Indian Institute of Technology, Kanpur

Department of Earth Sciences

ESO213A: Fundamentals of Earth Sciences

Lecture 32. Earthquakes - I

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Aims of this lecture

- Causes of Earthquake
- Historical Developments
- Faults
- Earthquake Terminologies

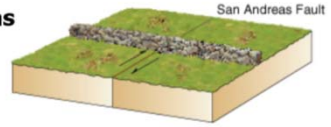
What is an earthquake?

- Release of stored energy (where?)
  - **Elastic rebound theory** explanation to how earthquakes occur
  - Plate movement concentrates energy in crust
  - When the stored energy exceeds the strength of the crust, the crust ruptures
  - The rupture generally occurs along faults (existing or new?) because this is the weakest point

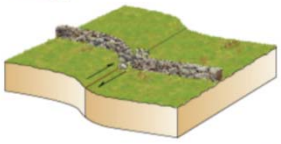
What is an earthquake?

...the release of built-up stress along faults

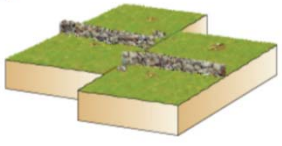
1. Stress builds up due as tectonic plates move past one another



2. Friction along the fault prevents slip, elastic deformation instead



3. Stress exceeds rupture strength, fault slips ... earthquake

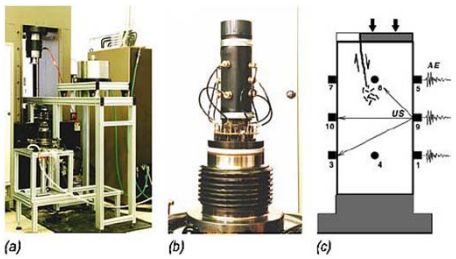


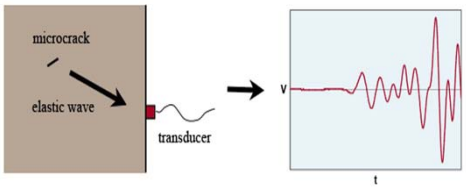
➔ **Elastic rebound theory: developed in the Lawson Report**

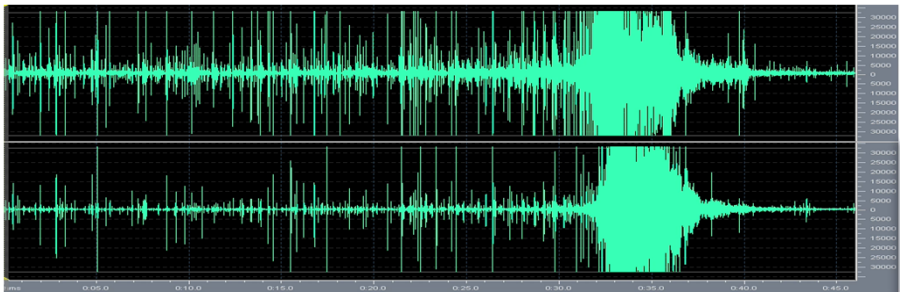
How Faulting Generates Earthquakes?

- Movement on the fault causes a release in energy
- As the energy passes through an area, the vibration is felt
- The energy is transferred through the earth and man-made structures
- The bigger the amount of slip the more energy released and therefore, the more vibrations are produced

Energy during faulting – an analogue "*visualization*"







What are the causes of Earthquakes

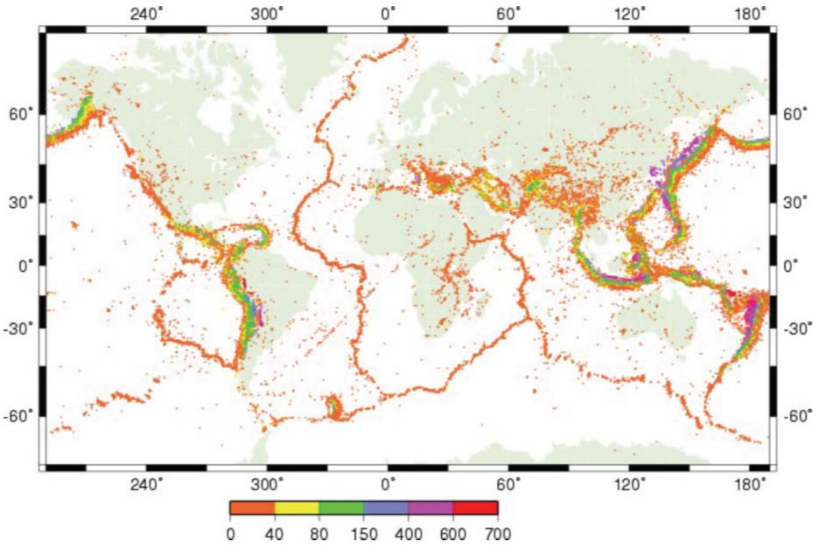
- **Tectonic stress** (most common)
- Water/disposal added under pressure (man-made)
- **Geothermal gradient** (variation due to boundary)
- Rock type
- Fast/Cold and slow/warm (brittle or ductile)

