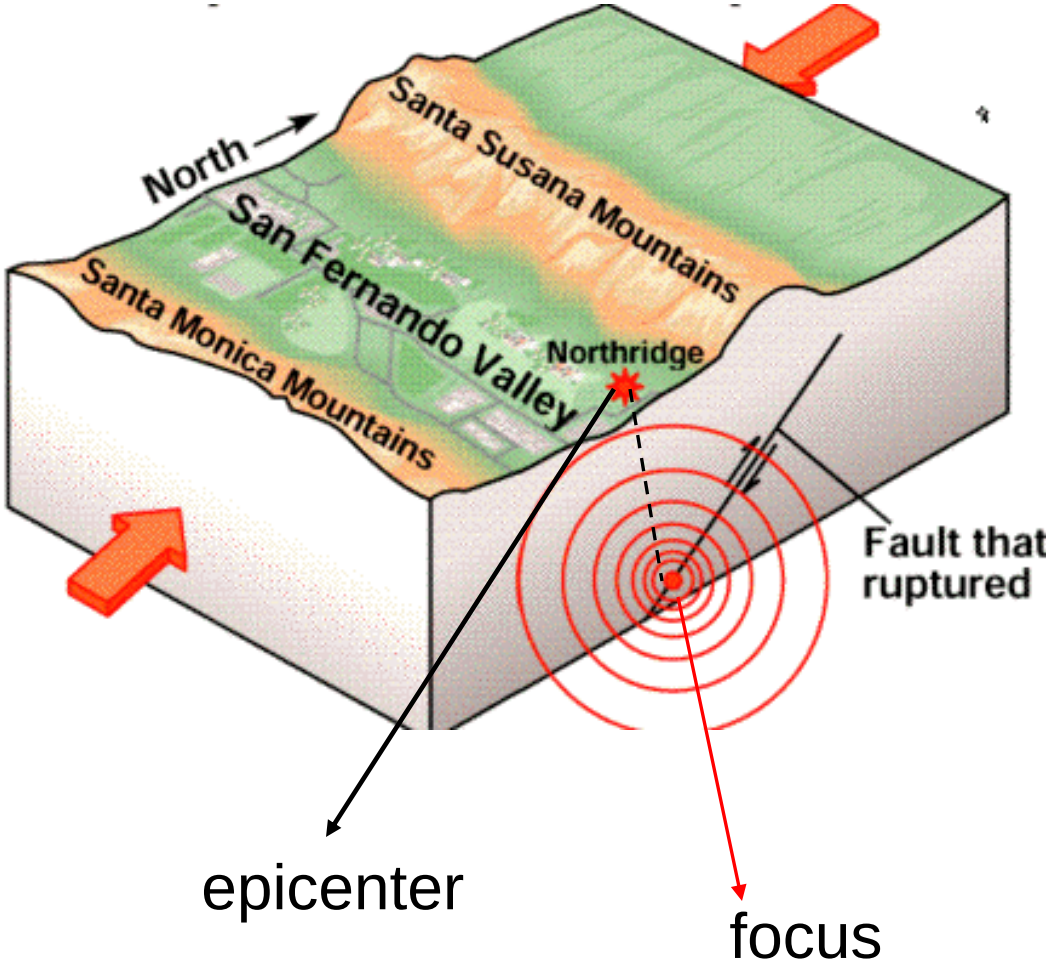
# Earthquakes

# Objectives

- Relate earthquake activity to plate tectonics
- Define earthquake, and identify the focus and epicenter of an earthquake.
- Describe the types of waves emitted during an earthquake.
- Distinguish between earthquake intensity and magnitude.
- Review some current methods of earthquake prediction.

# Why do earthquakes occur?




- *Fractures, faults*
- Energy released and propagates in all directions as seismic waves causing earthquakes

# Where do earthquakes occur:

1) Most earthquakes occur along the edge of the **oceanic** and **continental plate**

