Crustal Deformation and Mountain Building
S=slide

S1 Every rock body has a point at which it will fracture or flow
Deformation refers to all changes in the original shape and/or size of a rock body

S2 Crustal deformation generally occurs along plate margins

Plate motions and the interactions along plate boundaries generate forces that cause the rocks to deform

S3 Rocks subjected to forces (stresses) greater than their own strength begin to deform by fracturing, folding, or flowing

S4 When stress is applied gradually the rocks respond by deforming elastically
Elastic deformation – rock returns to nearly the initial size and shape when the force is removed – like a rubber band
When the elastic limit is reached the rock will break (like a rubber band) – brittle deformation - or it will flow – ductile deformation

S5 Rock Deformation
Temperature and confining pressure – brittle deformation – cool with low confining pressure; ductile deformation – hot with high confining pressure

Rock type- mineral composition and texture determines if rock breaks or flows

Time –force applied over a period of time

S6 Folds
During mountain building sedimentary and volcanic rocks (strata) are often bent into folds
Folds are the result of compressional forces that result in shortening and thickening of the crust
Types of folds
- anticlines (antiforms)
- synclines (synforms)
- monoclines

S7 The two most common folds are anticlines and synclines
Anticlines are the upfolding or arching of rock layers
Synclines are the troughs or downfolding
The limb of an anticline is also the limb of the adjacent syncline

S8 Symmetrical folds are when the limbs are mirror images of each other (left side below)
Asymmetrical fold is when the limbs are not mirror images (middle below)

Overturned (recumbant) is when a limb is tilted beyond vertical (right below)

S9 Plunge is when the axis of the fold penetrates into the ground

The outcrop pattern of a plunging anticline points in the direction of the plunge

The outcrop pattern of a plunging syncline points in the opposite direction

S10 Folds are often coupled with faults

Note the fracture along the axis of this fold

S11 Monoclines are large, step-like folds in horizontal strata and appear to be the result of reactivation of steeply dipping fault zones in the bedrock below the strata
As the fault in the bedrock moves the ductile sedimentary folds

S12 Domes and Basins
Domes are broad circular or elongate upward folds (Black Hills, South Dakota)

Basins are large circular or elongate downward folds (Michigan has a large basin) – the result of large accumulations of sediment, whose weight causes the crust to subside

S13 Black Hills, South Dakota

Dome with igneous and metamorphic rock in the center that is covered by sedimentary strata

S14 Michigan basin geologic map showing the youngest rock in the center with the age of the rock getting older away from the center
The age of the rock strata is the opposite for a dome

S15 Faults
Faults are fractures in the crust along which displacement has occurred

Dip-slip faults – movement along the fault is parallel to the dip of the fault

Strike-slip faults – movement along the fault is horizontal and parallel to the trend or strike of the fault surface

S16 Hanging wall is the surface above the fault– overhead where a lantern might be hung in a mine
Footwall is the surface below the fault – surface that is walked on in a mine

S17 Dip-slip faults
Two major types of dip-slip faults are normal and reverse

Normal – hanging wall moves down relative to the footwall and fault is usually steep
Reverse and thrust – hanging wall moves up relative to the footwall and the fault can be steep (reverse) or shallow (thrust)

S18 Normal faults accommodate lengthening, or extension, of the crust
Along mid-ocean ridges and areas undergoing extension a central block called a graben drops down along normal faults between the blocks on either side called horsts

S19 Normal faults in the Basin and Range Province produced horst and graben.

Note the steepness of the faults near the surface that get shallow at the base

S20 Types of forces

S21 Folds come in all sizes

S22 Dip-slip faults
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S24 Normal fault - due to tensional forces

S25 Reverse faults are high angle faults where the footwall drops down relative to the hanging wall due to compressional forces

S26 Thrust faults are shallow angle reverse faults due to compressional forces on all scales – local to regional (small to large)

S27 Example of a thrust fault, Chief Mountain, Glacier National Park, Montana

S28 Strike-slip Faults
Displacement is horizontal and parallel to the strike of the fault surface
Occur on all scales
Many large strike slip faults produce a trace that is visible over great distances
Large faults can be a series of parallel faults in a zone that may be several km wide
Crushed rock along a fault erodes easily producing linear valleys or troughs

S29 Changes in topography associated with strike slip faults

S30 Joints
Fractures with no appreciable displacement

Columnar jointing forms as igneous rocks cool and form shrinkage fractures

Some fractures associated with folding

S31 The various terranes along the west coast can be explained by plate tectonic interactions

S32 Vertical Movements of the Crust
Isostasy – floating crust in gravitational balance
Mountain belts are higher than the surrounding terrain due to crustal thickening – roots extend deep into the crust
Deeper as the height increases
Shallower as height decreases

S33 Compression causes shortening of the crust and mountain building – high mountains with deep roots

Erosion removes height and roots are uplifted

S34 Key Concepts
1. Crustal and rock deformation definitions
2. Types of folds and force(s) that create them
3. Types of faults and force(s) that create them
4. How to tell direction of movement on a fault
5. Isostasy, the vertical movement of the crust: what it is and how it affects mountain building