Global tour of quakes

- California
- Rest of country
- Biggest quakes
  - 1960 Chile, 1964 Alaska, 2004 Sumatra
- Rest of world
  - Japan, Turkey, India
  - 1755 Lisbon

International quakes

- Japan
  - 1923 Tokyo quake, horrific casualties
  - 1995 Kobe most expensive, $150 billion
- China - 1975 Haichang & 1976 Tangshan
  - Most fatalities, prediction experiment
- India - very active
- Europe - somewhat active

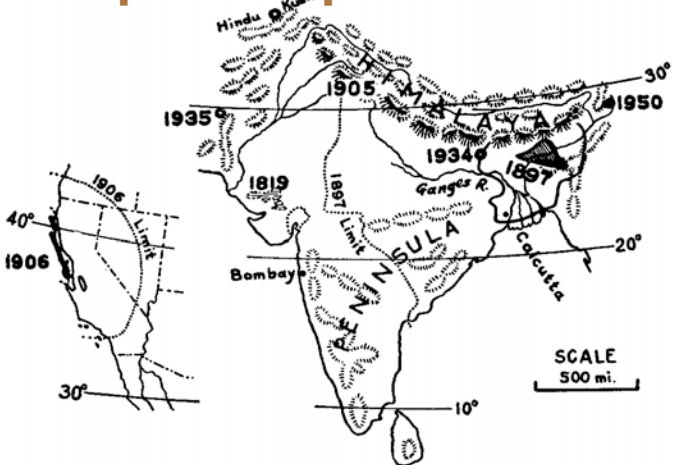
Great Kanto Earthquake. Destruction of Kokugikan (National Sumo Wrestling arena), Ryogoku district.

Tokyo 1923

India

- Quakes are the result of the India-Asia collision
- California quakes pale in comparison
- Many great quakes
  - 8.7 in 1897
  - 8.6 in 1905
  - 8.4 in 1934
  - 8.7 in 1950
- Prototype for intensity XII shaking

