Foreshock Characteristics in Taiwan: Potential Earthquake Warning

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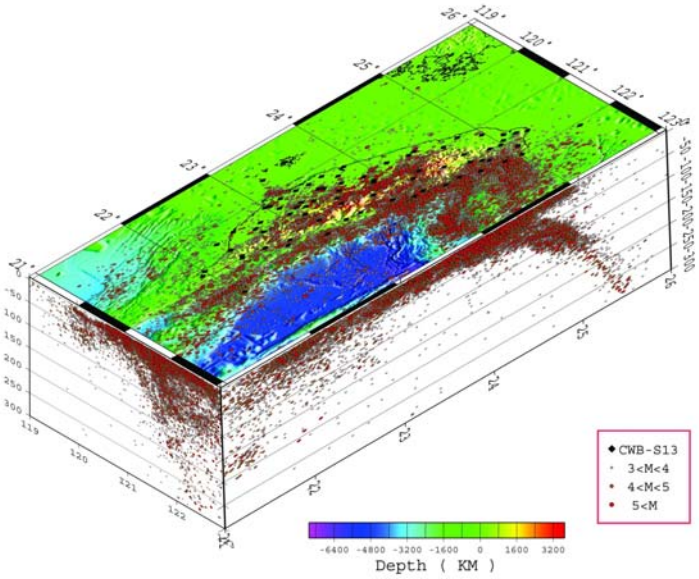


2010/9/14

Outline

- Foreshocks and potential applications
- Previous foreshock studies
- Foreshocks in Chengkung earthquake (ML=6.6)
- Examine other foreshocks in Taiwan
- Discussion and conclusions

地震前兆現象的機制(假說)

滿月之日，太陽與月球由完全相反的方向牽引地球，地殼因而出現龜裂(斷層)，並變得容易移動。地殼的伸縮造成地下水移動，水井和溫泉水位忽上忽下。含於花崗岩中的放射性元素變成氡氣溶於水中，再經由水井流出地面放射γ線。地底冒出的熱水使地表附近的溫度升高，冬眠中的動物因此誤以爲春天已至而爬出洞穴。在岩石上增加應力產生的壓電效應和在岩石與流水間因地下水流所形成的電，變成了地電流，偶而會放電。發光現象也是肇因於這種放電現象。地電流和放電刺激到感覺敏銳的動植物，導致這些動植物的行動和反應異於尋常。

Five Precursors listed by IASPEI

(International Association for Seismology and Physics of the Earth's interior)

*** Ground-water Chemistry and Temperature**

Izu-Oshima-Kinka Earthquake (M=7.0), Japan, 1978

*** Ground-water Level** (Roeloffs and Quilty)

Kettleman Hills earthquake (M=6.1), California, 1985

*** Foreshocks (days or weeks)** (Wu et al., 1991)

Haichen earthquake (M=7.3), China, 1975

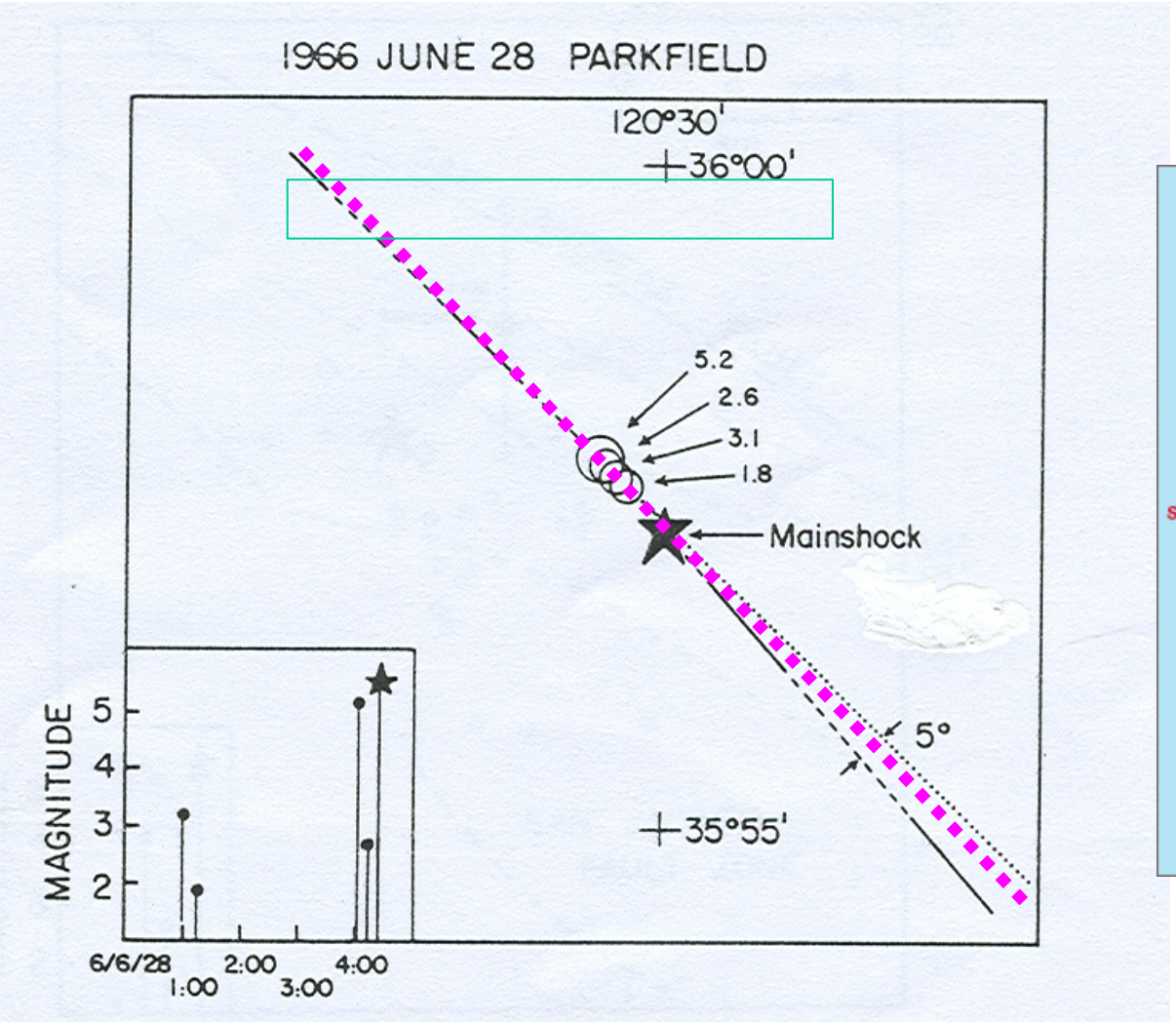
*** Preshocks (1-year before)** (Bowman, 1997)

Tennant Creek earthquake, Austria, 1988

*** Seismic quiescence** (Matsu'ura, 1986, 1991)

Several cases in Japan

What's foreshock ?



Foreshocks in Parkfield

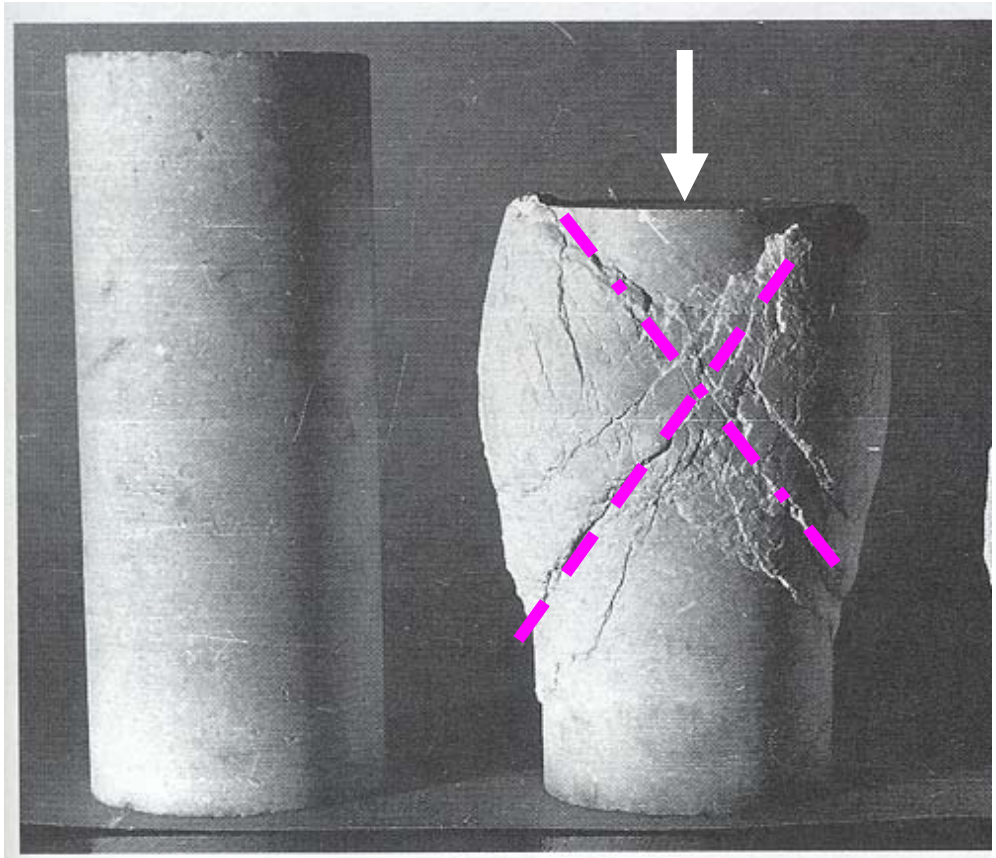
San Andreas Fault

(Jones, 1984, BSSA)