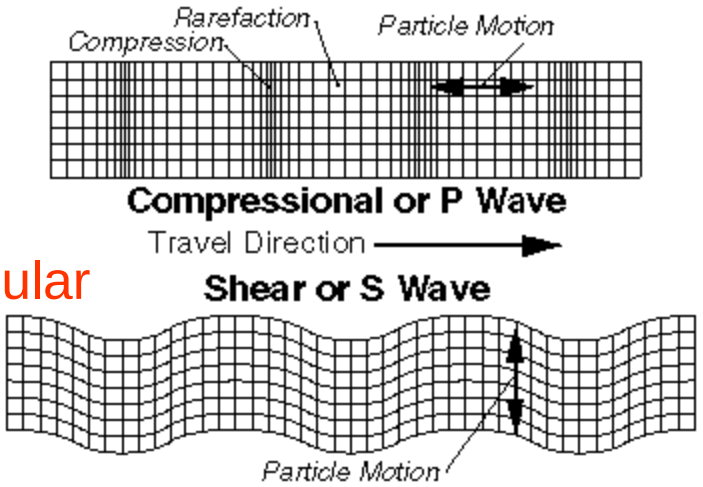
2) Along **faults:** normal, reverse, transform

# definitions

- Earthquake = Vibration of the Earth produced by the rapid release of energy
- Seismic waves = Energy moving outward from the focus of an earthquake
- Focus= location of initial slip on the fault; where the earthquake origins
- Epicenter= spot on Earth's surface directly above the focus

# Seismic waves: forms

- P-waves:
  - called compressional, or push-pull waves
  - Propagate parralel to the direction in which the wave is moving
  - Move through solids, liquids




- S-waves:
  - Called shear waves
  - Propagate the movement perpendicular to the direction in which the wave is moving

- Surface waves (L-waves or long waves).
  - Complex motion
  - Up-and-down and side-to-side
  - Slowest
  - Most damage to structures, buildings

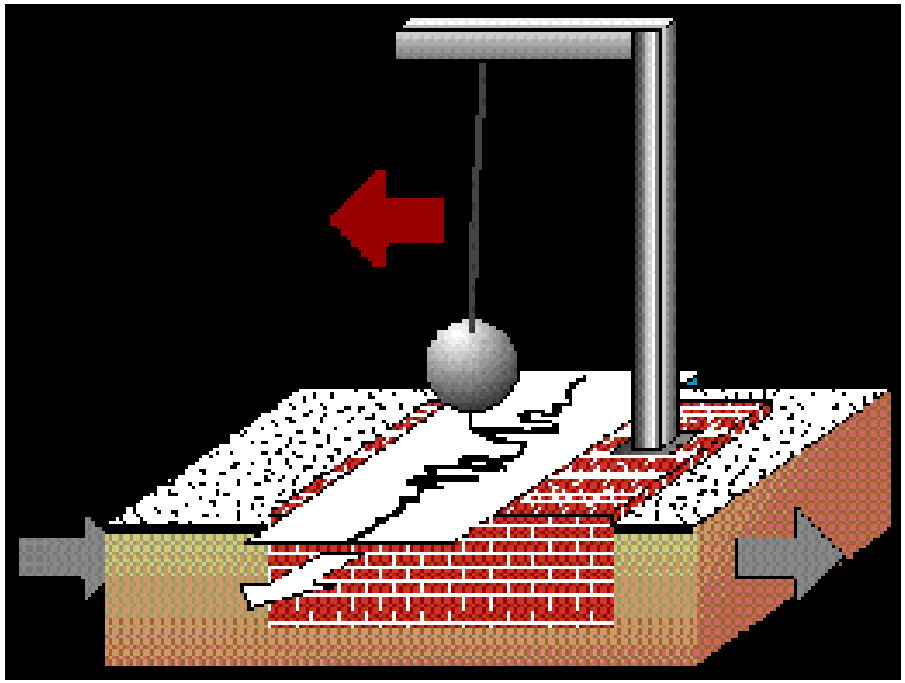
# Seismic waves: properties

- **Velocity**: function of the physical properties of the rock the wave is traveling through
  - Velocity *increases* with rock density
  - Velocity *changes* when passing from one material to another (increases/decreases)
  - Liquids: S-waves do not get transmitted through liquid; P-waves slow down

- Why is this important?
  - If we know the velocity of the wave, we can infer the type of rock it traveled through- that's how we map the interior of the Earth!!!

