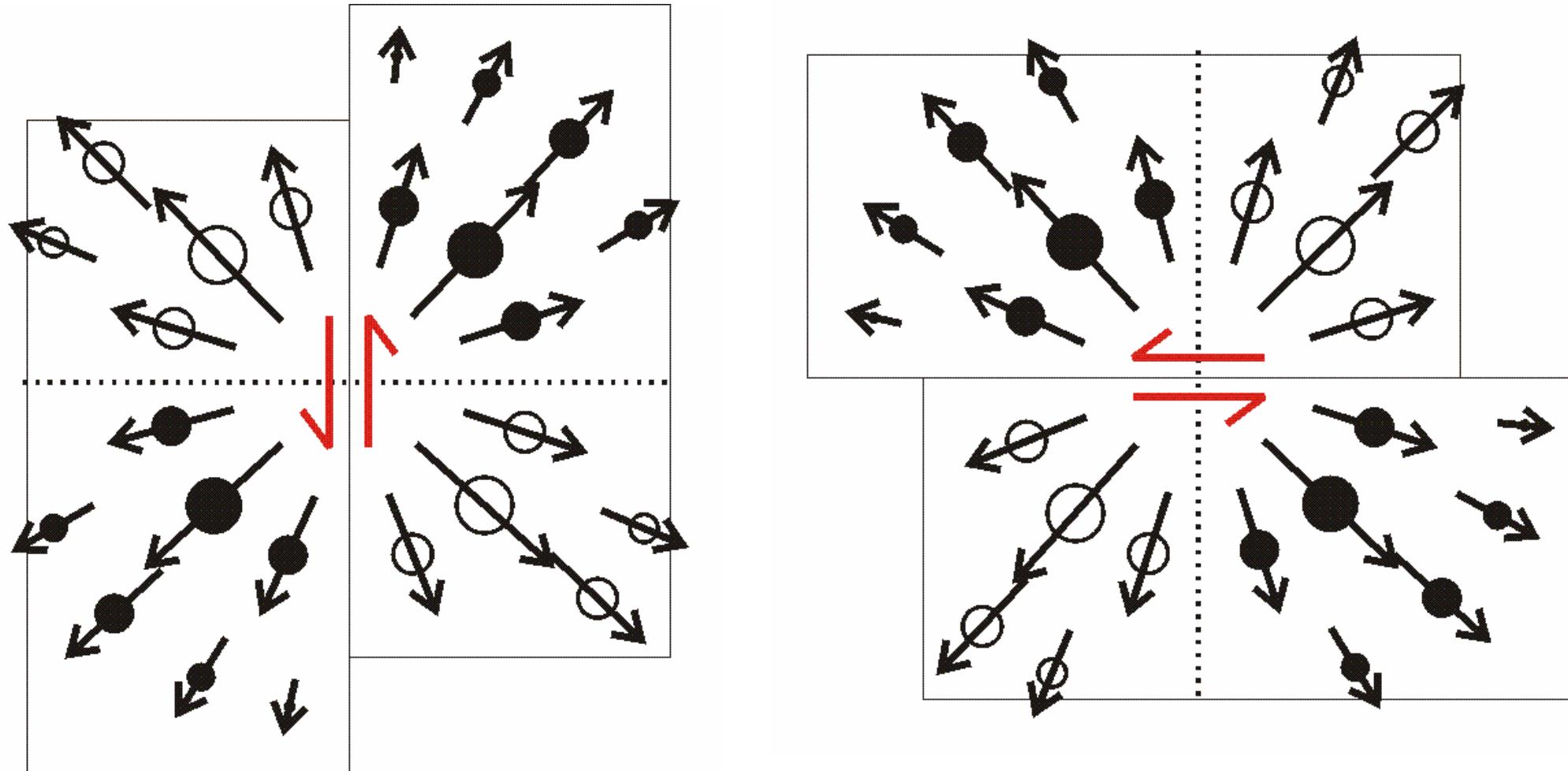


Energy & Polarity (極向) of “First Motions”

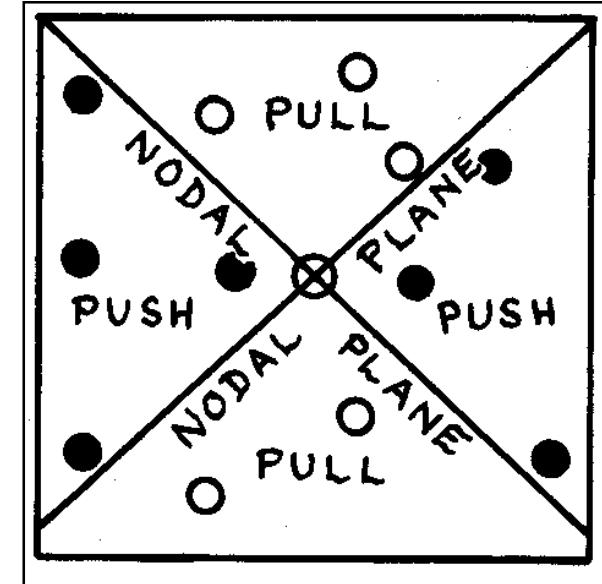
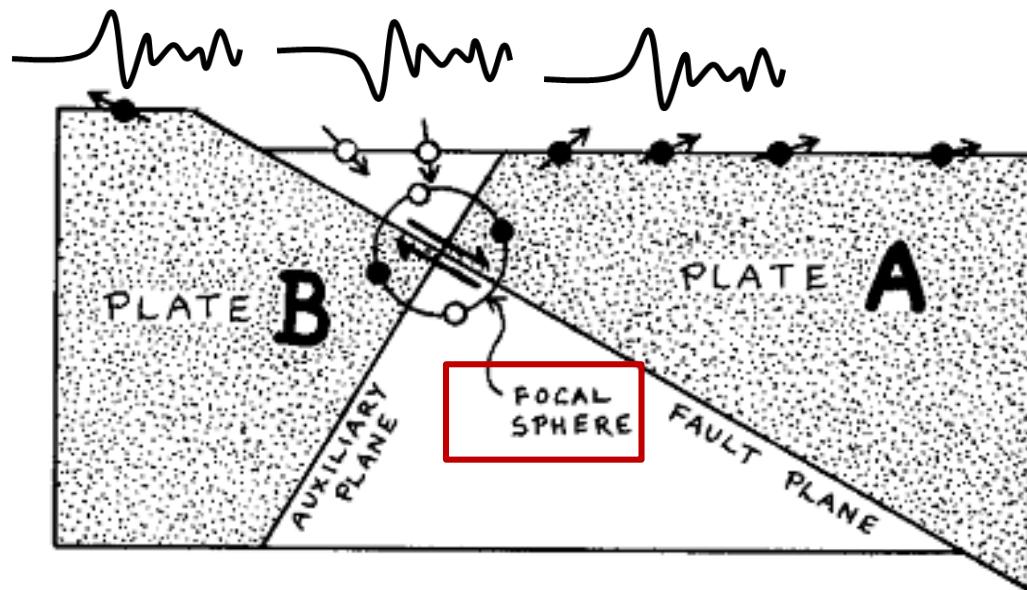
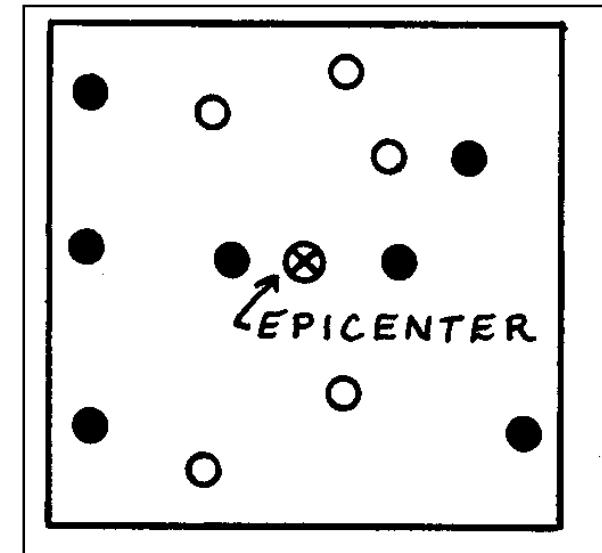
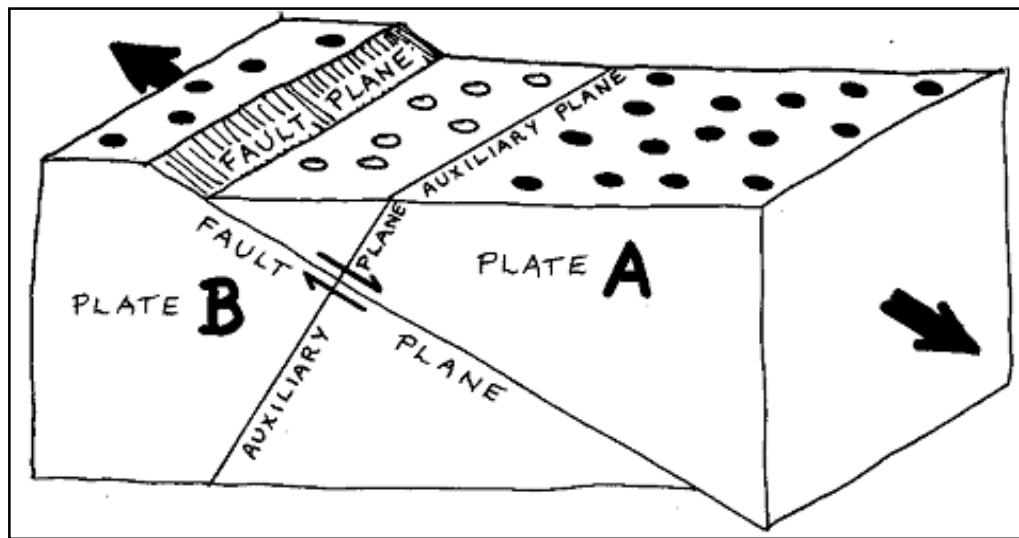


Cox and Hart. Plate Tectonics – How it works.

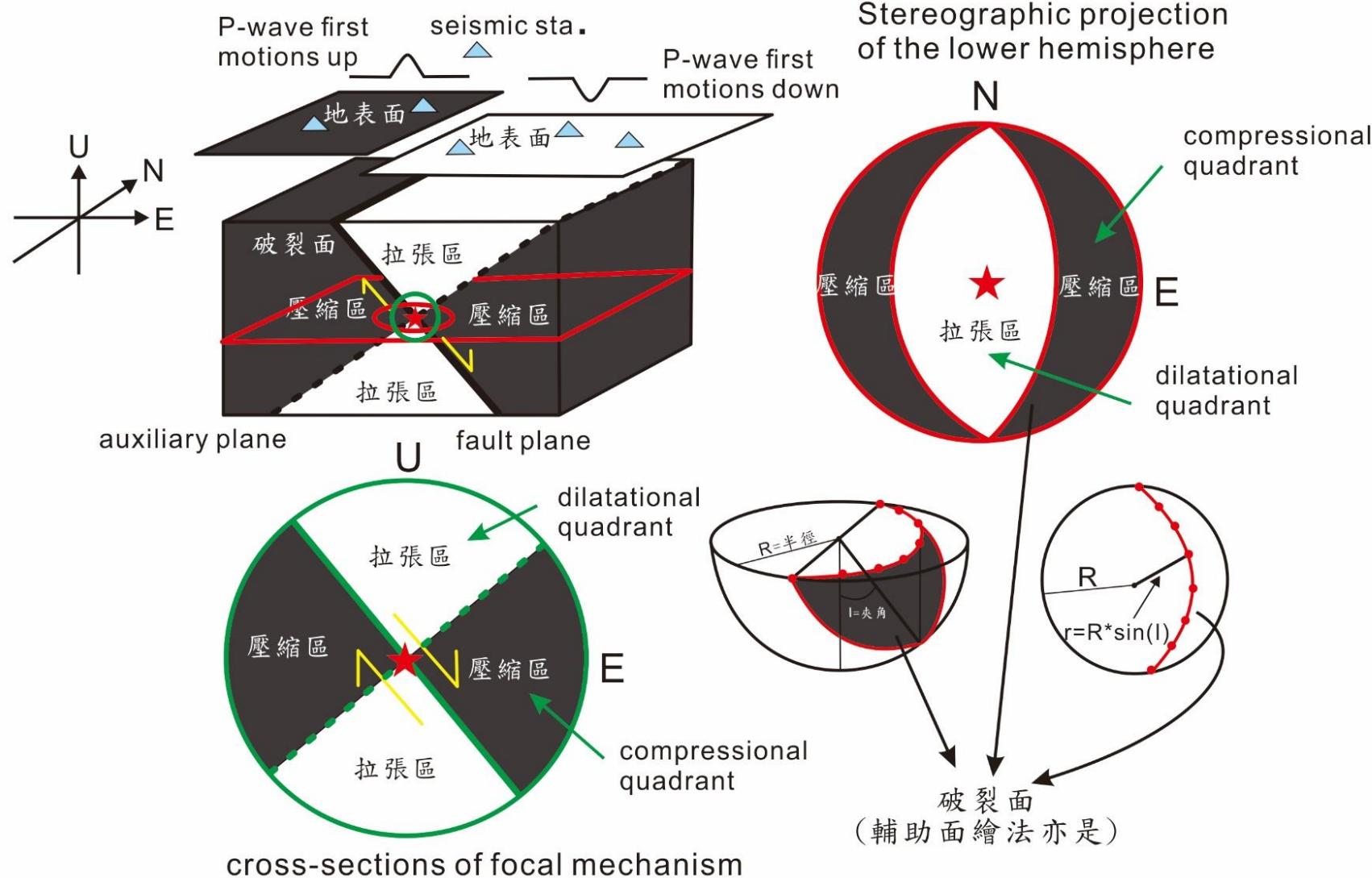
Earthquake on a vertical plane (Bird view)