Mechanisms

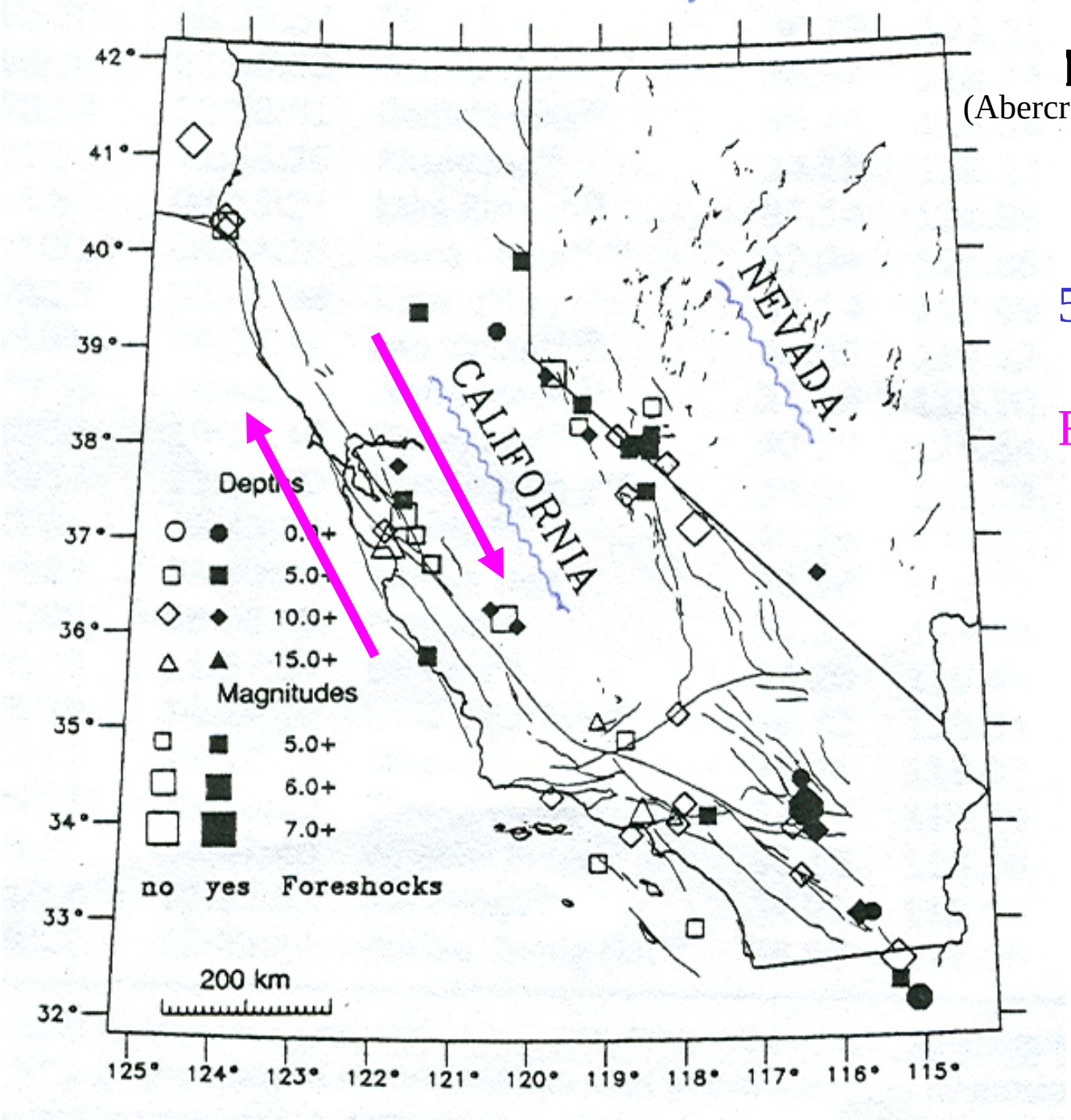
Dilatancy model:

Micro-cracking in Lab ⇔ Foreshocks?



- Why not all of the mainshocks with foreshocks?
- What's foreshock mechanism?
- Are there some foreshocks in Taiwan?

Previous Studies



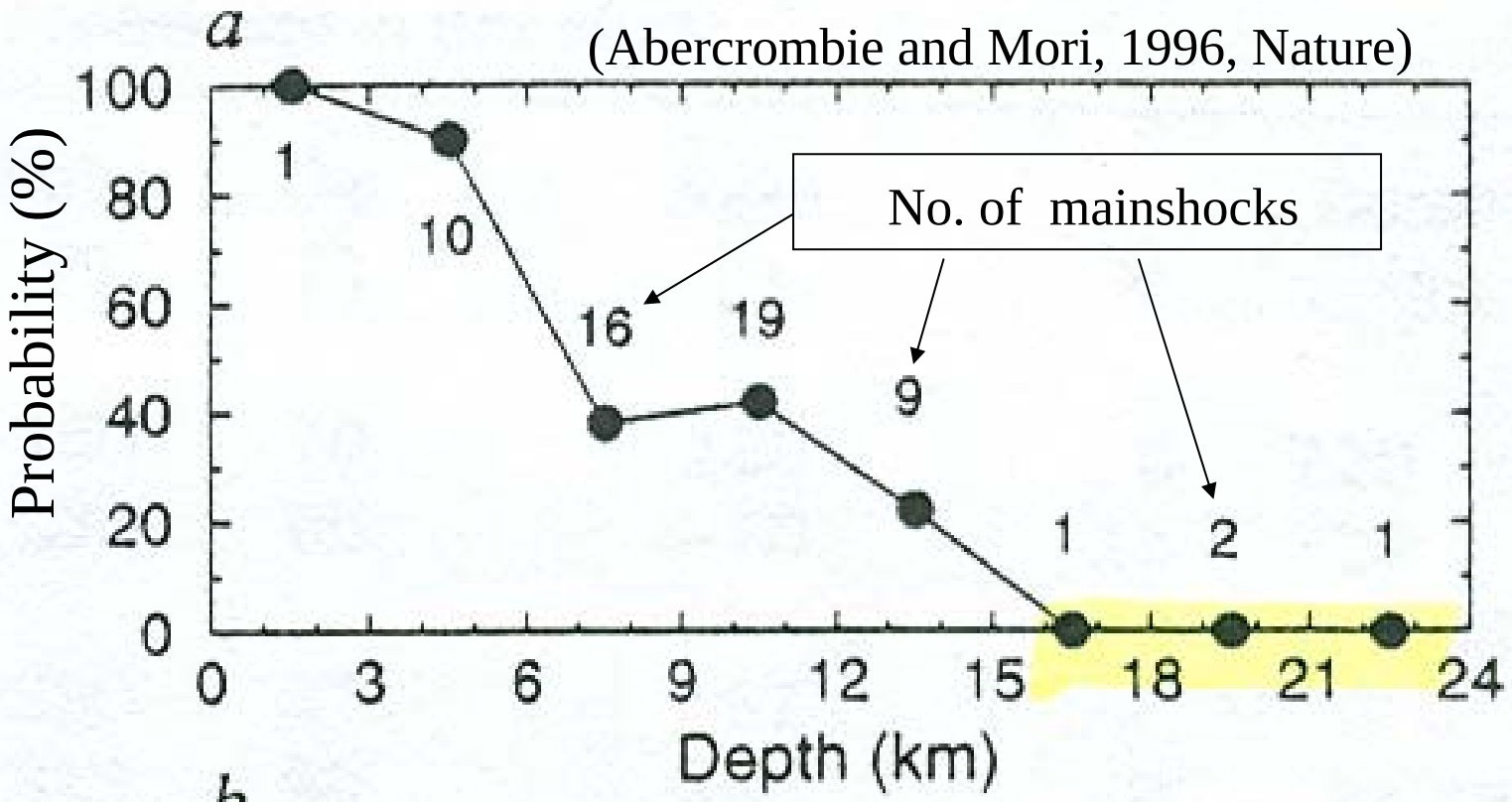
(Abercrombie and Mori, 1996, Nature)

59 events (M > 5)