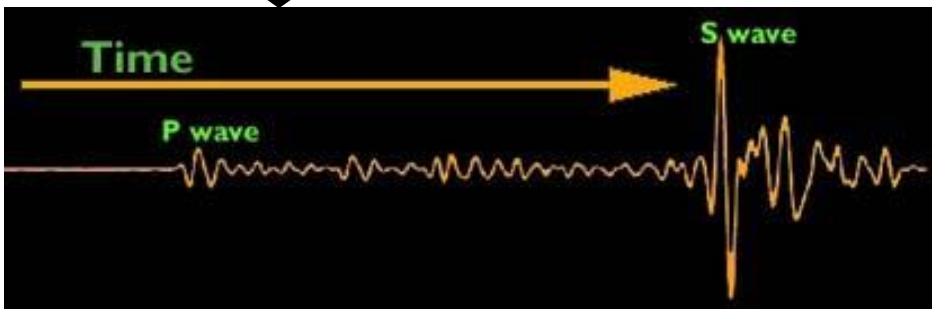
# Measuring earthquakes

- Seismometers: instruments that detect seismic waves



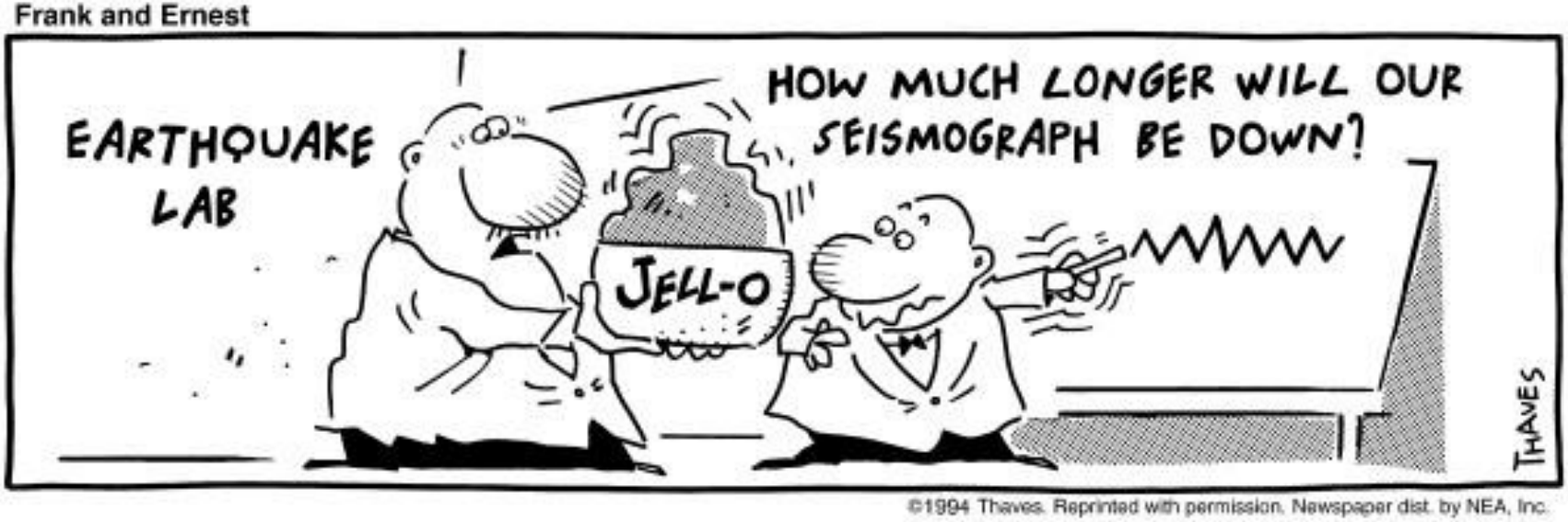
- Seismographs

Record intensity, height and amplitude of seismic waves



# Locating the shaking

- Measure time between P and S waves on a seismogram
- Need at least 3 seismographs



# Earthquake size: two ways to measure

1) **Magnitude**: Richter Scale
   - Measures the energy released by fault movement
   - related to the maximum amplitude of the S wave measured from the seismogram
   - Logarithmic-scale; **quantitative** measure
   - For each whole number there is a 31.5 times increase in energy
     - eg. an increase from 5 to 7 on the Richter scale = an increase in energy of 992 times!!