Determination of nodal planes



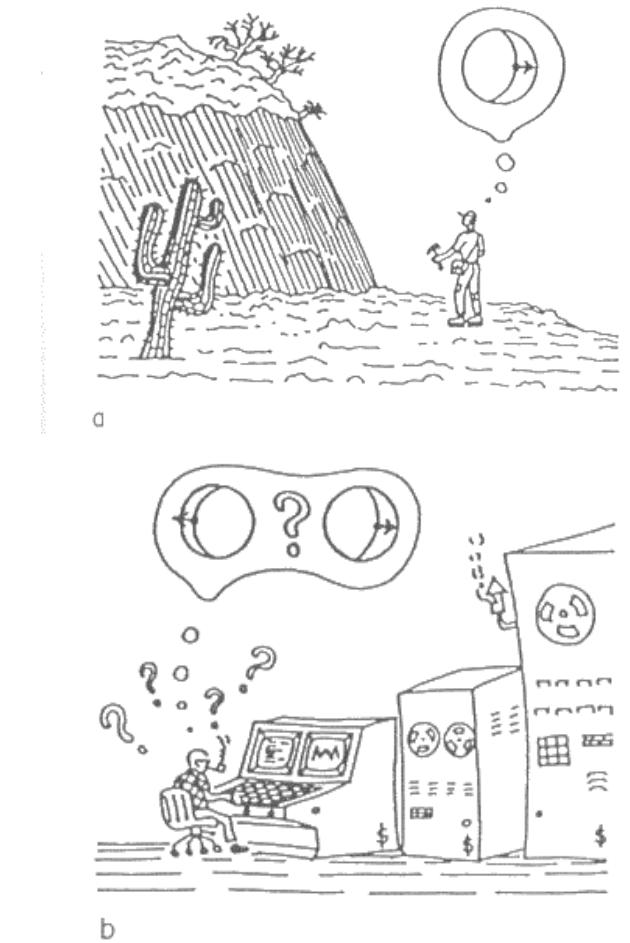
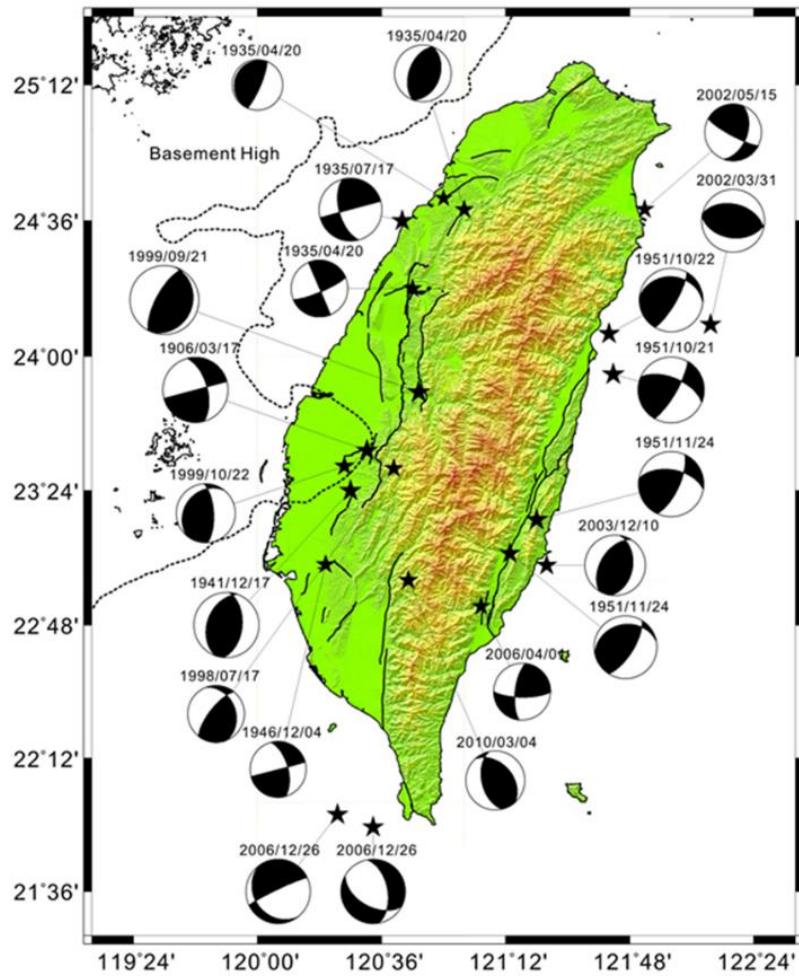
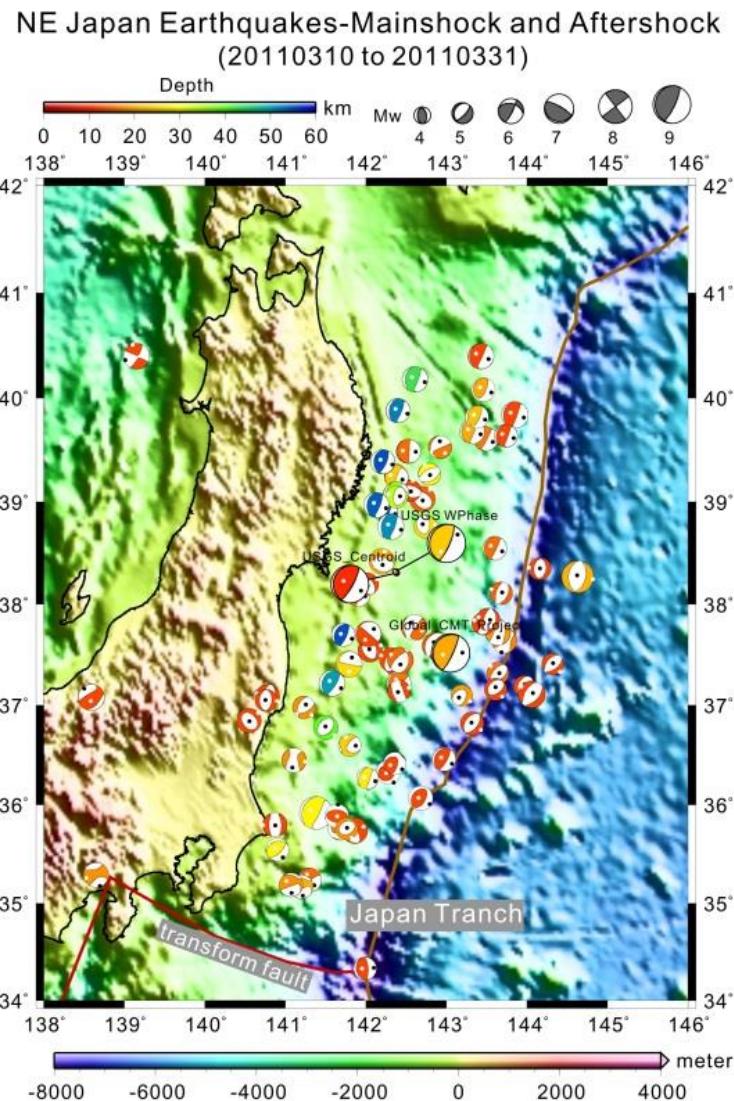
Projections: Lower or back hemisphere of the focal sphere



Central Geological Survey (中央地質調查所)

Which nodal plane is a fault plane?

Jacques Angelier, 1994
安朔葉



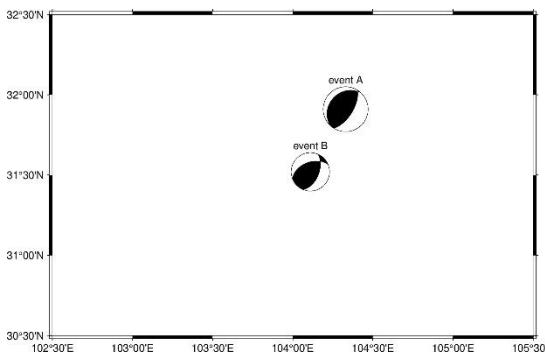
meca (繪製震源機制解)

Plot focal mechanisms

```
gmt meca [ table ] -Jparameters -Rregion -S<format><scale> ][+aangle]
[+ffont][+justify][+l][+m][+odx[/dy]][+sreference] [ -A[g[fill]]][+odx[/dy]][+ppen][+s[symbol]size] -
B[p/s]parameters ] [-Ccpt] [-Ddepmin/depmax] [ -Efill] [ -Fmode[args] ] [ -Gfill] [-H[scale] ] [-I[intens] ]
[ -L[pen] ] [ -N ] [ -Tnplane[pen] ] [ -U[stamp] ] [ -V[level] ] [ -Wpen ] [ -X[a|c|f|r][xshift[u]] ] [ -
Y[a|c|f|r][yshift[u]] ] [ -Zcpt] [-dinodata[+ccol] ] [ -eregexp ] [ -hheaders ] [ -iflags ] [ -pflags ] [ -qiflags ]
[ -ttransp ] [ -:[i/o] ] [ --PAR=value ]
```

Open & run test_meca01.bat or test_meca01.sh, examples from <https://docs.gmt-china.org/6.5/module/meca/>

```
echo 104.11 31.52 27.1 22 53 57 6 0 0 event B >> beachball.gmt
gmt meca beachball.gmt -JQ104/15c -R102.5/105.5/30.5/32.5 -Ba -Sa1c -jpg beachball01 -V
```



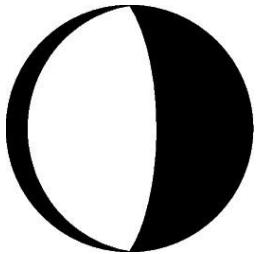
- **-Sformat[scale][+aangle][+ffont][+justify][+l][+m][+odx[/dy]][+sreference]:**
Selects the meaning of the columns in the data file. In order to use the same file to plot cross-sections, depth is in third column (指定斷層機制解的輸入檔案格式，第三欄為震源深度)
- **-Sa<scale>][+aangle][+ffont][+justify][+l][+m][+odx[/dy]][+sreference]:**
Focal mechanisms in Aki and Richards convention.

- **scale:** Adjusts the scaling of the radius of the “beach ball”, which will be proportional to the magnitude. scale is the size for magnitude = 5 i.e. scalar seismic moment $M_0 = 4.0 \times 10^{23}$ dynes-cm). (指定地震規模5級的海灘球直徑。預設為海灘球的直徑大小與規模成正比)

Open & run test_meca02.bat or test_meca02.sh

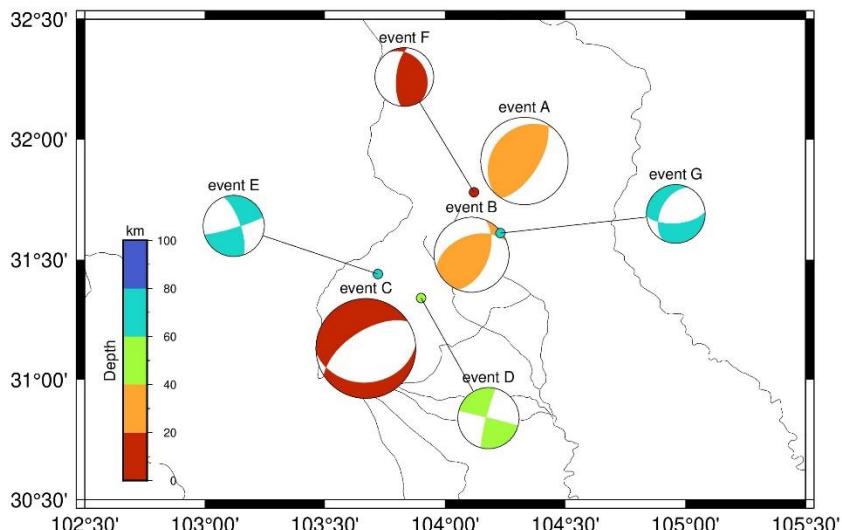
REM lon lat depth str dip slip st dip slip mant exp plon plat

```
echo 239.384 34.556 12. 180 18 -88 0 72 -90 5.5 0 0 0 | gmt meca -R239/240/34/35.2 -Jm4c -Sc2c -  
jpg beachball02
```

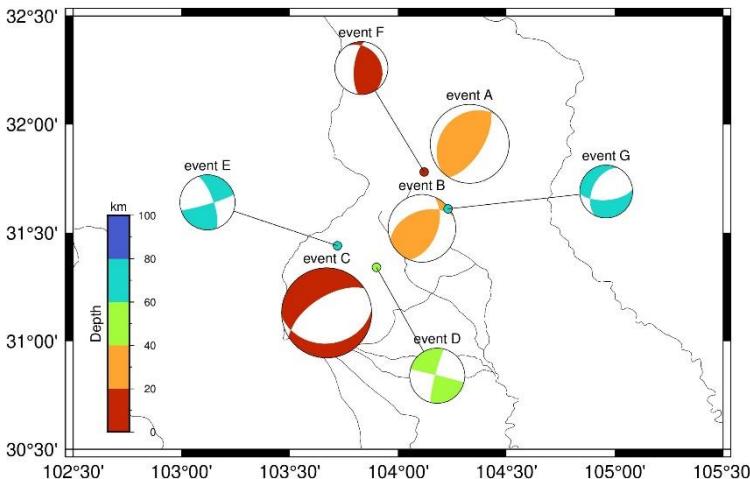


- **-Sformat[scale][+aangle][+ffont][+jjustify][+l][+m][+odx[/dy]] [+sreference]**: Selects the meaning of the columns in the data file. In order to use the same file to plot cross-sections, depth is in third column (指定斷層機制解的輸入檔案格式，第三欄為震源深度)
- **-Sc<scale>][+aangle][+ffont][+jjustify][+l][+m][+odx[/dy]] [+sreference]**: Focal mechanisms in Global CMT convention.

Open & run test_meca03.bat or test_meca03.sh, example modified from <https://docs.gmt-china.org/6.5/module/meca/>



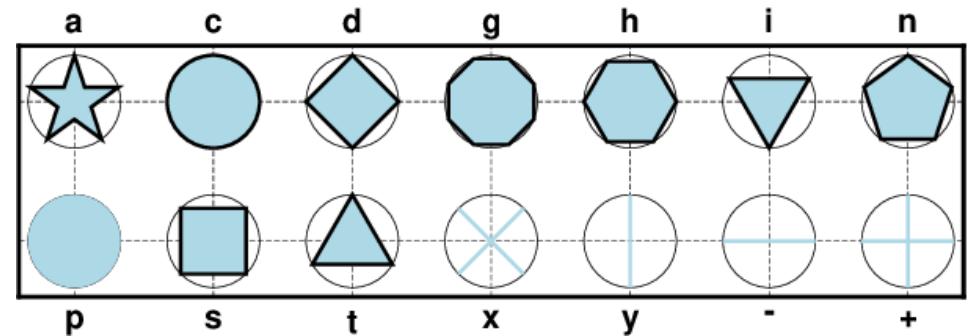
```
gmt begin beachball03 jpg A+m0.5c  
gmt basemap -JQ104/15c -R102.5/105.5/30.5/32.5 -Ba -BWSen  
gmt coast -Da -Ia/0.05,black  
gmt makecpt -T0/100/20 -I  
echo 104.33 31.91 39.8 32 64 85 7.0 0 0 event A | gmt meca -A+s0.2c  
-Sa1.3c -C  
....  
echo 103.90 31.34 43.6 194 84 179 4.9 104.18 30.84 event D | gmt  
meca -A+s0.2c -Sa1.3c -C
```



.....
echo 103.90 31.34 43.6 194 84 179 4.9 104.18 30.84 event D | gmt
meca -A+s0.2c -Sa1.3c -C

➤ **-A[+g[fill]][+odx[/dy]][+ppen][+s[symbol]size]**: Offsets focal mechanisms to the alternate longitudes, latitudes given in the last two columns of the input file before the (optional) text string (將震源機制偏移到輸入檔最後兩列（可選）文字字串之前給出的備用經度、緯度)

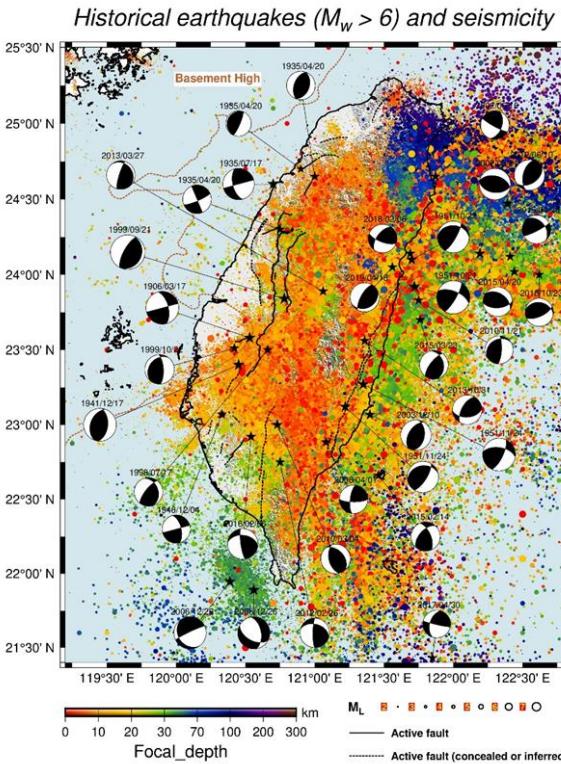
- **-Ccpt**: Give a CPT and let compressive part color be determined by the z-value in the third column. (指定CPT檔，根據數據檔中第三列的值（即地震深度）確定震源球的壓縮部分的顏色)
- Draw a line connecting the original and relocated beachball positions and optionally place a small symbol [circle] at the original location. (畫一條線連接原始和重新定位的沙灘球位置，並可選擇在原始位置放置一個小符號〔圓圈〕)
- Use **+ssize** to set the size of the symbol [no symbol]. Change from circle to any of the standard geometric symbols in plot, i.e., **a|c|d|g|h|i|n|p|s|t|x** [c].
- The line pen defaults to that given via **-W** but can be overridden by using **+ppen** [0.25p].



Please try:

1. **-A+sa0.3c+p0.5p,red**
2. **-A+sn0.5c+p1p,blue,- -Sa1c**

Lecto6A: focal mechanisms (Sa convention)



```
gmt set PROJ_LENGTH_UNIT=inch  
FORMAT_GEO_MAP=ddd:mm:ssG  
gmt makecpt -Cgray -T0/4000/500 -I -N > topo_gray.cpt -V  
REM ===== Plot title string =====  
echo 121 25.70 22,2 MC Historical earthquakes (M@-w@- \076 6)  
and seismicity | gmt text -F+f+j -N  
gawk " { if ($4 < 2) print $1, $2, $3}" 1900-201907EQs.txt | gmt plot -  
C%cpt2% -Sc.01 -V  
REM ===== Basement high =====  
gmt plot basement.gmt -W1,185/100/50,2_1:3p -V
```

- **-I**: Reverses the sense of color progression in the master cpt file. Also exchanges the foreground and background colors
 - **-N**: Does NOT skip symbols that fall outside frame boundary specified by **-R**
 - **M@-w@-**: @-, turn subscript on or off (開啟或關閉文字下標，請看Lecture 04)，Text Escape Sequences (轉義序列)
 - **2_1:3p**: alternates between long dashes (2 points), 1 point gap with pattern offset by 2 points from the origin

meca (繪製震源機制解)

Plot focal mechanisms

```
gmt meca [ table ] -Jparameters -Rregion -S<format><scale> ][+aangle]
[+ffont][+justify][+l][+m][+odx[/dy]][+sreference] [-A[+g[fill]]][+odx[/dy]][+ppen][+s[symbol]size] -
B[p|s]parameters ] [-Ccpt] [-Ddepmin/depmax ] [ -Efill] [ -Fmode[args] ] [ -Gfill] [-H[scale] ] [-I[intens] ]
[ -L[pen] ] [ -M ] [ -N ] [ -Tnplane[pen] ] [ -U[stamp] ] [ -V[level] ] [ -Wpen ] [ -X[a|c|f|r][xshift[u]] ] [ -
Y[a|c|f|r][yshift[u]] ] [ -Zcpt] [-dinodata[+ccol] ] [ -eregexp ] [ -hheaders ] [ -iflags ] [ -pflags ] [ -qiflags ]
[ -ttransp ] [ -:[i|o] ] [ --PAR=value ]
```

```
gmt meca 1935-2010_his_earthquake.txt -Sa0.3i+f8p+o2p -A -V
```

- **-Sformat[scale][+aangle][+ffont][+justify][+l][+m][+odx[/dy]] [+sreference]**: Selects the meaning of the columns in the data file. In order to use the same file to plot cross-sections, depth is in third column (指定斷層機制解的輸入檔案格式，第三欄為震源深度)
- **-Sa<scale>][+aangle][+ffont][+justify][+l][+m][+odx[/dy]] [+sreference]**: Focal mechanisms in Aki and Richards convention.