Where do Earthquakes occur

- Historic Records

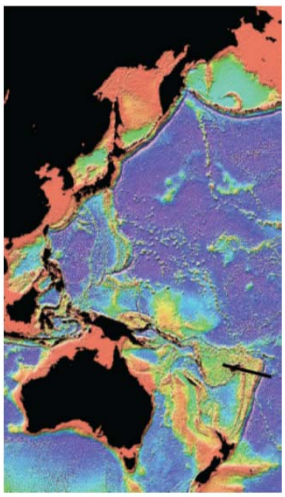
Where do Earthquakes occur

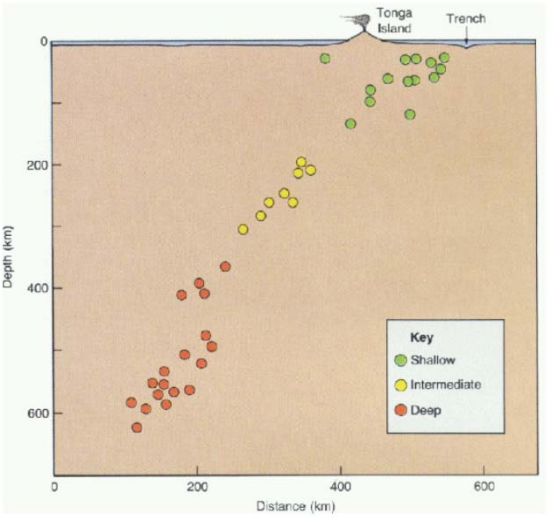
- Now we know, where…



Where do Earthquakes occur

Deep earthquakes





Historical development - I

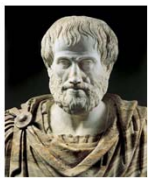
- Mythology: associated with giant creatures

- Japan: CATFISH
- China: FROG
- Philippines: SNAKE
- Native Indians: TURTLE

.. and yes, it generally happens when **HE** is angry and people do something bad to make him more angry.

Historical development - II

- First Theory: Aristotle was the first one, to suggest a theory..



Strong winds blew through caves inside the Earth, creating "*effects similar to those of the winds in our bodies whose force when it is pent up inside us can cause tremors and throbbing*."

Historical development - III

- A movie with no sound…

- 1906 San Francisco
  April, 18th
- M: 7.8
- ~3000 death
- 80% of the city destroyed and burnt

Historical development - IV

- A turning point for earthquake science – 1906 San Francisco Earthquake

- **Andrew Cowper Lawson** (July 25, 1861–June 16, 1952)
  - Cataloged descriptions of earthquake effects
  - Identified San Andreas Fault
  - Earthquakes associated with faults
  - Maps of the fault location and ground shaking distribution
  - Elastic rebound theory

Faults

- What are faults?

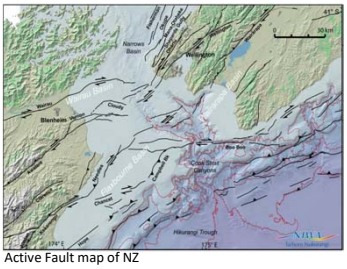
Fault produced during 1930 Napier Earthquake, NZ (Photo: S. Misra)

Guatemala (Photo: Rich Allen, UCB)

California (Photo: Rich Allen, UCB)

- What are ACTIVE faults?

  A fault that has moved at least once in last 11000 years is an ACTIVE FAULT.