# 2) **Intensity:** Mercalli Scale:

- *What did you feel?*
- Assigns an intensity or rating to measure an earthquake at a particular location (**qualitative)**
- I (not felt) to XII (buildings nearly destroyed)
- Measures the destructive effect

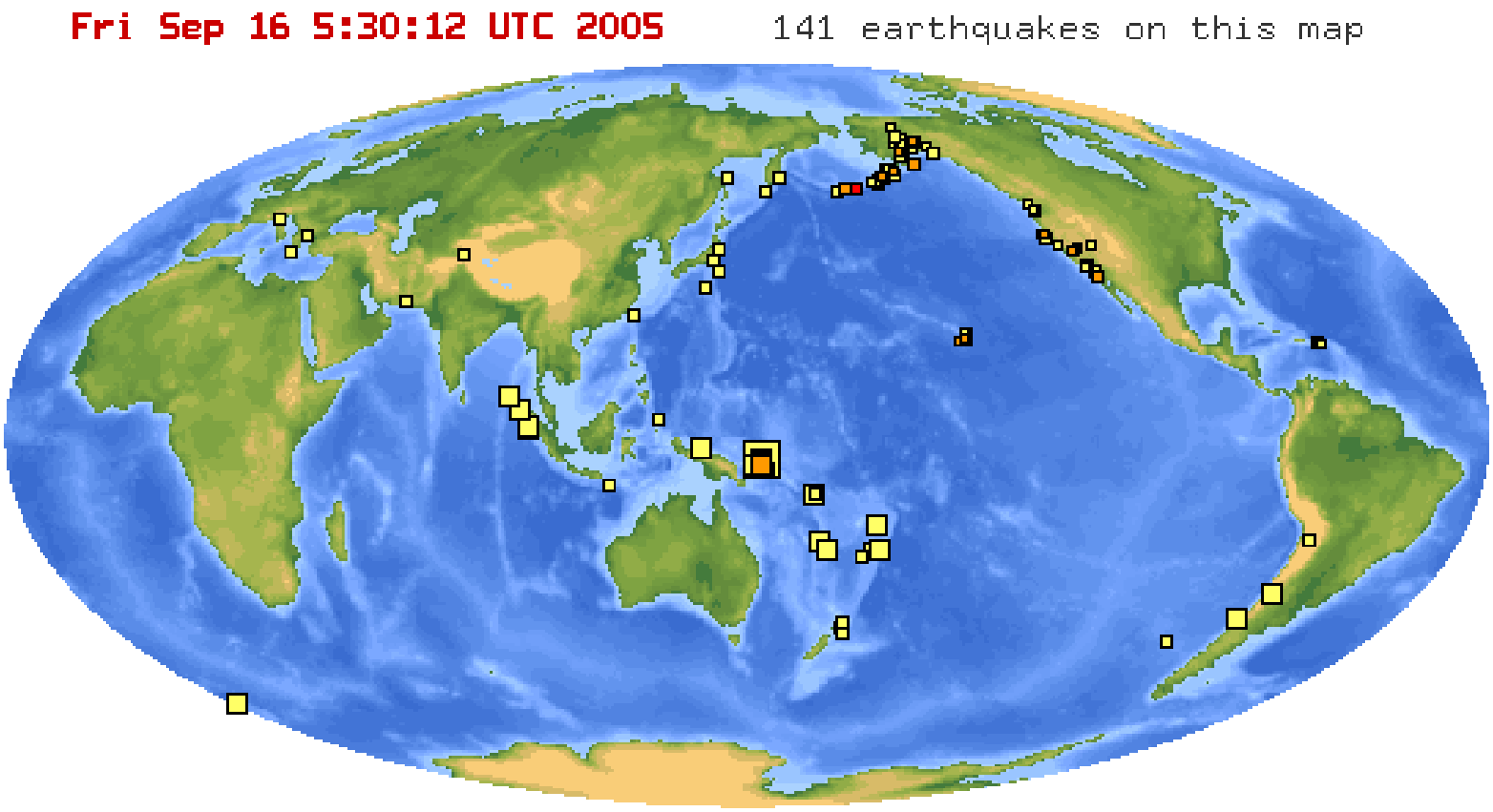
- Intensity is a function of:
  - Energy released by fault
  - Geology of the location
  - Surface substrate: can magnify shock waves e.g. Mexico City (1985) and San Francisco (1989)

# Frequency of Occurrence of Earthquakes

| Descriptor | Magnitude | Average Annually |
|---|---|---|
| Great | 8 and higher | 1 [1] |
| Major | 7 - 7.9 | 17 [2] |
| Strong | 6 - 6.9 | 134 [2] |
| Moderate | 5 - 5.9 | 1319 [2] |
| Light | 4 - 4.9 | 13,000 (estimated) |
| Minor | 3 - 3.9 | 130,000 (estimated) |
| Very Minor | 2 - 2.9 | 1,300,000 (estimated) |

[1] Based on observations since 1900.
[2] Based on observations since 1990.