Foreshocks ⇔

1. Focal depths
2. Fault types

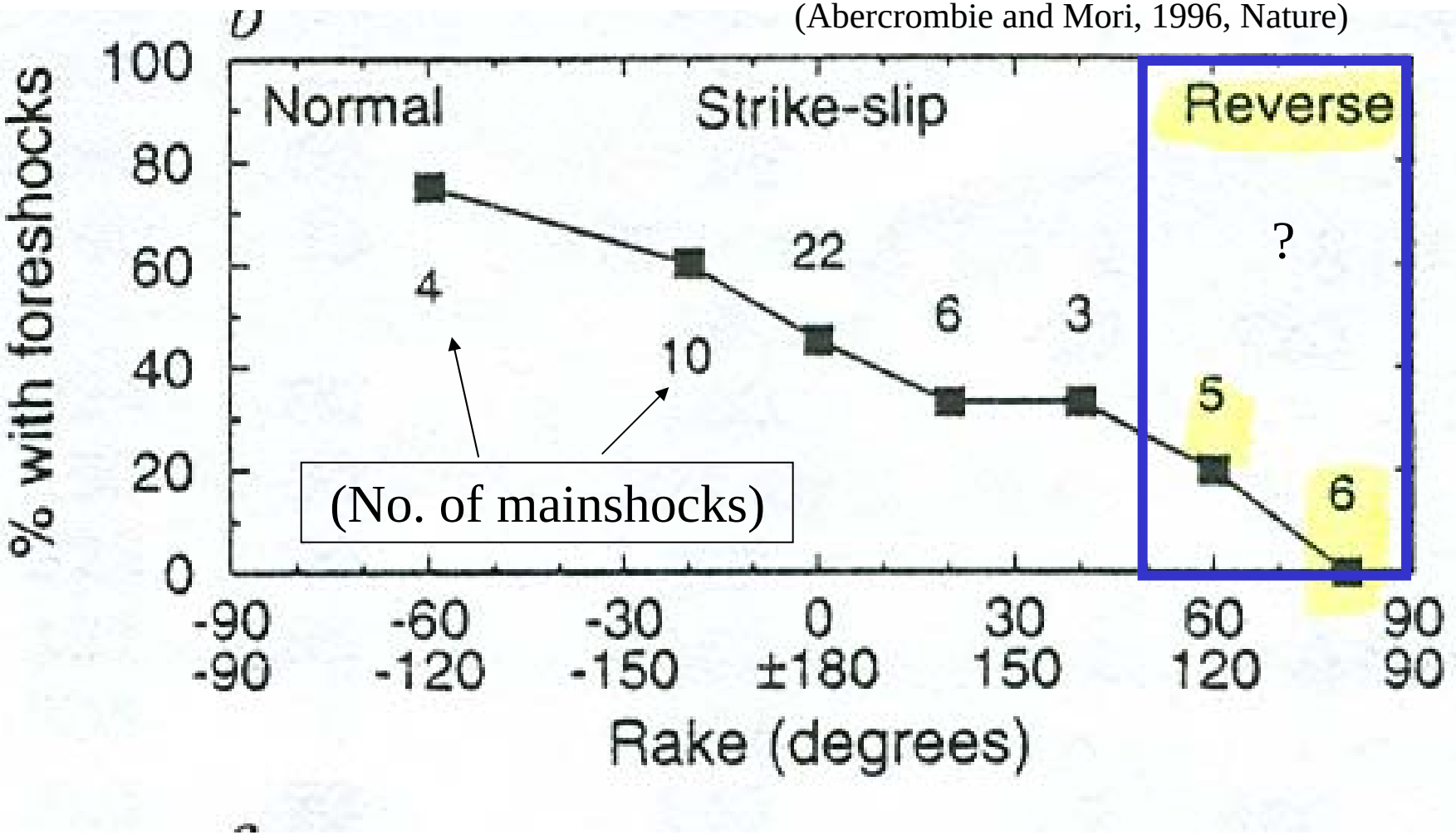
Foreshocks ⇔ focal depths



Heterogeneity ⬅==➔ Homogeneity

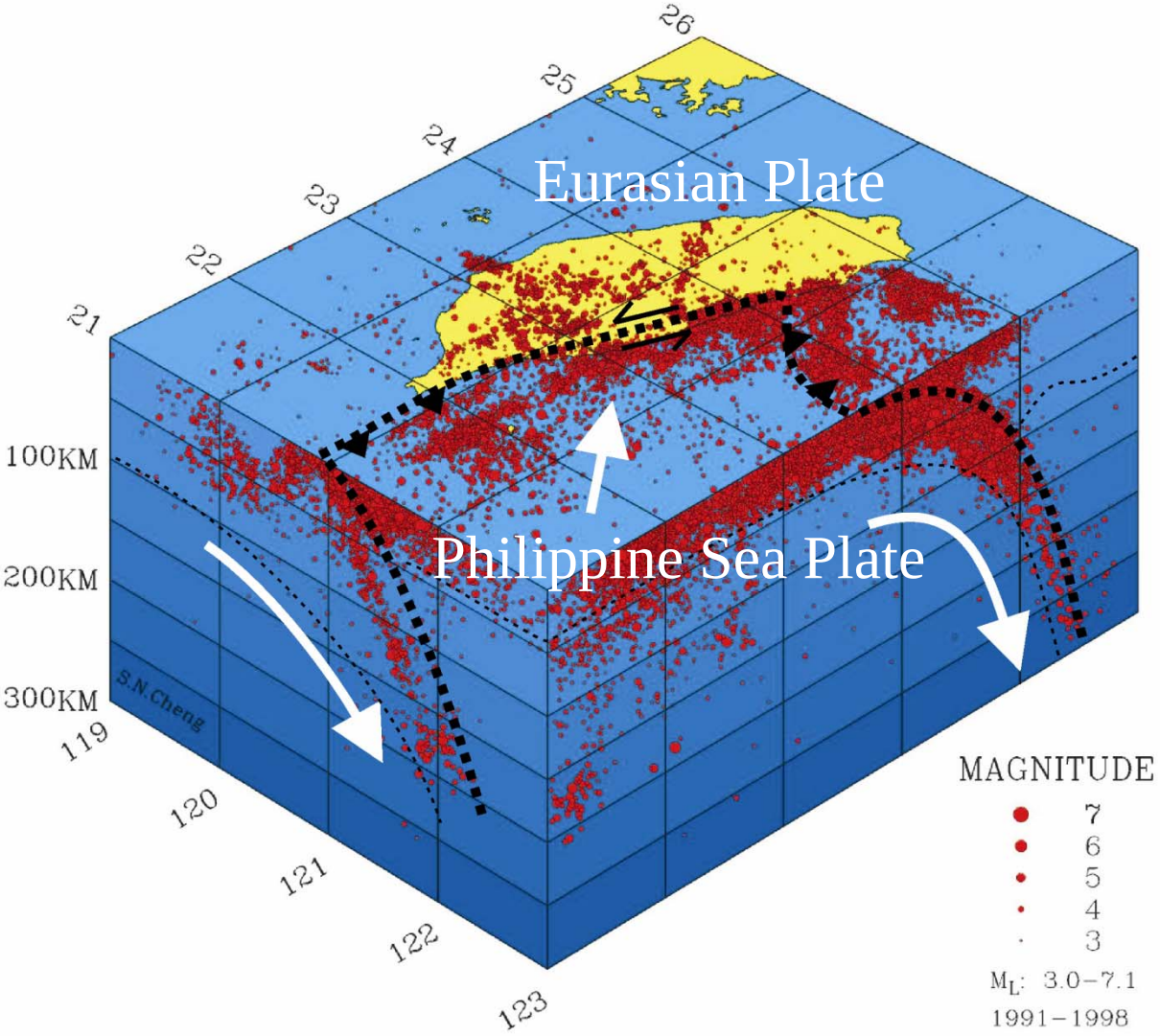
Foreshocks ⇔ Fault types

(Abercrombie and Mori, 1996, Nature)



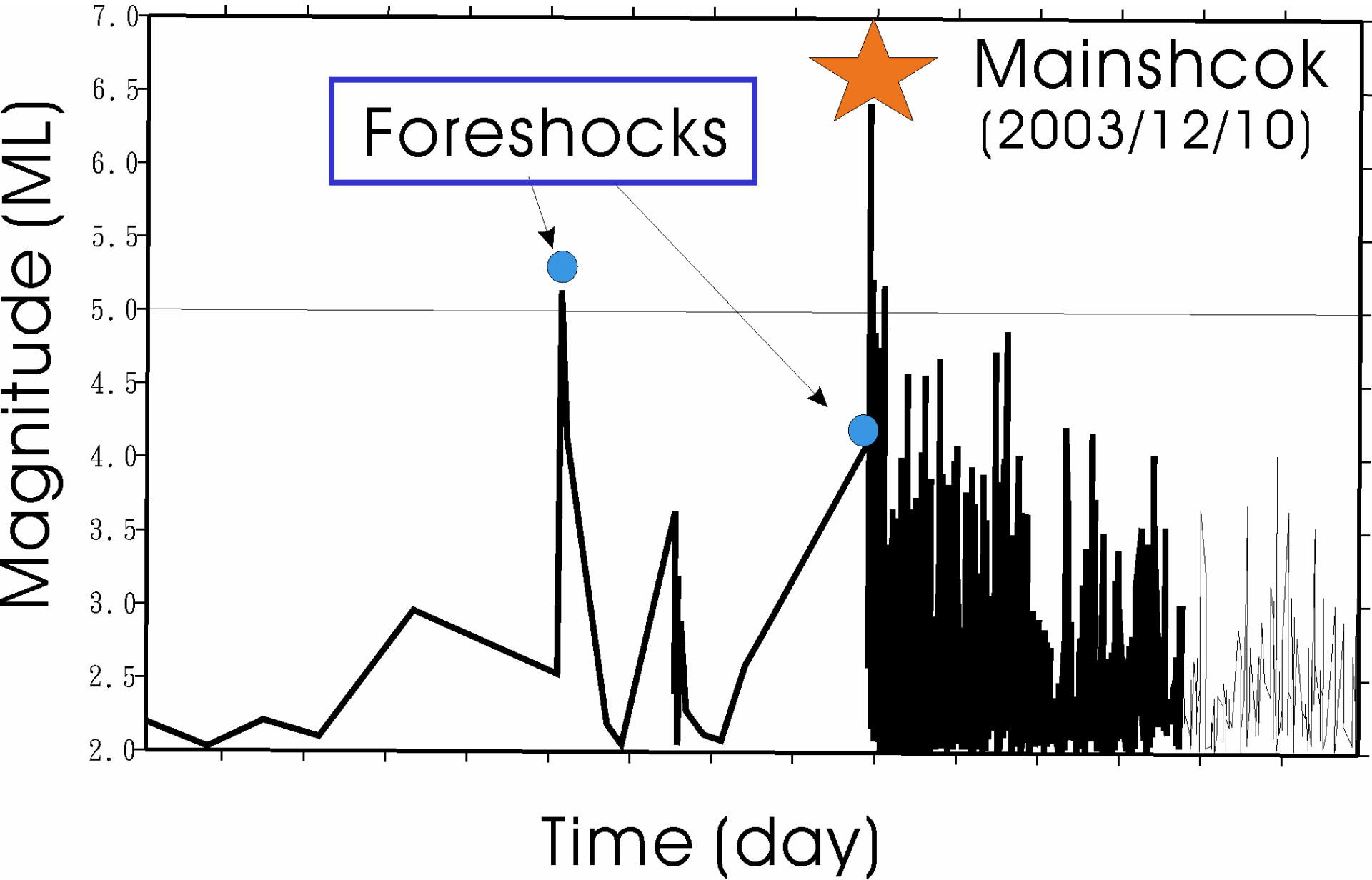
Foreshocks were largely found at **normal** and **strike-slip faults:**
