

## Crustal Deformation



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1

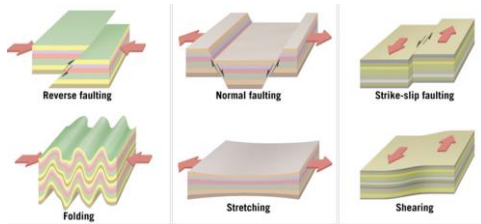
## Structural Geology

- 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:
  - Sites for major construction projects
  - Oil and gas reservoirs
  - Hydrothermal ore deposits



2

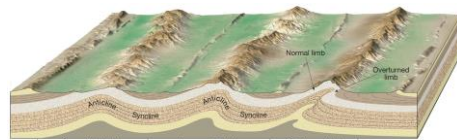
## Deformation



- 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

3

## Rock Deformations



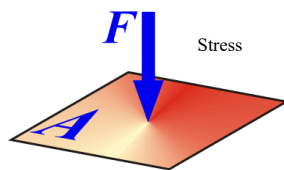
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Horizontally layered rocks can be tilted or deformed into...

- Folds (twists and bends in rocks)
- Joints (fractures in rocks)
- Faults (rocks on one side of dislocation displaced relative to rocks on the other side)

4

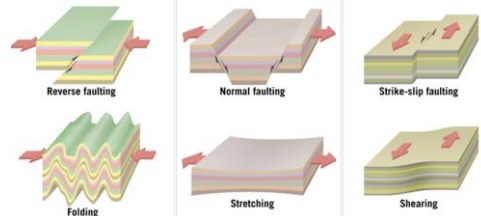
## Force and Stress



- Force:
  - That which tends to put stationary objects in motion or changes the motions of moving objects
- Stress:
  - Force applied to a given area ( $F/A$ )
- Differential Stress:
  - Stress applied unequally in different directions

5

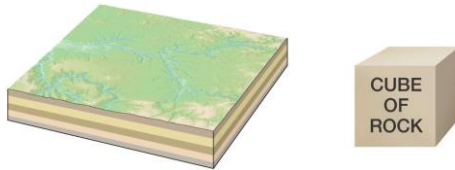
## Three Types of Differential Stress



- Compressional Stress squeezes and shortens a body
- Tensional Stress stretches and pulls a body apart
- Shearing Stress pushes different parts of a body in opposite directions

6

## Undeformed Strata



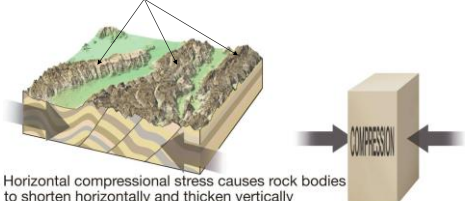
A. Undeformed strata (rock body)

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7

## Horizontal Compressional Stress

Crustal uplift and mountain building

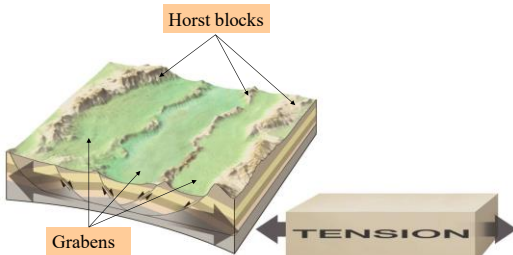


B. Horizontal compressional stress causes rock bodies to shorten horizontally and thicken vertically

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8

## Horizontal Tensional Stress



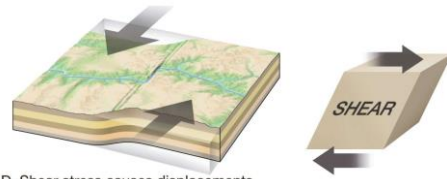
C. Horizontal tensional stress causes rock bodies to lengthen horizontally and thin vertically

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9

## Shear Stress

No significant uplift

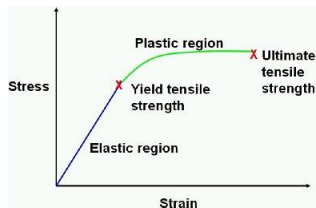


D. Shear stress causes displacements along fault zones or by ductile flow

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10

## Stress And Strain



- Strain is a measure of the change in shape of a rock resulting from stress:

- Elastic strain: Rock returns to its original shape after stress is released
- Plastic strain: Rock undergoes permanent deformation

$$\text{strain} = \frac{\Delta L}{L}$$

11

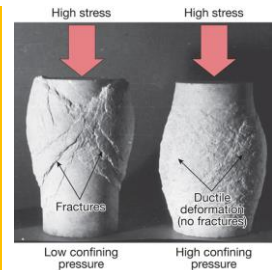
## Brittleness and Ductility

### Brittle Deformation:

- Increasing stress causes rock to deform by fracturing
- Typical of the upper crust where lower temperatures and pressures prevail

### Ductile Deformation:

- Increasing stress causes rock to undergo smooth and continuous deformation
- Rock contorts and changes shape without fracturing
- Typical of the deep crust characterized by high temperatures and pressures



