The Science (& Pseudo-science) of Earthquake Prediction

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Why are earthquakes so interesting?  

**The Impact**

<table>
<thead>
<tr>
<th>Earthquake</th>
<th>Date</th>
<th>Magnitude</th>
<th>Number of Deaths</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chile (&amp; tsunami)</td>
<td>May 22, 1960</td>
<td>9.5</td>
<td>4,000 to 5,000</td>
</tr>
<tr>
<td>Alaska (&amp; tsunami)</td>
<td>Mar. 28, 1964</td>
<td>9.2</td>
<td>125</td>
</tr>
<tr>
<td>Sumatra (&amp; tsunami)</td>
<td>Dec. 26, 2004</td>
<td>9.0</td>
<td>283,106</td>
</tr>
<tr>
<td>Maule, Chile (&amp; tsunami)</td>
<td>Feb. 27, 2010</td>
<td>8.8</td>
<td>521</td>
</tr>
<tr>
<td>San Francisco</td>
<td>Apr. 18, 1906</td>
<td>7.8</td>
<td>3,000</td>
</tr>
<tr>
<td>Sichuan, China</td>
<td>May 12, 2008</td>
<td>7.9</td>
<td>69,180</td>
</tr>
<tr>
<td>Pakistan</td>
<td>Oct. 8, 2005</td>
<td>7.6</td>
<td>80,361</td>
</tr>
<tr>
<td>Tangshen, China</td>
<td>Jul. 27, 1976</td>
<td>7.5</td>
<td>255,000 (estimates as high as 655,000)</td>
</tr>
<tr>
<td>Haiti</td>
<td>Jan. 12, 2010</td>
<td>7.0</td>
<td>220,000+</td>
</tr>
<tr>
<td>Loma Prieta</td>
<td>Oct. 18, 1989</td>
<td>6.9</td>
<td>63</td>
</tr>
<tr>
<td>Kobe, Japan</td>
<td>Jan. 16, 1995</td>
<td>6.9</td>
<td>5,502</td>
</tr>
<tr>
<td>Northridge</td>
<td>Jan. 17, 1994</td>
<td>6.7</td>
<td>60</td>
</tr>
</tbody>
</table>

Source: USGS

ENGR 100w
Casualties (Deaths and Injuries)

- The majority of deaths occur in collapsed buildings
  - (China schools).
- In addition to deaths, there are many less severe casualties
  (hospitalized and non-hospitalized).
Haiti

Typical Concrete Frame & Masonry Block House

Typical Shanty house:
Light weight – little damage
(remember Newton F=Ma)
Why are earthquakes so interesting?
The Human Dimension

Refugee camp San Francisco Earthquake, 1906
400,000 people homeless
Source: The California Historical Society

Temporary shelters in Kobe, 1995
300,000 people homeless
www.lib.kobe-u.ac.jp/repository/eqb/photo/sakai/eng/e-V4/e-VA_4_01.html
Why are earthquakes so interesting?

The Human Dimension

Haiti

- September 22: 1.3 million people are still homeless
- Tropical Storm Matthew dropped 10 in. of rain on tent dwellers

http://www.readyforanything.org/?p=1090
Why are earthquakes so interesting?
The Devastation and the Inequality

1999
Izmit, Turkey EQ
M7.6
17,118 deaths
Source: Mehmet Celebi, USGS
Why are earthquakes so interesting?  
A Global Problem

Source: USGS
Why are earthquakes so interesting?

Increasing Losses

1995
Kobe: $100 billion

1999
Izmit: $13 billion
Taiwan: $12 billion
Typhoon Bart
Hurricane Floyd
Swiss floods

For comparison:
Hurricane Katrina
$100 billion

Source: Munich Reinsurance
Is earthquake prediction a solution?

• Wouldn’t it be great if we could predict earthquakes? Then we could:
  – Evacuate people
  – Turn off the gas
  – Have emergency services & shelters in place
  – Alert trains to slow down or stay in the station
  – Turn off equipment
  – Open fire station doors
  – Program elevators not to operate
  – …much more
Earthquake Prediction

• How is earthquake prediction defined?

Turn to your neighbor and discuss what are the elements of an “earthquake prediction”
Earthquake Prediction

- A reliable earthquake prediction should occur **BEFORE** the event and include:
  - Location
  - Time
  - Size
  - How likely
  - Reasons behind prediction (justification)
What might you need to know to make an EQ prediction?