# Recent Earthquake Activity in the World



# Largest earthquake in the world

**Chile : 1960 May 22**
**19:11:14 UTC**
**Magnitude 9.5**

- **More than 2,000 killed, 3,000 injured, 2,000,000 homeless, and $550 million damage in southern Chile**
- **tsunami caused 61 deaths**
- **$75 million damage in Hawaii;**
- **138 deaths and $50 million damage in Japan;**
- **32 dead and missing in the Philippines; and $500,000 damage to the west coast of the United States.**

## Table 12.2 A Sampling of Significant Earthquakes**

| Year | Date | Location | Number of Deaths | Mercalli Intensity | Moment Magnitude (Richter) |
|---|---|---|---|---|---|
| 1556 | Jan. 23 | Shaanxi Province, China | 830,000 | * | * |
| 1737 | Oct. 11 | Calcutta, India | 300,000 | * | * |
| 1812 | Feb. 7 | New Madrid, Missouri | Several | XI–XII | * |
| 1857 | Jan. 9 | Fort Tejon, California | * | X–XI | * |
| 1870 | Oct. 21 | Montreal to Québec, Canada | * | IX | * |
| 1886 | Aug. 31 | Charleston, South Carolina | * | IX | 6.7 |
| 1906 | Apr. 18 | San Francisco, California | 3,000 | XI | 7.7 (8.25) |
| 1923 | Sept. 1 | Kwanto, Japan | 143,000 | XII | 7.9 (8.2) |
| 1939 | Dec. 27 | Erzincan, Turkey | 40,000 | XII | 7.6 (8.0) |
| 1960 | May 22 | Southern Chile | 5,700 | XII | 9.5 (8.6) |
| 1964 | Mar. 28 | Southern Alaska | 131 | X–XII | 9.2 (8.6) |
| 1970 | May 31 | Northern Peru | 66,000 | * | 7.9 (7.8) |
| 1971 | Feb. 9 | San Fernando, California | 65 | VII–IX | 6.7 (6.5) |
| 1972 | Dec. 23 | Managua, Nicaragua | 5,000 | X–XII | 6.2 (6.2) |
| 1976 | Jul. 28 | Tangshan, China | 250,000 | XI–XII | 7.4 (7.6) |
| 1978 | Sept. 16 | Iran | 25,000 | X–XII | 7.8 (7.7) |
| 1985 | Sept. 19 | Mexico City, Mexico | 7,000 | IX–XII | 8.1 (8.1) |
| 1988 | Dec. 7 | Armenia–Turkey border | 30,000 | XII | 6.8 (6.9) |
| 1989 | Oct. 17 | Loma Prieta (near Santa Cruz, California) | 66 | VII–IX | 7.0 (7.1) |
| 1991 | Oct. 20 | Uttar Pradesh, India | 1,700 | IX–XI | 6.2 (6.1) |
| 1994 | Jan. 17 | Northridge (Reseda), California | 66 | VII–IX | 6.8 |
| 1995 | Jan. 17 | Kobe, Japan | 5,500 | XII | 6.9 |
| 1996 | Feb. 17 | Indonesia | 110 | X | 8.1 |
| 1997 | Feb. 28 | Armenia–Azerbaijan | 1,100 | XII | 6.1 |
| 1997 | May 10 | Northern Iran | 1,600 | XII | 7.3 |
| 1998 | May 30 | Afghanistan–Tajikistan | 4,000 | XII | 6.9 |
| 1998 | Jul. 17 | Papua, New Guinea | 2,200 | X | 7.1 |
| 1999 | Jan. 26 | Armenia, Colombia | 1,000 | VIII–IX | 6.0 |
| 1999 | Aug. 17 | Izmit, Turkey | 17,100 | VIII–XI | 7.4 |
| 1999 | Sept. 7 | Athens, Greece | 150 | VI–VIII | 5.9 |
| 1999 | Sept. 20 | Chi-Chi, Taiwan | 2,500 | VI–X | 7.6 |
| 1999 | Sept. 30 | Oaxaca, Mexico | 33 | VI | 7.5 |
| 1999 | Oct. 16 | Hector Mine, California | 0 | * | 7.1 |
| 1999 | Nov. 12 | Düzce, Turkey | 700 | VI–X | 7.2 |
| 2001 | Jan. 26 | Gujarat state, India | 19,998 | X–XII | 7.7 |

*Data not available.
**There is not a recent increase in earthquakes; this table merely reflects more detail on the recent record.

