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Objectives

- **Summarize** the principle of isostasy.
- **Identify** the three main types of stress.
- **Compare** folds and faults.

End Of Slide

Isostasy

deformation the bending , tilting, and breaking of Earth's crust; The change in shape of volume of rock in response to stress

- Deformation can occur when the weight of some part of Earth's crust changes. Earth's crust is part of the lithosphere.
- When the forces acting on the lithosphere are balanced, the lithosphere and asthenosphere are balanced, and in a state of *isostasy.*

Isostasy, *continued*

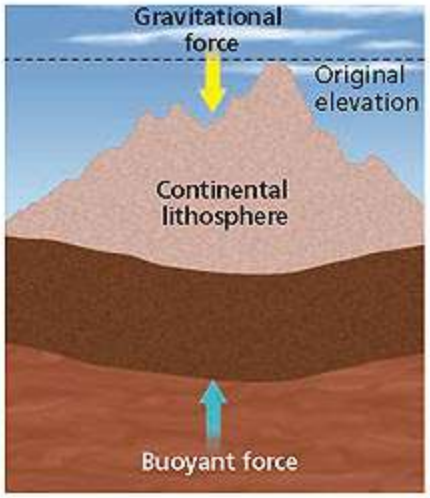
isostasy a condition of gravitational and buoyant equilibrium between Earth's lithosphere and asthenosphere

- When the weight of the lithosphere changes, the lithosphere sinks or rises until a balance is reached once again.
- The movements of the lithosphere to reach isostasy are called isostatic adjustments.

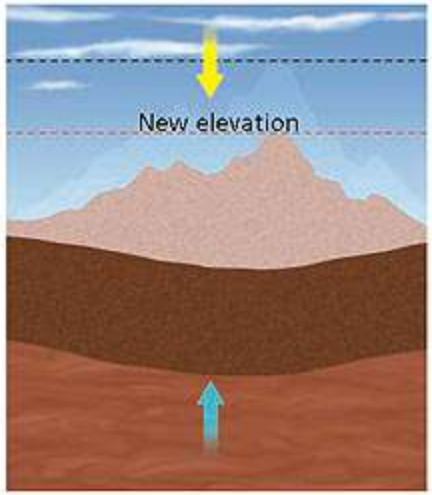
End Of Slide

Isostasy, *continued*

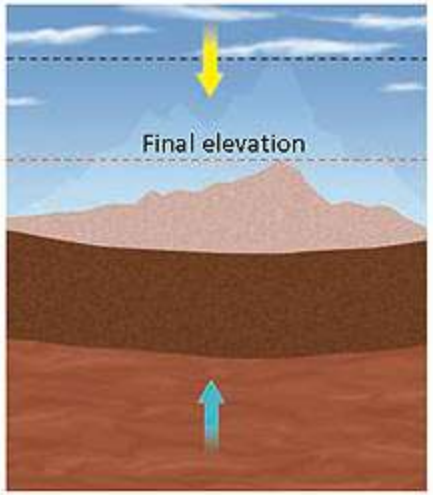
The diagram below shows isostatic adjustments as a result of erosion.



When the gravitational force equals the buoyant force, the lithosphere and asthenosphere are in isostasy.



As erosion wears away the crust, the lithosphere becomes lighter and is pushed up by the asthenosphere.



As erosion continues, the isostatic adjustment also continues.

Isostasy, *continued*

Mountains and Isostasy

- Isostatic adjustments regularly occur in mountainous regions.
- The surface of mountains is worn away by erosion over millions of years, resulting in a reduction of height and weight of the mountain range.
- The surrounding crust becomes lighter, and the area rises by isostatic adjustment in process called *uplift*.

End Of Slide

Isostasy, *continued*

Deposition and Isostasy

- Isostatic adjustments occur in areas where rivers carrying a large load flow into large bodies of water, such as an ocean.
- Most of the material that the river carries is deposited on the ocean floor.
- The added weight to the area causes the ocean floor to sink by isostatic adjustment in a process called *subsidence*.