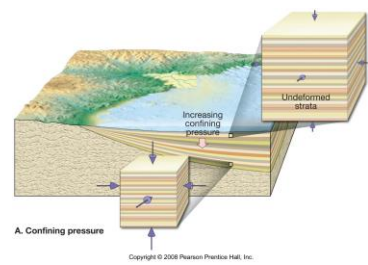
12

### Ductile Deformation



13

### Confining Pressure



- Confining pressure is caused by the weight of the overlying rock pushing downward and from all sides
- Like the pressure you feel when diving deep underwater
- Stresses push against buried rock equally in all directions
- Rock is squeezed from all sides

14

### What Determines How Rocks Form

- **Confining Pressure:**
  - Brittle deformation more likely at shallower depths and lower confining pressures: Rocks deform by fracturing and faulting
  - Ductile deformation more likely at greater depths and higher confining pressures: Rocks flow and deform without fracturing
- **Temperature:**
  - Brittle deformation at lower temperatures
  - Ductile deformation at higher temperature

15

### What Determines How Rocks Form

- **Rock Type:**
  - Rock salt susceptible to ductile deformation
  - Granite will more likely fracture
  - Igneous and metamorphic rocks are stronger and resist deformation to a greater extent than sedimentary rocks
- **Time:**
  - The longer the stress is applied, the more likely the rock will deform and the greater the deformation

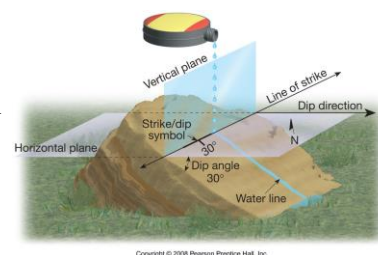
16

### Crustal Depth And Type Of Stress Exerted Determines The Type Of Deformation

How Rocks Respond to Differential Stress			
TYPE OF STRESS	COMPRESSION (Causes shortening)	TENSION (Causes stretching)	SHEAR (Causes tearing)
At shallow depths rocks exhibit brittle fracture			
At greater depths rocks deform by ductile flow			

17

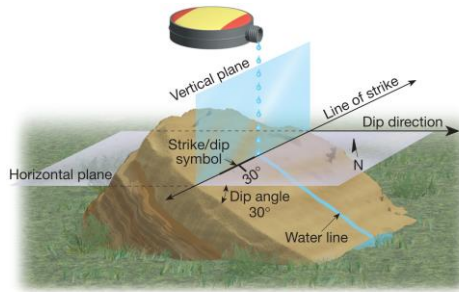
### Strike and Dip



The orientation of rock layers, folds, fractures, and faults can be measured in three-dimensional space using strike and dip

18

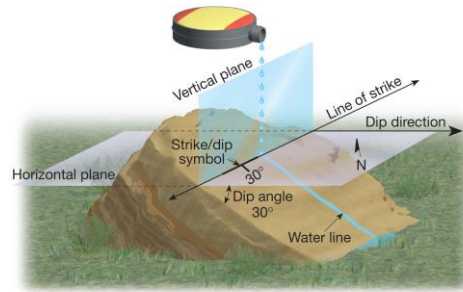
Strike is the direction of a line formed by the intersection of a rock layer with a horizontal plane



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19

The dip is measured at right angles to the strike and is a measure of the angle at which the rock layer tilts relative to the horizontal plane

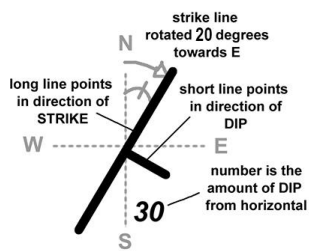


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20

**A strike and dip map symbol**  
for compass measurement

**N20E, 30SE**  
(STRIKE) (DIP)



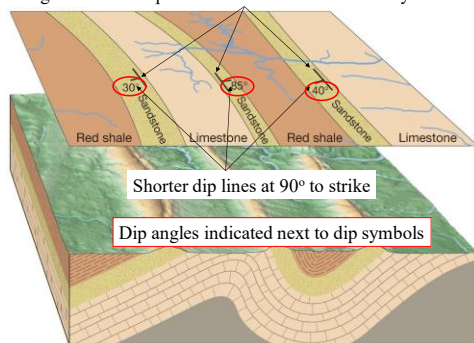
21

Dipping Limestone and Shale Beds



22

Longer strike lines parallel contacts between rock layers

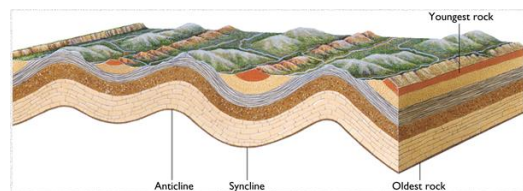


B. Block diagram

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23

Types of Folds

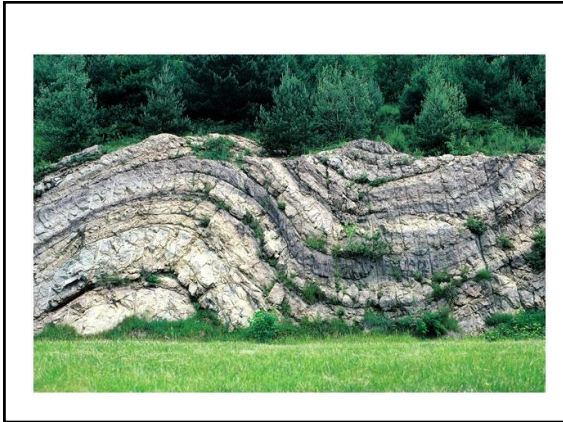


Folds result from ductile deformation of rocks in response to external forces:

- Anticlines are layered rocks that were folded into arches
- Synclines are layered rocks folded into troughs

24

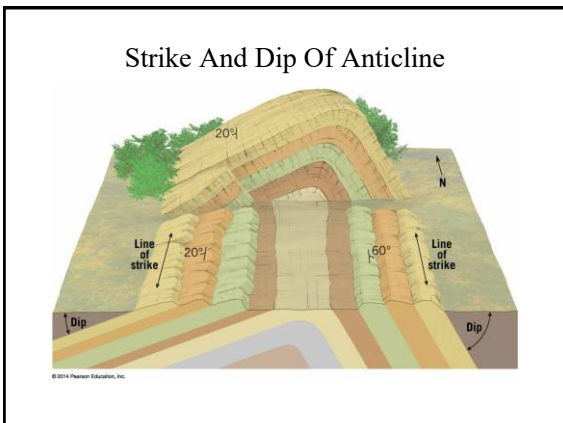




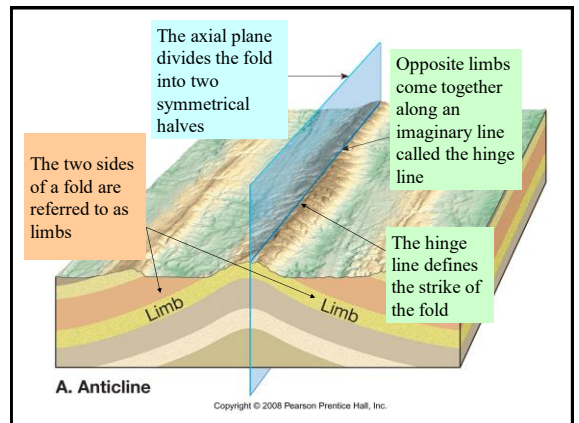
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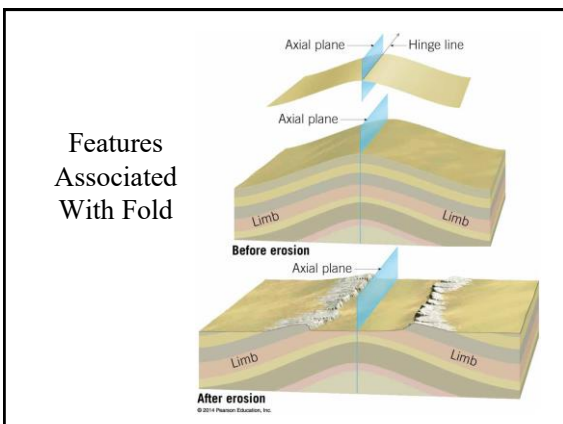
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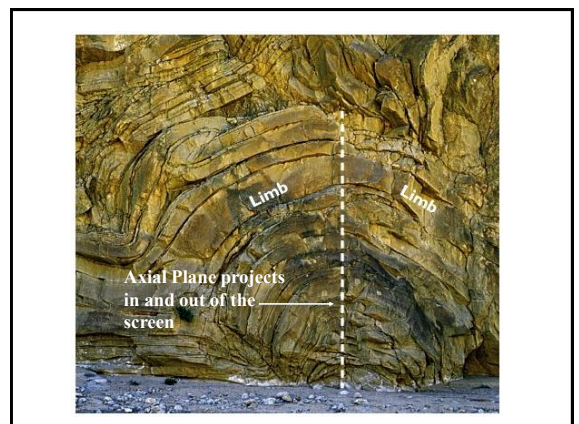
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28

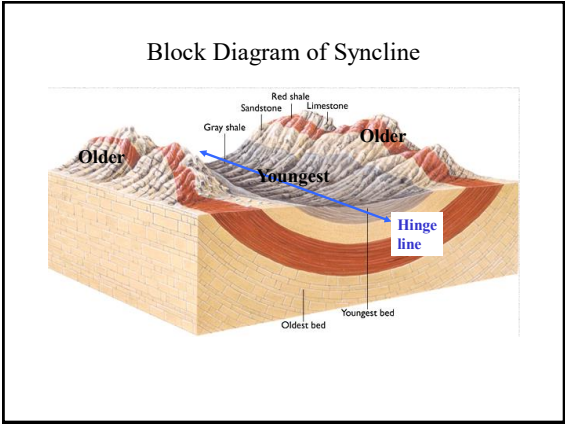


29



30





37