Map: Indian quakes

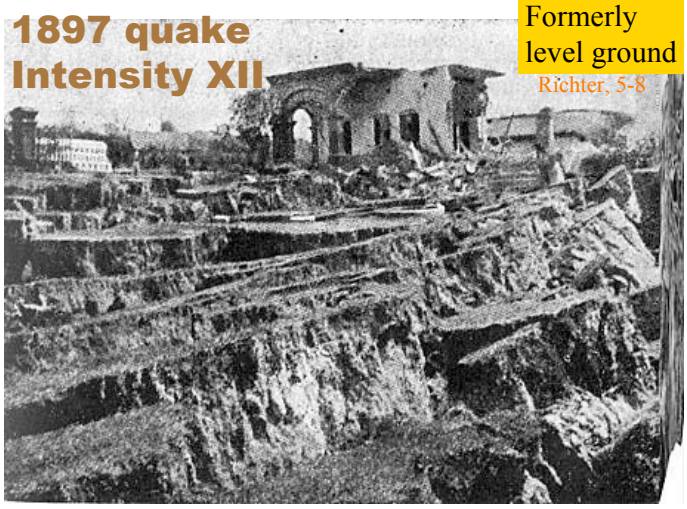


1897: Intensity XII

Judge's house: Before and after

Richter, 5-6

1897 quake Intensity XII



Formerly level ground

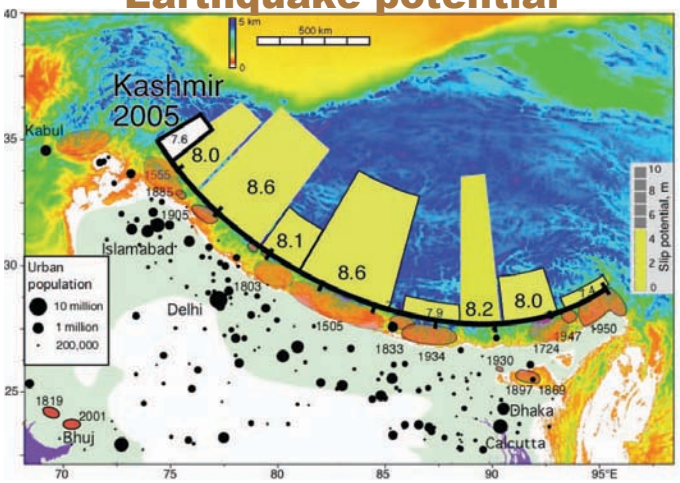
Richter, 5-8

Deadly quake in Pakistan, October 8, 2005

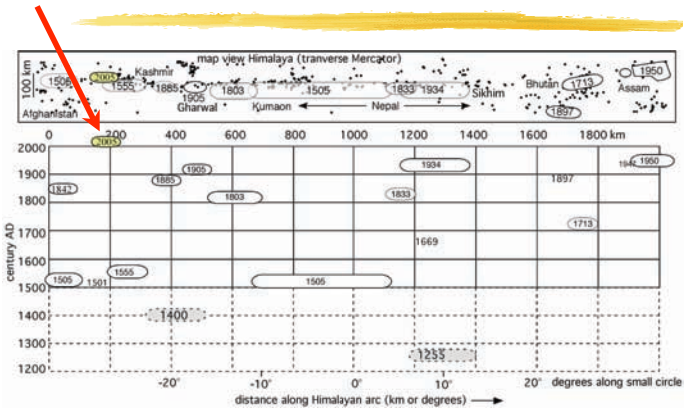
- M7.6, a shade bigger than Landers
- 9am, 70,000+ fatalities
- Losses about $5,000,000,000
  - Had to talk at dawn on MSNBC
    - Earbrow trim, make-up, Godiva choc
    - 8:30am east coast time

Landslides

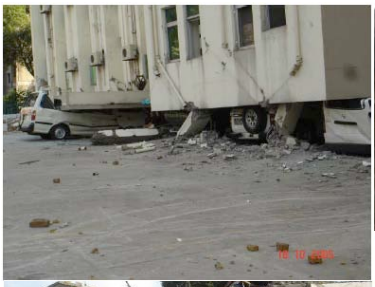
Earthquake potential



Space-time EQ's across Tibet



Poor construction

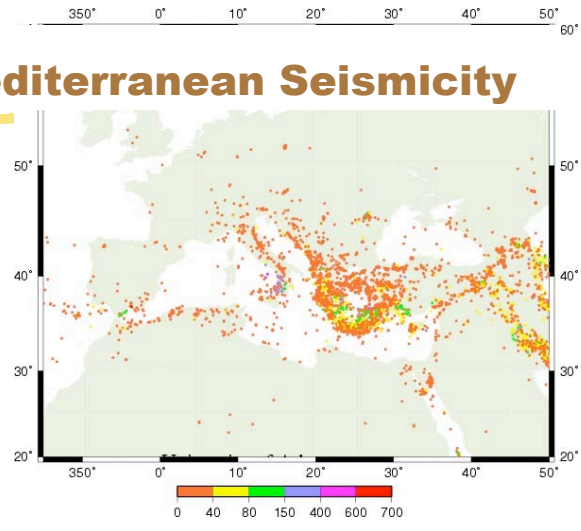


Cracked hilltop, and damage

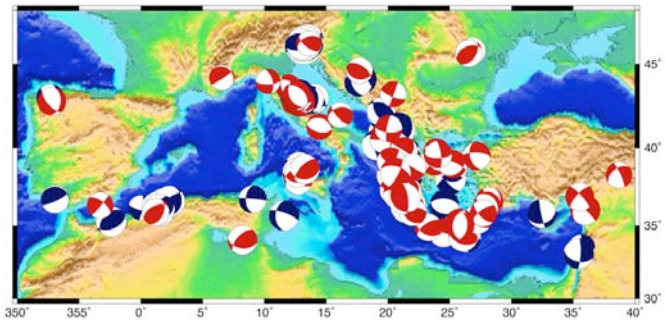
Quakes in Europe

- Plate boundaries complicated
- Italy and Greece
  - Some damaging moderate quakes
    - Old buildings, in 2000, there was $1 billion M=5.
  - Volcanoes also a hazard, like Etna
- Turkey and Israel like California
  - Big strike-slip quakes
  - Sequence in 1940's showed alarming series of events marching along Anatolian Fault
- Lisbon 1755 an important event

Mediterranean Seismicity



Focal mechanisms



1980 Naples, Italy quake

4000 killed
250,000 homeless

Deadly quake in Turkey, August 17, 1999

- M7.4, like Landers
- 20,000 to 30,000 fatalities
- Losses about $10,000,000,000
- Govt. heavily criticized for slow response
- Sumatran earthquake well reported