Foreshocks ⇔ normal stress

Foreshocks in Taiwan?
(Reverse-faulting)



Strike-slip faulting

成功地震（2003/12/10）


Foreshocks
Mainshcok
(2003/12/10)
Magnitude (ML)
Time (day)
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0

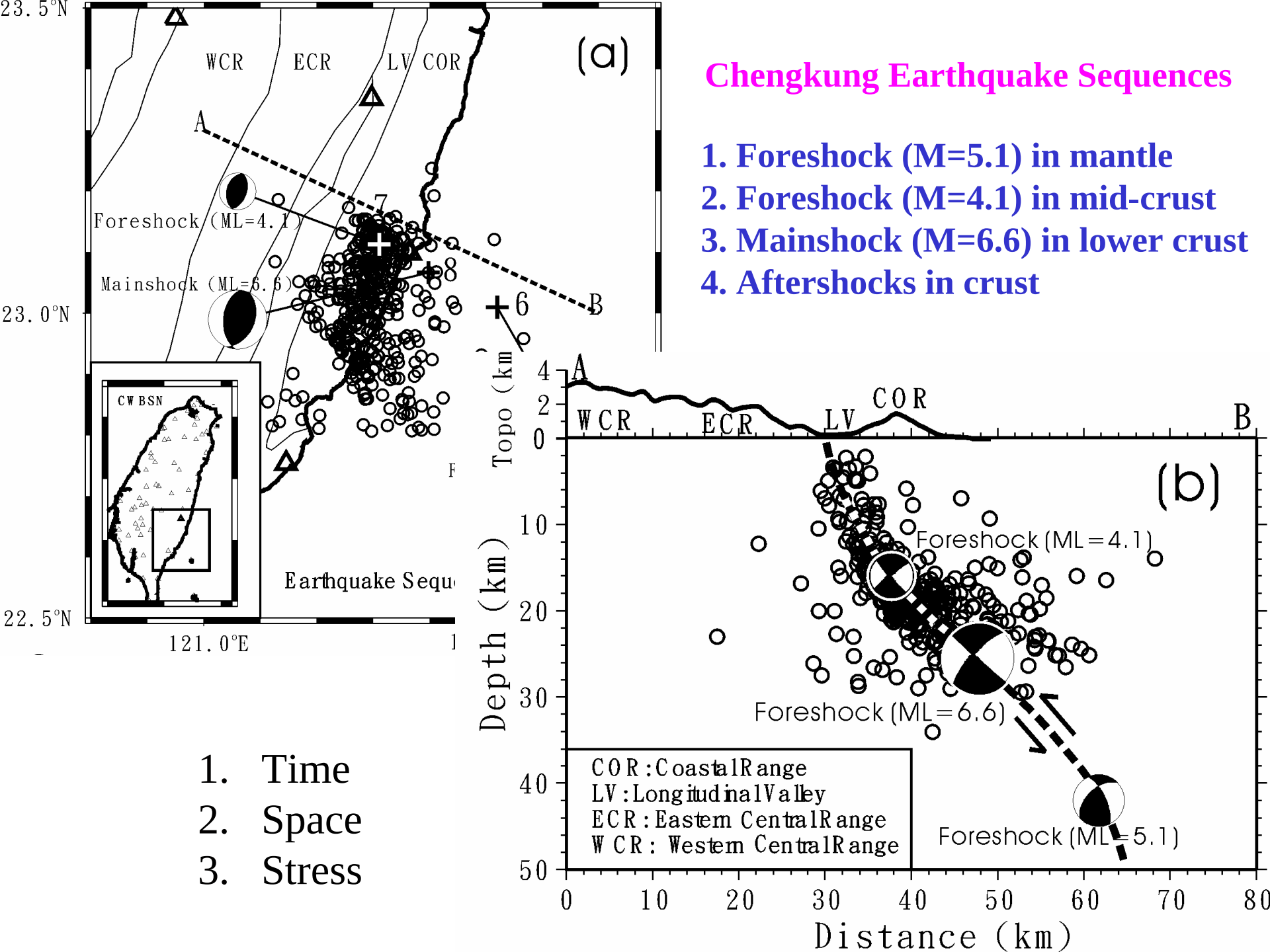
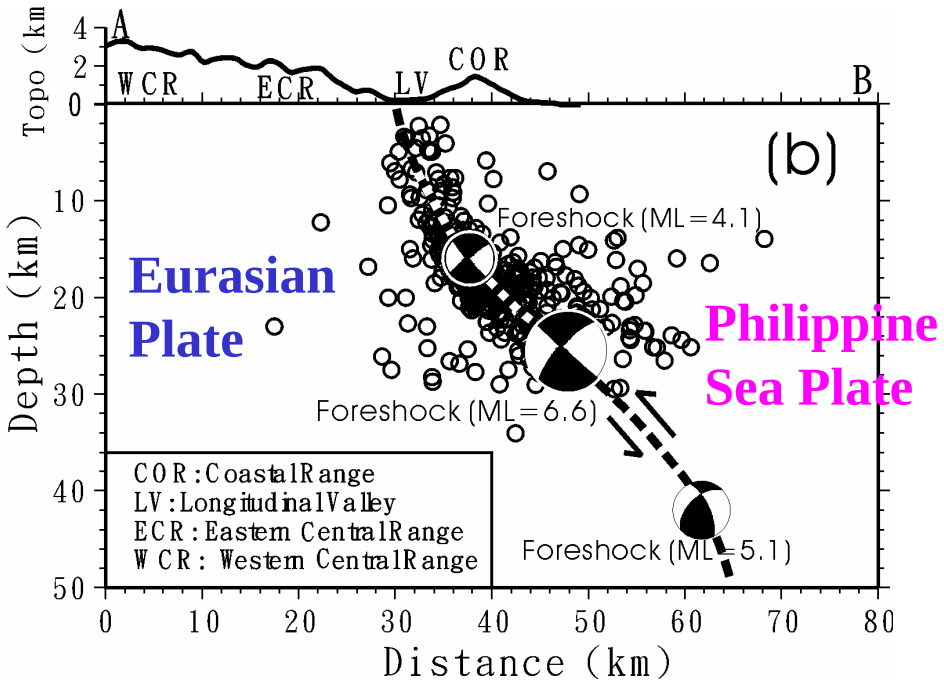
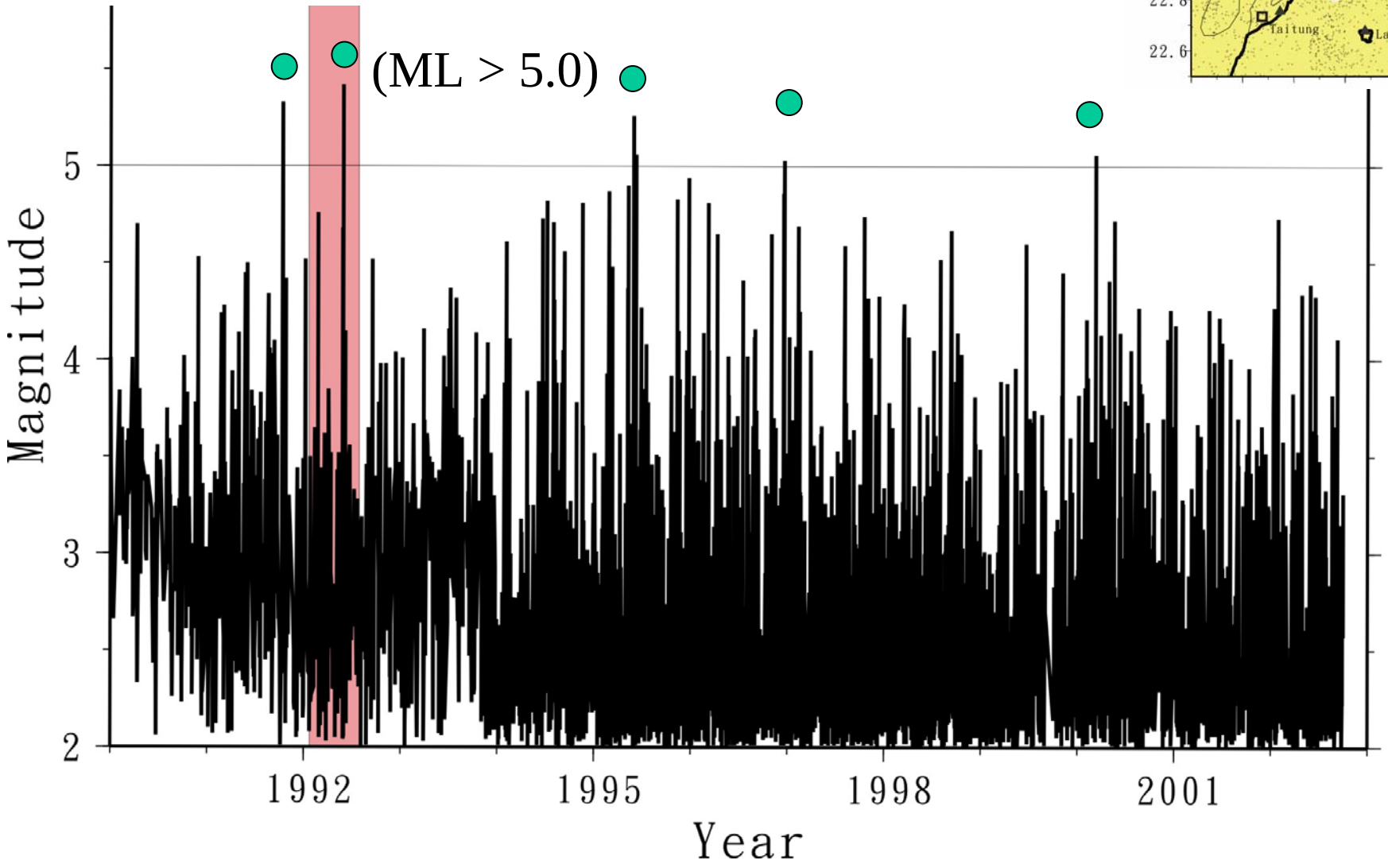