Active Fault map of NZ

- What are fault ZONES?

  Areas within 50 feet of identified / mapped active fault.

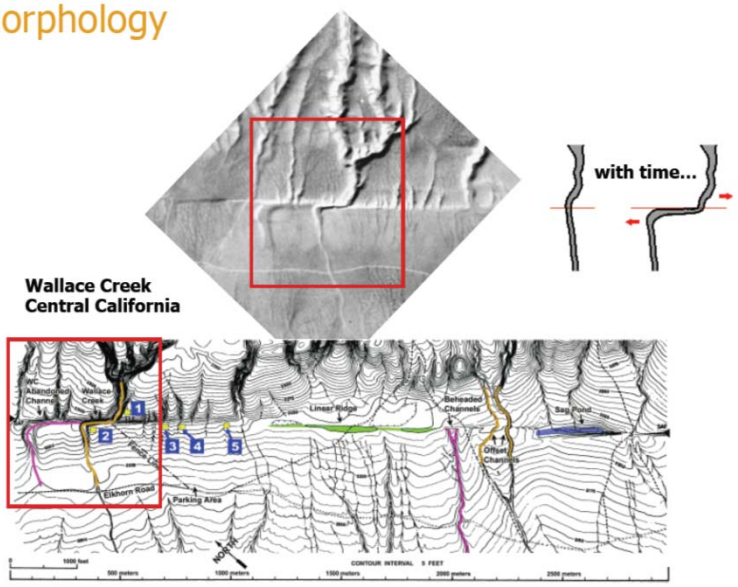
Active Faults

Still active?

Kuangfu Middle School
1999 Chi-Chi earthquake, Taiwan

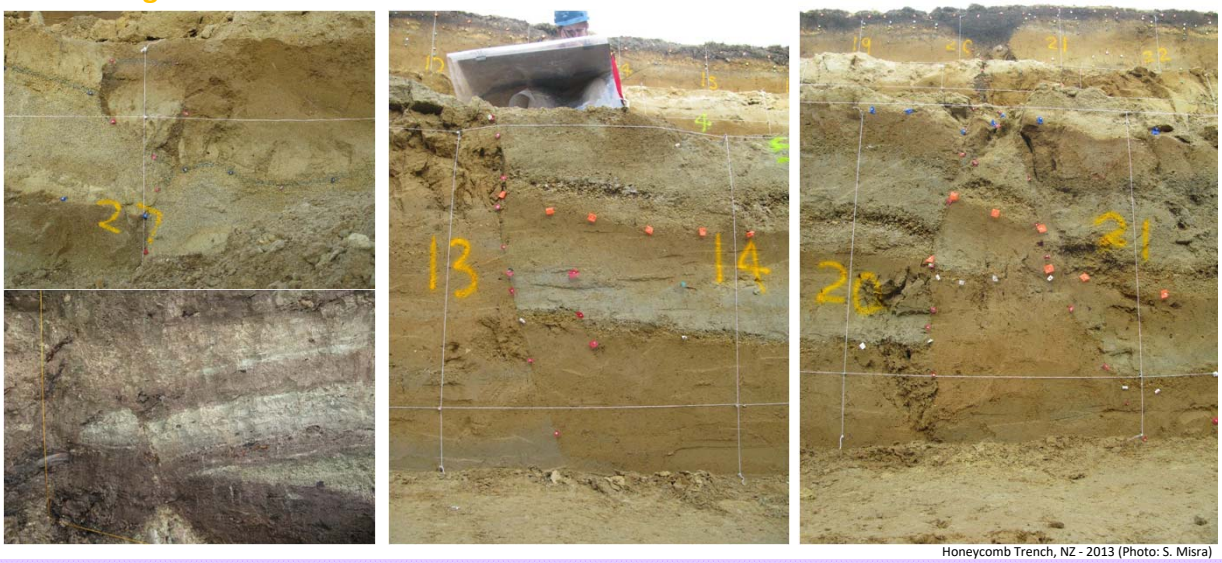
Faults

Geomorphology



Faults

Trenching

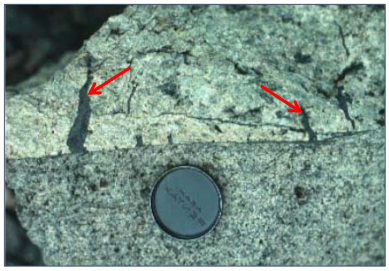


Honeycomb Trench, NZ - 2013 (Photo: S. Misra)