- Tectonic environment
  - Edge of a plate? Interior of a plate?
  - Transform fault? Subduction zone?
  - Rate at which plates are moving
- History of earthquakes in the area
- What types of precursors precede EQs?
  - EQ swarms?
  - Dogs missing?
  - Changes in water table?
  - Anomalous electrical activity in the ground?
- What triggers earthquakes
  - Tides?
  - High stress?
Successful and Unsuccessful Predictions in China

- **Winter 1975, Haicheng evacuated (pop. ~150,000)**
- Unusual observations over months
  - changes in land elevation
  - changes in ground water levels
  - widespread accounts of peculiar animal behavior
  - regional increase in seismicity
  - finally, increase in foreshock activity triggered evacuation warning
- M7.3 EQ occurred Feb. 4, 1975
- Possibly 150,000 lives saved

- **July 28, 1976, M 7.6 EQ hits Tangshan (pop. ~1 million)**
  - No precursors
  - 250,000 to 600,000 people died
Tangshan after EQ

85% of buildings collapsed

(hi.baidu.com, 2009)
Tectonic Information: Spaced-based measurements (VLBI and GPS) show that PAC-NA motion in CA is \( \sim 50 \text{ mm/yr.} \)

**VLBI** = Very Long Baseline Interferometry using radio telescopes
Precursor?

• Each cross marks one of 4000+ earthquakes recorded in the New Madrid seismic zone since 1974. Source: USGS

• What does this mean? Is a major earthquake imminent?
1989 Browning Prediction

- Dr. Iben Browning (a climatologist) predicted an earthquake of M7.0 or larger on the New Madrid Fault Zone on December 3, 1990
  - Bulging in the earth’s crust caused by the gravitational pull of the earth and the moon would trigger an earthquake on December 3.
  - Tides were at a peak on December 3.
  - Published in the *Browning Newsletter*
  - News media picked it up, gave it credibility, and claimed he had previously predicted the Loma Prieta earthquake
1989 Browning Prediction

• Believing the prediction was baseless, the scientific community did little to debunk the claim
  – 6 weeks before 12/3/90 the National EQ Prediction Evaluation Council (NEPEC) issues a report: prediction is as accurate as throwing darts at a calendar
  – but report is too late
• The midwest goes wild
  – Schools close, factories close, people flee
  – Many buy EQ insurance
  – Becomes tourist attraction, sell “It’s our fault!” t-shirts
• No EQ occurs on December 3
Browning’s “Loma Prieta Prediction”

• On October 10, 1989 Browning gave a speech in San Francisco in which he said:
  – ...on or about October 16 there will probably be several earthquakes around the world, Richter 6+, and there may be a volcano or two.

• According to NEPEC an EQ of 6+ occurs on average every three days around the world
"New Madrid" by Uncle Tupelo
Scientific Method