Chengkung Earthquake Sequences
1. Foreshock (M=5.1) in mantle
2. Foreshock (M=4.1) in mid-crust
3. Mainshock (M=6.6) in lower crust
4. Aftershocks in crust
(a)
WCR
ECR
LV
COR
A
B
Foreshock (ML=4.1)
Mainshock (ML=6.6)
CWBSN
Earthquake Sequ
23.5°N
23.0°N
22.5°N
121.0°E
(b)
Topo (km)
Depth (km)
Distance (km)
Foreshock (ML=4.1)
Foreshock (ML=6.6)
Foreshock (ML=5.1)
COR: Coastal Range
LV: Longitudinal Valley
ECR: Eastern Central Range
WCR: Western Central Range
1. Time
2. Space
3. Stress

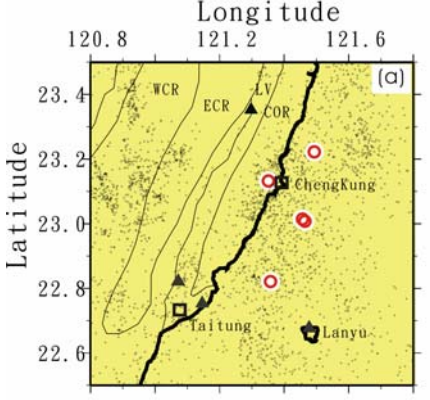
Plate Boundary

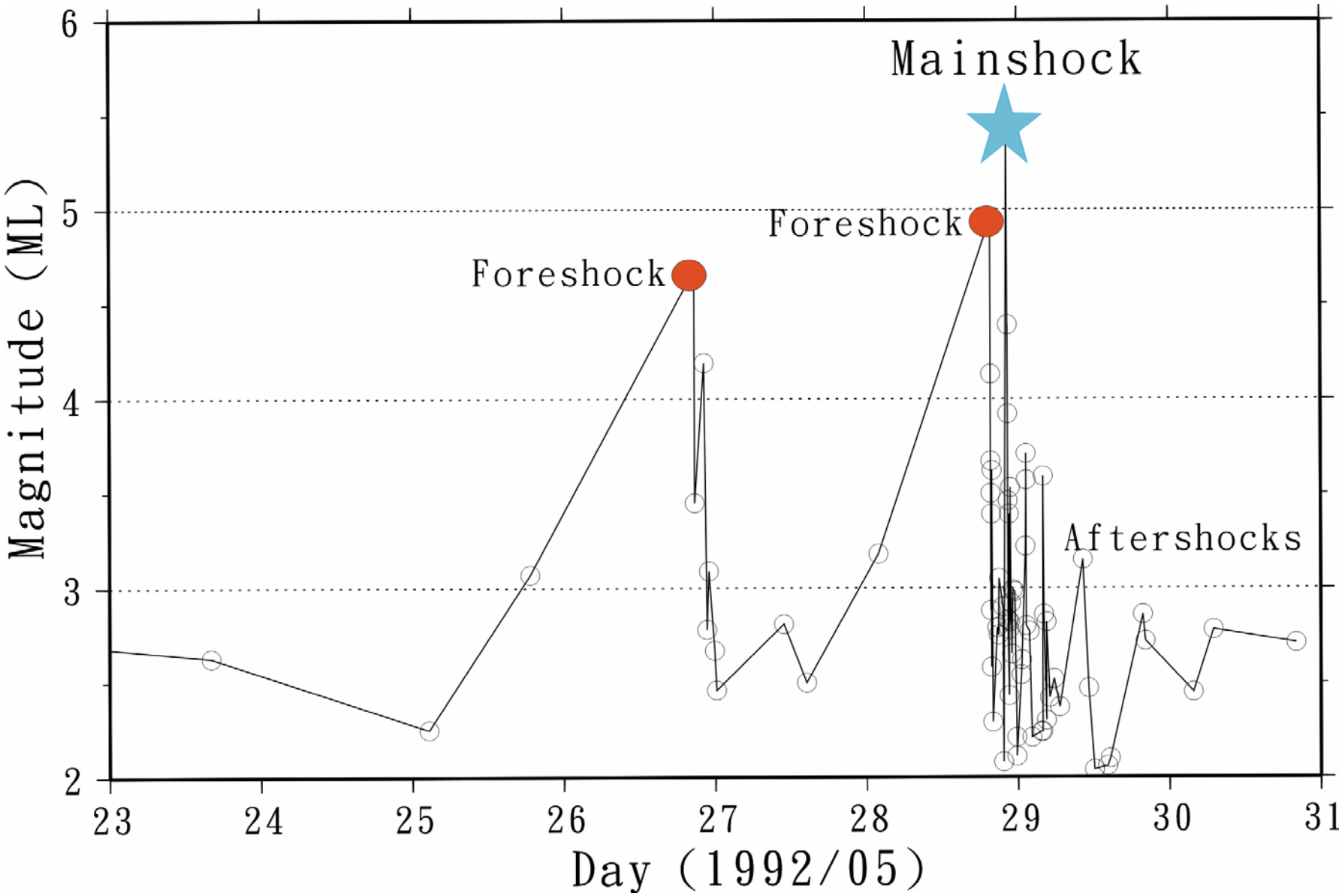


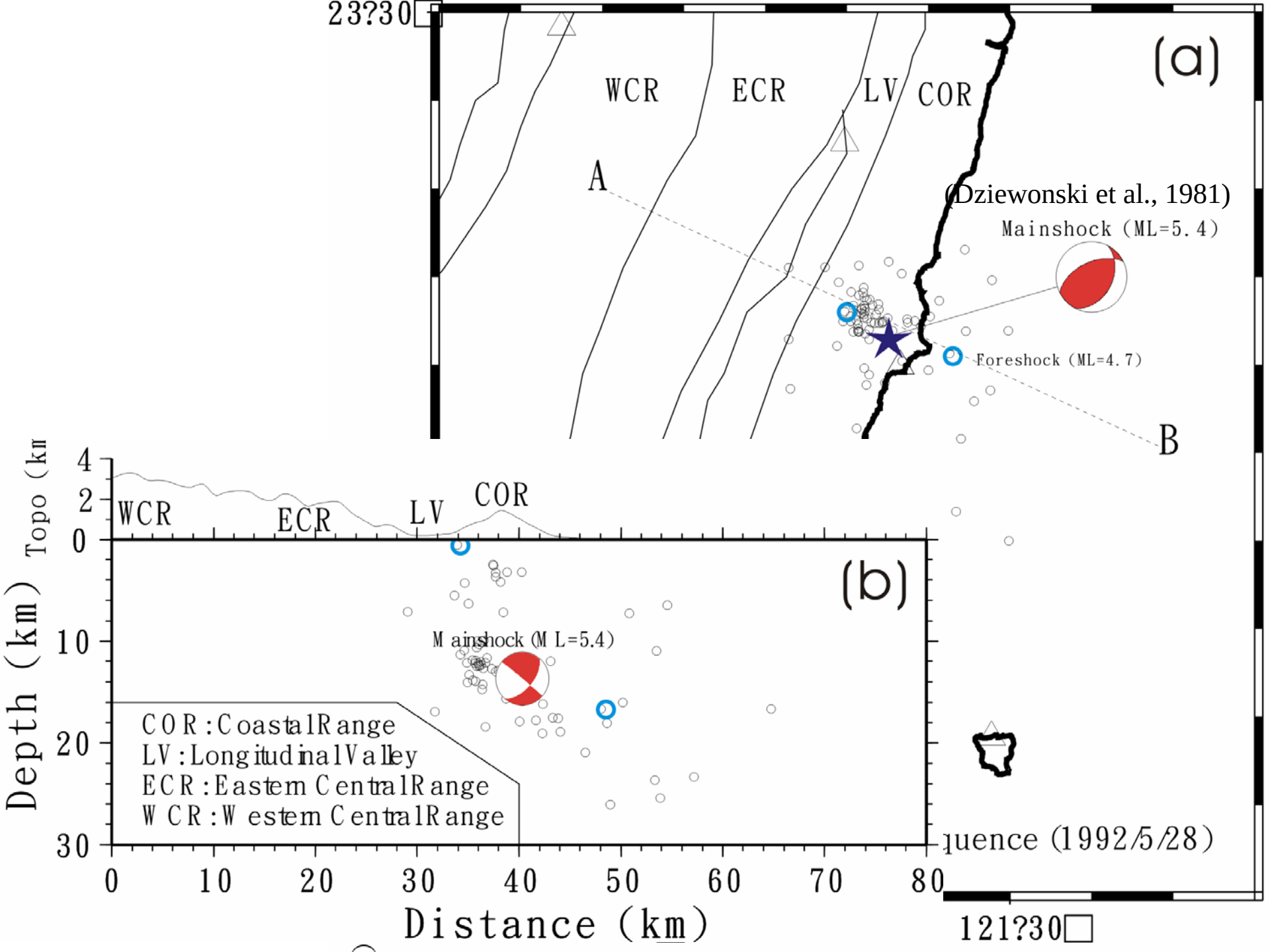
The major plate boundary between the Philippine Sea plate and the Eurasian plate along the suture in the eastern Taiwan area could be clearly delineated by a variable-dip plane according to **the 2003 earthquake sequence** (foreshocks, the mainshock and aftershocks) from the surface down to **42 km** at least.

Other larger events in the past

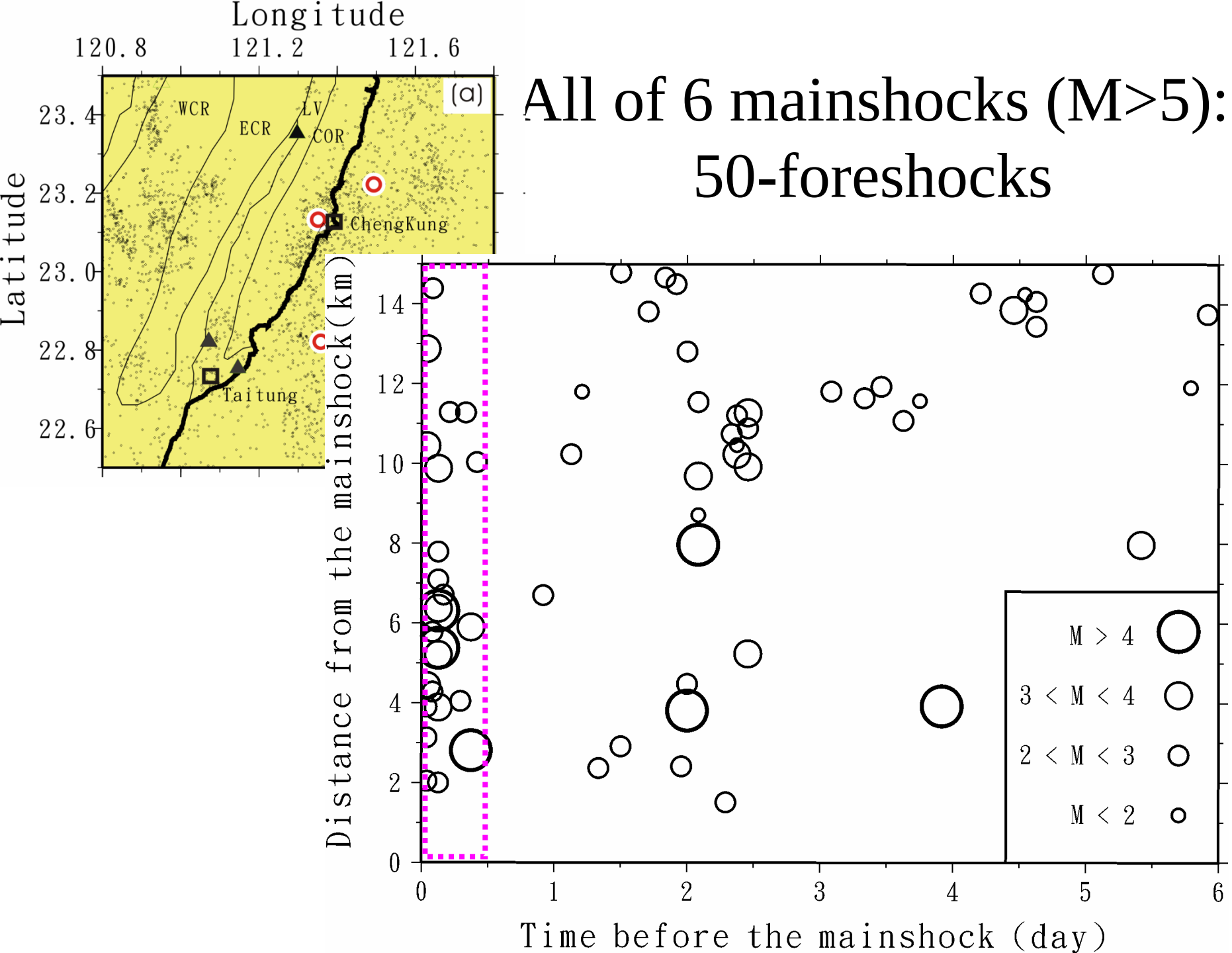


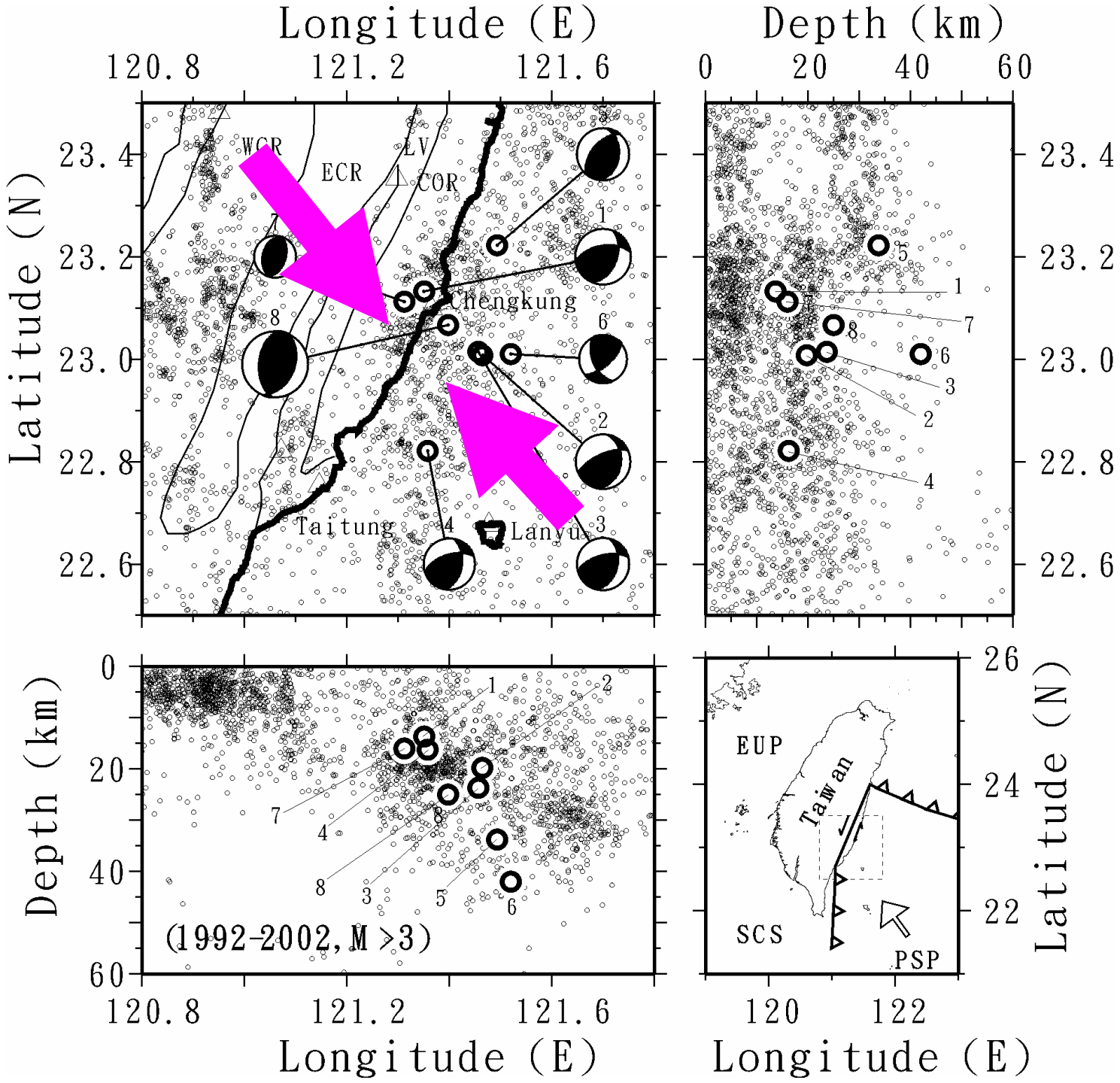



Mainshock
Foreshock
Foreshock
Aftershocks
Magnitude (ML)
Day (1992/05)
6
5
4
3
2
23
24
25
26
27
28
29
30
31


23?30
(a)
WCR
ECR
LV
COR
A
B
(Dziewonski et al., 1981)
Mainshock (ML=5.4)
Foreshock (ML=4.7)
Topo (km)
4
2
0
WCR
ECR
LV
COR
(b)
Mainshock (ML=5.4)
COR:CoastalRange
LV:LongitudinalValley
ECR:EasternCentralRange
WCR:WesternCentralRange
Depth (km)
10
20
30
0
10
20
30
40
50
60
70
80
Distance (km)
quence (1992/5/28)
121?30

All of 6 mainshocks (M>5): 50-foreshocks




Longitude (E)
120.8
121.2
121.6
Depth (km)
0
20
40
60
Latitude (N)
23.4
23.2
23.0
22.8
22.6
WCR
ECR
LV
COR
Chengkung
Taitung
Lanyu
1
2
3
4
5
6
7
8
(1992-2002, M >3)
EUP
Taiwan
SCS
PSP
26
24
22
120
122

Foreshocks ⇔ Heterogeneity

The foreshocks in the **reverse faulting** system might **not** be associated with **normal stress** on the fault plane,

but they may largely depend on **a higher degree of heterogeneity** in the crust.

Potential Precursors

All of six larger earthquakes (M>5) had significant **foreshocks** in the Chengkung area of eastern Taiwan during the past two decades.