# Most Destructive Known Earthquakes on Record in the World

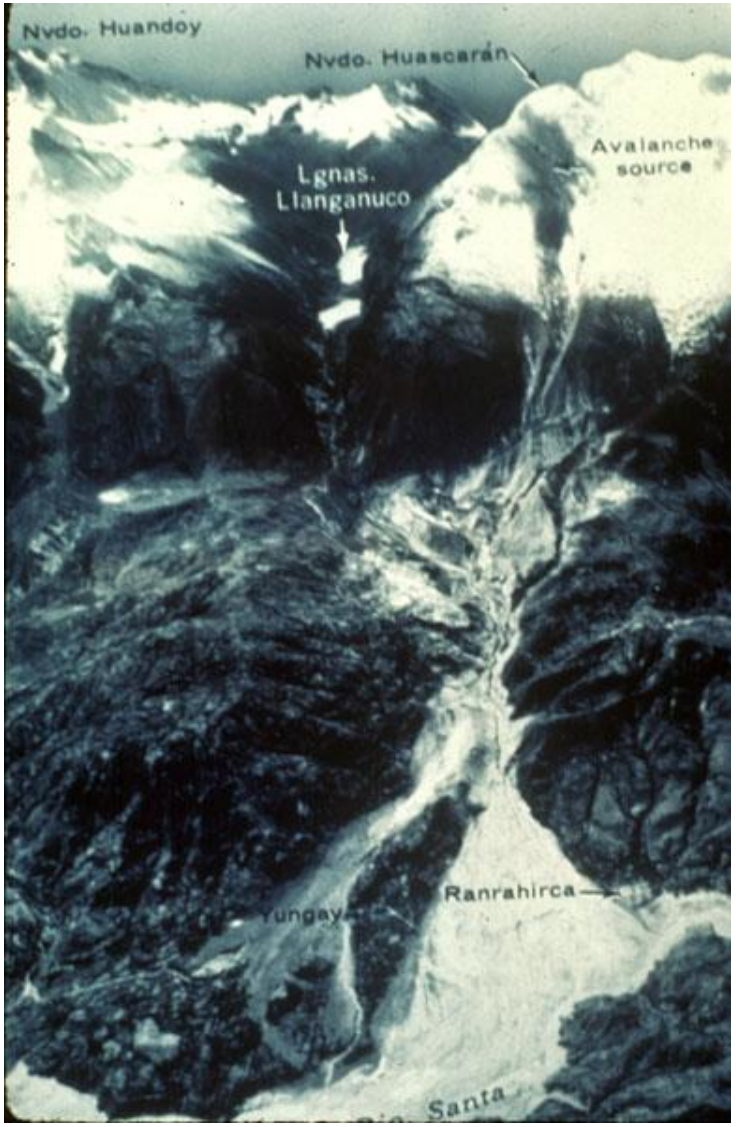
| Date | Location | Deaths | Magnitude | Comments |
|---|---|---|---|---|
| May 31, 1970 | Peru | 66,000 | 7.9 | $530,000,000 damage, great rock slide, floods. |
| July 27, 1976 | China, Tangshan | 255,000 (official) | 7.5 | Estimated death toll as high as 655,000. |
| Sept 19, 1985 | Mexico Michoacan | 9500 (official) | 8.0 | Estimated death toll as high as 30,000 Old lake bed magnified shock waves by 500% |
| 2001 Jan 26 | India | 20,023 | 7.7 | 166,836 injured, 600,000 homeless . |
| 2004 Dec 26 | Sumatra | 283,106 | 9.0 | Deaths from earthquake and tsunami |

# Earthquake damage

- Ground Failure - constructions collapse
- Fires - from broken gas and electrical lines
- Landslides - EQ's triggered; occur in hilly/mountainous areas.
- Liquefaction - water-saturated, unconsolidated materials flow
- Tsunami (seismic sea waves; "tidal" waves) - can grow up to 65 m

# Earthquakes and the San Andreas Fault

# Landslides: May 30, 1970 Peru disaster




Magnitude: 7.9

•A large mass of ice and rock slid from a vertical face on Nevado Huascaran, the highest peak in Peru

•Debris reached a velocity of 280 km/hr

•traveled 11 km horizontally in about 4 minutes at a mean velocity of 165 km/hr.