High-speed fault movement - PSEUDOTACHYLITE

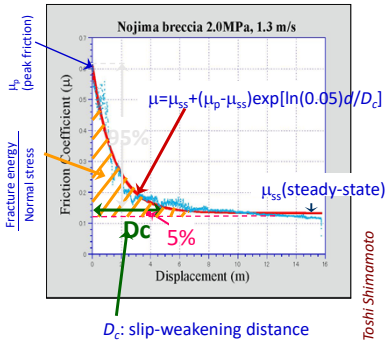
Finding a fossilized Earthquake in Nagaland (S. Misra as scale)

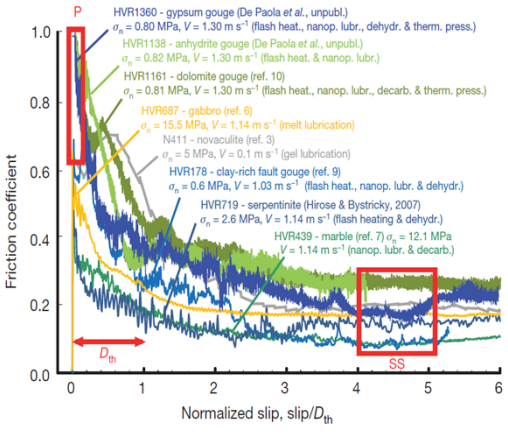
Pseidotachylite in Serpentinite (Photo: S. Misra)



Pseidotachylite in gabbroic rock 2015 (Photo: G. Di Toro)

High-speed fault movement - PSEUDOTACHYLITE





Di Toro et al., 2011; Nature

High-speed fault movement - PSEUDOTACHYLITE

High velocity Rotary Shear Apparatus

Some terminologies…

- Normal / Reverse / Thrust / Strike-slip/ oblique Faults
- Fault plane / Fault trace / Dip / Hanging and Foot walls
- Focus / Hypocenter / Epicenter
- Foreshocks and Aftershocks
- Seismic waves
- Shear Wave Splitting (fast and slow arrival)
- Earthquake / Seismic Cycle
- Earthquake Source Mechanism (beach ball)
- Ground Motion

Some terminologies…

- Normal / Reverse / Thrust / Strike-slip/ oblique Faults
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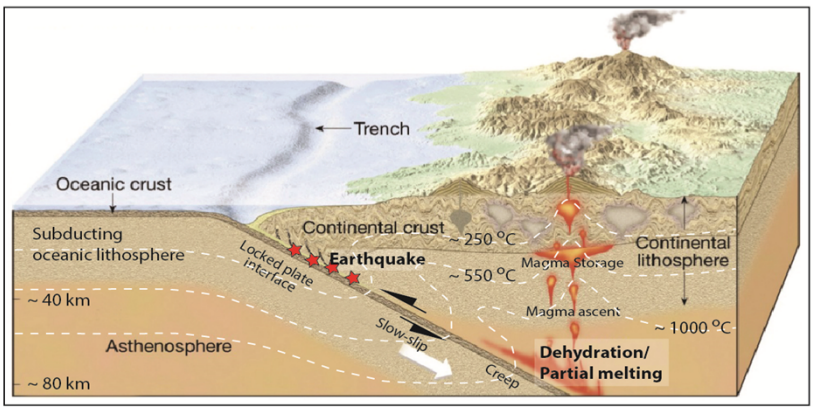
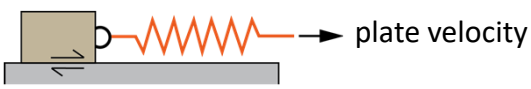
- **Foreshocks and Aftershocks**
- **Seismic waves**
- **Shear Wave Splitting (fast and slow arrival)**
- **Magnitude**
- Earthquake / Seismic Cycle
- **Earthquake Source Mechanism (beach ball)**
- Ground Motion