Therefore, foreshocks might be considered as a **precursor** for the future large earthquake in the Chengkung area, eastern Taiwan.

How to identify Foreshocks?

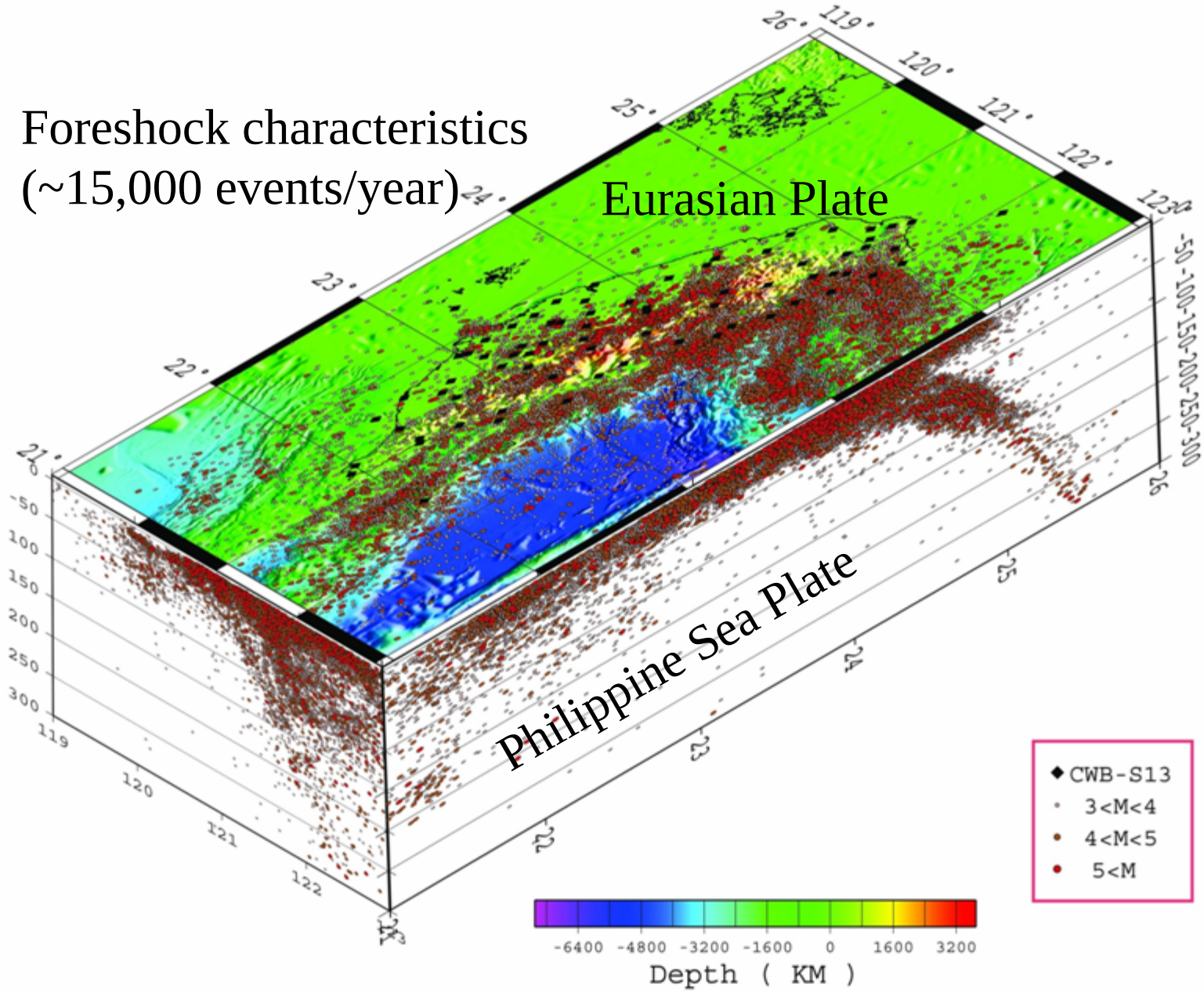
If a felt earthquake (i.e., M=5) occurs now, how do we know it is the **mainshock**

or just a **foreshock**?

If we can know it is a **foreshock**,

then a short-term earthquake warning can be issued.

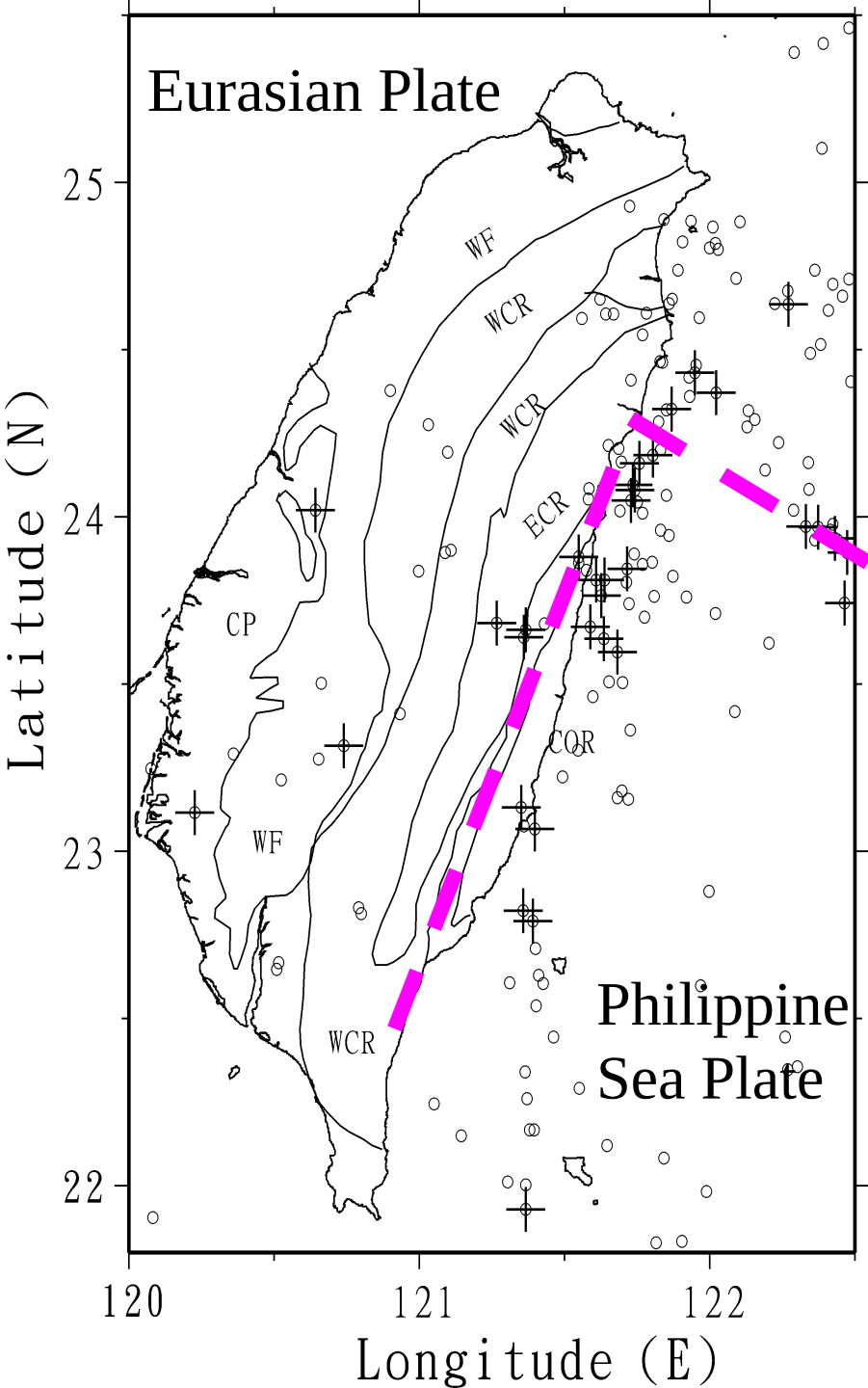
Foreshock characteristics
(~15,000 events/year)