Aki & Richard convention: -Sa

- **-S<format>**: Selects the meaning of the columns in the data file (指定斷層機制解的輸入檔案格式)
- **-Sa**: Focal mechanisms in Aki and Richards convention

1,2: longitude, latitude of event

3: depth of event in kilometers

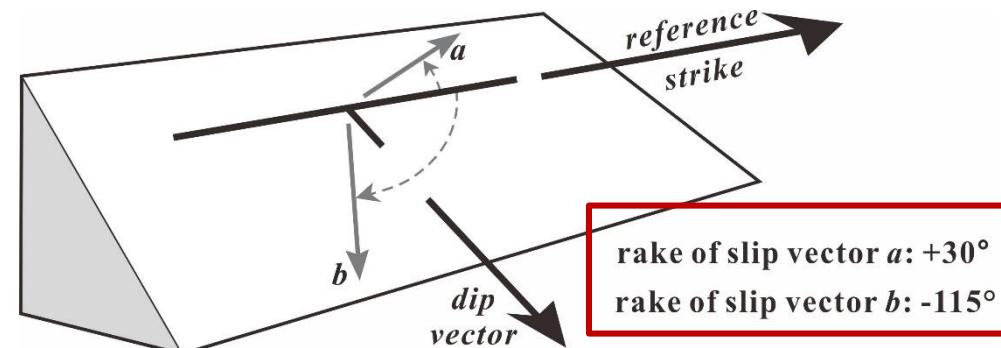
4,5,6: strike, dip and rake (滑移角) in degrees

7: magnitude

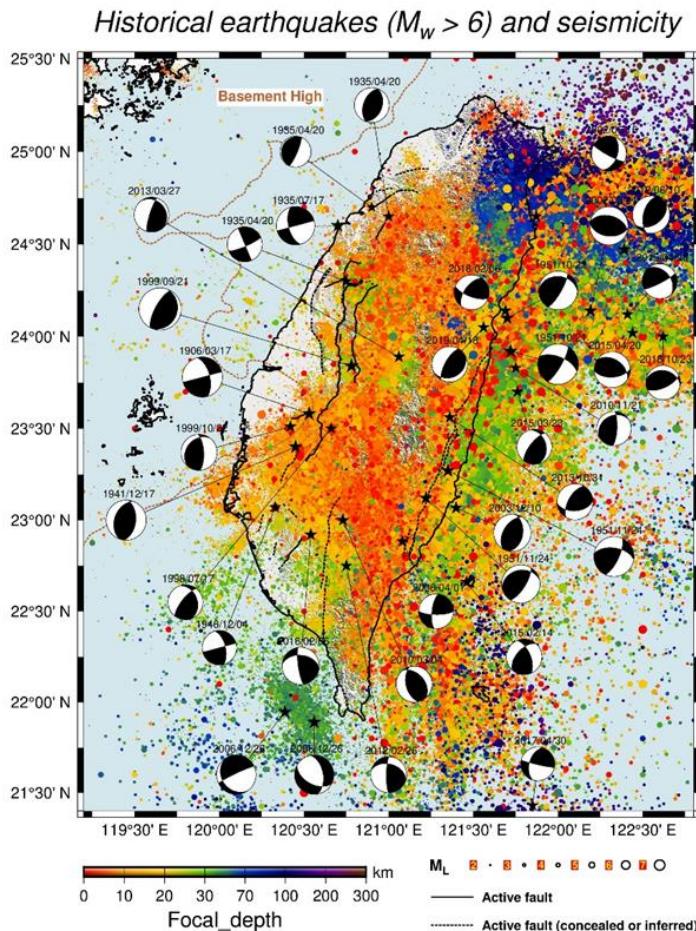
8,9: longitude, latitude at which to place beach ball. Entries in these columns are necessary with the **-C** option. *Using 0,0 in columns 8 and 9 will plot the beach ball at the longitude, latitude given in columns 1 and 2.* The **-:** option will interchange the order of columns (1,2) and (8,9).

10: Text string to appear above the beach ball (optional).

-Sa: Aki and Richards制訂的格式，輸入的資料格式共**10個欄位**，依序為震央經度、震央緯度、深度、走向、傾角、滑移角、規模、圖案經度、圖案緯度及標題。圖案經度及緯度表示海灘球放置的位置。



Lecto6A: focal mechanisms (Sa convention)



REM ===== Beachballs =====

```
gmt meca 1935-2010_his_earthquake.txt -Sa0.3i+f8p+o2p -C -V
```

```
gawk "{print $1, $2, $3*0.022}" epicenters_2010.txt | gmt plot -Sa -G0/0/0 -V
```

gmt meca 201011-201904CMT.txt -Sa0.3i+f8p+o2p -C -V

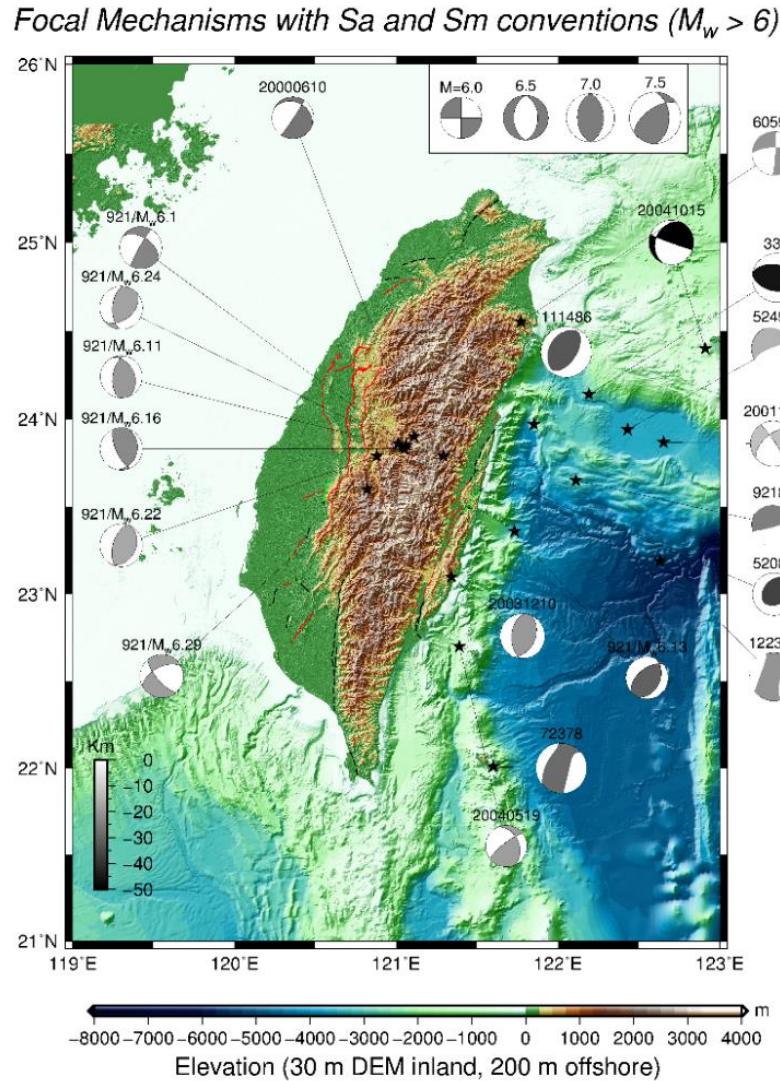
```
gawk "{print $1, $2, $3*0.022}" epicenters_201011-201904.txt | gmt plot -Sa -G0/0/0 -V
```

[Open 1935-2010_his_earthquake.txt](#)

120.75	24.30	3.0	67	80	180	6.2	120.15	24.50	1935/04/20
121.00	24.65	9.0	200	50	90	6.2	120.90	25.25	1935/04/20
120.90	24.70	2.0	203	10	90	5.5	120.45	25.00	1935/04/20
120.70	24.60	30.0	165	60	0	6.8	120.45	24.60	1935/07/17

Try changing scale of beachballs, values in modifiers +f and +o

Lecto6B: focal mechanisms with Sa & Sm conventions



REM Make a composite cpt with two master cpt

gmt makecpt -Cocean -T-8000/0/250 -N > %cpt%

gmt makecpt -Cdem2 -T0/4000/250 >> %cpt%

REM Make gray-scale for focal depth and plot scale bar

gmt makecpt -Cgray -T-50/0/5 -Z > fd_gray.cpt

gmt makecpt -Cgray -T0/50/5 -Z -I > fd_gray+.cpt

REM Plot title string

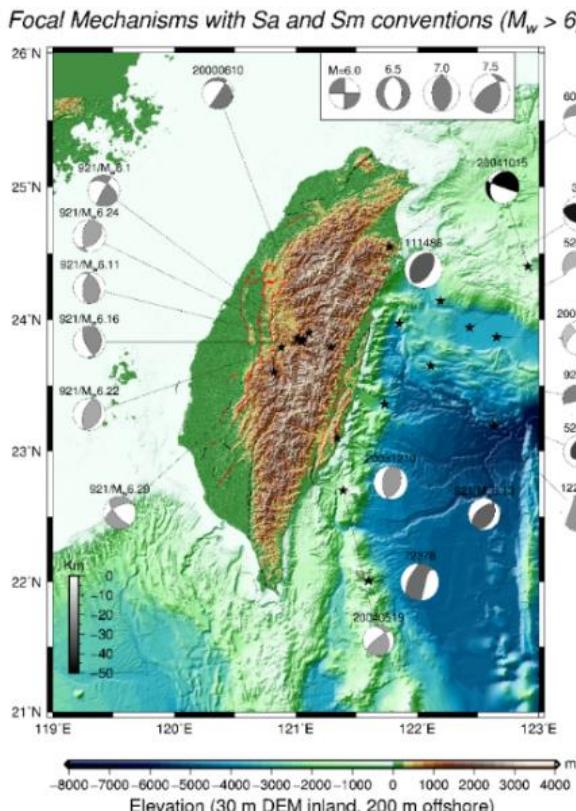
echo 121 26.25 20,2 MC Focal Mechanisms with Sa and Sm conventions (M@-w@- \076 6)| gmt text -JM -R -F+f+j -N -V

- -I: Reverses the sense of color progression in the master cpt file. Also exchanges the foreground and background colors
- M@-w@-: @-, turn subscript on or off, 開啟或關閉文字下標，請看 Lecture 04 , Text Escape Sequences (轉義序列)

meca (繪製震源機制解)

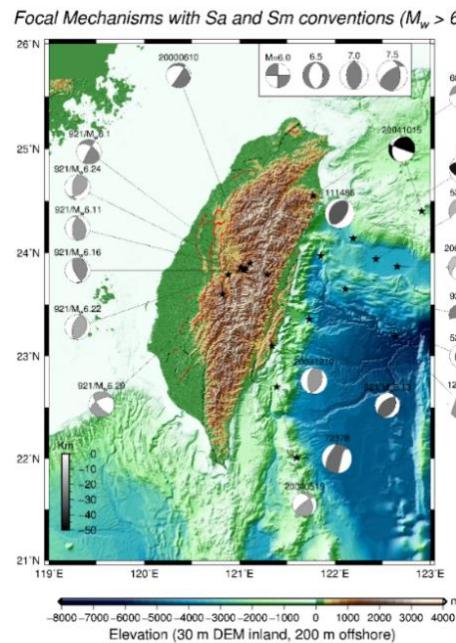
Plot focal mechanisms

```
gmt meca [ table ] -Jparameters -Rregion -S<format><scale>[+ffont][+justify][+odx[/dy]] [ -B[p/s]parameters ]  
[ -C[pen][+spointsize] ] [ -Ddepmin/depmax ] [ -Efill] [ -Fmode[args] ] [ -Gfill] [ -L[pen] ] [ -M ] [ -N ] [ -  
Tnplane[/pen] ] [ -U[stamp] ] [ -V[level] ] [ -Wopen ] [ -X[a|c|f|r][xshift[u]] ] [ -Y[a|c|f|r][yshift[u]] ] [ -Zcpt ] [ -  
dinodata ] [ -eregexp ] [ -hheaders ] [ -iflags ] [ -pflags ] [ -ttransp ] [ -:[i|o] ] [ --PAR=value ]
```



```
gmt meca tweq1995_2005(sa).txt -Sa0.2c -Zfd_gray+.cpt -C -L -N -V
```

- **-S<format><scale> [+ffont][+justify][+odx[/dy]]**: Selects the meaning of the columns in the data file. In order to use the [same file to plot cross-sections](#), **depth** is in **third column** (指定斷層機制解的輸入檔案格式，第三欄為震源深度)
- **-Sa<scale> [+ffont][+justify][+odx[/dy]]**: Focal mechanisms in Aki and Richards convention.
- **scale**: Adjusts the scaling of the **radius of the “beach ball”**, which will be proportional to the magnitude. **scale** is the size for magnitude = 5 (指定地震規模5級的海灘球直徑。預設為海灘球的直徑大小與規模成正比)



meca (繪製震源機制解)

```
gmt meca tweq1995_2005(sa).txt -Sa0.8c+u -Zfd_gray+.cpt -C+s5p -L -N -V
```

-S<format><scale> [][<j>][<o>[<d>]]:

- **+f:** Adjusts fontsize (海灘球標題的字體大小)
- **+o:** 海灘球標題相對於海灘球的偏移量
- **+u:** have the text appear below the beach ball (default is above) (海灘球標題位於海灘球的下方)

-N: Does NOT skip symbols that fall outside frame boundary specified by **-R** [Default plots symbols inside frame only] (可繪製超出底圖範圍(-R)外之圖樣)

-C[<pen>][<size>]: Offsets focal mechanisms to the longitude, latitude specified in the last two columns of the input file before the (optional) text string. A **small circle** is plotted at the initial location and a line connects the beachball to the circle (繪製震央經緯度及圖案經緯度的小圓連線及震央點，需定義線的屬性和點圓的大小)

-Z<cpt>: Give a **color palette file** & let compressive part color be determined by the z-value in the third column (色階檔，指定深度變化的色階檔，繪製在壓縮象限)

-L[<pen>]: Draws the “beach ball” outline with pen attributes instead of with the default pen set by **-W** (定義海灘球外部輪廓線的屬性)

Input format for -Sa: tweq1995_2005(sa).txt

[Open tweq1995_2005\(sa\).txt](#)

```
# lon  lat   depth  str   dip    slip   mant   plon   plat   text
120.88 23.79  17  24.99  32.2  97.02  6.22  119.30 23.28 921/M@-w@-6.22
121.06 23.85  24  303.3  49.15  6.52   6.1   119.42 24.97 921/M@-w@-6.1
121.04 23.84  20  337.05 37.8   64.73  6.11  119.30 24.24 921/M@-w@-6.11
120.82 23.6   19  242.48 55.4   -157.59 6.29  119.55 22.53 921/M@-w@-6.29
```

```
gmt meca tweq1995_2005(sa).txt -Sa0.8c -Zfd_gray+.cpt -C -L -N -V
```

- **Scale:** Adjusts the scaling of the radius of the "beach ball", which will be **proportional to the magnitude**. Scale is the size for magnitude = 5 in inch (unless **c**, **i**, **m**, or **p** is appended).
- **-C[pen][PpointsizE]:** Offsets focal mechanisms to the **longitude**, **latitude** specified in the **last two columns of the input file** before the (optional) text string. A **small circle** is plotted at the initial location and a line connects the beachball to the circle. Specify pen and/or pointsizE to change the line style and/or size of the circle. [Defaults: pen as given by **-W**; pointsizE 0].