Offset wall

Faulted barn

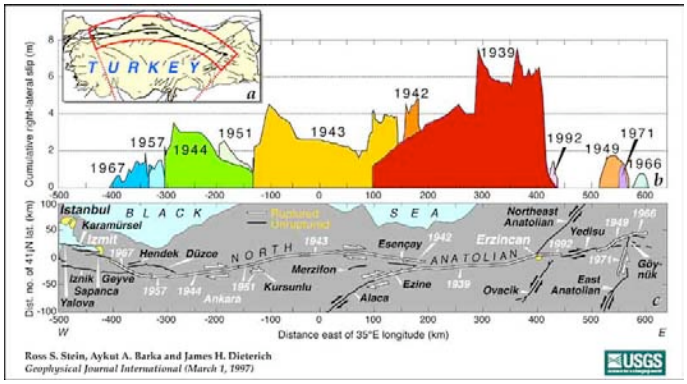
Fault scarp

Faulted building

"pancaking"

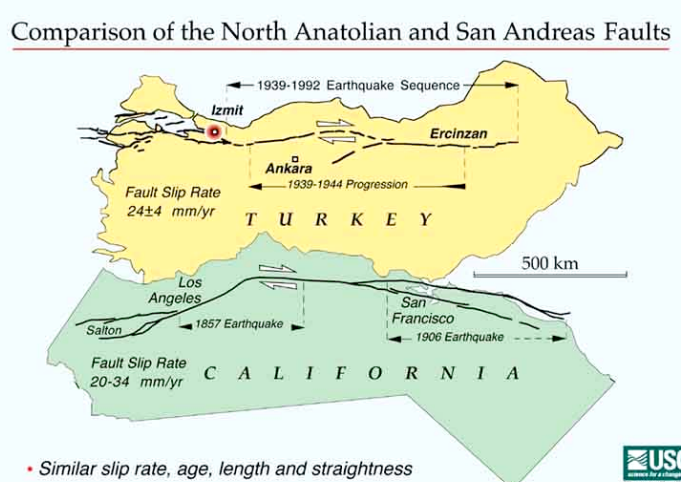
??

History of Turkish quakes



A worry

- Fault much like California
  - M6 in 1939
  - M8 in 1939
  - M7.3 in 1942
  - M7.6 in 1943
  - M7.6 in 1944
- What if this happened in California?



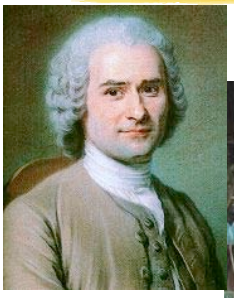
A mosque stood with a few other structures amid the rubble of collapsed buildings in the town of Golcuk, 60 miles east of Istanbul.

Associated Press Photo by Enric Marti
Taken from New York Times, August 20, 1999

1755 Lisbon quake

- M = 8.5?, felt across most of Europe
- We still don't know what fault it was on
- Timing unlucky, 9:30 am on Nov. 1
  - All Saint's Day, people were in church
  - Also brought fires and a big aftershock at noon
- Tsunami - water receded then smashed boats
  - 10 m waves
  - As high as 3 m in Holland and the Caribbean

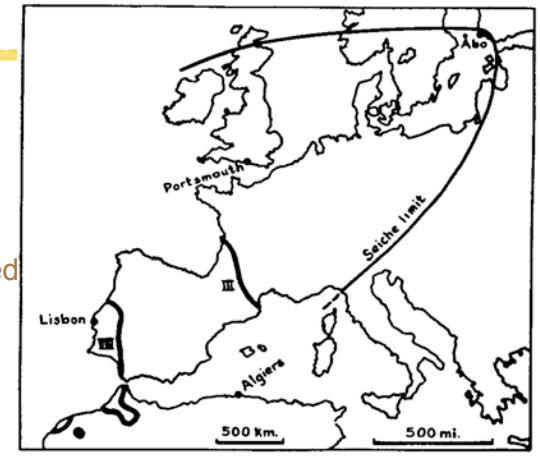
Rousseau concluded "Live Outdoors!"