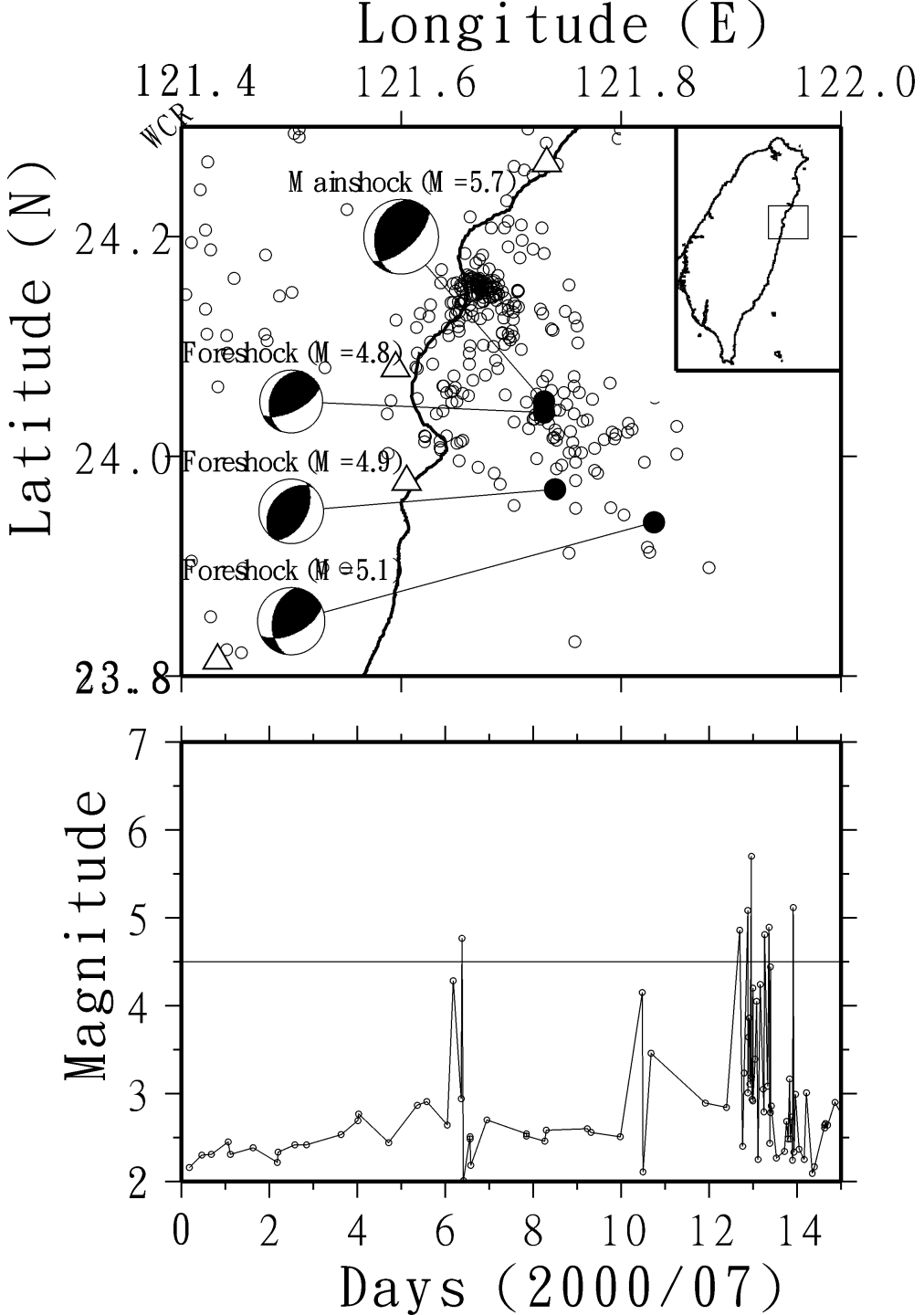


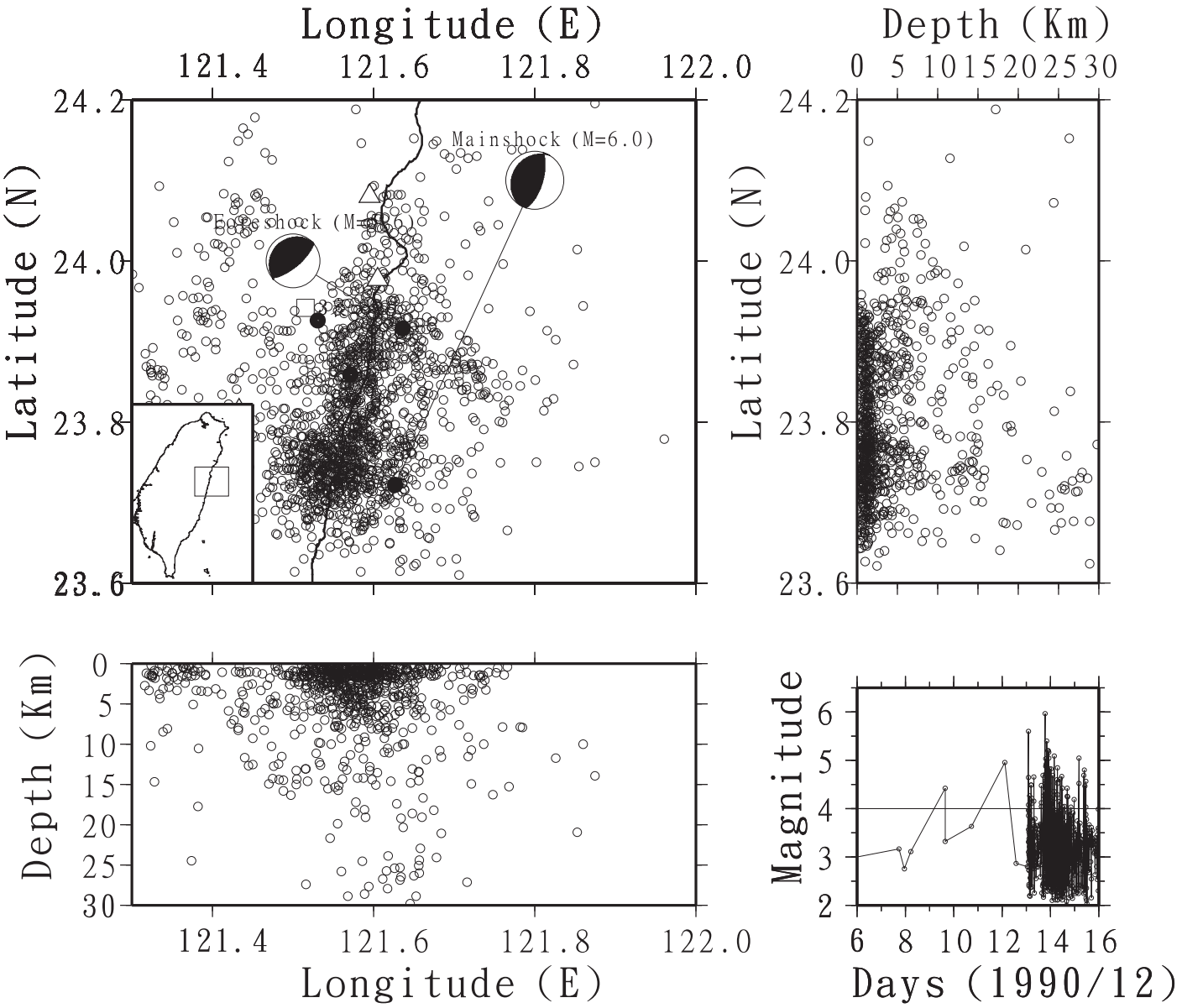
Examine 161 events (M>5) in the past.

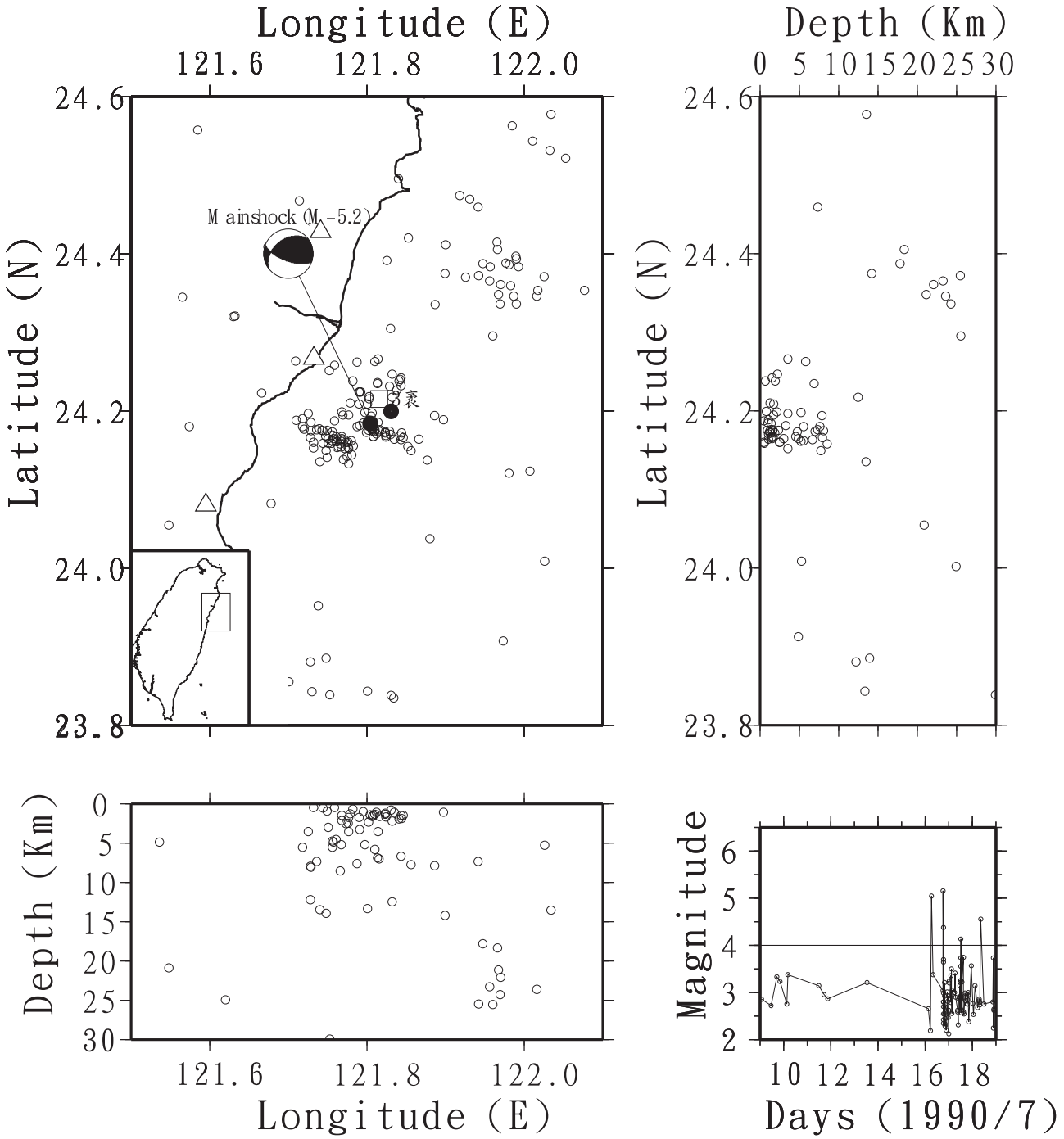
Foreshock criteria:

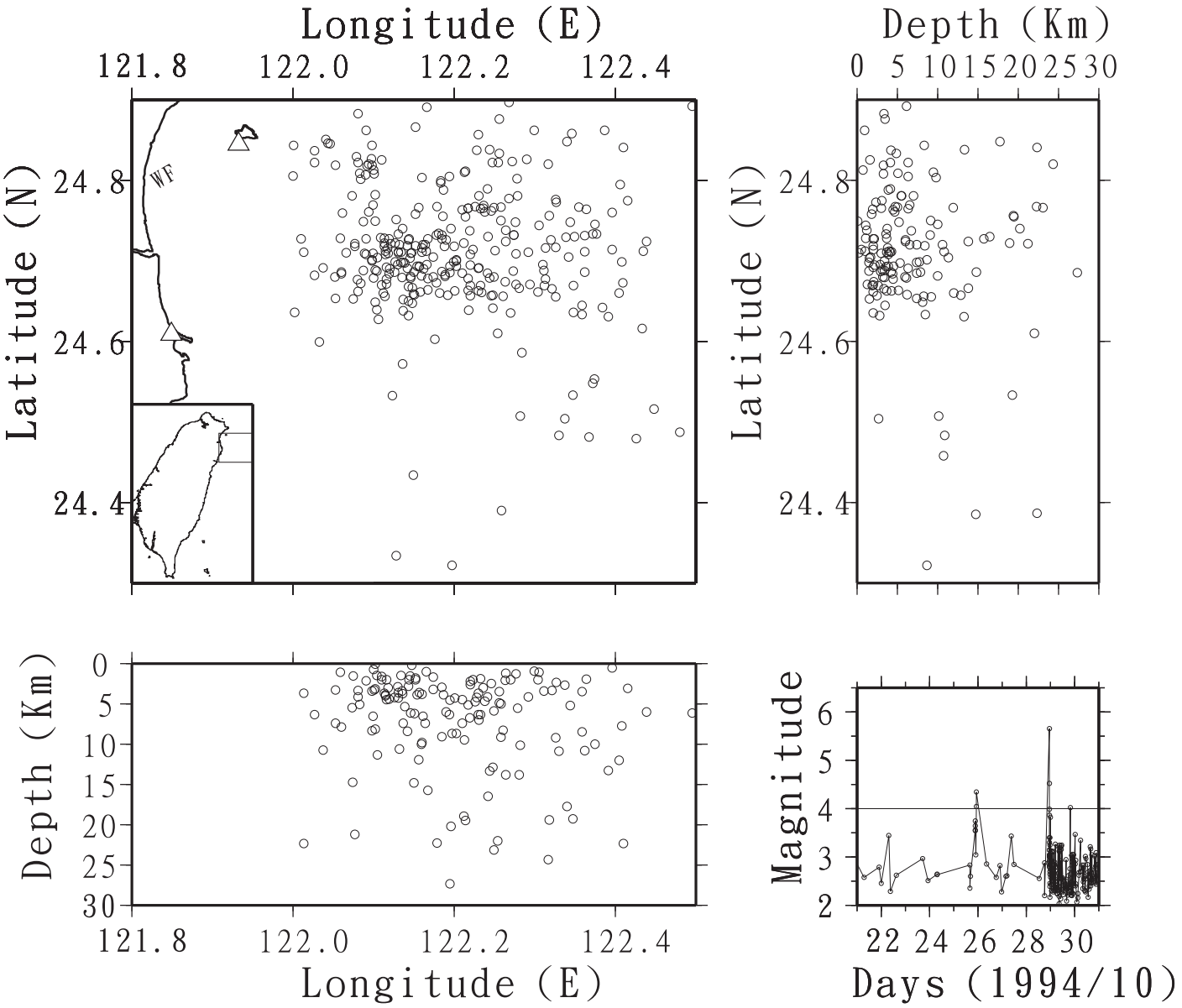
1. Time <5 days
2. Distance < 15 km
3. M>4.0 (felt events)

