Wenchuan Earthquake (12.5.2008), Sichuan

Magnitude: 8.0
Focal Depth: 10 km
Ground shaking > 80sec
Epicentral intensity: MMI = X
Felt over 1500 km
Quake lakes formed = 34
Deaths: >69,000 people
GPS data show a convergence between Tibet and South China along Longmenshan at 4.0 mm ± 2.0 mm (Zhang et al., 2004)

**Magnitude 震级**

Magnitude measures the size of the earthquake.

**Richter Scale (ML)**
**Moment Magnitude Scale (Mw)**

Each order of increase in magnitude corresponds to a 32 times increase in seismic energy.
Earthquake Size vs Frequency

<table>
<thead>
<tr>
<th>Description</th>
<th>Mag (M)</th>
<th>Frequency/year*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Great Earthquake</td>
<td>&gt; 8.0</td>
<td>1</td>
</tr>
<tr>
<td>Major Earthquake</td>
<td>7.0 - 7.9</td>
<td>18</td>
</tr>
<tr>
<td>Strong Earthquake</td>
<td>6.0 - 6.9</td>
<td>~200</td>
</tr>
<tr>
<td>Moderate Earthquake</td>
<td>5.0 - 5.9</td>
<td>~2000</td>
</tr>
<tr>
<td>Light Earthquake</td>
<td>4.0 - 4.9</td>
<td>Increase exponentially</td>
</tr>
<tr>
<td>Minor Earthquake</td>
<td>3.0 - 3.9</td>
<td></td>
</tr>
<tr>
<td>Microearthquake</td>
<td>&lt; 3.0</td>
<td></td>
</tr>
</tbody>
</table>

*For entire world

Moment Magnitude Estimates

Determination of moment magnitude requires long-range seismogram data

Initial report (May 12): 7.6
Revised (May 12): 7.8
US Geological Survey: 7.9
Seismological Bureau of China (May 18): 8.0
Latest (pending confirmation): 8.3

Seismic moment depends on force and displacement of the fault
= $4.4 \times 10^{21}$ Nm for Sichuan earthquake

Intensity 烈度

Intensity measures the degree of damage (ground motion) at a place caused by an earthquake.

Modified Mercalli Intensity Scale (MMI)
12 divisions: I-XII

Intensity depends on earthquake magnitude, epicentral distance, focal depth, geology and construction structures
Beichuan Fault:
Mainly a reverse fault with a lateral-motion component

Rupture propagation: towards NE for 300 km
Propagation speed: 3.1 km/s
Duration of rupture: 80 sec

Aftershocks map from USGS

Fault plane dimension: 600 km x 50 km
Orientation: 230°, inclining at 39° towards NW

Maximum ground displacement ~10 m in Wenchuan

Fault displacement data from Seismological Bureau of China

Geology of Longmenshan Area
based on Bureau of Geology and Mineral Resources of Sichuan Province

Diexi Quake-dammed Lake 叠溪堰塞湖
1933 M=7.5
160m-tall dam burst 45 days after earthquake and drowned 2500 people downstream.
A water wall over 60m high was reported.

Diexi Quake-dammed Lake 叠溪堰塞湖
叠溪堰塞湖
Nature of Natural Processes

- **Deterministic** e.g. object falling under gravity
- **Random** e.g. radioactive disintegration
- **Chaotic** e.g. turbulence
  - Deterministic but unpredictable
  - Not random
  - Strongly controlled by initial conditions

Scientific Earthquake Prediction

- The occurrence of earthquake is a chaotic process
- Scientific earthquake predictions should state *where, when, how big, and how probable* the predicted event is, and *why* the prediction is made

Types of earthquake prediction

- **Earthquake forecast**: statement on long-term statistical probability of earthquake in a certain area
- **Long-term** and **medium-term** prediction
- **Short-term prediction**: a few weeks
- **Earthquake warning**: actionable declaration, up to a few days

Possible earthquake precursors

<table>
<thead>
<tr>
<th>Seismological precursors</th>
<th>L: long-term, years</th>
<th>M: a few months - a few years</th>
<th>S: short term – days/weeks</th>
</tr>
</thead>
<tbody>
<tr>
<td>seismicity</td>
<td>L, M, S</td>
<td></td>
<td></td>
</tr>
<tr>
<td>seismic gaps, b-value</td>
<td>L, M, S</td>
<td></td>
<td></td>
</tr>
<tr>
<td>seismic wave velocity, velocity ratio</td>
<td>L, M, S</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Crustal strain and stress</td>
<td>ground tilt, uplift rate, liquefaction focal mechanism</td>
<td>M, S</td>
<td>M, S</td>
</tr>
<tr>
<td>Gravity anomalies</td>
<td>absolute gravity value</td>
<td>trend in gravity change</td>
<td>M, S</td>
</tr>
<tr>
<td>Electrical and geomagnetic anomalies</td>
<td>electrical potential, resistivity, magnetic field intensity, magnetic declination</td>
<td>S</td>
<td></td>
</tr>
<tr>
<td>Groundwater</td>
<td>water level, flow rate, temperature, clarity, odor</td>
<td>M, S</td>
<td></td>
</tr>
<tr>
<td>Hydrochemical</td>
<td>radon emanation rate</td>
<td>S</td>
<td></td>
</tr>
<tr>
<td>Animal behavior</td>
<td>various</td>
<td>S</td>
<td></td>
</tr>
<tr>
<td>Electromagnetic phenomena</td>
<td>ground noise, light emission, earthquake cloud</td>
<td>S</td>
<td></td>
</tr>
</tbody>
</table>