End Of Slide

Isostasy, *continued*

Glaciers and Isostasy

- Isostatic adjustments also occur as a result of the growth and retreat of glaciers and ice sheets.
- The weight of the ice causes the lithosphere to sink, while the ocean floor rises because the weight of the overlying water is less.
- When glaciers or ice sheets melt, the land rises and the ocean floor sinks.

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Stress

stress the amount of force per unit area that acts on a rock

- As Earth's lithosphere moves, or when tectonic plates collide, these actions exert force on the rock called stress.
- There are three types of stress: compression, tension, and shear stress.

Stress, *continued*

Compression

- Compression is the type of stress that squeezes and shortens a body of rock.
- Compression commonly reduces the amount of space that rock occupies, and pushes rocks higher up or deeper down into the crust.
- Compression occurs at or near convergent boundaries.

Stress, *continued*

Tension

- Tension is stress that stretches and pulls a body of rock apart.
- When rocks are pulled apart by tension, the rocks tend to become thinner.
- Tension occurs at or near divergent boundaries.

Stress, *continued*

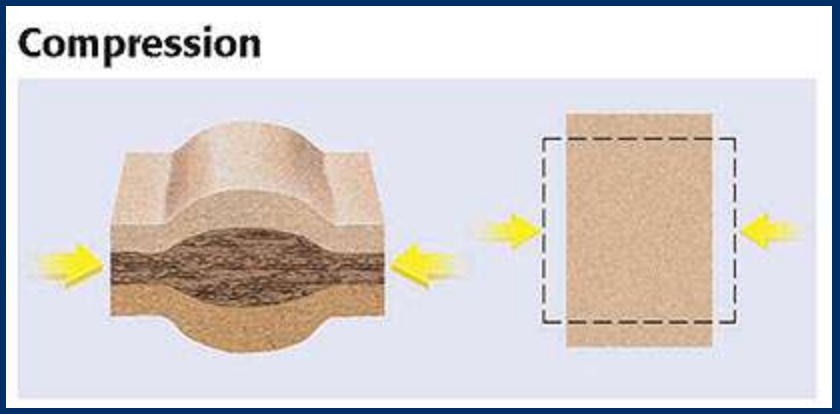
Shear Stress

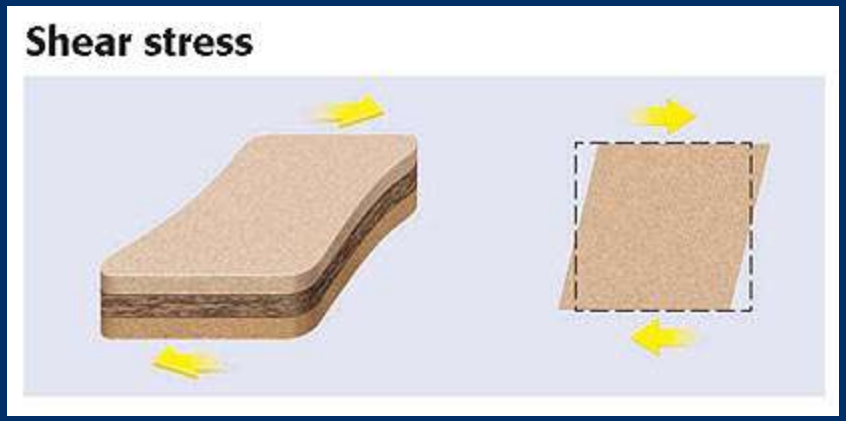
- Shear stress distorts a body of rock by pushing parts of the rock in opposite directions.
- Sheared rocks bend, twist, or break apart as they slide past each other.
- Shear stress occurs at transform boundaries.

