Structural Geology and Geothermal Resources

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(slides from Björn S. Hardarson and Sigurður G. Kristinsson)
Plate Tectonics – Overview

1. Plate tectonics
2. Structural Geology
3. Rifting
Plate Tectonics Theory

- Description of the large scale motions of Earths lithosphere
- The tectonic plates are composed of two types of crust (lithosphere): thicker continental and thin oceanic crust
- Continental drift theory developed in the 20th century (Alfred Wegener)
- Concepts of Seafloor Spreading developed in 1950-60’es
Structure of the Earth

- Solid iron inner core (5150–6370 km)
- Liquid iron outer core (2891–5150 km)
- Crust (0–40 km)
- Mantle (40–2891 km)
What is the difference between the crust and lithosphere?

- The crust (whether continental or oceanic) is the thin layer of distinctive chemical composition overlying the ultramafic upper mantle.

- Oceanic and continental crust are formed by entirely different geological processes: the former is typically 6 - 7 km thick, the latter about 35 - 40 km.
Mantle Convection and Plate Tectonics
Geomagnetic Anomalies

[Diagram of geomagnetic anomalies, showing normal and reversed magnetic polarity, mid-oceanic ridge, and age profile from oceanographic survey.]
Main Tectonic Plates of the World
Earthquakes, Volcanoes and Plate Boundaries

Global Seismicity (1910-99, magnitudes >= 4.5)

Depth: Red <100 km;
Purple: 100 – 300 km;
Black: > 300 km;

1509 Holocene and Active Volcanos
Plate Boundaries
Plate Boundaries

- Divergent boundaries -- where new crust is generated as the plates pull away from each other.
- Convergent boundaries -- where crust is destroyed as one plate dives under another.
- Transform boundaries -- where crust is neither produced nor destroyed
  as the plates slide horizontally past each other.
- Plate boundary zones -- broad belts in which boundaries are not well defined and the effects of plate interaction are unclear
Convergent Plate Boundaries

Convergent Boundaries
(a) Ocean-ocean convergence

-oceanic trench, volcanic island arc, and deep earthquakes

Mariana Islands
Marianas Trench

Convergent Boundaries
(b) Ocean-continent convergence

volcanic mountain chain, folded mountains, and deep earthquakes

Andes Mountains
Peru-Chile Trench

Convergent Boundaries
(c) Continent-continent convergence

-crustal thickening, folded mountains, and earthquakes

Himalaya Mountains
Tibetan Plateau

Marianas Trench
Mariana Islands
Indian-Australian Plate
Pacific Plate
Philippine Plate
South American Plate
Nazca Plate
Eurasian Plate
Faults

DIP-SLIP FAULTING

(a) Foot wall
(b) Fault plane
(c) Hanging wall

Normal faulting is caused by tensional forces that stretch a rock and tend to pull it apart.

Reverse faulting is caused by compressive forces that squeeze and shorten a rock.

A thrust fault is a reverse fault with a shallow-dipping fault plane.

Figure 7.8a-c
Understanding Earth, Sixth Edition
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Faults

STRIKE-SLIP FAULTING

(d) Left-lateral strike-slip fault
(e) Right-lateral strike-slip fault
Normal Faults
Normal Faults
Reverse Fault

- Reverse fault (dip-slip fault)

Diagram showing:
- Normal fault with a hanging wall and a footwall, inclined at approximately 60°
- Reverse (thrust) fault with a hanging wall and a footwall, inclined at approximately 30°

Image of a natural reverse fault in geological context.
Strike slip Fault

Sinistral (left-lateral) strike-slip fault

Dextral (right-lateral) strike-slip fault

NB: This is a plan view of the Earth's surface

San Andreas Fault
Oblique-slip Fault

Oblique-slip faulting is caused by a combination of forces, in this case left-lateral shearing with tension.
A thrust fault has the same sense of motion as a reverse fault, but with the dip of the fault plane at $< 45^\circ$.

Thrust faults typically form ramps, flats and fault-bend (hanging wall and foot wall) folds. Thrust faults form nappes and klippen in the large thrust belts.
Horst and Graben

Horst

Graben

Normal fault
Example from Kenya Rift

Topographic profile along yellow line showing horst and graben structures
Dip-slip faults

- Normal or reverse faults.
- A normal fault occurs when the crust is extended.
- A downthrown block between two normal faults dipping towards each other is called a **graben**.
- An upthrown block between two normal faults dipping away from each other is called a **horst**.
- Low-angle normal faults with regional **tectonic** significance may be designated **detachment faults**.
Faulting and breccia
Faulting and breccia
High Temperature Geothermal Activity

Geothermal Reservoir

Rainwater

Hot Water

Hot Rock

Rainwater