•Buried the towns of Yungay and Ranrahirca, The death toll in both villages was 20,000.

# The town of Huaraz flattened

# India, Gujarat earthquake Jan 26, 2001

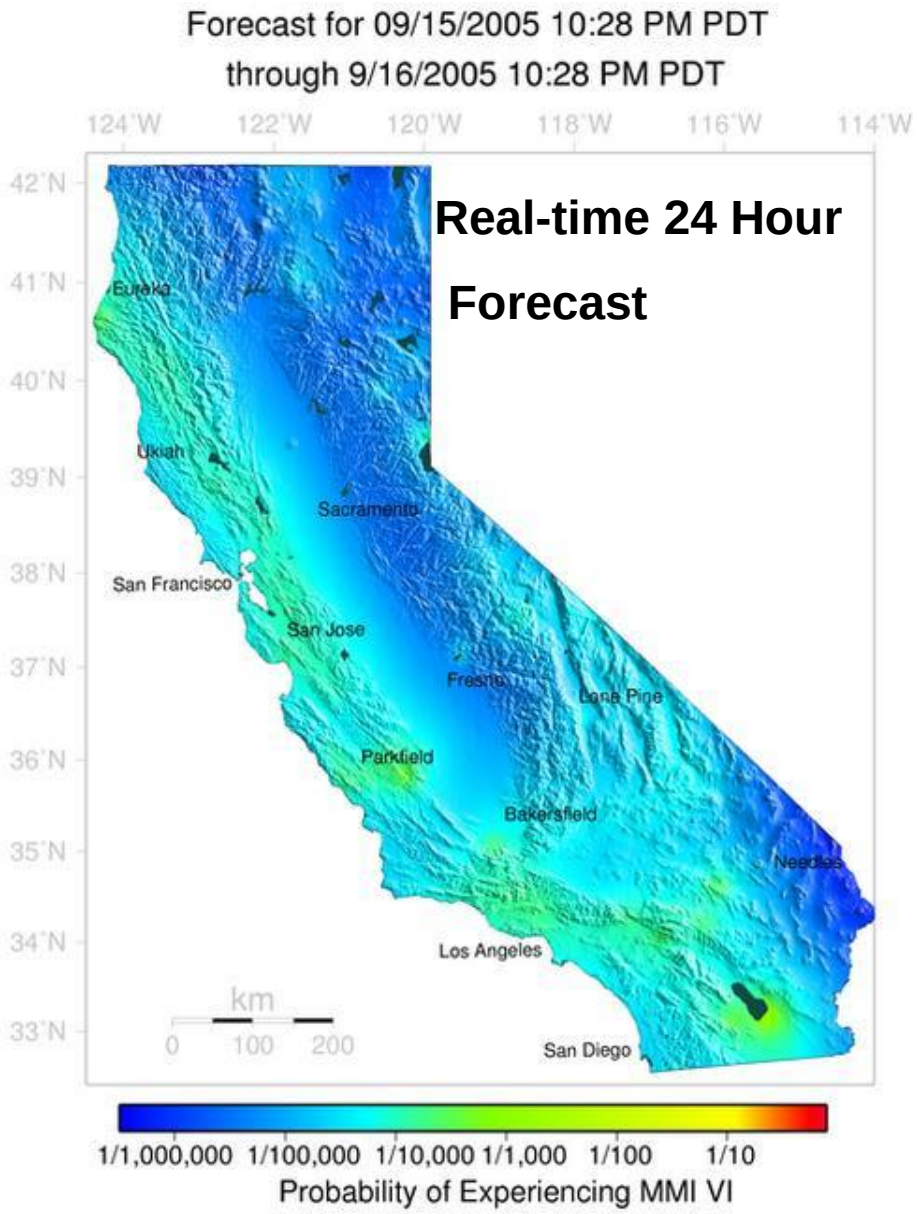

# Jun 23, 2001 S.Peru earthquake

# Earthquake risk and prediction

- Long-term methods

1) seismic hazard maps

2) probability analysis based on:
- historical EQ records
- geologic EQ records
- slip-rate on active faults
- frequency and magnitude of recent EQ's



# Short-term predictions

Precursor phenomena (<1 year to days)

1. **Foreshocks:** usually increase in magnitude

2. **Ground deformation**

3. **Fluctuations in water well levels**

4. **Changes in local radio wave characteristics**

5. **Anomalous animal behavior???**

# Impacts of Earthquake Prediction