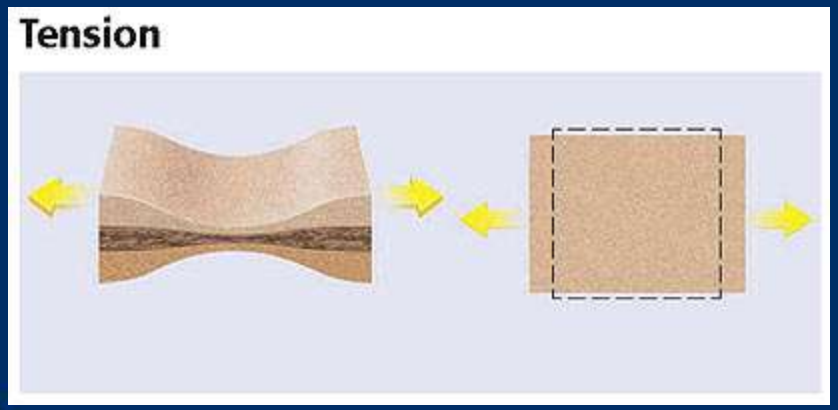
End Of Slide

Stress, *continued*

The diagram below shows the three types of stress







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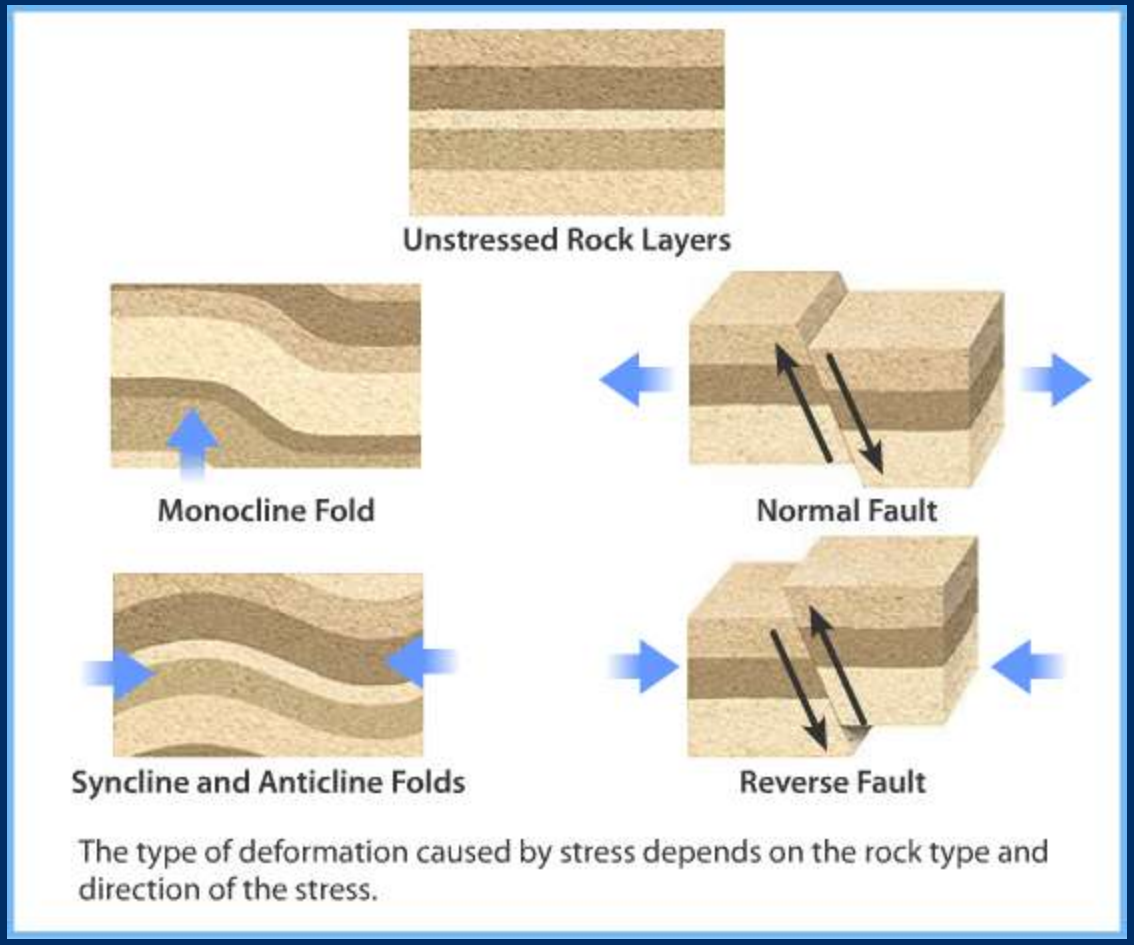
Stress



