Deformation of Rocks

Rock Deformation

- Large scale deformation of the Earth’s crust = Plate Tectonics
- Smaller scale deformation = structural geology
Deformation of rocks

- Folds and faults are geologic structures
- Structural geology is the study of the deformation of rocks and the effects of this movement

Small-Scale Folds
Small-Scale Faults

Deformation – Stress vs. Strain

- Changes in volume or shape of a rock body
- = strain
**Stress**

- The *force* that acts on a rock unit to change its shape and/or its volume
- Causes strain or deformation
- Types of directed Stress include
  - Compression
  - Tension
  - Shear

**Compression**

Action of coincident oppositely directed forces acting towards each other
Tension
Action of coincident oppositely directed forces acting away from each other

Shear
Action of coincident oppositely directed forces acting parallel to each other across a surface

Right Lateral Movement

Left Lateral Movement
**Strength**

- **Ability of an object to resist deformation**
  - **Compressive**
    - Capacity of a material to withstand axially directed pushing forces – when the limit of compressive strength is reached, materials are crushed
  - **Tensile**
    - Measures the force required to pull something such as rope, wire, or a rock to the point where it breaks
Strain
Any change in original shape or size of an object in response to stress acting on the object

Kinds of deformation
- Elastic vs Plastic
- Brittle vs Ductile
Elastic Deformation

Temporary change in shape or size that is recovered when the deforming force is removed
Ductile (Plastic) Deformation

- Permanent change in shape or size that is not recovered when the stress is removed
- Occurs by the slippage of atoms or small groups of atoms past each other in the deforming material, without loss of cohesion

![Diagram showing the stress-strain curve with yield point and rupture point, indicating plastic deformation](image)
Brittle Deformation (Rupture)

- Loss of cohesion of a body under the influence of deforming stress
- Usually occurs along sub-planar surfaces that separate zones of coherent material
Factors that affect deformation

- Temperature
- Pressure
- Strain rate
- Rock type

*The variation of these factors determines if a rock will fault or fold.*

Rocks are:

- Elastic and brittle near the earth's surface
- More plastic and ductile deeper in the crust
  - Because of the increasing temperature and pressure
Folds

- Most common ductile response to stress on rocks in the earth's crust

Experimental Deformation of Marble

| Brittle Deformation (low confining pressure) | Ductile Deformation (high confining pressure) |
Effects of Rock Type on Deformation

Some rocks are stronger than others:

- **Competent**: rocks that deform only under great stress
- **Incompetent**: rocks that deform under moderate to low stresses

Tectonic Forces and Resulting Deformation

- **Compressive Forces**: Folding
- **Tensional Forces**: Stretching and thinning
- **Shearing Forces**: Shearing
- **Faulting**
Geometry of Anticlines & Synclines

Types of Folds
(bent planar structures)

*anticline*: older rocks on the inside
*syncline*: older rocks on the outside

*(scale - from mm to tens of km)*
Anticlines and Synclines

Anticline

Syncline

Oldest rock

Youngest rock

Syncline

Red shale

Sandstone

Limestone

Gray shale

Youngest bed

Oldest bed
Fold Terms

- **axial plane**: the plane of mirror symmetry dividing the fold into two limbs
- **axis**: line formed by the intersection of the axial plane and a bedding plane
- **horizontal fold**: where the fold axis is horizontal
- **plunging fold**: where the fold axis is not horizontal

Fold Terminology

(a) Horizontal fold

(b) Plunging fold
Symmetrical, Asymmetrical and Overturned Folds

(a) Symmetrical folds
(b) Asymmetrical folds
(c) Overturned folds

Axial plane is vertical
Beds in one limb dip more steeply than those in the others
Both limbs dip in same direction but one limb has been tilted beyond vertical

Asymmetric Folds
Overturned Folds

Map View of Overturned Folds

Map View of Plunging Folds

Plunging anticline

Plunging syncline
Oil Field at Crest of Plunging Anticline
Fracture

- Most common brittle response to stress
- With No displacement = Joint
- With displacement = Fault

Joints commonly form when the surface of a volcanic rock cools and contracts
Devil’s Tower, Wyoming
Faults

- Occur when large stresses build up in the crust
- Classified according to the kind of movement that has occurred along them
Normal Fault
Hanging wall drops down
Rift Valley Formed by Extension
Tilted Normal Fault Blocks, e.g. Basin and Range Province

(c) Fault block
Wildrose Graben, Southern California

Reverse Fault
Hanging wall moves up
Reverse Fault

Large-Scale Overthrust Sheet
Stacked Sheets of Continental Crust
Due to Convergence of Continental Plates

Overlapping Thrust Faults,
*e.g.* the Himalayas
Lewis Overthrust began 170 mya forming the ancestral Rocky Mountains

Stresses shoved a huge rock wedge several miles thick and several hundred miles wide, eastward more than 80 km.

Erosion stripped away some Precambrian rocks and exposed the rocks and structures visible in the park.

- Chief Mountain is a remnant of the Precambrian overthrust
- Klippe
- Lewis Overthrust is a significant structural feature
- Lateral displacement of up to 80 km.
- Also exposed ancient sediments possessing an unparalleled degree of preservation
Cross Section of the Keystone Thrust West of Las Vegas

- Limestone and dolostone (Paleozoic, older)
- Dark-colored limestone
- Sandstone (Jurassic, younger)
- Hanging-wall block
- Keystone thrust
- Footwall block
- Shale and sandstone (Triassic)

French Thrust, Wyoming

- Mississippian Limestone
- Cretaceous Shale
- Faults may move several meters in a second or so
- This movement within the earth's crust usually generates an earthquake