.. In the next lecture

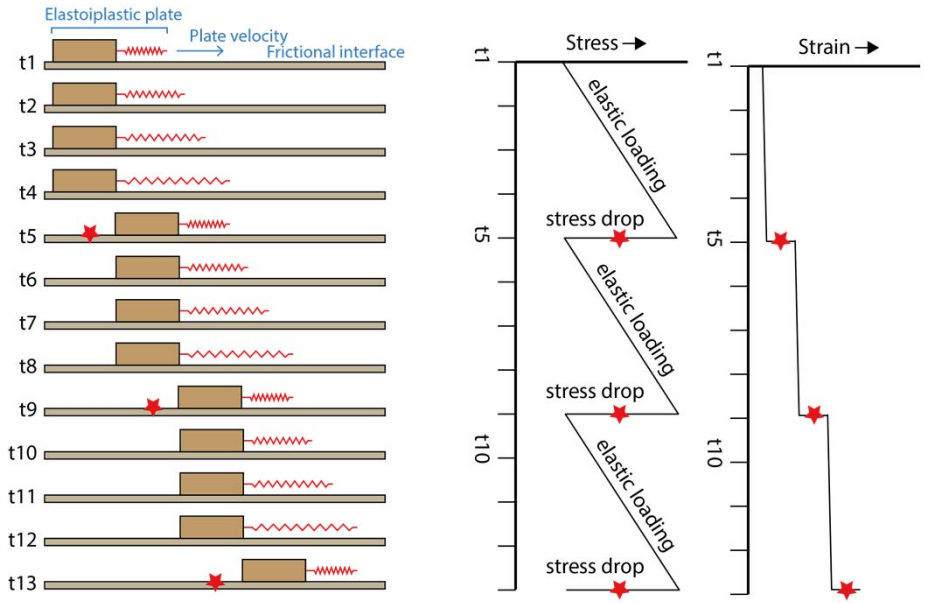
Earthquake Mechanics – simple model



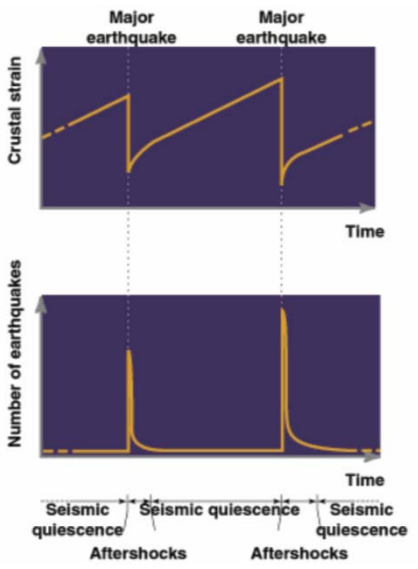
elastoplastic plate



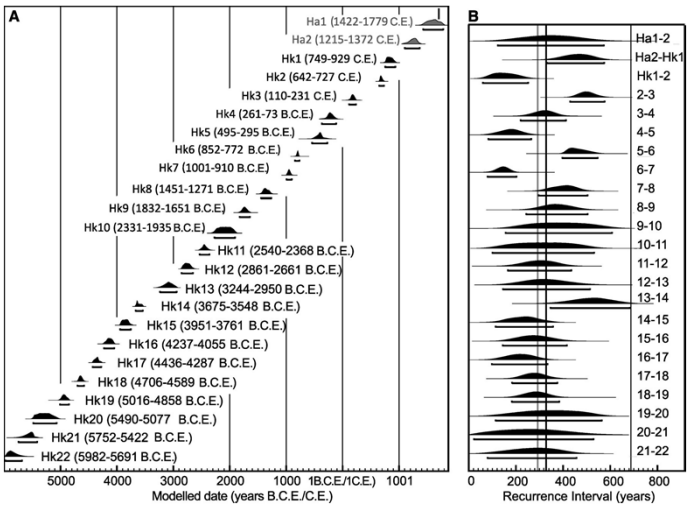
Example I: Rebound due to deglaciation



Earthquake cycle…



Ages of surface-rupturing earthquakes on the Alpine Fault



Details are here: http://www.sciencemag.org/content/336/6089/1690.full.pdf

What should you do if there is an earthquake and you are feeling it?

??

Run away from the building?

Pray to god

Post in social media

Mark yourself safe in social media

Call a friend and share

What should you do if there is an earthquake and you are feeling it?

DROP
COVER &
HOLD ON

Next Lecture

More on Earthquakes