The type of deformation caused by stress depends on the rock type and direction of the stress.

End of Slide

Stress, *continued*

Reading Check

Which two kinds of stress pull rock apart?

Stress, *continued*

Reading Check

Which two kinds of stress pull rock apart?

Tension and shear stress can both pull rock apart.

Strain

strain any change in a rock's shape or volume caused by stress

- When stress is applied slowly, the deformed rock may regain its original shape when the stress is removed.
- The amount of stress that rock can withstand without permanently changing shape is limited.
- If a stress exceeds the rock's limit, the rock's shape permanently changes.

End Of Slide

Strain, *continued*

Types of Permanent Strain

- Brittle strain and ductile strain are types of permanent strain.
- Materials that respond to stress by breaking or fracturing are *brittle*. Brittle strain appears as cracks fractures.
- *Ductile* materials respond to stress by bending or deforming without breaking. Ductile strain is a change in the volume or shape of rock in which the rock does not crack or fracture.

Strain, *continued*

Factors that Affect Strain

- The composition of rock determines where rock is ductile or brittle, but temperature and pressure also affect how rock deforms.
- At lower temperature and pressure, rock is likely deform in a brittle way. At higher temperature and pressure, rock will deform in a ductile way.

End Of Slide

Strain, *continued*

Factors that Affect Strain, *continued*

- The amount and type of stress and the rate at which stress is applied affects strain.
- The greater the stress on the rock is, the more likely rock is to undergo brittle strain.
- The more quickly stress is applied to rock, the more likely rock is to respond in a brittle way.

End Of Slide

Folds

fold a form of ductile strain in which rock layers bend, usually as a result of compression.

- When rock deforms in a ductile way, folds form.
- A fold is most easily observed where flat layers of rock were compressed or squeezed inward.
- Although a fold commonly results from compression, it can also from as a result of shear stress.

End Of Slide

Folds, *continued*

Anatomy of a Fold

- Folds have several features by which they are described.
- The sloping sides of a fold are called limbs.
- The limbs meet at the bend in the rock layers, which is called the hinge.

Folds, *continued*

Anatomy of a Fold

- If both halves of a fold are symmetrical, then the fold has an axial plane.
- The axial plane is a place that could slice the fold into two symmetrical halves.
- If a fold is overturned, it appears to be lying on its side.

Folds, *continued*

Reading Check

Name two features of a fold.

Folds, *continued*

Reading Check

Name two features of a fold.

Limbs and hinges

Folds, *continued*

Types of Folds

- To categorize a fold, scientists study the relative ages of the rocks in the fold.
- An *anticline* is a fold in which the oldest layer is in the center of the fold. Anticlines are commonly arch shaped.

Folds, *continued*

Types of Folds

- A *syncline* is a fold in which the youngest layer is in the center of the fold. Synclines are commonly bowl shaped.
- A *monocline* is a fold in which both limbs are horizontal or almost horizontal. Monoclines form when one part of Earth's crust moves up or down relative to another part.