Note: L indicates long-term, M indicates medium-term, and S indicates short-term.
Premonitory earthquake parameters

- seismic events
- seismic velocity ratio
- electrical resistivity
- groundwater flow
- radon emanation rate
- crustal movement
- electromagnetics
- gravity

The 5 Stages based on dilatancy model

Precursory changes before 1978 Izu earthquake

Earthquakes with reported anomalous animal behaviour

- 中国地震資料年表: 126
- 1966 邢台地震以来: >41 (M>5)

利用動物預報地震

- 60年代在河北建立多個生物預報觀察站
- 根据鸽子和猫的異常行爲“成功”預測多次地震
- 所謂預測，多是根据地震后憶敘
- 太多民間性報導，缺乏科學性描述
- 對成因缺乏系統性、歸納性研究
- 沒有失敗個案數字
全世界最可愛的動物有預報地震能力嗎?

<table>
<thead>
<tr>
<th>日期</th>
<th>地點</th>
<th>震級</th>
<th>异常行為</th>
</tr>
</thead>
<tbody>
<tr>
<td>1937.8.1</td>
<td>山東荷澤</td>
<td>7</td>
<td>上床嚎叫</td>
</tr>
<tr>
<td>1969.7.26</td>
<td>山東荷澤</td>
<td>6.4</td>
<td>母貓幾次將小貓叼上床</td>
</tr>
<tr>
<td>1970.1.5</td>
<td>河北豐南</td>
<td>5.5</td>
<td>惊惶、嚎叫、不捉老鼠</td>
</tr>
<tr>
<td>1970.5.25</td>
<td>北京豐南</td>
<td>5.2</td>
<td>貓不回家</td>
</tr>
<tr>
<td>1971.8.16</td>
<td>四川馬邊</td>
<td>5.9</td>
<td>貓跑掉</td>
</tr>
<tr>
<td>1974.5.11</td>
<td>云南昭通</td>
<td>7.1</td>
<td>貓搬家</td>
</tr>
<tr>
<td>1976.7.28</td>
<td>青山</td>
<td>7.8</td>
<td>憂惶不安、抓門抓人、逃跑</td>
</tr>
</tbody>
</table>

结论与建议

从以上所进行的推算与预测结果看，在2008年左右，川滇地区有可能发生≥6级强烈地震。
Most prediction studies are by means of reverse tracing of precursors.

To study earthquake premonitory phenomena, scientists need to ‘trap an earthquake’.

The Parkfield Experiment

Previous earthquakes in Parkfield
1857 (+24)
1881 (+20)
1901 (+21)
1922 (+12)
1934 (+32)
1966
average return period: 22 years
1988?

Alert scheme

Status Level for Parkfield
E: normal
D: minor anomaly
C: moderate anomaly; alert major life-support services
B: ~10% of major earthquake in a few days; state may decide on action
A: >30% of major earthquake in a few days; state have to issue warning

Monitoring equipment
- Creepmeters
- Strainmeter
- 2-color laser: ranging device with thickness of 1 mm over 10 km range
1991: A-level alert, public warning issued waited 3 earthquakes, no major earthquake

1993: Another A-level alert

Vladimir Keilis-Borok
Professor of Geophysics
UCLA

...The prediction is for a magnitude 6.4 or greater earthquake to occur between January 5 and September 5, 2004, within a 12,440 sq. miles area of southern California...

<table>
<thead>
<tr>
<th>Storm/Flood</th>
<th>Earthquake</th>
</tr>
</thead>
<tbody>
<tr>
<td>Advance warning</td>
<td>Sudden</td>
</tr>
<tr>
<td>Magnitude, time and space</td>
<td>No</td>
</tr>
<tr>
<td>specific</td>
<td></td>
</tr>
<tr>
<td>Frequent in one’s life-time</td>
<td>Infrequent in one’s lifetime</td>
</tr>
<tr>
<td>Incremental warning</td>
<td>Incremental warning difficult</td>
</tr>
<tr>
<td>Premonitory phenomena visible</td>
<td>Premonitory phenomena in form of geophysical fields</td>
</tr>
<tr>
<td>If event did not occur, it</td>
<td>Predicted event still may occur</td>
</tr>
<tr>
<td>would not occur</td>
<td></td>
</tr>
<tr>
<td>Visible reasons for</td>
<td>Public has no visible evidence to confirm that an earthquake could have occurred</td>
</tr>
<tr>
<td>non-occurrence</td>
<td></td>
</tr>
</tbody>
</table>

All of these considerations can affect public policy on issuing earthquake warning
Counter-productive consequences

\[
\text{Cost of failed prediction} = \text{Total loss} - \text{Cost if prediction was made + adjustment measures}
\]

- Economic disruption
- Legal liability
- Capital outflow
- Emigration
- Falling land value
- Unemployment

Policy makers must continuously weigh the relative merits of making and not making a warning. The tendency is tilted towards non-issuing of warnings as the nation progresses towards prosperity.

Prediction vs. Warning

- A prediction is a neutral statement made based on accumulated observations
- A warning is a declaration that normal life routines should be altered to deal with the impending hazard
- Prediction: based on science
- Warning: Interpretations of prediction that take public policy into account