Effects of 1755 Lisbon quake

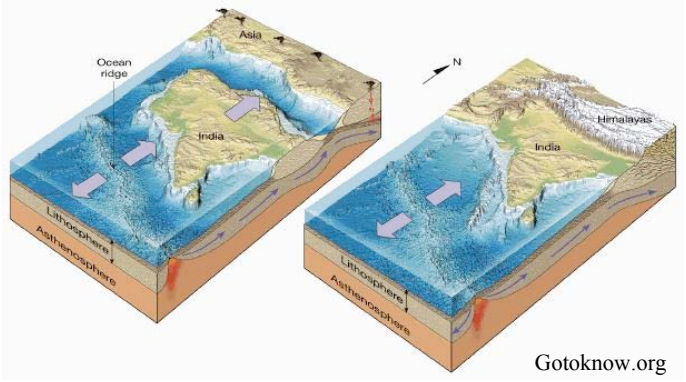
60,000 killed

Portugal devastated

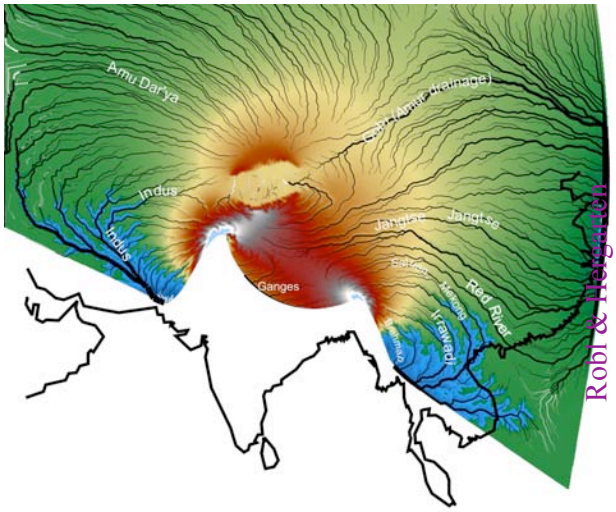


Richter, 9-1

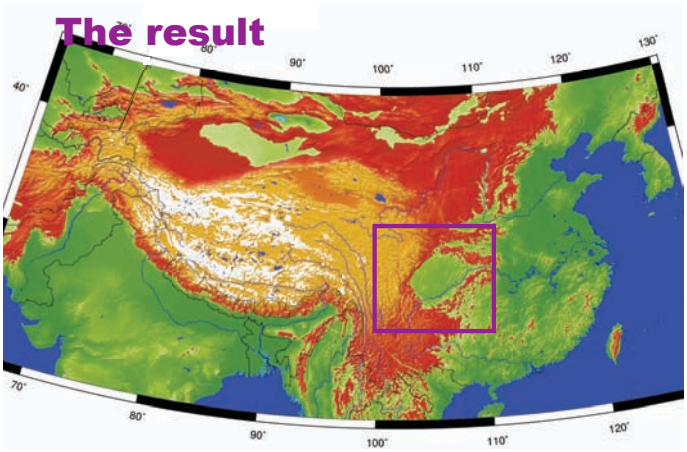
Tectonic bumper cars



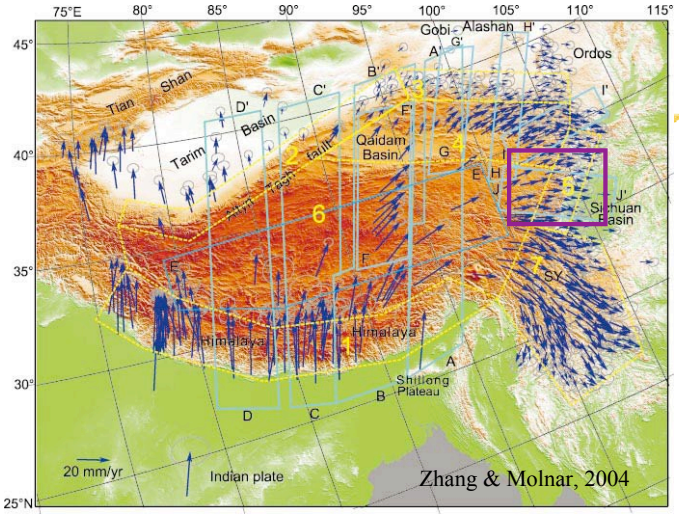
A numerical model



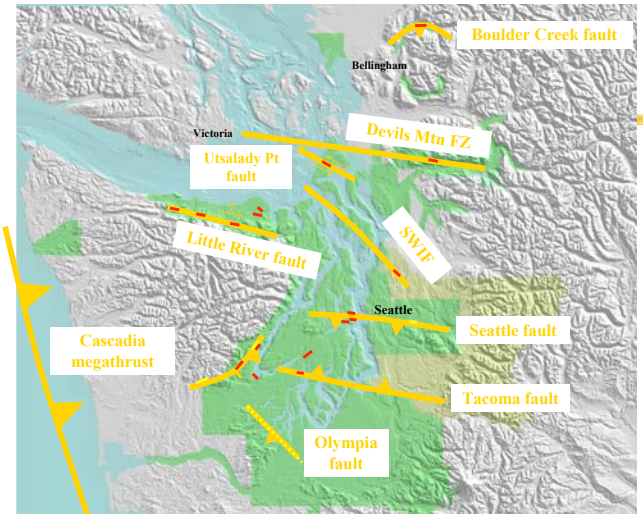
The result



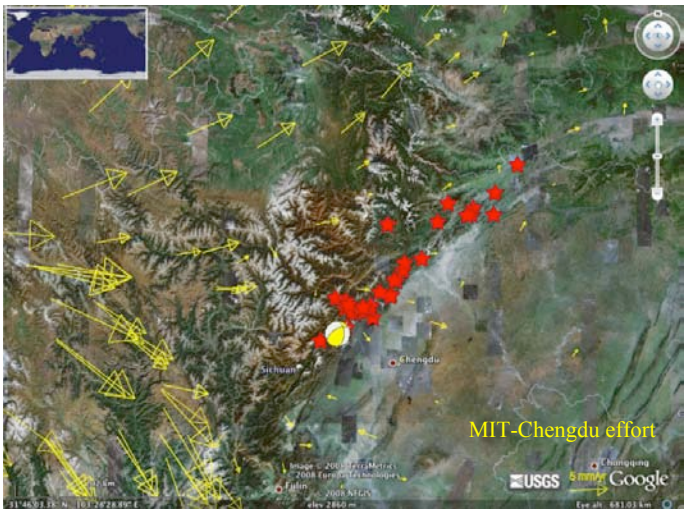
Arrowsmith & Strecker, 1999



The landscape