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Folds, *continued*

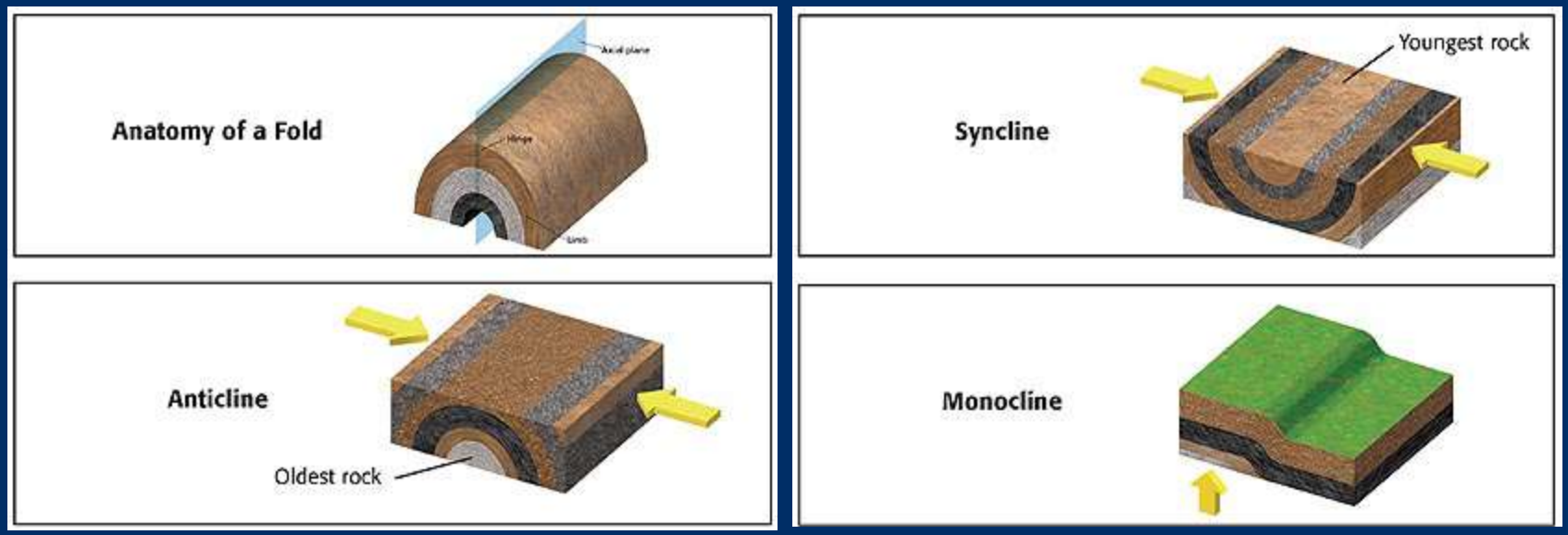
Sizes of Folds

- Folds vary greatly in size. Some folds are small enough to be contained in a hand-held rock specimen.
- Other folds cover thousands of square kilometers can be seen only from the air.
- A large anticline may form a ridge, which is a large, narrow strip of elevated land that can occur near mountains.
- A large syncline may form a valley.

End Of Slide

Folds, *continued*

The diagram below shows the major types of folds.



End Of Slide

Faults

fault a break in a body of rock along which one block slides relative to another; a form of brittle strain