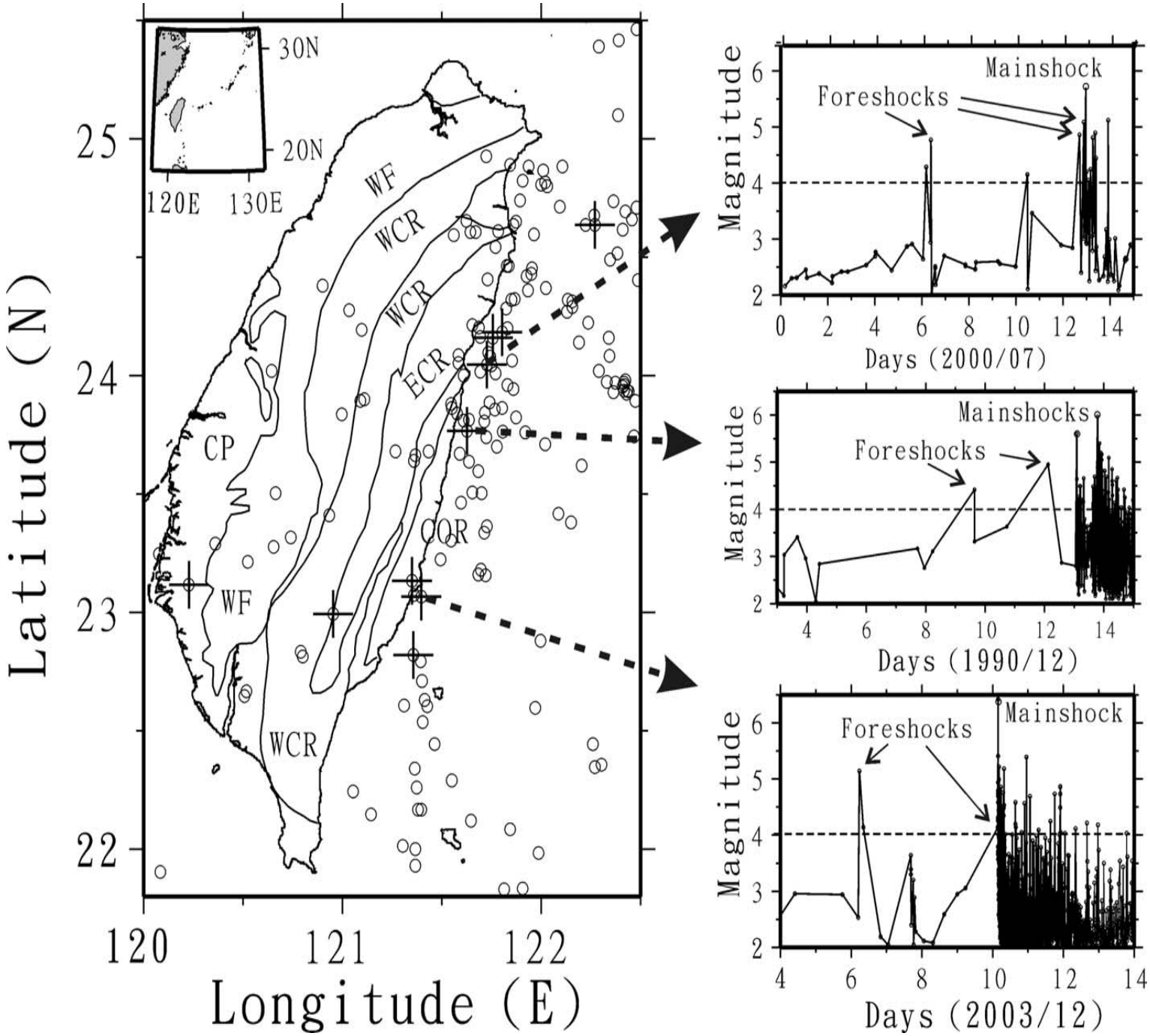



Longitude (E)
121.4
121.6
121.8
122.0
WCR
Mainshock (M =5.7)
Foreshock (M =4.8)
Foreshock (M =4.9)
Foreshock (M =5.1)
Latitude (N)
24.2
24.0
23.8
Magnitude
7
6
5
4
3
2
0
2
4
6
8
10
12
14
Days (2000/07)


Longitude (E)
121.4
121.6
121.8
122.0
24.2
24.0
23.8
23.6
Latitude (N)
Mainshock (M=6.0)
Foreshock (M=5.6)
Depth (Km)
0 5 10 15 20 25 30
Depth (Km)
0
5
10
15
20
25
30
Magnitude
6
5
4
3
2
6 8 10 12 14 16
Days (1990/12)


Longitude (E)
121.6
121.8
122.0
24.6
24.4
24.2
24.0
23.8
Latitude (N)
Mainshock (M=5.2)
Depth (Km)
0 5 10 15 20 25 30
Depth (Km)
Magnitude
6
5
4
3
2
10 12 14 16 18
Days (1990/7)

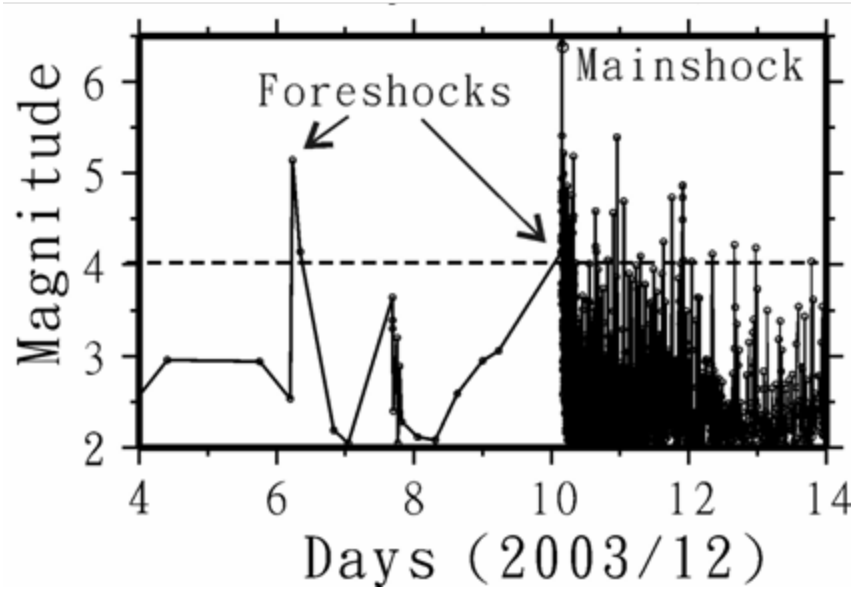

Longitude (E)
121.8
122.0
122.2
122.4
Latitude (N)
24.8
24.6
24.4
WF
Depth (Km)
0 5 10 15 20 25 30
Depth (Km)
0
5
10
15
20
25
30
Longitude (E)
Magnitude
2
3
4
5
6
22 24 26 28 30
Days (1994/10)


30N
20N
120E
130E
WF
WCR
WCR
ECR
CP
COR
WF
WCR
25
24
23
22
120
121
122
Latitude (N)
Longitude (E)
Mainshock
Foreshocks
Magnitude
Days (2000/07)
Mainshocks
Foreshocks
Days (1990/12)
Foreshocks
Mainshock
Days (2003/12)

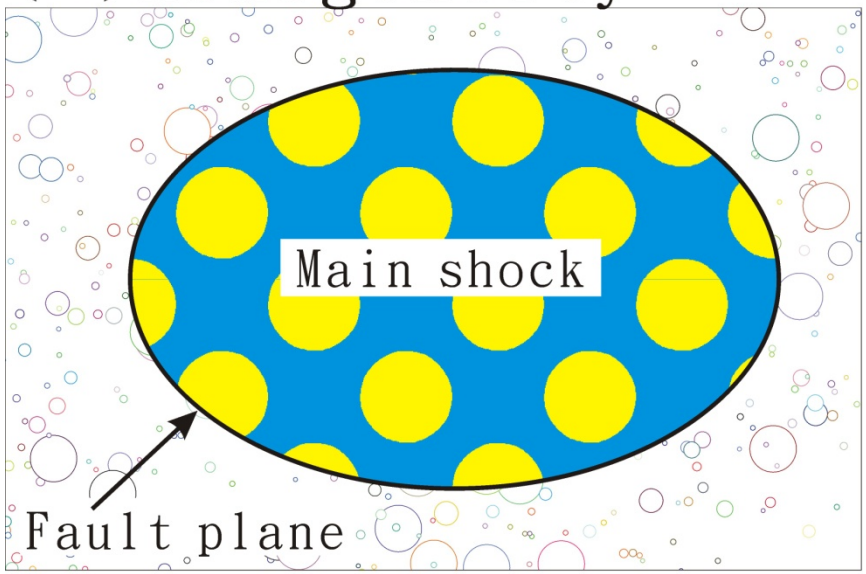
How to distinguish foreshocks from the mainshock?

The absence of clustered earthquakes after the felt foreshocks ⇔

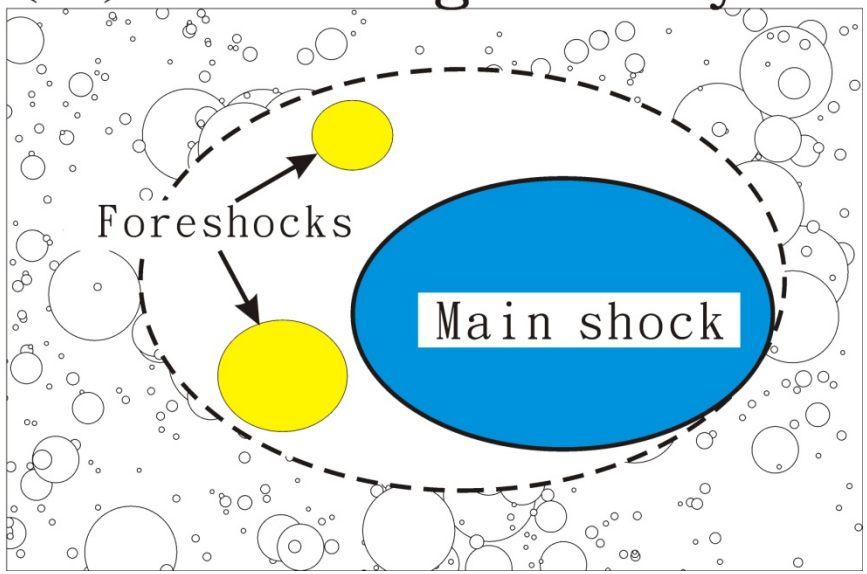
a criterion to distinguish **foreshocks** from the main shock.



(a)Homogeneity



(b) Heterogeneity



Conclusions

1. **Repeated foreshocks** in the Cheng-Kung area imply they might be considered as a **precursor** for future larger earthquakes.

2. The foreshocks may largely depend on a higher degree of **heterogeneity** in the crust, particularly along the suture zone.

3. The absence of clustered earthquakes after **the felt foreshocks** may provide a criterion to distinguish foreshocks from the main shock and may add to our ability of earthquake warnings.

Thanks!

Foreshocks ⇔ Normal stress

Normal stress increases with both of
(1) focal depths and
(2) also from **normal** to **reverse** faulting environments.

Therefore, **increasing** normal stress **inhibits** foreshock occurrence!?

Foreshocks ⇔ Normal stress

Therefore, **increasing** normal stress **inhibits** foreshock occurrence!?