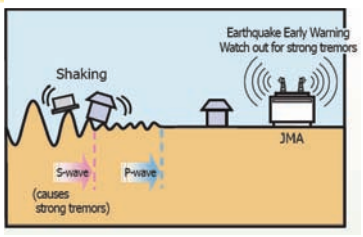


Courtesy R. Haugerud, USGS



Problems

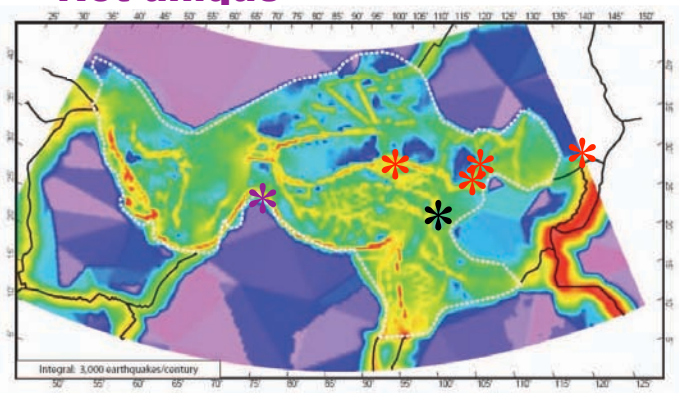
- Buildings
- Ill-founded rumors
- Monitoring
- Not enough mapping



Progress

- Growing monitoring
- Continued fault mapping
- Possible “early warning”
  - 20s warning for Chengdu, for example

Not unique

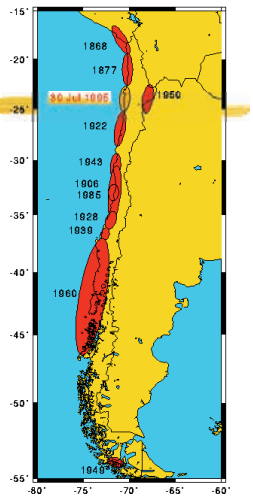


Previous quakes in China, with 200K+ fatalities:
1556, 1920, 1927, 1976
Pakistan, 2005, 80K

