Plate Tectonics

Big Moves!

Geology for Engineers

- **These overheads are made available for private study purposes only.**
- **All care, no responsibility, and best wishes to the user!**

Portions of this presentation are taken from Microsoft Bookshelf and from Press and Siever ***Understanding Earth***

Plate Tectonics

MGp132, §4.5; W §9

Introduced here because it's…

- **The Way The Earth Works**
- **Basic Knowledge**
- **Explain/Justify Forces on Rocks**
- **Framework for Seismicity**

Definitions —

- **Tectonics**
  - **"building blocks": the study of the major components of the Earth's crust**
- **Seismicity**
  - **the present-day distribution of earthquakes**

Major Earth Divisions

MG f 4.29

- **Crust**
- **Mantle**
- **Core**

- **These are distinguished by their elastic properties**

Seeing through the crust

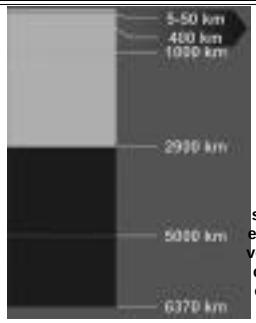
- **The structure of the interior of the Earth has been discerned by studying earthquake wave propagation (part of seismology).**
- **The internal structure is therefore based on elastic properties, which control seismic wave propagation.**

Zones in the Earth

Crust E < 100 GPa

Mantle E ~ 500 GPa

Core E ~ 0 GPa



Earthquake zone

Note! This sketch over-estimates the volume of the core — 16% of the Earth

Zones in the Earth

Crust E < 100 GPa

Mantle E ~ 500 GPa

Core E ~ 0 GPa

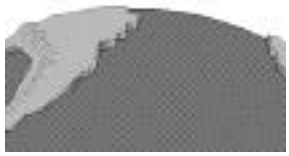
Lithosphere
Asthenosphere

Mesosphere

The Earth is a Heat Engine

- **The interior is hot and viscous**
- **Mantle-rock properties imply convection**
- **The surface is cold and so "rigid"**
- **The surface moves with the convection, each convection cell moves separately**
- **The rigid plates interact along their edges**