Seismic moment tensor (Global CMT, with zero trace). -Sm,

-Sm|d|z: 跡數為0的地震矩張量(Seismic moment tensor with zero trace, 零跡矩張量解)，輸入的資料格式共13個欄位，依序為震央經度、震央緯度、深度、mrr、mtt、mff、mrt、mrf、mtf、地震矩張量指數、圖案經度、圖案緯度、標題。m只繪製跡數，d只繪製雙力偶(double couple)的部份，z只繪製非均向性(anisotropic part of moment tensor)部份。

1,2: longitude, latitude of event

3: depth of event in kilometers

4,5,6,7,8,9: mrr, mtt, mff, mrt, mrf, mtf in 10^{*} exponent
dynes-cm (scalar seismic moment)

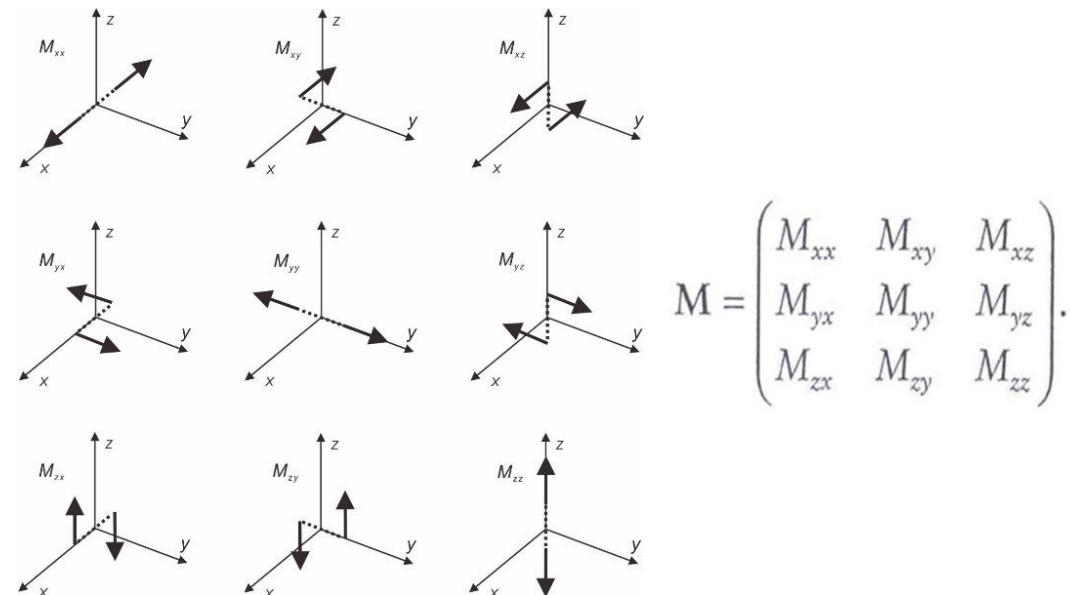
10: exponent (地震矩的指數部分)

11,12: longitude, latitude at which to place beach ball.

Entries in these columns are necessary with the **-C** option.

Using (0,0) in columns 11 and 12 will plot the beach ball at the longitude, latitude given in columns 1 and 2.

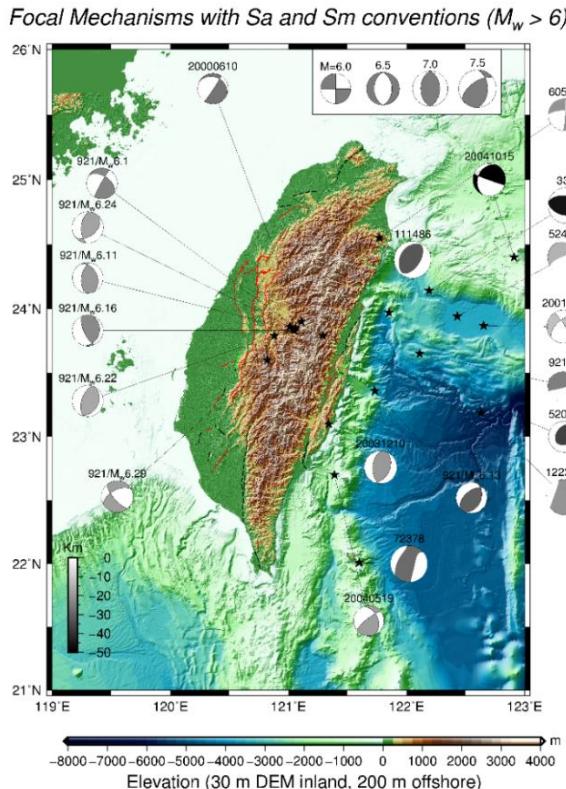
13: Text string appeared above the beach ball (optional).



Input for -Sm: tweek1977_1995(sm).txt

Open twek1977_1995(sm).txt

#	lon	lat	depth	mrr	mtt	mff	mrt	mrf	mtf	exp	plon	plat	text
121.6	22.01	29	6.04	1.25	-7.29	-0.11	4	-4.17	26	122.0204	20.4799	72378	
122.63	23.19	21	1.99	1.71	-3.7	0.23	1.38	-1.94	26	124.2164	22.5264	122378	
122.11	23.65	25	1.71	-2.13	0.42	4.43	1.46	0.19	25	124.1641	23.2839	92183	



-T[num_of_planes][/pen]: Plots the nodal planes and outlines the bubble which is transparent (繪製節面和海灘球之外框屬性). If num_of_planes is:

0: both nodal planes are plotted;

1: only the first nodal plane is plotted;

2: only the second nodal plane is plotted.

Append `/pen` to set the pen attributes for this feature. Default `pen` is as set by `-W`.

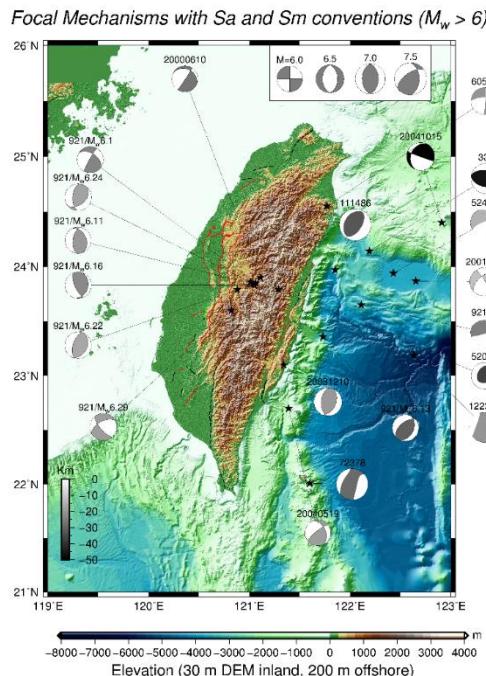
Please try adding -TO or -TO/0.8p,red:

```
gmt meca tweq1977_1995(sm).txt -Sm.0.8c+f10p -T0/0.8p,red -Zfd_gray+.cpt -C  
-h1 -N -L -V
```

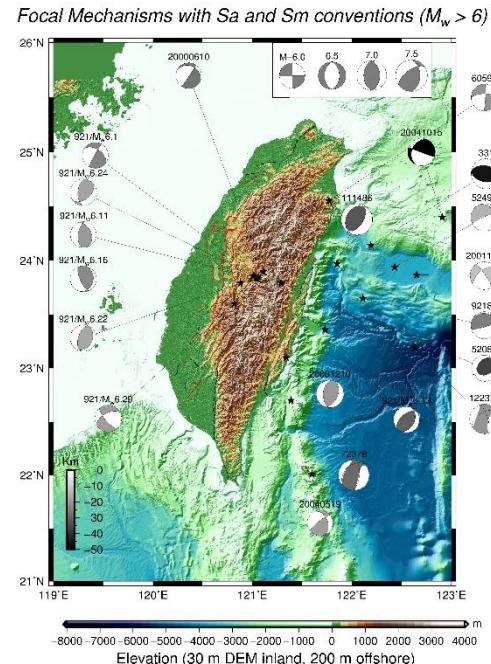
Standard input -Sm: twek1977_1995(sm).dat

#	lon	lat	depth	mrr	mtt	mff	mrt	mrf	mtf	exp	plon	plat	text
121.6	22.01	29	6.04	1.25	-7.29	-0.11	4	-4.17	26	122.0204	20.4799	72378	
122.63	23.19	21	1.99	1.71	-3.7	0.23	1.38	-1.94	26	124.2164	22.5264	122378	
122.11	23.65	25	1.71	-2.13	0.42	4.43	1.46	0.19	25	124.1641	23.2839	92183	

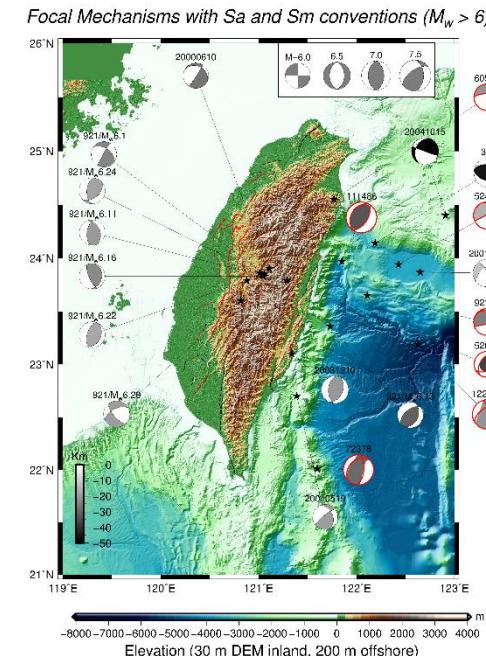
gmt psmeca tweq1977_1995(sm).txt -Sm0.8c -Zfd_gray+.cpt -C -h1 -L -N -V



Adding: -T0



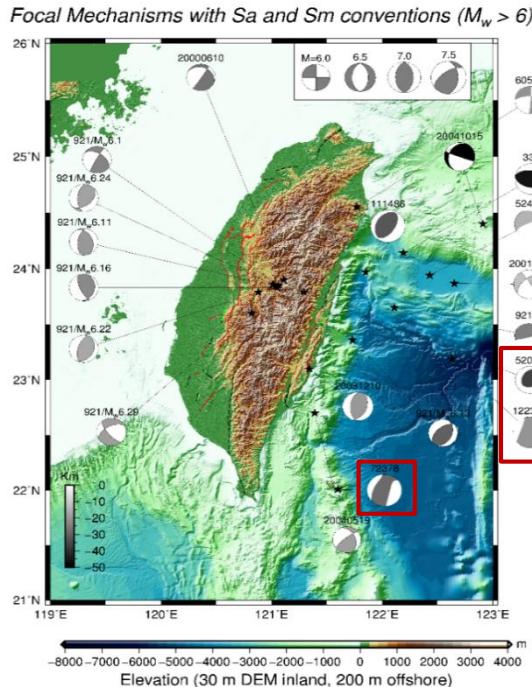
Adding: -T0/0.8p,red



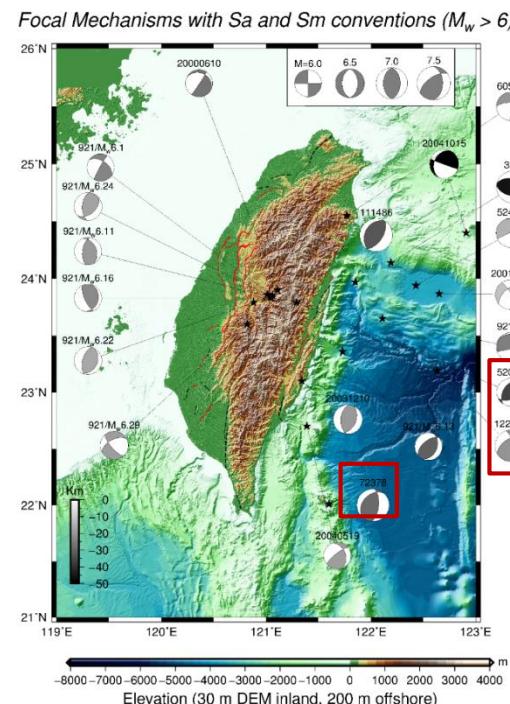
Comparison of -Sm, -Sd, -Sz

- **-Sm|d|z**: 零跡地震矩張量(Seismic moment tensor with zero trace) **m**只繪製跡數，**d**只繪製雙力偶(double couple)的部份，**z**只繪製非均向性(anisotropic part of moment tensor)部份。
- 地震矩張量可以分解成等向性(ISO, isotropy)、雙力偶(DC, double couple)和補償線性向量偶極(CLVD, compensated linear vector dipole)三部分。
- **m** 繪製完整的地震矩張量(ISO+DC+CLVD)；**d** 僅繪製地震矩的雙力偶部分(DC); **z**僅繪製地震矩的各向異性部分(DC+CLVD)

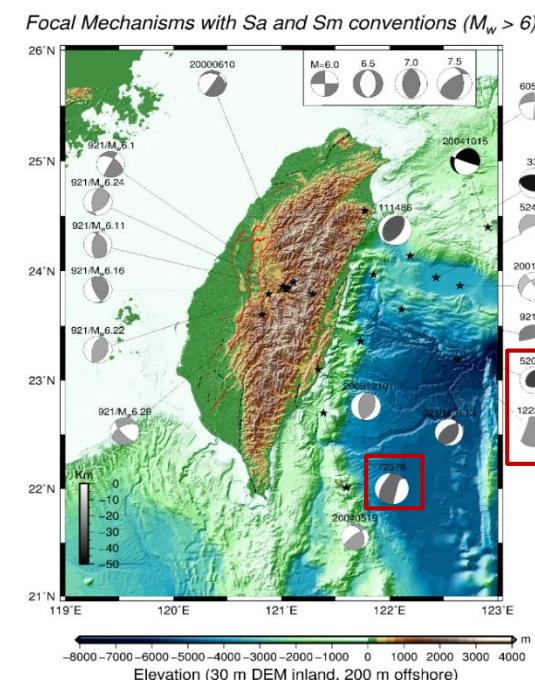
-Sm



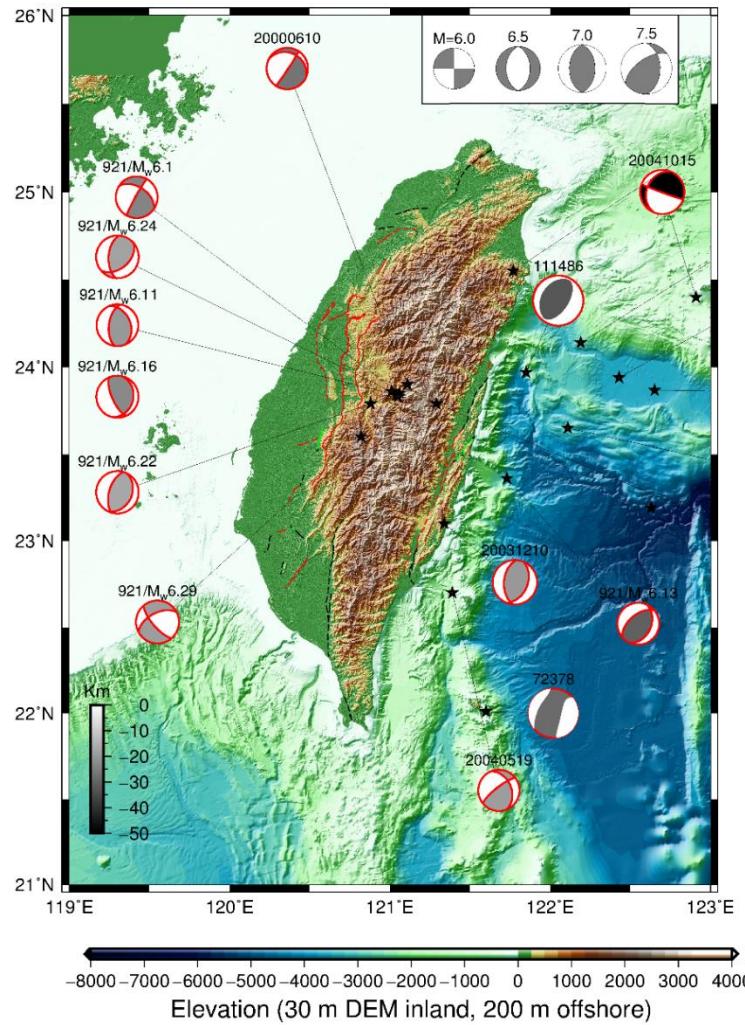
-Sd



-Sz



Focal Mechanisms with Sa and Sm conventions ($M_w > 6$)



Please try adding **-L1p,red** and
deleting **-N**

```
gmt meca tweq1977_1995(sm).txt -Sm0.8c -T0/0.8p,red -N -  
Zfd_gray+.cpt -C -h1 -L -V
```

```
gmt meca tweq1995_2005(sa).txt -Sm0.8c -Zfd_gray+.cpt -C  
-h1 -L -N -V
```

-Lpen: Draws the “beach ball” outline with pen attributes instead of with the default pen set by **-W** (海灘球外框輪廓線，取代原-W定義之線屬性)

-N: Does not skip symbols that fall outside frame boundary specified by **-R** [Default plots symbols inside frame only].

