Foreshock Characteristics in Taiwan: Potential Earthquake Warning

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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）

福爾日，太陽與月亮由完全相反的方向牽引地殼，地殼因此出現細裂（斷層），並變得容易移動。地殼的伸縮造成地下水外移，水井和溫泉水位會忽高忽低。含於花崗岩中的放射性元素變成氫氣溶於水中，再經由水井流出地表放射出白光，使地表附近的溫度升高，冬眠中的動物因而誤以爲春天已至而爬出洞穴。在岩石上增加壓力產生的應力效應和在岩石與流水間因地下水流所形成的電，形成了地電流，偶爾會放電。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電敏感的動物，導致這些動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 $\Leftrightarrow$ Foreshocks?
• Why not all of the mainshocks with foreshocks?

• What’s foreshock mechanism?

• Are there some foreshocks in Taiwan?
Previous Studies
The strike-slip system (Abercrombie and Mori, 1996, Nature)

59 events (M > 5)

Foreshocks ⇔
1. Focal depths
2. Fault types
Foreshocks ↔ focal depths

Heterogeneity ↔ Homogeneity

(Abercrombie and Mori, 1996, Nature)
Foreshocks ↔ Fault types

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

Foreshocks ↔ normal stress

(Abercrombie and Mori, 1996, Nature)
Foreshocks in Taiwan?
(Reverse-faulting)

Strike-slip faulting
成功地震（2003/12/10）
Foreshocks
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

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

(ML > 5.0)
(Dziewonski et al., 1981)

Mainshock (ML=5.4)

Foreshock (ML=4.7)

COR: Coastal Range
LV: Longitudinal Valley
ECR: Eastern Central Range
WCR: Western Central Range

Influence (1992/5/28)
All of 6 mainshocks (M>5): 50-foreshocks
Reverse-faultings
Foreshocks $\Leftrightarrow$ 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)

Eurasian Plate

Philippine Sea Plate
Examine 161 events ($M>5$) in the past.

**Foreshock criteria:**

1. Time $<5$ days
2. Distance $<15$ km
3. $M>4.0$ (felt events)
How to distinguish foreshocks from the mainshock?

The absence of clustered earthquakes after the felt foreshocks is a criterion to distinguish foreshocks from the main shock.
(a) Homogeneity

Fault plane

Main shock

(b) Heterogeneity

Foreshocks

Main shock
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 $\Leftrightarrow$ Normal stress

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