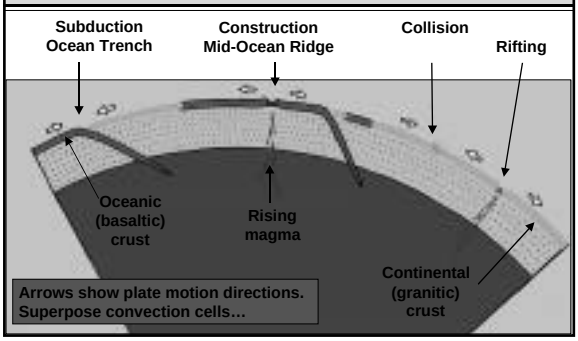
Cartoon view of the engine



- **A little more detail, later…**

Large-scale section

DM 3.11



Global Seismicity

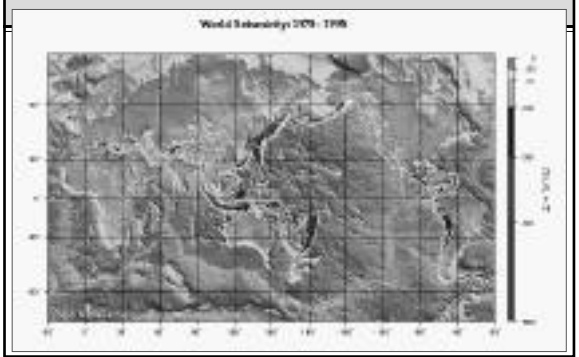


Plate Distribution

MG 4.30a

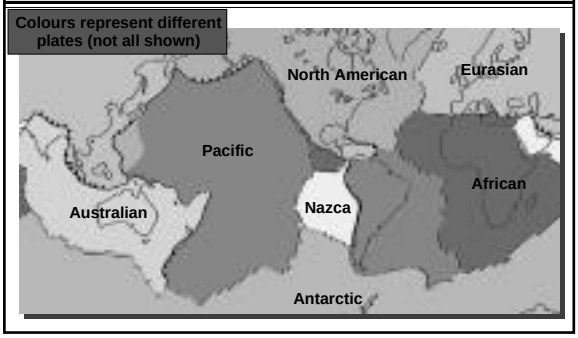


Plate Distribution

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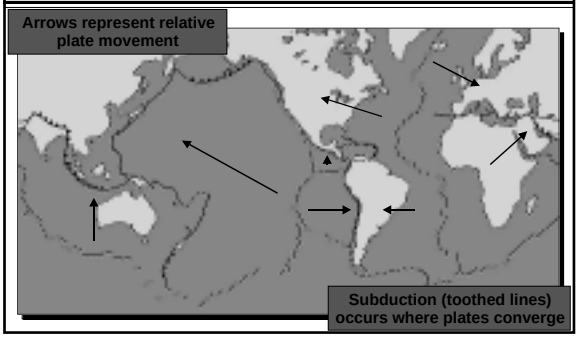


Lithosphere Plates

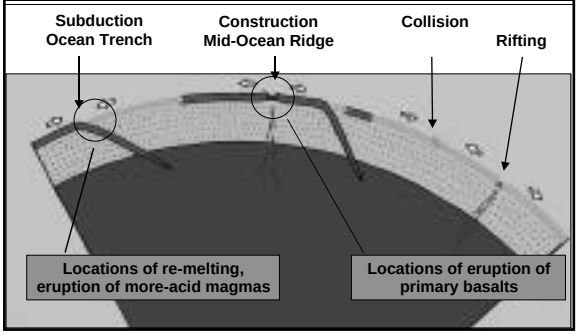
- **The cold surface layer is the Lithosphere**
- **The lithosphere plates are bounded by**
  - **Ridges (where crust is "created")**
  - **Trenches (where crust is destroyed)**
  - **Faults (where relative movement is horizontal)**
  - **The Asthenosphere**

Crustal Accretion

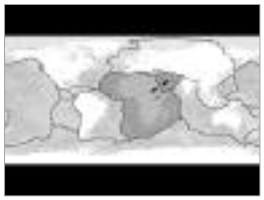
- **Plate Tectonics cartoons show how crust is reworked over time**
- **Accretion (creation) of crust occurs at**
  - **Mid-ocean Ridges (freshly separated from mantle material)**
  - **Island Arcs and near Subduction Zones (selectively melted from basalts , sediments)**

Large-scale section—accretion

DM 3.11



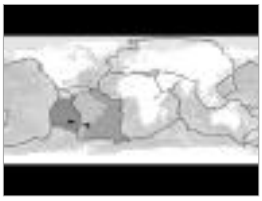
Boundary Examples



At spreading ridges, magma segregated from the mantle rises, freezes, and forms new oceanic crust.

Note sediment collecting on the crust with time

Boundary Examples



At oceanic trenches, oceanic crust (and sediment, not shown) is taken under continental crust, and partly remelts forming new continental crust.

Boundary Examples

DM 3.11

At spreading ridges — new oceanic crust.

At oceanic trenches, — new continental crust.

Other boundaries also occur — most important is strike-slip fault, at which neither construction nor subduction occurs.

Crustal Accretion

- Plate Tectonics cartoons show how crust is reworked over time
- Colliding boundaries result in uplift (one plate rides over another)
- These are sources of sediments, because of uplift
- Sediments differ from primary rocks because of weathering changes

Mountain-Building

- Mountains now rising actively are all associated with plate collisions
- The cause may be
  - deformation (buckling), or
  - over-riding of one plate on another, or
  - injection of new material into the crust

Large-scale section

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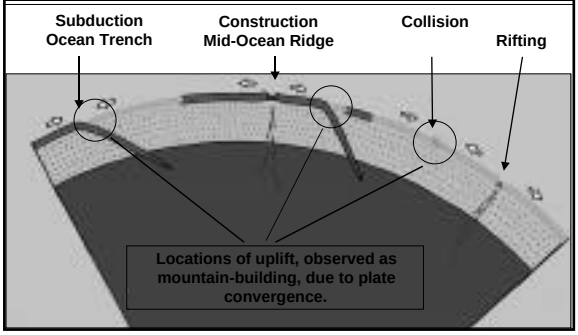


Mountain-Building

- Mountains now rising actively are all associated with plate collisions
- In each case, the energy source is heat, through the convection within the Earth