- Identify a question
- Formulate hypothesis
- Make a prediction to test hypothesis
- Collect data
- Interpret data
- Confirm or disprove hypothesis
- RESULTS ARE REPEATABLE
<table>
<thead>
<tr>
<th>Date</th>
<th>Randomly Picked Date or Earthquake</th>
<th>Lost Cats</th>
<th>Dogs</th>
<th>Other</th>
<th>Total</th>
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</thead>
<tbody>
<tr>
<td>Dec. 09, 85</td>
<td>Random</td>
<td>2</td>
<td>11</td>
<td>0</td>
<td>13</td>
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<tr>
<td>Oct. 07, 86</td>
<td>Random</td>
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<td>11</td>
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<td>14</td>
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<tr>
<td>Mar. 23, 91</td>
<td>Earthquake M=4.5</td>
<td>7</td>
<td>09</td>
<td>1</td>
<td>17</td>
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<tr>
<td>Nov. 29, 92</td>
<td>Random</td>
<td>6</td>
<td>11</td>
<td>0</td>
<td>17</td>
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<td>Dec. 23, 84</td>
<td>Random</td>
<td>4</td>
<td>14</td>
<td>0</td>
<td>18</td>
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<tr>
<td>Dec. 01, 85</td>
<td>Random</td>
<td>3</td>
<td>15</td>
<td>0</td>
<td>18</td>
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<td>Aug. 07, 89</td>
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<td>4</td>
<td>14</td>
<td>1</td>
<td>19</td>
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<td>Feb. 01, 93</td>
<td>Random</td>
<td>8</td>
<td>11</td>
<td>0</td>
<td>19</td>
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<td>Jun. 12, 88</td>
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<td>15</td>
<td>1</td>
<td>20</td>
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<tr>
<td>Mar. 30, 86</td>
<td>Earthquake M=5.6</td>
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<td>18</td>
<td>1</td>
<td>21</td>
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<tr>
<td>Jun. 27, 88</td>
<td>Earthquake M=5.1</td>
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<td>13</td>
<td>3</td>
<td>21</td>
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<td>Apr. 24, 84</td>
<td>Earthquake M=6.1</td>
<td>5</td>
<td>16</td>
<td>1</td>
<td>22</td>
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<tr>
<td>Nov. 09, 88</td>
<td>Earthquake M=4.8</td>
<td>3</td>
<td>17</td>
<td>2</td>
<td>22</td>
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<tr>
<td>Apr. 02, 89</td>
<td>Earthquake M=4.6</td>
<td>5</td>
<td>16</td>
<td>1</td>
<td>22</td>
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<tr>
<td>Jun. 10, 91</td>
<td>Random</td>
<td>4</td>
<td>14</td>
<td>5</td>
<td>23</td>
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<tr>
<td>Feb. 27, 93</td>
<td>Random</td>
<td>8</td>
<td>16</td>
<td>1</td>
<td>25</td>
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<td>Dec. 10, 91</td>
<td>Random</td>
<td>5</td>
<td>20</td>
<td>1</td>
<td>26</td>
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<td>Aug. 11, 93</td>
<td>Earthquake M=4.6</td>
<td>9</td>
<td>14</td>
<td>4</td>
<td>27</td>
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<tr>
<td>Oct. 17, 89</td>
<td>Earthquake M=7.1</td>
<td>9</td>
<td>15</td>
<td>4</td>
<td>28</td>
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<tr>
<td>Aug. 14, 91</td>
<td>Random</td>
<td>6</td>
<td>17</td>
<td>6</td>
<td>29</td>
</tr>
</tbody>
</table>
Browning’s Method

- Calculated the increased strain on the Earth’s crust by the alignment of the Earth, sun and moon.
- Looked for places around the world where fault could have accumulated significant strain – New Madrid hadn’t had an event since 1812
- Did Browning use the scientific method?
The Parkfield Experiment

- Began in 1985
- Led by USGS and State of California
- **Goals:**
  - To better understand the physics of earthquakes
  - To understand what happens on the fault and in the surrounding region before, during and after an earthquake.
  - To provide a scientific basis for earthquake prediction

Source: USGS
The Parkfield Experiment

- Began in 1985
- Led by USGS and State of California
- **Hypothesis:** Moderate-size “Characteristic” EQ ~ M6 occur on Parkfield section of San Andreas Fault at fairly regular intervals – 1857, 1881, 1901, 1922, 1934, and 1966.
- **Prediction:** Next M6.0 EQ would occur between 1988 and 1993 (p=0.95)

Source: USGS
The Parkfield Experiment

- **Data Collection:**
  - Recordings show events to be almost identical
  - GPS data show amount of slip accumulating on fault
  - Electronic Distance Meter (EDM) network and Borehole Tensor Strainmeter (BTSM) network measure strain
  - Fluid pressures along the fault are monitored (may correlate with frictional strength of fault)

Source: USGS
The Parkfield Experiment

M6.0 earthquake occurred September 28, 2004

- Ruptured 1966 fault segment
- **Data Interpretation:** events are very regular, same rupture mechanism, constrained by bends in fault, fault is very straight at depth but curved at surface...and much more
- Research is providing results about the feasibility of a real-time warning system, fault motion at depth, shaking close into the fault, etc.

Source: USGS
Conclusion

- Reliable EQ prediction is a long way off
- Some progress is being made as we collect more data on EQ mechanisms
- **California Earthquake Prediction Evaluation Council** formed to prevent predictions like Browning’s which are not based on good science from creating havoc
  - In Feb. 2004 concluded prediction by Dr. Vladamir Keilis-Borok, of M6.4 in So. Cal. did not warrant public policy actions
  - Authors have insufficient statistical evidence to validate methodology
References


• *Report to the Director, Governor’s Office of Emergency Services By the California Earthquake Prediction Evaluation Council* (2004), Retrieved October, 10, 2006 from http://www.cisn.org/news/cepec.04.03.02.html