


1  **Crustal Deformation**

Earth 9th edition, Chapter 10

2  **Crustal deformation: summary in haiku form**

Anticline and syn-
normal, reverse, strike-slip faults
all a big crack-up!

3  **Key Concepts**

- "Structural Geology" – The study of Earth's geometry and its evolution.
- Deformation: Force, stress and strain, and factors affecting how rocks deform.
- Mapping geologic structures.
- Folds – bends in rocks.
- Faults – movement of rocks past each other.
- Joints – near-surface cleavage in rocks.

4  **Structural geology**

- Structural geologists study the architecture and processes responsible for deformation of Earth's crust
- A working knowledge of rock structures is essential to our modern way of life

5  **Deformation**

- Deformation is a general term that refers to all changes in the original form and/or size of a rock body
- Most crustal deformation occurs along plate margins

6  **Deformation**

- Deformation involves
 - ☒ Force
 - ◆ that which tends to put stationary objects in motion or changes the motions of moving objects
 - ☒ Stress
 - ◆ Force applied to a given area

7  **Deformation**

- Types of stress
 - ☒ Compressional stress
 - ◆ shortens a rock body
 - ☒ Tensional stress
 - ◆ tends to elongate or pull apart a rock unit
 - ☒ Shear stress
 - ◆ produces a motion similar to slippage that occurs between individual playing cards when the top of the stack is moved relative to the bottom

8 

9 

10 

11 

12  **Deformation**

- Strain
 - ☒ Changes in the shape or size of a rock body caused by stress
 - ☒ How rocks deform
 - ◆ Rocks subjected to stresses greater than their own strength begin to deform usually by folding, flowing, or fracturing

13  **Deformation**

- How rocks deform
 - ☒ General characteristics of rock deformation
 - ◆ Elastic deformation

- the rock returns to nearly its original size and shape when the stress is removed
 - ◆ Once the elastic limit (strength) of a rock is surpassed, it either flows (ductile deformation) or fractures (brittle deformation)
- 14 **Deformation**
- How rocks deform
 - ☒ General characteristics of rock deformation
 - ◆ Factors that influence the strength of a rock and how it will deform
 - Temperature
 - Confining pressure
 - Rock type
 - Time
- 15 **Mapping geologic structures**
- When conducting a study of a region, a geologist identifies and describes the dominant rock structures
 - ☒ Usually only a limited number of outcrops (sites where bedrock is exposed at the surface) are available
 - ☒ Work is aided by advances in aerial photography, satellite imagery and Global Positioning Systems (GPS)
- 16 **A geologic map illustrates the geologic structures of an area**
- 17 **Mapping geologic structures**
- Describing and mapping the orientation or attitude of a rock layer or fault surface involves determining the features
 - ☒ Strike (trend)
 - ◆ The compass direction of the line produced by the intersection of an inclined rock layer or fault with a horizontal plane
 - ◆ Generally expressed as an angle relative to north
- 18 **Mapping geologic structures**
- Dip (inclination)
 - ☒ The angle of inclination of the surface of a rock unit or fault measured from a horizontal plane
 - ☒ Includes both an of inclination and a direction toward which the rock is inclined
- 19 **Mapping geologic structures**
- Dip (inclination)
 - ☒ The angle of inclination of the surface of a rock unit or fault measured from a horizontal plane
 - ☒ Includes both an of inclination and a direction toward which the rock is inclined
- 20 **Strike and dip of a rock layer**
- 21 **Folds**
- During crustal deformation rocks are often bent into a series of wave-like undulations called folds
 - Characteristics of folds
 - ☒ Most folds result from compressional stresses which shorten and thicken the crust
- 22 **Folds**
- Characteristics of folds
 - ☒ Parts of a fold
 - ◆ Limbs – refers to the two sides of a fold
 - ◆ Axis – a line drawn down the points of maximum curvature of each layer
 - ◆ Axial plane – an imaginary surface that divides a fold symmetrically
- 23 **Folds**
- Common types of folds
 - ☒ Anticline – upfolded or arched rock layers
 - ☒ Syncline – downfolds or troughs of rock layers

- Depending on their orientation, anticlines and synclines can be described as
 - Symmetrical
 - Asymmetrical
 - Recumbent (an overturned fold)
 - Plunging
- 24 ***A horizontal (A) and plunging (B) anticline***
- 25 ***A series of anticlines and synclines***
- 26 ***Plunging anticlines and synclines***
- 27 **Sheep Mountain anticline, Wyoming**
- 28 ***Folding***
- 29 ***Folds***
 - Common types of folds
 - Monoclines
 - Large, step-like folds in otherwise horizontal sedimentary strata
 - Other types of folds
 - Dome
 - Upwarped displacement of rocks
 - Circular or slightly elongated structure
 - Oldest rocks in center, younger rocks on the flanks
- 30 ***Monoclines are often the result of movement along buried faults***
- 31 ***My favorite monocline:***
- 32 ***Image from WorldWind software:***
- 33 ***Topo map:***
- 34 ***Black Hills, South Dakota: a large dome***
- 35 ***Folds***
 - Other types of folds
 - Basin
 - Circular or slightly elongated structure
 - Downwarped displacement of rocks
 - Youngest rocks are found near the center, oldest rocks on the flanks
- 36 ***Circular outcrop patterns are typical for both domes and basins***
- 37 ***Faults***
 - Faults are fractures in rocks along which appreciable displacement has taken place
 - Sudden movements along faults are the cause of most earthquakes
 - Classified by their relative movement which can be
 - Horizontal
 - Vertical
 - Oblique
- 38 ***Faults***
 - Types of faults
 - Dip-slip faults
 - Movement is mainly parallel to the dip of the fault surface
 - May produce long, low cliffs called *fault scarps*
 - Parts of a dip-slip fault include:
 - hanging wall* (rock surface above the fault)
 - footwall* (rock surface below the fault)
- 39 ***Faults***
- 40 ***Concept of a hanging wall and a footwall along a fault***
- 41 ***Faults***
 - Types of dip-slip faults
 - Normal fault

- ◆ Hanging wall block moves down relative to the footwall block
- ◆ Accommodate lengthening or extension of the crust
- ◆ Most are small with displacements of a meter or so
- ◆ Larger scale normal faults are associated with structures called fault-block mountains

42  **Normal fault:**

43  **Faults**

● Types of dip-slip faults

☒ Reverse and thrust faults

- ◆ Hanging wall block moves up relative to the footwall block
- ◆ Reverse faults have dips greater than 45° and thrust faults have dips less than 45°
- ◆ Accommodate shortening of the crust
- ◆ Strong compressional forces

44  ***On a reverse fault, the hanging wall moves up relative to the footwall***

45  ***Thrust fault: Lewis Thrust, Montana***

46  **Faults**

● Strike-slip fault

☒ Dominant displacement is horizontal and parallel to the strike of the fault

☒ Types of 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


47  ***A block diagram showing the features along a strike-slip fault***

48  **Faults**

● Strike-slip fault

☒ Transform fault

- ◆ Large strike-slip fault that cuts through the lithosphere
- ◆ Accommodates motion between two large crustal plates

49  ***The San Andreas fault system is a major transform fault***

50  **Joints**

- Joints are among the most common rock structure
- Technically, a joint is a fracture with no movement
- Most occur in roughly parallel groups
- Significance of joints
 - ☒ Chemical weathering tends to be concentrated along joints

51  **Joints**

● Significance of joints

- ☒ Many important mineral deposits are emplaced along joint systems
- ☒ Highly jointed rocks often represent a risk to construction projects
- ☒ Jointed granitic rocks hold groundwater

52 