Crustal Deformation
AKA – Structural geology
(adapted from Brunkel, 2012)
Study the architecture and processes responsible for deformation of Earth’s crust.

Folding and Faulting
How Rocks Deform: 4 Controls

- Rock Type – i.e., sandstone is more brittle than shale.
- Temperature – higher T = more ductile
- Confining Pressure – high lithostatic stress = more ductile
- Time – more time = more ductile (i.e., karate chop)
Stress and Strain Relationships

The result of rock deformation can be seen at the surface as folds and faults.
A few things we need to know

• Law of original horizontality
• Superposition
• Cross-cutting relationships
• Strike and dip
Law of original Horizontality
Superposition

- Youngest on the top
- Oldest on the bottom
i.e., These sandstone beds were deposited as horizontal layers before they were faulted.
Strike and Dip - when rocks are no longer horizontal
Strike and Dip- how do we describe their orientation
Strike and dip rules

• Strike is the direction on the surface of the rock formation – described by two directions ie. N-S, E-W, NE-SW
• Dip is always perpendicular to strike and is described by only one direction – N, S, E, W or NW, SE etc.
• Often it is easier to find the dip of a rock unit first and then describe the strike
Strike and Dip

Dip and Strike
(Courtesy of Dresser Atlas)
Folds

- How do rocks fold?
- Ductile deformation
- What environments lead to ductile deformation?
Folds

- **Folds** wave-like undulations in rock that form mainly from compressional stress that shortens and thickens the crust.
Fold Parts

- **Limbs** – the two planar sides of a fold
- **Axis** – imaginary line marking the crest or trough of each layer
- **Axial plane** – an imaginary plane of symmetry through the center of the fold
Types of folds

• Anticlines – “A” shape
Folds

Syncline - think of a sink
Paired and tilted anticline and syncline
folds
folds
Overturned folds
folds
Folding on a large scale to produce large landforms
Sheep Mountain, WY: **Plunging Anticline & Syncline**

- Note Outcrop “V”s, Plunge Arrows, Anticline Symbol, Syncline Symbol
- Note Oldest & Youngest Layers

- Mississippian Rocks
- Triassic Rocks
- Jurassic Rocks
- Cretaceous Rocks
Plunging folds

- Fold axis dips below the surface
• **Anticline** – upfold
  – Oldest rock in center
  – Point of mapped outcrop “V” in the direction of plunge.

• **Syncline** - downfold
  – Youngest rock in center
  – Open end of mapped outcrop “V” is in the direction of plunge.

*arrow on end of fold axis symbol indicates plunge direction*
DOME

Oldest formation exposed on the surface

Youngest formation

Gas

Oil
Sinclair Dome, WY

oldest rocks

younger rocks
Folds in map view

Anticlines - eroded tops of anticlines reveal a characteristic map pattern of rock ages

- Oldest rocks exposed in the middle with bands getting younger as you go out
- The direction of dip of the bed will provide clues to what type of structure it is
Folds in map view

Synclines - eroded synclines reveal a characteristic map pattern of rock ages

- Youngest rocks exposed in the middle with bands getting older as you go out
- The direction of dip of the bed will provide clues to what type of structure it is
Geologic Maps

A. Map view

anticline axis symbol  syncline axis symbol

Strike & dip symbol

30°  Sandstone  85°  Sandstone  40°  Sandstone

Red shale  Limestone  Red shale  Limestone

contact between rock units of different ages

B. Block diagram
Faults

- **Faults** - fractures in rocks along which appreciable displacement has taken place – brittle deformation of the rock or layers of rock

- 2 basic Types:
  - **Dip Slip** – Movement is mainly parallel to the dip of the fault surface
  - **Strike Slip** - Movement is mainly parallel to the strike of the fault surface
Dip-Slip Faults

- Two main types –
- **Normal** – Hanging wall moves down in relation to foot wall
- **Reverse or Thrust** – Hanging wall moves up relative to foot wall
Faults

- **Tensional forces cause normal faulting**
Normal Faults
Scarps
Normal Faults

• Form **fault-block mountains**

• **Horst** = high upthrown block

• **Graben** = low downthrown block
Grand Tetons, WY - fault block mountains
Reverse Faults

Reverse Fault

Thrust Fault
Faults

- **Thrust Faults** are a low angle reverse fault.
Overlapping thrust sheets build up mountain ranges.

Thrusted sheets

Thrusted are low angle reverse faults.
The Canadian Rockies were built up as a series of thrust sheets
Faults

- Shear stresses cause **strike-slip faulting**
Strike-Slip Faults

- **Right-lateral** — as you face the fault, the block on the opposite side of the fault moves to the right
- **Left-lateral** — as you face the fault, the block on the opposite side of the fault moves to the left
SAN ANDREAS FAULT

large right lateral offset in drainage pattern

small-scale drainage pattern also shows right lateral offset
Engineering and Faults

- Fractures to Faults
- Shear Zones