Quake risk across Asia, Liu & Bird, 2008

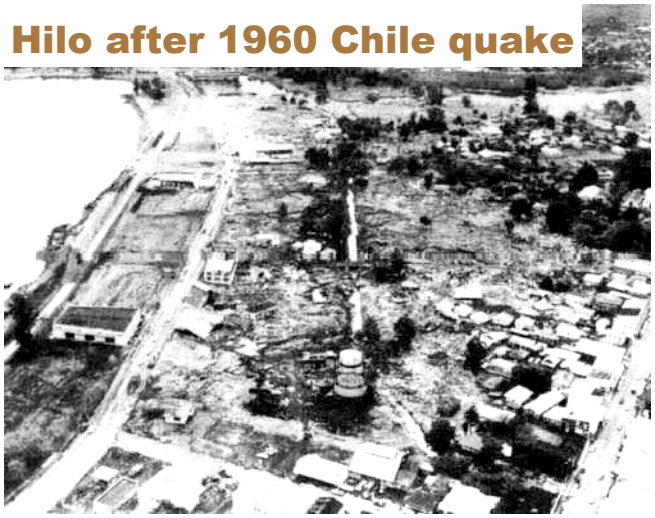
1960 Chile earthquake

- M 9.5!!
  - 160,000 square km fault
  - 21 meter average slip
- Loss of life and property in Chile, Hawaii, and Japan



Isla Chiloe, Chile

Hilo after 1960 Chile quake

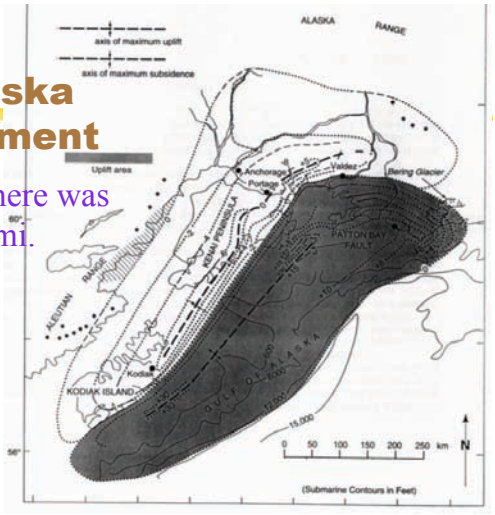


1964 Alaska

- M 9.2 !
  - Several meters of uplift over a huge fault area
- 119 deaths in Alaska and California
- 2-7m waves along open California coast
- Crescent City hardest hit
  - Thirty blocks of Crescent City were devastated
  - Gas truck smashed into electric wires
  - Texaco tank fire burned for three days

1964 Alaska displacement

No wonder there was a large tsunami.