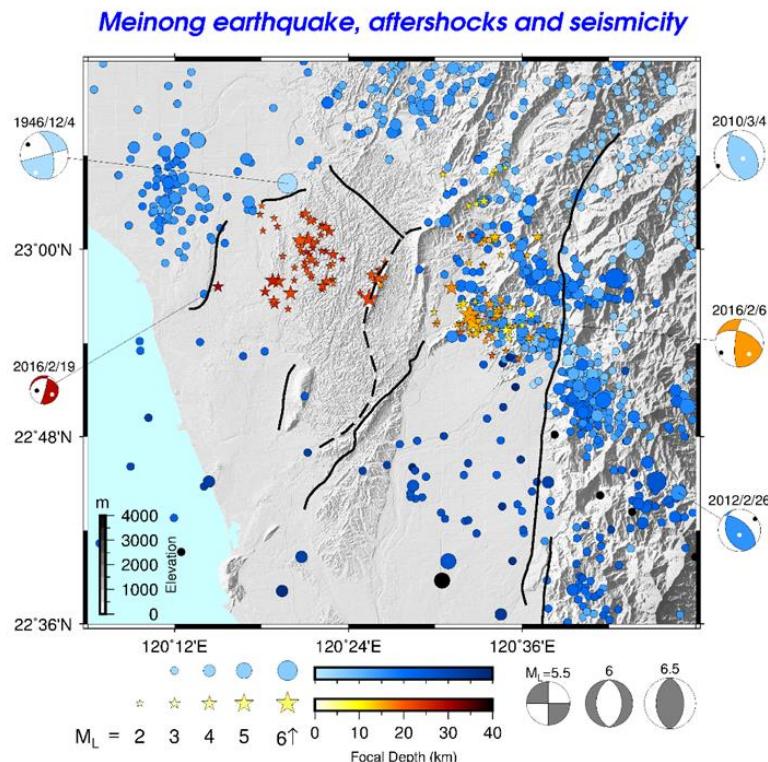
-Gfill: Selects filling of focal mechanisms. By convention, the compressional quadrants of the focal mechanism beach balls are shaded. [Default is black]. (海灘球壓縮象限的顏色，預設為黑色)

-Zcptfile: Give a color palette file and let compressive part color be determined by the z-value in the third column.

Lecto6C: Plot P & Taxes

```
echo 120.54 22.93 16 288.36 51.02 19.79 6.11 120.9 22.9 2016/2/6 | gmt meca -  
-Sa1c+f10p+o3p -Fa4p/cc -Zfd_hot+.cpt -C -N -L -V  
echo 120.33 23.07 2 75 90 -151 6.1 120.05 23.1 1946/12/4 | gmt meca  
-Sa1c+f10p+o3p -Fa4p/cc -Zfd_blue+.cpt -C -L -N -V
```

-Fa[size[/Psymbol[Tsymbol]]]: Computes and plots P & T axes with symbols.



- Optionally specify size and (separate) P and T axis symbols. [Default: 6p/cc]
 - P and T axis symbols : (c) circle, (d) diamond, (h) hexagon, (i) inverse triangle, (p) point, (s) square, (t) triangle, (x) cross.

-Zcptfile: Give a color palette file and let compressive part color be determined by the **z-value** in the third column.

Global CMT convention (GCMT): -Sc

- **-Sc**scale[+ffont][+jjustify][+odx[/dy]]: Focal mechanisms in Global CMT convention
- Scale: size for magnitude = 5 (that is $M_0 = 4.0E23$ dynes-cm).

1,2: longitude, latitude of event

3: depth of event in kilometers

4,5,6: strike, dip, and rake of plane 1

7,8,9: strike, dip, and rake of plane 2

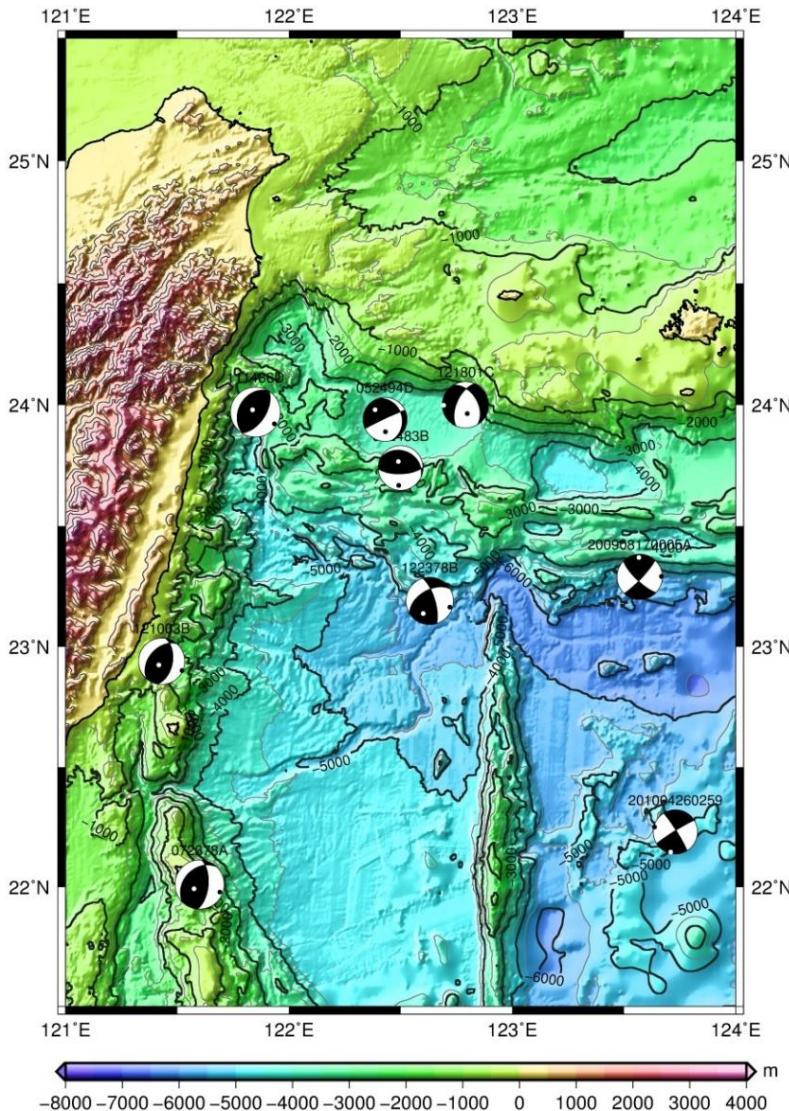
10, 11: mantissa and exponent of moment in dyne-cm (scalar moment) (地震標量矩的尾數和指數部分。如
地震標量矩為 $1.23e+26$ dyne-cm，則 mantissa=1.23，exponent=26)

12,13: longitude, latitude at which to place beach ball. Entries in these columns are necessary with the **-C** option. Using (0,0) in columns 11 and 12 will plot the beach ball at the longitude, latitude given in columns 1 and 2.

14: Text string appeared above the beach ball (optional).

```
gmt meca -R239/240/34/35.2 -Jm4c -Sc2c -h1 -pdf test << END
#lon lat depth str dip slip str dip slip mant exp plon plat
239.384 34.556 12. 180 18 -88 0 72 -90 5.5 24 0 0
END
```

Lecto6D



```
gawk "{print $1, $2, $3, $5, $6, $7, $8, $9,  
$10, $11, $12, $13, $14, $15}"  
eq_tw_gcmt.txt > eq_m65.txt
```

```
gmt meca eq_m65.txt -Sc0.3i -Fa0.1c/c -  
C1pP0.1 -h1 -N -V
```

-Fa[size[/Psymbol[Tsymbol]]]: Computes and plots P & T axes with symbols.

Optionally specify size & P and T axis symbols from the following: (c) circle, (d) diamond, (h) hexagon, (i) inverse triangle, (p) point, (s) square, (t) triangle, (x) cross.

-Fefill: Sets the color or fill pattern for the T axis symbol. [Default as set by -E]

-Fgfill: Sets the color or fill pattern for the P axis symbol. [Default as set by -G]

Please try -Fa0.2c/cd and add -Fe255/0/0 -Fg0/0/255

Input for -Sc: eq_m65.txt

Focal mechanisms in Global CMT convention: -Sc

```
# Lon lat depth str1 dip1 rake1 str2 dip2 rake2 mantissa exponent lonp latp text
121.60 22.01 28.9 224 36 123 5 61 69 8.64 26 121.60 22.01 072378A
122.63 23.19 20.7 239 53 158 343 72 39 3.56 26 122.63 23.19 122378B
```

-Scscale[/fontsize[/offset[u]]]: Harvard CMT定義的格式，輸入的資料格式共**14個欄位**，依序為震央經度、震央緯度、深度、走向1、傾角1、滑移角1、走向2、傾角2、滑移角2、地震標量矩尾數(mantissa)、地震標量矩指數(exponent) 圖案經度、圖案緯度、標題。若地震矩張量 $M_0 = 4.0E23$ dyne-cm，則尾數為4.0，指數為23。

1,2: longitude, latitude of event

3: depth of event in kilometers

4,5,6: strike, dip, and rake of plane 1

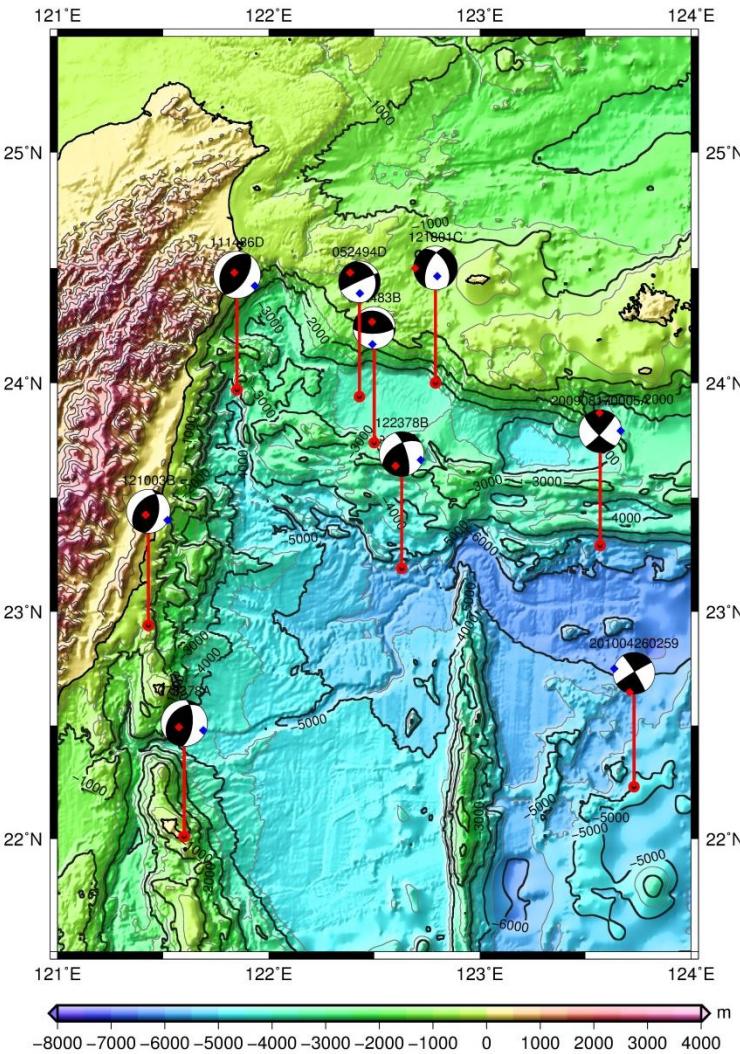
7,8,9: strike, dip, and rake of plane 2

10,11: mantissa and exponent of moment in dyne-cm

12,13: longitude, latitude at which to place beach ball. Entries in these columns are necessary with **-C** option. Using (0,0) in columns 11 & 12 will plot the beach ball at the longitude, latitude given in columns 1 & 2.

14: Text string to appear above the beach ball (**optional**).

Lecto6D



```
gawk "{print $1, $2, $3, $5, $6, $7, $8, $9, $10, $11,  
$12, $13, $14, $15}" eq_tw_gcmt.txt > eq_m65.txt
```

```
gmt meca eq_m65.txt -Sc0.3i -Fa0.1c/c -C1p+s0.1p -  
h1 -N -V
```

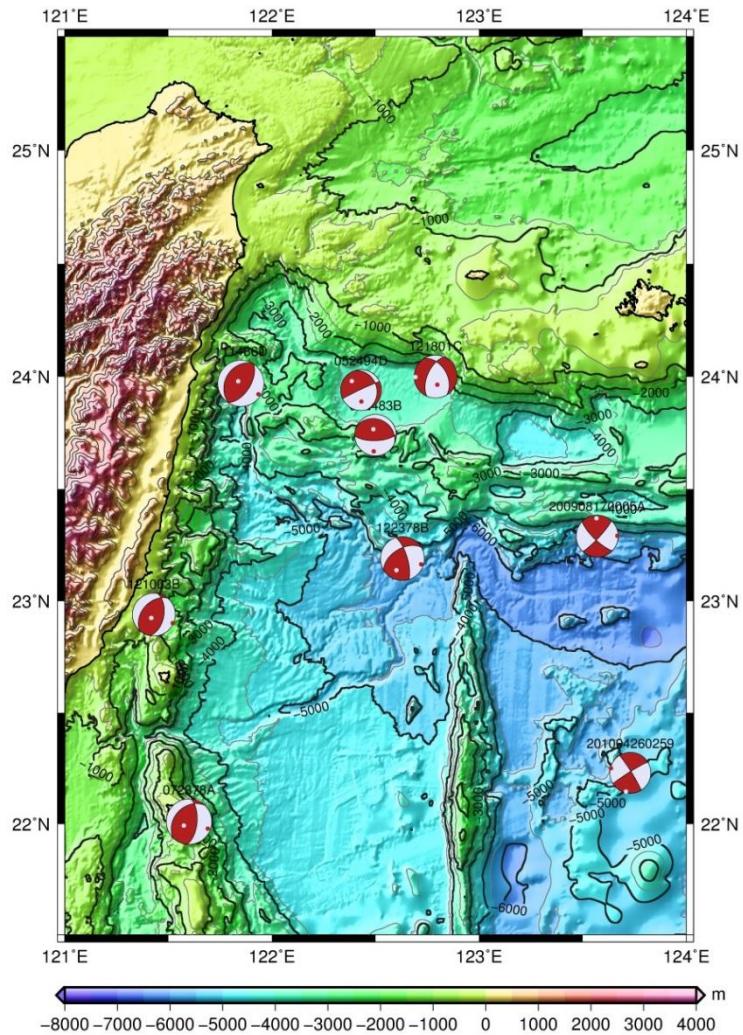
-C[pen][+spointsize]: Offsets focal mechanisms to the longitude, latitude specified in the last two columns of the input file before the (optional) text string.

Please try:

```
gawk "{print $1, $2, $3, $5, $6, $7, $8, $9, $10, $11, $12,  
$13, $14+0.5, $15}" eq_tw_gcmt.txt > eq_m65.txt
```

```
gmt meca eq_m65.txt -Sc0.3i  
-Fa0.2c/dh -Fe255/0/0 -Fg0/0/255  
-C2p,red+s0.2p -h1 -N -V
```

Lecto6D



```
gmt meca eq_m65.txt -Sc0.3i -Fa0.1c/c -C1p+s0.1p  
-h1 -N -V
```

-Efill: Selects filling of **extensive quadrants**. Usually **white**. Set the color [Default is 255/255/255, white]. (海灘球伸張象限的顏色，預設值是白色，建議不改變此象限之顏色，或用淡色表示之)

-Gfill: Selects filling of focal mechanisms. By convention, the **compressional quadrants** of the focal mechanism beach balls are **shaded**. Set the shade (0–255) or color (r/g/b) [Default is 0/0/0, black]. (海灘壓縮象限的顏色，預設值是黑色)