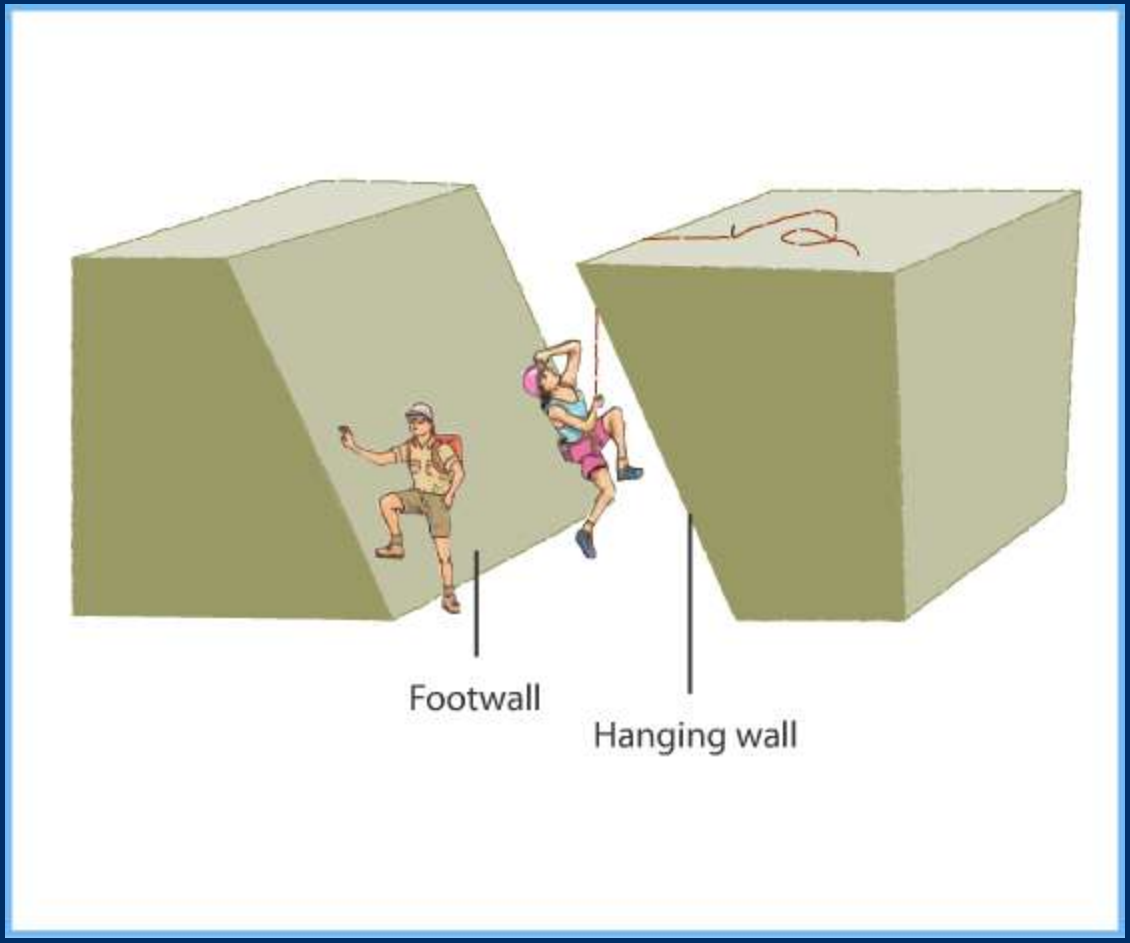
- Stress on rock can cause rock to break.
- Breaks in rock along which there is no movement of the surrounding rock is called a *fracture.*
- A break along which the surrounding rock moves is called a fault.

End Of Slide

Faults, *continued*

- The surface or plane along which the motion occurs is called the *fault plane*.
- In a nonvertical fault, the *hanging wall* is the rock above the fault plane.
- The *footwall* is the rock below the fault plane.

Hanging Walls and Footwalls



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Faults, *continued*

Normal Faults

- A normal fault is a fault in which the hanging wall moves downward relative to the footwall.
- Normal faults commonly form at divergent boundaries, where the crust is being pulled apart by tension.
- Normal faults may occur as a series of parallel fault lines, forming steep, steplike landforms.

End Of Slide

Faults, *continued*

Reverse Faults

- When compression causes the hanging wall to move upward relative to the footwall, a *reverse fault* forms.
- A *thrust fault* is a special type of reverse fault in which the fault plane is at a low angle or is nearly horizontal.
- Reverse faults and thrust faults are common in steep mountain ranges, such as the Rockies and the Alps.

End Of Slide

Faults, *continued*

Reading Check

How does a thrust fault differ from a reverse fault?

Faults, *continued*

Reading Check

How does a thrust fault differ from a reverse fault?

A thrust fault is a type of reverse fault in which the fault plane is at a low angle relative to the surface.