USGS Prof. Paper 5460

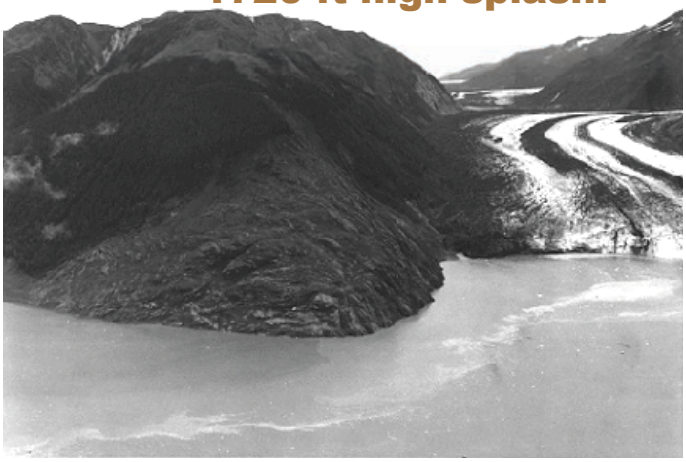
Port

Lituya Bay

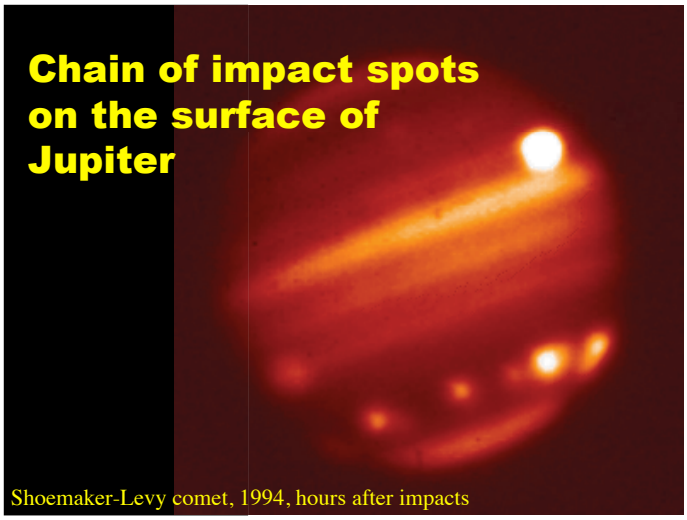
- This image shows Lituya Bay, Alaska, after a huge, landslide-generated tsunami occurred on July 9, 1958. The earthquake-induced rockslide, shown in upper right-hand corner of this image, generated a 525 m splash-up immediately across the bay, and razed trees along the bay and across LaChausse Spit before leaving the bay and dissipating in the open waters of the Gulf of Alaska. Source: Lander, and P. Lockridge

Lituya Bay slide

1720 ft high splash!



Tsunami from impact



Meteorites

- Roughly once a year, a meteorite 2-3 meters across hits Earth.

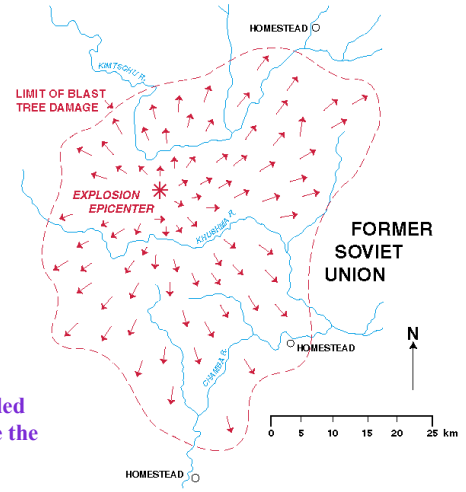
Powerful meteorites

- A former asteroid pierces the atmosphere and releases the energy equivalent of five kilotons (5,000 tons) of TNT about once a year. In comparison, the explosive power is almost half that of the bomb dropped on Hiroshima, Japan during World War II.

Tungushka in 1908

- An object big enough to cause destruction, like the approximately 60-meter-wide asteroid or comet that exploded over Tungushka, Siberia in 1908, hits about once a millennium.
- (Conspiracy theorists think otherwise.)
- The blast, equivalent to 10 megatons of TNT, flattened 500,000 acres (2,000 square km) of uninhabited forest. Had the bull's-eye been on New York City, it would have been destroyed.

Tree Fall



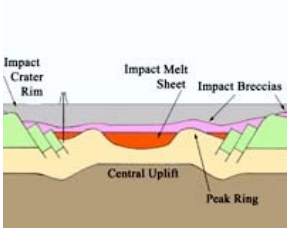
Probably exploded about 6 km above the ground

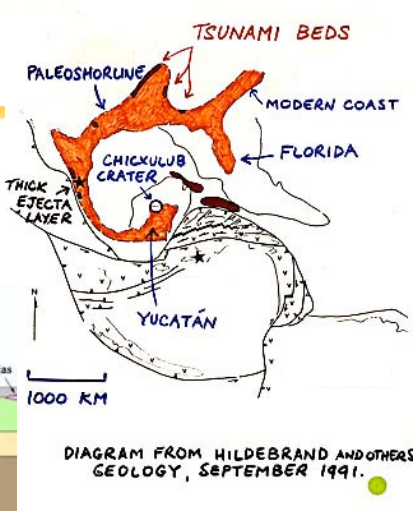
Meteor crater, Arizona

King of known impacts

- Cretaceous-Tertiary boundary impact
- Probably 10 km radius meteorite
- Caused the downfall of the dinosaurs
  - Many other animals and plants
- Global fires?
- Greenhouse effect?
- Darkness for days? Years?
- Sprayed a lot of vaporized rock across the western hemisphere

Chicxulub impact crater





King of suspected impacts

- Moon-forming impact
- Probably collision of two Mars-sized objects
- More than 4 billion years ago
- Sprayed out large amounts of pulverized and melted rock and iron
- Much of spray captured in orbit
- Collected to formed the Moon
- King of possible impacts
  - Colliding super-massive black holes …

Earthquakes M>5, 1963-1988

Quakes that we've discussed