Plate Tectonics

- **is a concept which largely explains the changes, in space and time, of the major features of the Earth.**
- **Explicit predictions from Plate Tectonics help us to understand Earthquakes**

Earthquake Geography

- **Motion on boundaries is generally "stick-slip"**
- **When plates "stick", elastic energy is stored by deforming rocks**
- **When plates "slip", stored energy is released, much as acoustic energy**
- **Most earthquakes (most big ones) therefore occur on plate boundaries**

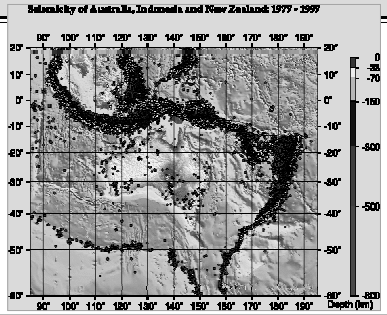
Stick-Slip

- **Refers to motion of one rough surface on another**
  - **chalk on board**
  - **brick on pavement**
  - **bow on violin strings**
- **In each case, force applied is uniform over "long" time, but motion is episodic as resistive forces are overcome.**

Earthquake Prediction (?)

- **Average movement between plates is known**
- **Mode of energy release is understood**
- **Seismic activity therefore predictable — in statistical sense**

Recent Regional Earthquakes



Most of the events (and energy release) are at convergent boundaries.

Quantifying Seismic Risk

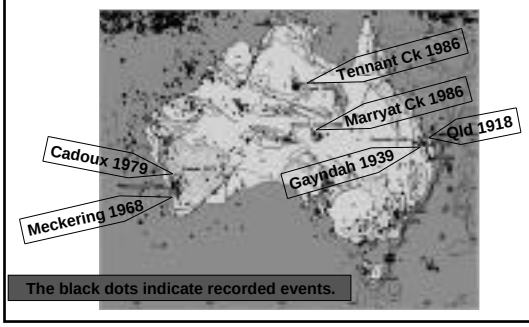
- **is almost predictable near plate boundaries (regions of relative plate motion)**
- **is much less predictable within plates**
- **The effect of ground motion on structures in earthquakes is now quite well understood, and used in design.**

Faults and Earthquakes

Actual physical failure of rocks does occur on faults, relieving stresses. Faults occur at all scales, but..

"...most faults are fossilized evidence of past events and are not seismically active today. They are of concern to the engineer because of associated broken ground..."

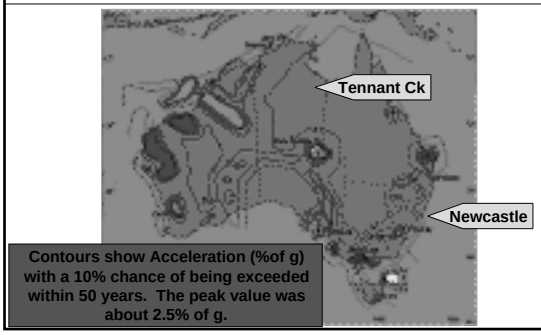
Australian Earthquakes until 1988



Intraplate Earthquakes

- **Within plates, earthquakes do occur**
- **The association of these with ambient stress fields in rocks can often be shown**
- **Stresses, and rock properties, result in some localization of intraplate events**
- **Rate of accumulation of deformation is not understood (generally much slower)**
- **Intraplate events are likely to remain "unpredictable"**

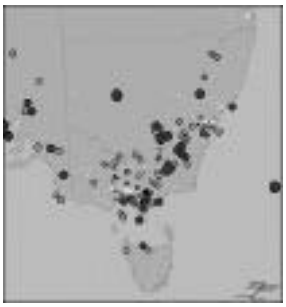
Pre-1988 Earthquake Risk map



Near-Current Activity

- **Activity is continuously monitored**
- **Risk maps are revised, or**
  - **drafted to suit specific engineering projects**
- **Summaries are necessarily statistical**

1998 Events in SE Australia



Forces on Rocks

- **Rocks show many kinds of deformation response (apart from faults)**
- **All of these can be explained as the response to mild forces applied over very long times (Ma to Ba)**
- **These forces are all, ultimately, the result of plate/plate interactions (present or past)**

Next…

Ages!