Faults, *continued*

Strike-Slip Faults

- In a strike-slip fault, the rock on either side of the fault plane slides horizontally in response to shear stress.
- Strike-slip faults got their name because they slide, or *slip*, parallel to the direction of the length, or *strike*, of the fault.
- Strike-slip faults commonly occur at transform boundaries.

End Of Slide

Faults, *continued*

Strike-Slip Faults

- Strike-slip faults also occur at fracture zones between offset segments of mid-ocean ridges.
- Commonly, strike-slip faults occur as groups of smaller faults in areas where large-scale deformation is happening.

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Faults, *continued*

Sizes of Faults

- Like folds, faults vary greatly in size. Some faults are so small that they affect only a few layers of rock in a small region.
- Other faults are thousands of kilometers long and may extend several kilometers below Earth's surface.
- Large faults that cover thousands of kilometers are composed of systems of many smaller, related faults.

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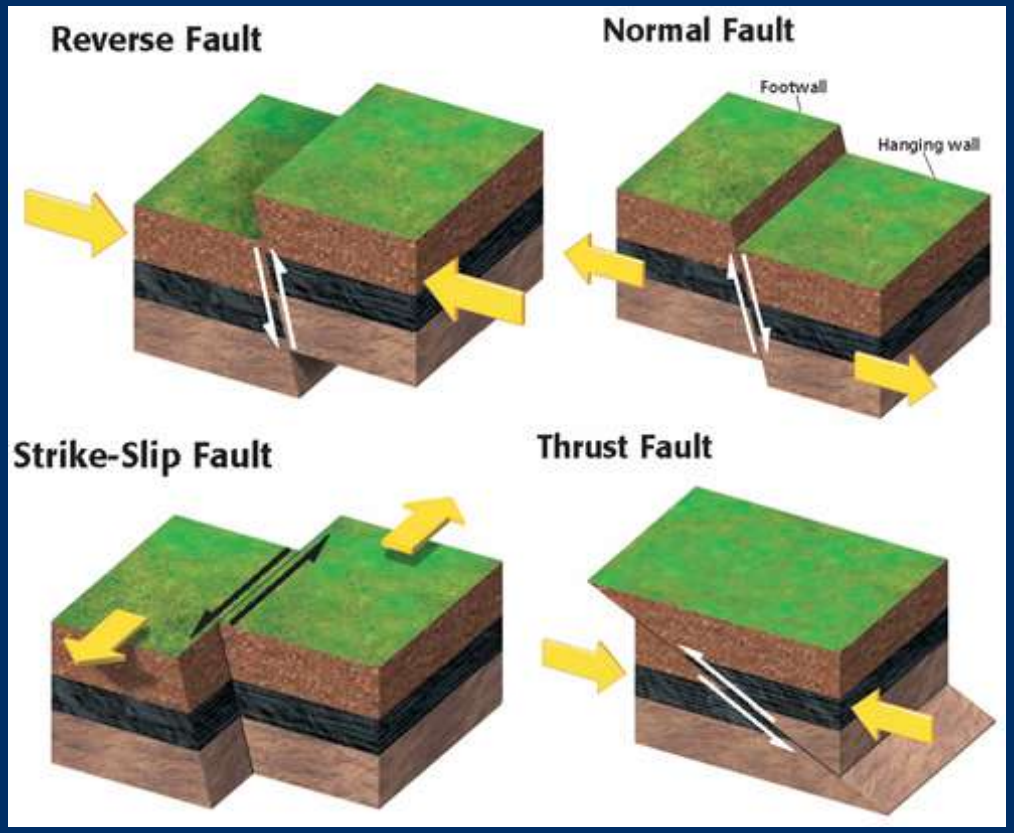
Faults, *continued*

The diagram below shows the major types of faults.



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Objectives

- **Identify** the types of plate collisions that form mountains.
- **Identify** four types of mountains.
- **Compare** how folded and fault-block mountains form.