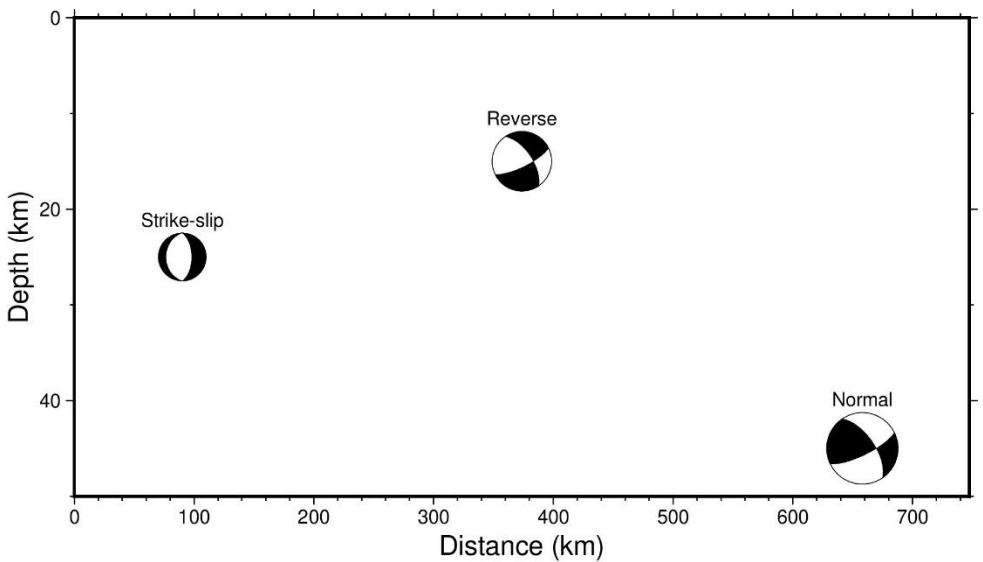
Please try:

```
gmt meca eq_m65.txt -Sc0.3i -Fa0.1c/c -Elavender -Gfirebrick  
-h1 -N -V
```

coupe

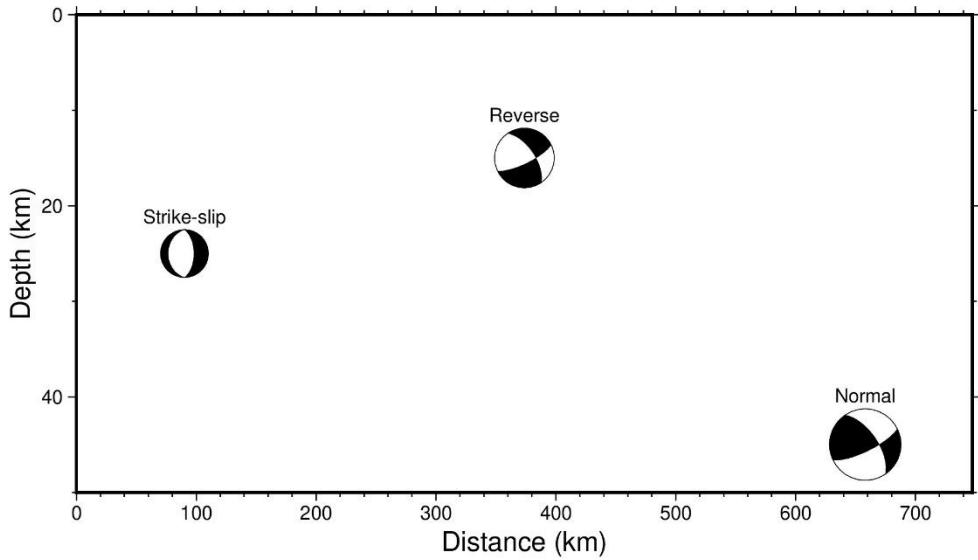
Plot cross-sections of focal mechanisms (震源機制)

```
gmt coupe [ table ] -Jparameters -Rregion -Aa/b/c/dparams[+c[n|t]][+ddip][+r [a|e|dx]][+width][+z
[s]a|e|dz/min/max] -S<format><scale>[+aangle+ffont][+justify] [+l][+m] [+odx[/dy]] [ -B[p|s]parameters ]
[-Ccpt ] [ -D[+c][+g[fill]]][+odx[/dy]][+ppen][+s[symbol]size] ] [ -Efill ] [ -Fmode[args] ] [ -Gfill ] [ -H[scale] ]
[ -I[intens] ] [ -L[pen] ] [ -M ] [ -N ] [ -Q ] [ -T[plane][+ppen] ] [ -U[stamp] ] [ -V[level] ] [ -Wpen ] [ -
X[a|c|f|r][xshift] ] [ -Y[a|c|f|r][yshift] [-dinodata[+ccol]] ] [ -eregexp ] [ -hheaders ] [ -iflags ] [ -pflags ] [ -
ttransp ] [ -:i[o] ] [ --PAR=value ]
```



REM Lon Lat depth strike dip rake Lon1(opt) Lat1(opt) text
echo 112 32 25 30 90 0 4 Strike-slip > coupe01.gmt
echo 115 34 15 30 60 90 5 Reverse >> coupe01.gmt
echo 118 32 45 30 60 -90 6 Normal >> coupe01.gmt
gmt coupe coupe01.gmt -Sa1c -
Aa111/33/119/33+d90+w500+z0/50+r -Q -JX15c/-8c -
Bxaf+l"Distance (km)" -Byaf+l"Depth (km)" -BWSen -jpg
test_couple01

-Q: Suppress the production of files with cross-section and mechanism information (默認會生成一些臨時檔，其中包含了剖面和剖面上的震源機制的資訊，供調試時使用。 使用該選項，則不會生成這些臨時檔).



```

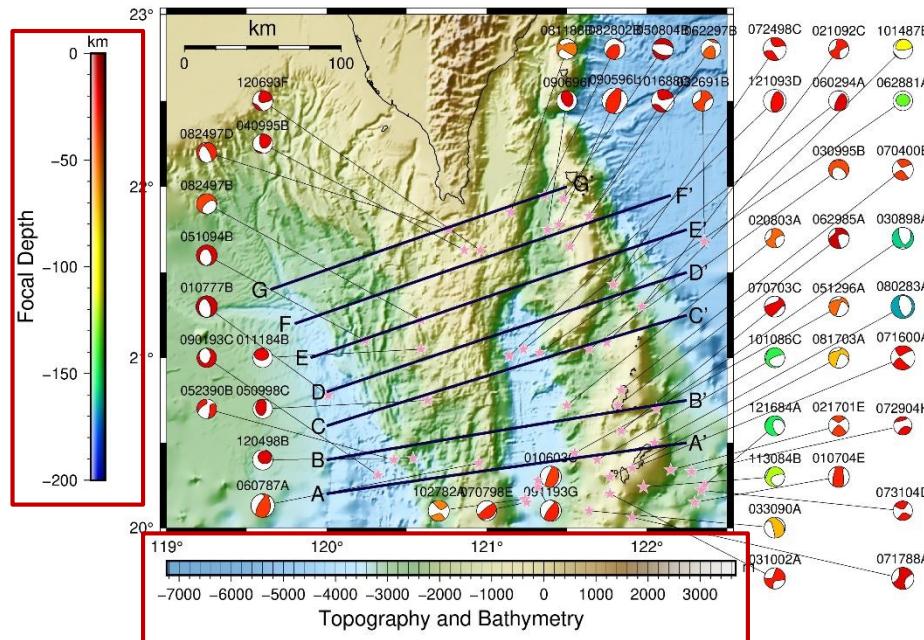
REM Lon Lat depth strike dip rake Lon1(opt) Lat1(opt) text
echo 112 32 25 30 90 0 4 Strike-slip > coupe01.gmt
echo 115 34 15 30 60 90 5 Reverse >> coupe01.gmt
echo 118 32 45 30 60 -90 6 Normal >> coupe01.gmt
gmt coupe coupe01.gmt -Sa1c -
Aa111/33/119/33+d90+w500+z0/50+r -Q -JX15c/-8c -
Bxaf+l"Distance (km)" -Byaf+l"Depth (km)" -BWSen -jpg
test_coupe01

```

-Q: Suppress the production of files with cross-section and mechanism information (默認會生成一些臨時檔，其中包含了剖面和剖面上的震源機制的資訊，供調試時使用。使用該選項，則不會生成這些臨時檔).

Lecto6E

Seismicity offshore southern Taiwan

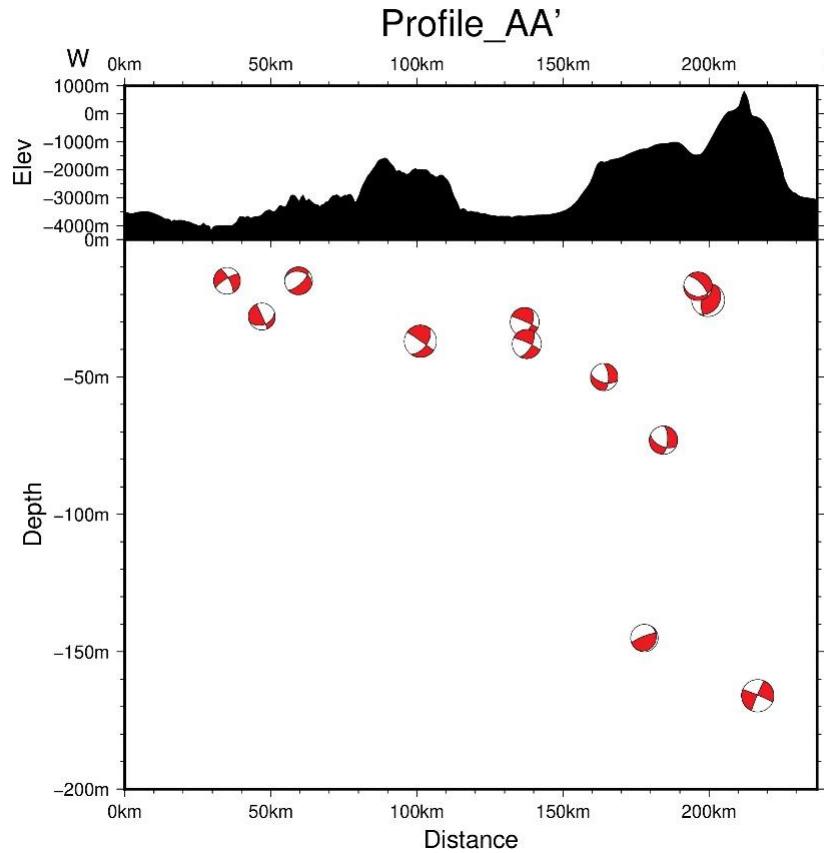


```
gmt meca fm_sm.txt -Sm0.2i+f10p -Zfd_seis.cpt -C -  
N -L -V  
gmt plot fm_sm.txt -Sa0.15i -G244/154/193 -  
W0.2,255 -V  
gmt colorbar -Cfd_seis+.cpt  
-Dx-0.8i/0.5i+w4.5i/0.15i+m  
-Bx50f10+l"Focal Depth"  
-By+lkm -V -I
```

Copy ~\Lect06\cpt\wiki-2.0 cpt to
C:\programs\gmt6\share\cpt

```
gmt makecpt -Cseis -T0/200/5 -Z -V >  
fd_seis.cpt  
gmt makecpt -Cseis -T-200/0/5 -I -Z -V >  
fd_seis+.cpt  
gmt makecpt -Cwiki-2.0 -T-6000/4000/200 -V  
> topo_wiki-2.0.cpt  
gmt begin %prefix% jpg A+m0.5c  
gmt basemap -R%range% -JM11/15c -  
Bxa1f0.5 -Bya1f0.5 -BWeSn+t"Seismicity  
offshore southern Taiwan" -V  
gmt grdimage %grd% -C%cpt% -I+d -V  
gmt coast -Dh -W0.5c,0 -  
Lg119.6/22.8+c23.5+w100k+l+f -V  
gmt colorbar -C%cpt% -Dx0i/-0.5i+w6i/0.15i+h  
-Bx1000f200g200+l"Topography and  
Bathymetry" -By+Im -V
```

Lecto6E



```
set startA=120/20.8
set endA=122.25/21.5
gmt project -C%startA% -E%endA% -G.5 -Q >
trackA.xyp
gmt grdtrack trackA.xyp -G%grd% | gawk "{ print $3, $4 }"
> trackA.d
echo 236.931 -5000 >> trackA.d
echo 0 -5000 >> trackA.d
gmt plot trackA.d -R0/237/-4500/1000 -JX6.3i/1.4i -L -G0 -
W1p -X2.5 -Y6 -Bxa50f10+ukm -Bya1000f500+IElev+um
-BWNse+tProfile_AA' -V
```

-L: Force closed polygons: connect the endpoints of the line-segment(s) and draw polygons (強制關閉多邊形)

Q1: Why using "echo 236.931 -5000 >> trackA.d" and "echo 0 -5000 >> trackA.d"?

Standard Input files

trackD.xyp

120	20.8	0
120.005	20.8015	0.5
120.009	20.8029	1
.....		
122.241	21.4973	245
122.246	21.4987	245.5
122.25	21.5	245.972

trackD.d

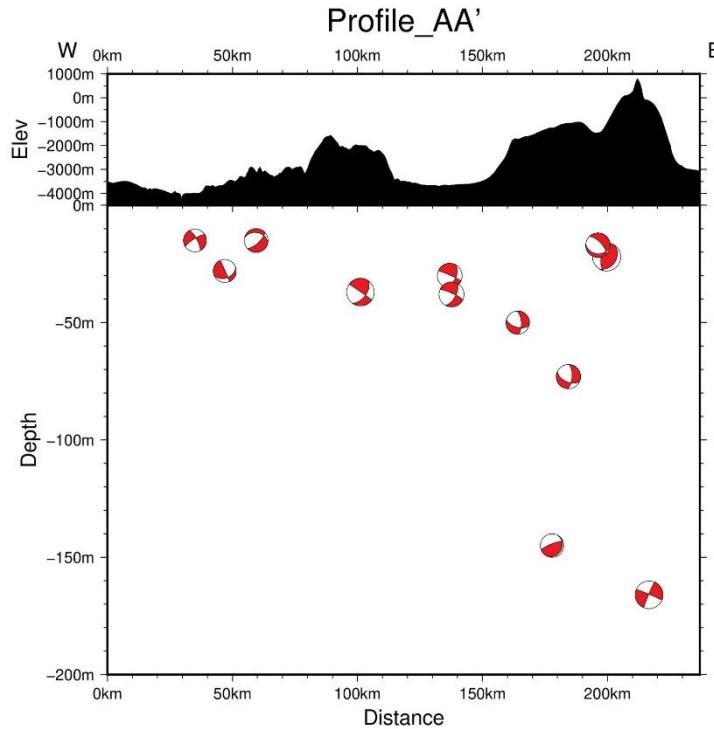
0	-3615.8
0.5	-3611.85
1	-3625.19
.....	
245	-4750.58
245.5	-4755.12
245.972	-4758.54

focal4.txt for –Sc (Focal mechanisms in Global CMT convention)

120.01	20.78	-10	194	29	-62	343	65	-105	3.88	24	0	0	010777B
121.33	21.03	-132	266	40	87	89	50	92	8.10	23	0	0	062881A
121.24	20.17	-57	56	78	-173	325	83	-12	2.52	24	0	0	102782A
122.05	20.50	-166	0	23	-79	168	67	-95	2.85	25	0	0	080283A
120.59	21.05	-20	324	22	138	94	75	73	7.11	23	0	0	011184B

coupe

Plot cross-sections of focal mechanisms (震源機制)



-Gfill: Sets color or fill pattern for compressional quadrants [Default is black].

-Efill: Sets color or fill pattern for extensive quadrants [Default is white].

```
gmt coupe [ files ] -Jparameters -Rregion -Aparameters -  

  S<format><scale>[+ffont][+justify][+odx/dy]] [ -  

  B[p|s]parameters ] [ -Ecolor ] [ -Fmode[args] ] [ -Gcolor ]  

  [ -L[pen] ] [ -M ] [ -N ] [ -Q ] [ -Tnplane[pen] ] [ -U[stamp] ]  

  [ -V[level] ] [ -Wpen ] [ -X[a|c|f|r][xshift[u]] ] [ -  

  Y[a|c|f|r][yshift[u]] ] [ -Zcpt ] [ -dinodata ] [ -eregexp ] [ -  

  hheaders ] [ -iflags ] [ -pflags ] [ -ttransp ] [ -:[i|o] ] [ --  

  PAR=value ]
```

```
gawk "{ print $1, $2, $3, $4, $5, $6, $7, $8, $9, $10, $11,  

$12, $13 }" focal4.txt > focal4.gmt  

gmt coupe focal4.gmt -Sc0.6c  

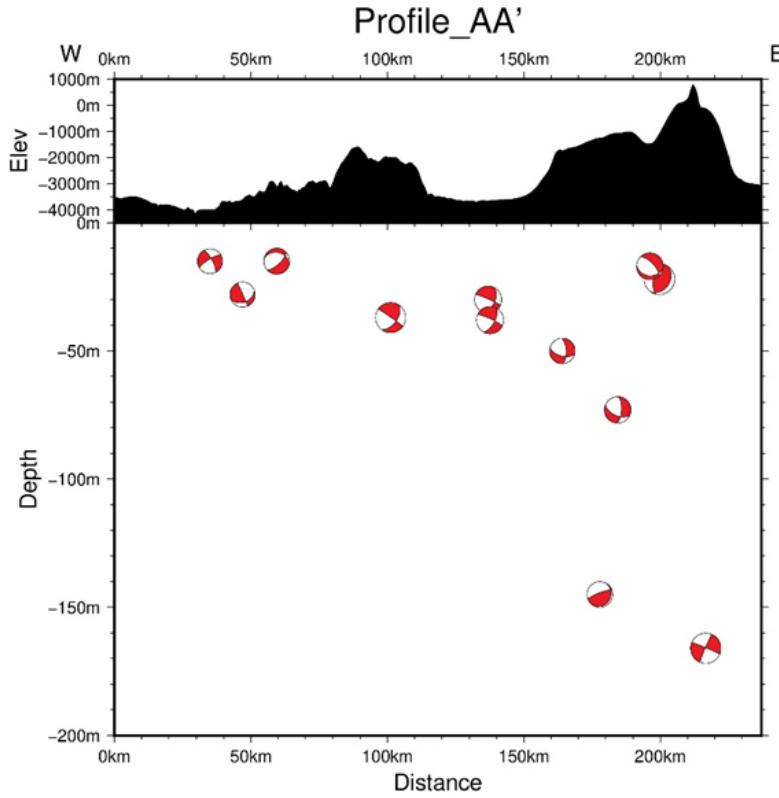
-Aa120/20.2/122.25/20.5/90/20/0/200  

-G237/28/36 -E255 -JX6.3i/5i -R0/237/-200/0  

-Bxa50f10+IDistance+ukm  

-Bya50f10+IDepth+um -BWSen -Y-5 -V
```

coupe



```
gawk "{ print $1, $2, $3, $4, $5, $6, $7, $8, $9,  
$10, $11, $12, $13 }" focal4.txt > focal4.gmt
```

```
gmt pcoupe focal4.gmt -Sc0.6c  
-Aa120/20.2/122.25/20.5/90/20/0/200  
-G237/28/36 -E255 -JX6.3i/5i  
-R0/237/-200/0  
-Bxa50f10+IDistance+ukm  
-Bya50f10+IDepth+um -BWSen -Y-5 -V
```

- **-A**: Selects the cross-section
- **-Aalon1/lat1/lon2/lat2/dip/p_width/dmin/dmax[f]**
- **lon** and **lat**: longitude and latitude of points 1 & 2 limiting the length on the cross-section.
- **dip**: dip of the plane on which the cross-section is made.
- **p_width**: width of the cross-section on each side of a vertical plane or above and under an oblique plane.

- **dmin** and **dmax**: distances min and max from horizontal plane, along steepest descent direction.
- Add **f** to get the frame from the cross-section

Broadband Array in Taiwan for Seismology

<https://bats.earth.sinica.edu.tw/>

Broadband Array in Taiwan for Seismology

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THSIS: Taiwan Earthquake Science Informatin System



Time(UTC)	Lat(°)	Lon(°)	Depth(km)	M _L
2024-04-03T08:38:01	23.74	121.57	15.3	4.9
2024-04-03T08:17:12	24.03	121.63	22	4.7
2024-04-03T07:24:47	23.99	121.59	11.8	4.5
2024-04-03T07:05:19	24.23	121.7	11.3	4.4
2024-04-03T06:33:57	24.21	121.88	5	4.8
2024-04-03T06:33:57	23.91	121.53	10.5	4.7

Data period :1996/03/28 ~ 2024/02/29 (Archived)
2013/05/23 ~ 2024/04/03 (Realtime)

Output:

Standard Format

Start Time:

YYYY-MM-DD



End Time:

YYYY-MM-DD



Search Criteria:

ML

Mw

Archived

Realtime

Min. Magnitude:

ML 0-10

Max. Magnitude:

ML 0-10

Min. Depth (km):

Max. Depth (km):

P-Axis Plunge*:

Min P-axis 0-90

Max P-axis 0-90

B-Axis Plunge*:

Min B-axis 0-90

Max B-axis 0-90

T-Axis Plunge*:

Min T-axis 0-90

Max T-axis 0-90

AutoBATS CMT Catalog

Standard Format

Standard Format

Full Format in CSV

GMT psmeca (-Sa) Plane #1

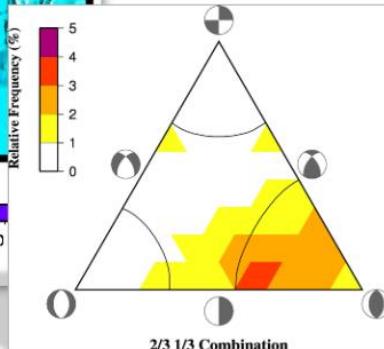
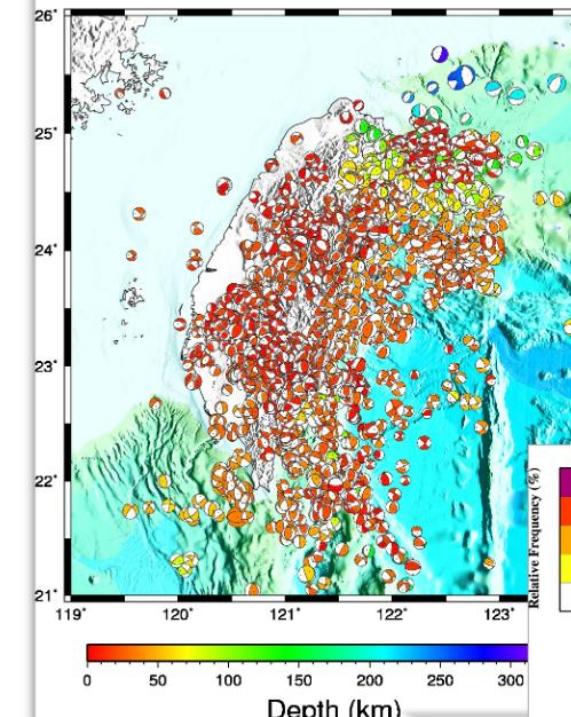
GMT psmeca (-Sa) Plane #2

GMT psmeca (-Sm)

Event List

AutoBATS Format

AutoBATS CMTs (1996–2018)



Standard Format

- 搜尋1996-03-28迄今，地震矩規模(M_w)大於等於6.0的地震，標準輸出選擇：1. standard format; 2. Full Format in CSV; 3. GMT psmeca (-Sa) plane #1, 4. GMT psmeca (-Sm)
- 請開啟~/Lect06/BATS/下的20200426103123_psmeca.txt、20200426103217_psmeca.txt 和 20200426102440_csv.txt (最完整的海灘球資訊，含P, T, B軸位態)



AutoBATS CMT Catalog

AutoBATS Standard Format Output:

[19990920181154A](#)

CWB Report:

Origin Time = 1999/09/20 18:11:54.21 (UT)

Hypocenter : Lat. = 23.8648 Long. = 121.0671 Depth = 12.49 km

AutoBATS Solution : gap / nsta / misfit = 242.891 / 3 / 0.409

Centroid Depth = 25 km Mw = 6.06 CLVD(%) = 23.6

Fault Plane #1 : strike = 339.32 / dip = 24.82 / slip = 43.15

Fault Plane #2 : strike = 208.92 / dip = 73.31 / slip = 108.65

Moment Tensor : Expo = 24 8.7294 0.8715 -9.6009 -7.914 -9.6568 0.0681

Standard Format

Standard Format

Full Format in CSV

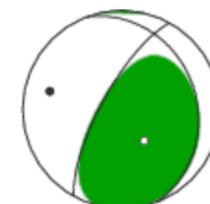
GMT psmeca (-Sa) Plane #1

GMT psmeca (-Sa) Plane #2

GMT psmeca (-Sm)

Event List

AutoBATS Format



BATS Web Services : Final AutoBATS CMT Catalog URL Builder

Data period : 1996/03/28 ~ present

Data type: final CMTs, output format: GMT psmeca format (psmeca for GMT classic mode)

Output:	<input type="button" value="CSV File"/>	<input type="button" value="GMT psmeca (-Sa)"/>	
Start Time:	<input type="button" value="CSV File"/>	<input type="button" value="GMT psmeca (-Sm)"/>	
End Time:	<input type="button" value="Event List (Text file)"/>	<input type="button" value="YYYY-MM-DDThh:mm:ss"/>	
Magnitude Type:	<input type="button" value="ML"/>	<input type="button" value="Mw"/>	
Min. Magnitude:	<input type="text" value="Mw 0-10"/>		
Max. Magnitude:	<input type="text" value="Mw 0-10"/>		
Min. Depth (km):	<input type="text"/>		
Max. Depth (km):	<input type="text"/>		
Location:	<input type="button" value="All"/>	<input type="button" value="Box"/>	<input type="button" value="Radius"/>

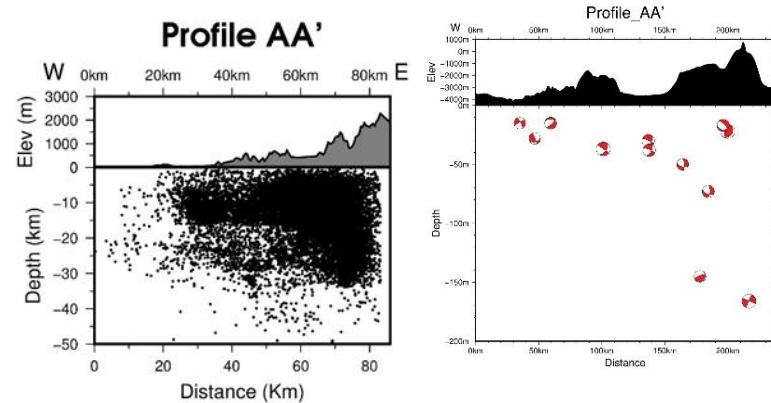
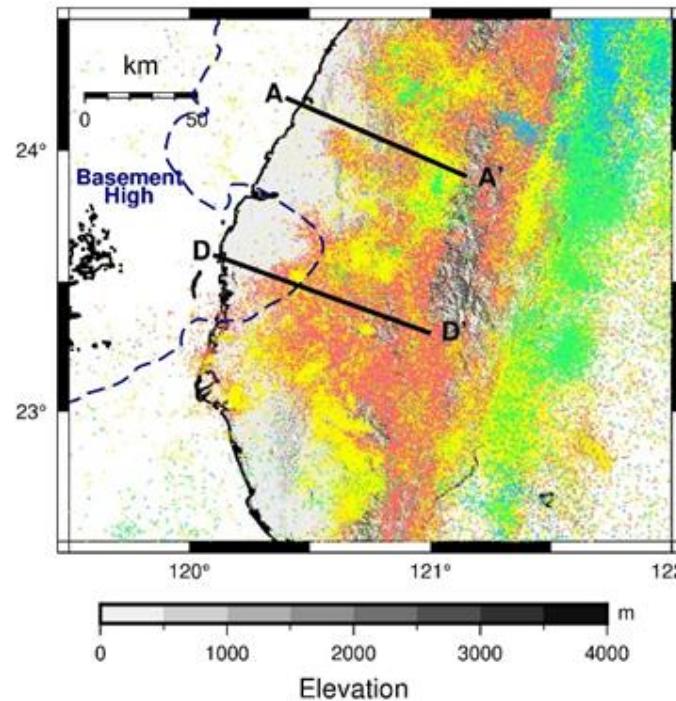
Label:

Download as file:

Submit & download GMT format file

Background seismicities of Taiwan

Depth 0-15 15-30 30-50 > 50 km
Projection width:
20 km (each side)

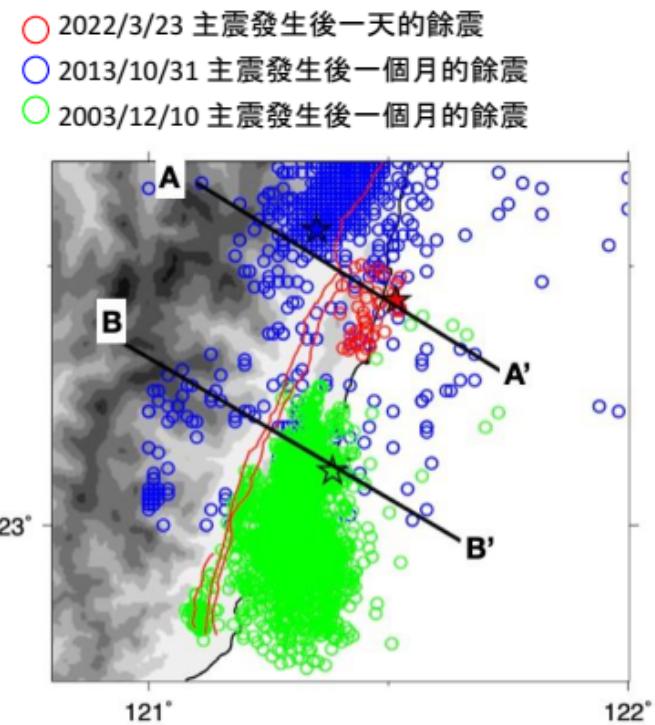


Exercise 06

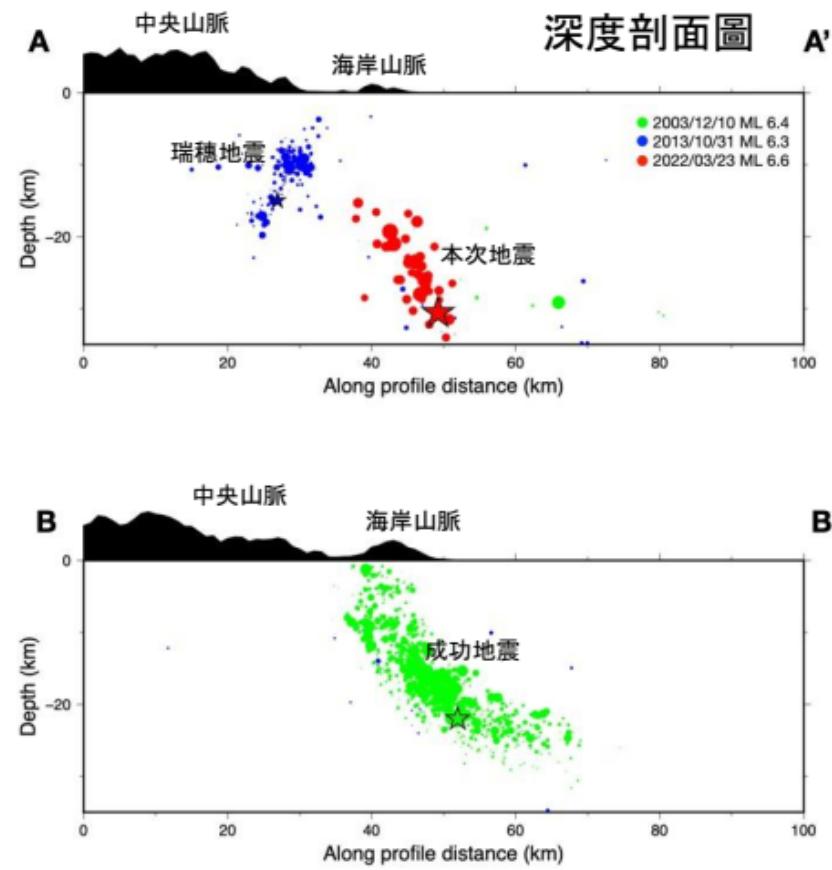
- Using Lect05A.bat or Lect05A.sh as a template
- Draw focal mechanisms in mapview of $Mw \geq 6.0$ in and around Taiwan in **AutoBATS CMT Catalog**
- Make a profile with elevation for focal mechanisms central Taiwan from Taiwan strait to offshore east Taiwan across **Chelungpu fault Longitudinal fault**.
- With **active faults** of CGS version 2020
- It's obligatory to separate the events which are superimposed together
- Draw the **P and T axes**
- **Suggestion:** First draw focal mechanism without topography, if it's fully successful, then put it with relief and active faults

此區歷史主餘震序列

震央區過去發生的重要歷史地震，分別為2003年成功地震(主震規模6.4)、2013年瑞穗地震(主震規模6.4)和本次地震(主震規模6.6)。如下圖A-A'及B-B'剖面所示，顯示2003和2022的地震群位於向東傾的縱谷斷層上，而2013的地震群則為向西傾的中央山脈斷層上。本次地震群位置深度皆在5 km以下，和縱谷斷層的「池上段」空間緊鄰，皆為向東傾之發震構造。

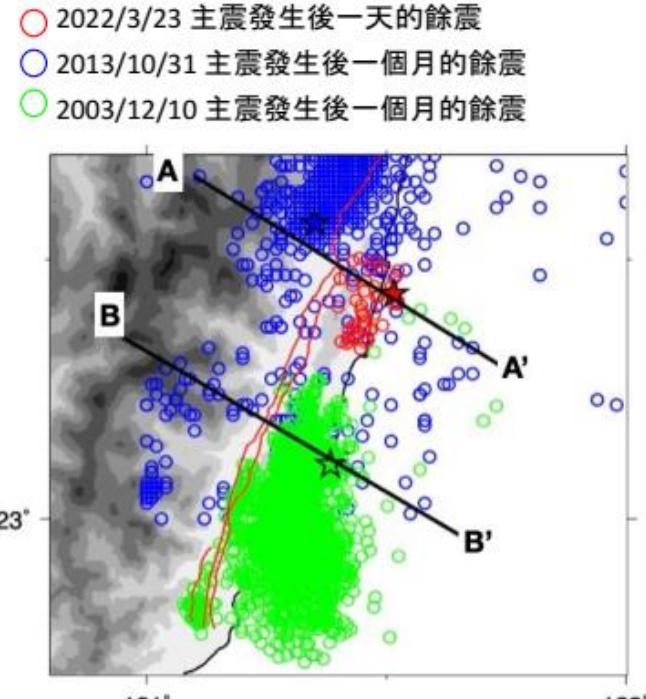


(圖由彭葦博士提供)

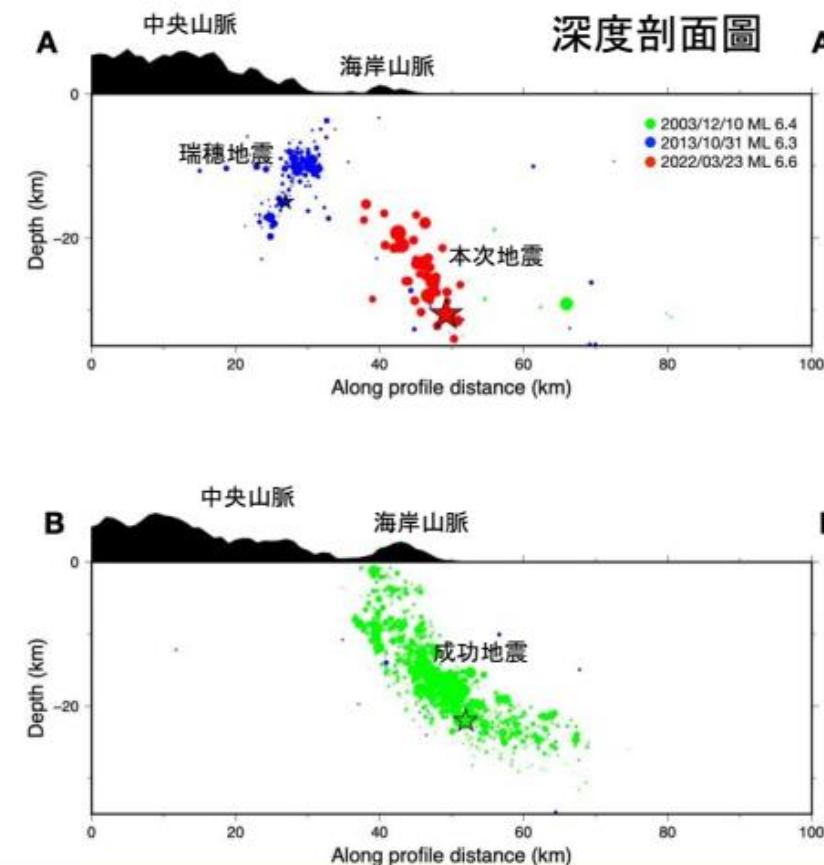


(台灣地震科學中心，2022)





(圖由彭葦博士提供)



(台灣地震科學中心，2022)

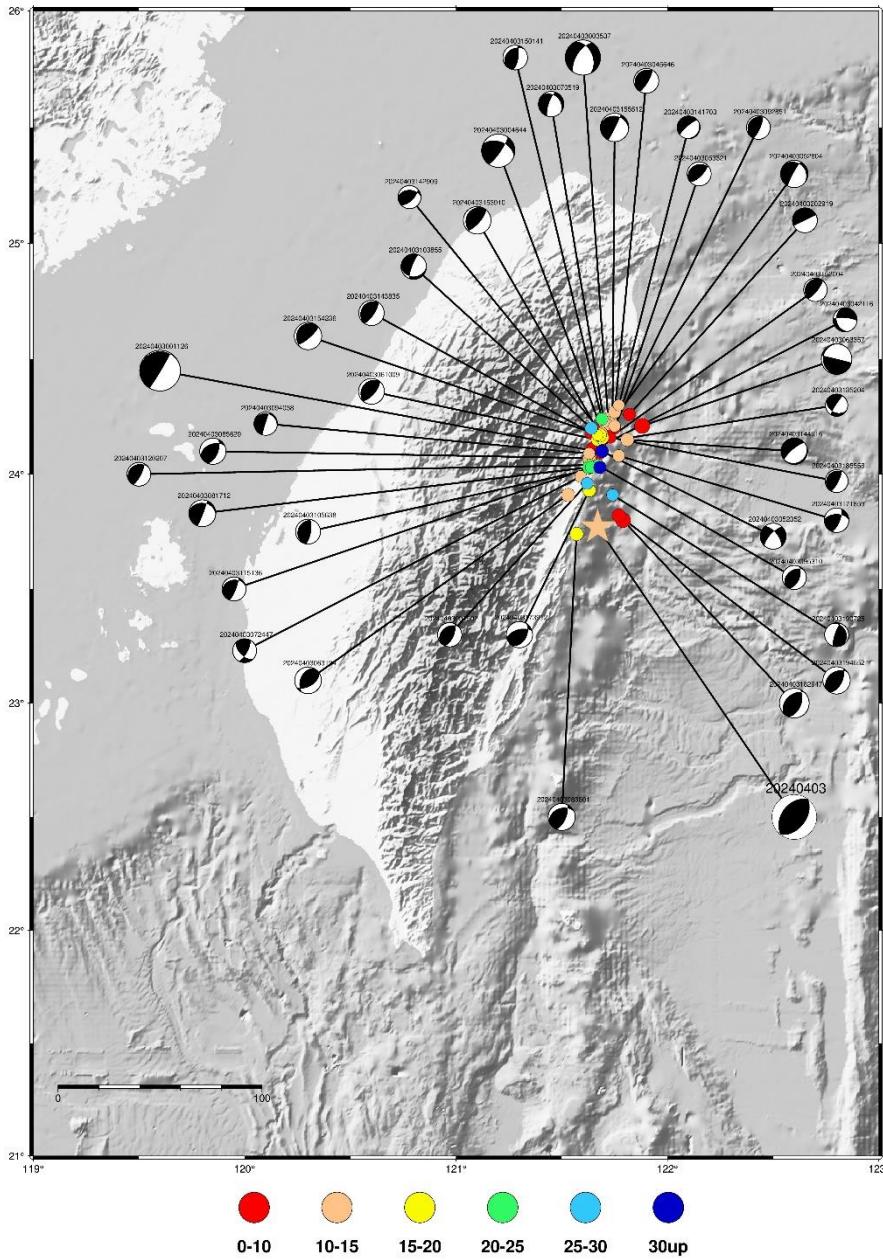
1. In the directory “EQ20220323”, all files related to 2022-03-23 Yuli Earthquake are inside. Plot the **focal mechanisms of mainshock and aftershocks** for 2022-03-23 Yuli Earthquake.
2. Search the focal mechanisms for 2003 Chengkung earthquake and 2013 Juisui Earthquake, and plot them with Yuli Earthquake. (You must plot them in proper symbol to distinguish them.)
3. Plot the profile for 2022-03-23 Yuli Earthquake.



資料說明

- EQ_catalog: 1990~2021 earthquake catalog from CWB
- EQ20220323_large: sensible earthquakes for 20220323 event
- EQ20220323_small: regional records for 20220323 event
- EQ20220323_meca_sa: Realtime focal mechnisms for 20220323 event

Homework 06a



- Draw focal mechanisms of mainshock 0403 Hualien event and aftershocks > 4.5 color-coded with focal depths on gray-shaded relief map
- Data: ~\Lecture 06\Focal mechanisms_2024HualienEQ\AS.xlsx or AS_TS.txt

Homework 06b

- Draw focal mechanisms of **Historic World Earthquakes in a region (orogenic belt) or a country with $Mw > 7.5$** from **Global CMT Catalog** on global **15 arc-second elevation (GEBCO_2019.nc)** (using gmt grdcut to cut a region or a country)
- Draw a location map of this event by @
- with Hemisphere map by using inset command



gmt coast -Rg -JA280/30/5.5i
-Bg -Dc -A1000 -Gnavy

- If the data of plunges of P-, T- and B axes are available, please classified the focal mechanisms as shown in lecture 06e.
- Put plate boundaries in your plot: see ~/plate boundaries/PB2002,

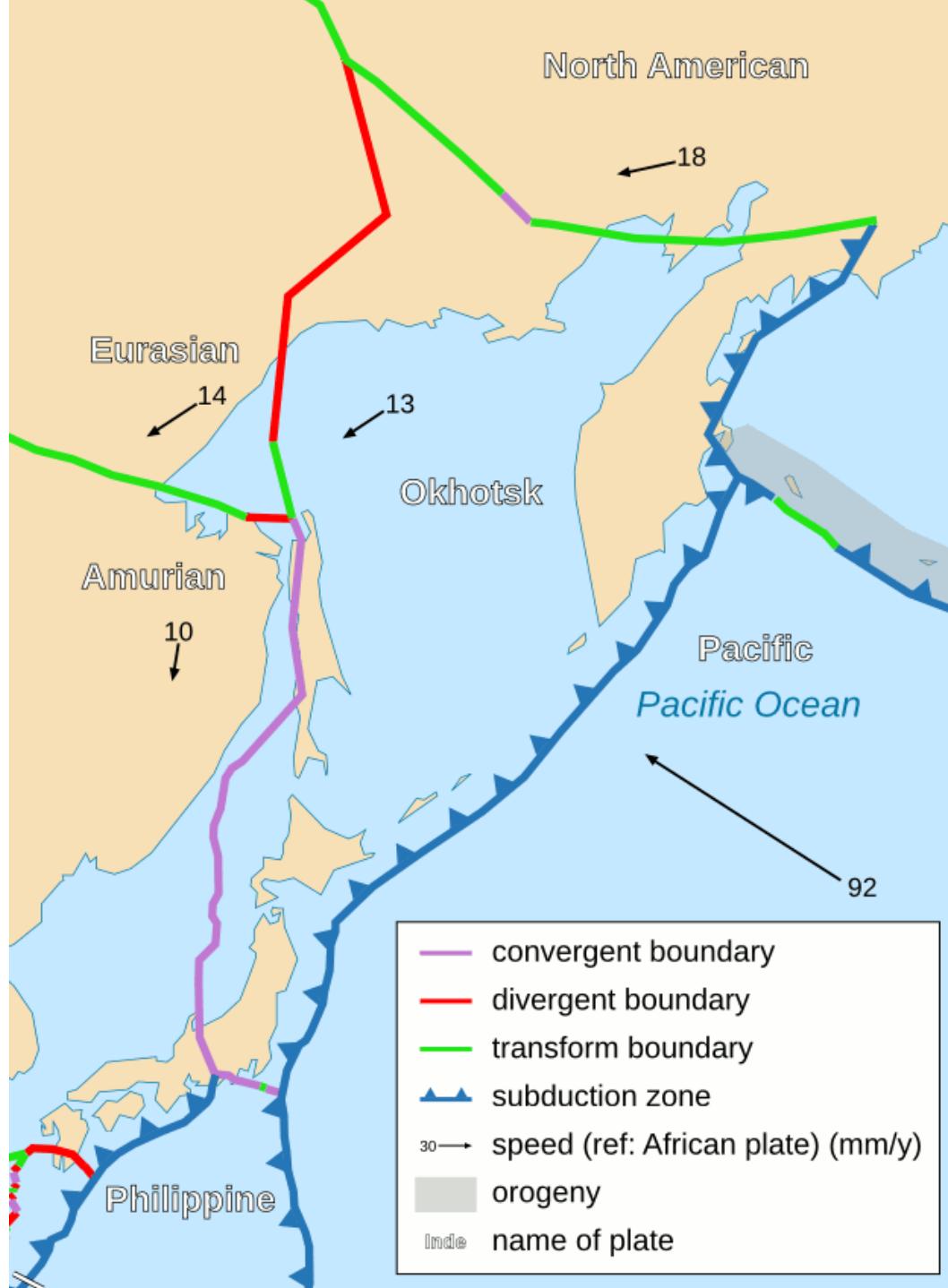
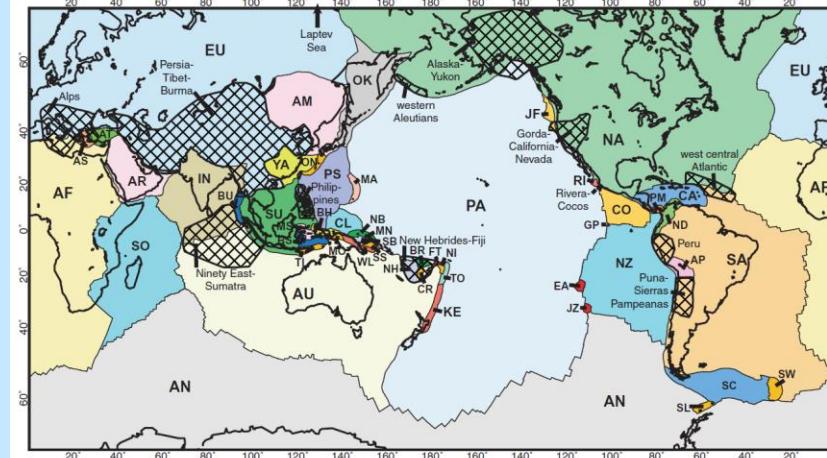


Plate boundaries

Plate boundaries:

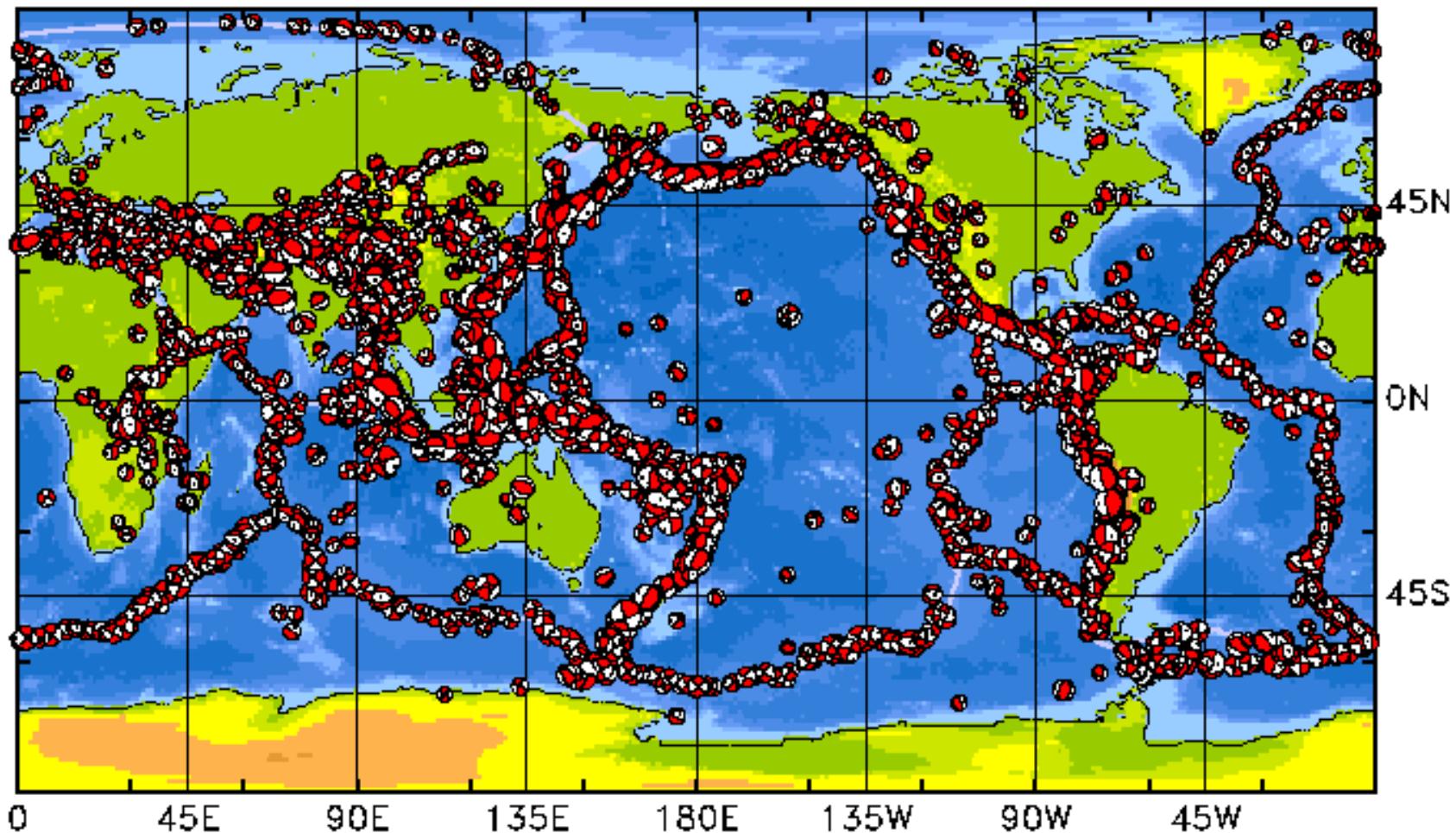
1. ridge.gmt, transform.gmt, trench.gmt
 2. Bird, P., 2003. An updated digital model of plate, G³



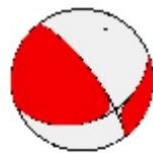
Global CMT Web Page

<http://www.globalcmt.org/>

Shallow earthquakes, 1976-2005.



Global CMT Catalog Search



Global CMT Catalog Search

Search form

If you use CMT results in published work, please provide an appropriate citation; see [here](#) for information on how to cite the catalog. Thanks!

Enter parameters for CMT catalog search. All constraints are 'AND' logic.

Date constraints: catalog starts in 1976 and goes through present

There are several methods to choose date ranges--use the radio buttons to select which method you want to use

Starting Date:		Ending Date:			
<input checked="" type="radio"/> Year: 1976	Month: 1	Day: 1	<input type="radio"/> Year: 1976	Month: 1	Day: 1
<input type="radio"/> Year: 1976	Julian Day: 1		<input type="radio"/> Year: 1976	Julian Day: 1	
			<input checked="" type="radio"/> Number of days: 1	Including starting day	

- Output type:**
- Standard
 - List of event names
 - [GMT psvelomeca input](#)
 - [GMT psmeca input](#)
 - CMTSOLUTION format
 - Full format