End Of Slide

Mountain Ranges and Systems

mountain range a series of mountains that are closely related in orientation, age, and mode of formation

- A mountain is the most extreme type of deformation.
- A group of mountain ranges that are adjacent is called a *mountain system*.
- The largest mountain systems are part of two larger systems called *mountain belts.*

End Of Slide

Mountain Ranges and Systems, *continued*

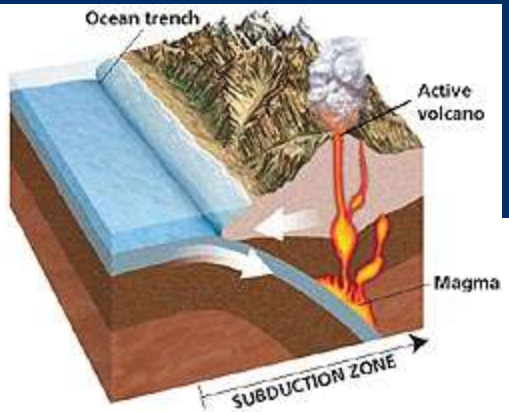
- Earth's two major mountain belts are the circum-Pacific belt and the Eurasian-Melanesian belt.
- The circum-Pacific belt forms a ring around the Pacific Ocean.
- The Eurasian-Melanesian belt runs from the Pacific islands through Asia and southern Europe and into northwestern Africa.

End Of Slide

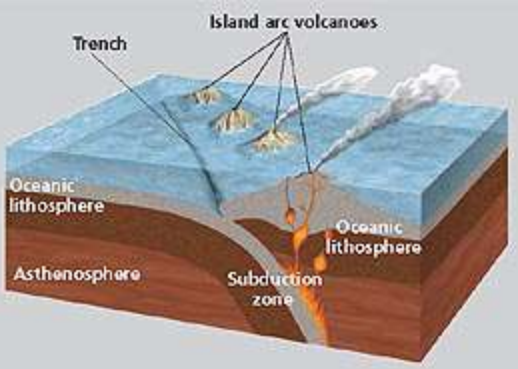
Plate Tectonics and Mountains

The diagram below shows how mountains form.

Collisions Between Continental and Oceanic Crust



Collisions Between Oceanic Crust and Oceanic Crust



Collisions Between Continents

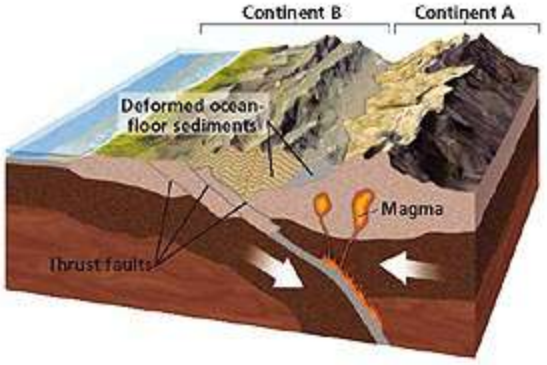


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Plate Tectonics and Mountains, *continued*

- The circum-Pacific and the Eurasian-Melanesian mountain belts are both located along convergent plate boundaries.
- Scientists think that the location of these two mountain belts provides evidence that most mountains form as a result of collisions between tectonic plates.

End Of Slide
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Plate Tectonics and Mountains, *continued*

Collisions between Continental and Oceanic Crust

- Some mountains form when oceanic lithosphere and continental lithosphere collide at convergent plate boundaries.
- In this type of collision, the oceanic lithosphere subducts beneath the continental lithosphere, producing large-scale deformation which uplifts high mountains.

End Of Slide

Plate Tectonics and Mountains, *continued*

Collisions between Continental and Oceanic Crust

- In addition, the subduction of the oceanic lithosphere causes partial melting of the overlying mantle and crust.
- This melting produces magma which can erupt to form volcanic mountains on Earth's surface.

Plate Tectonics and Mountains, *continued*

Collisions Between Oceanic Crust and Oceanic Crust

- Volcanic mountains commonly form where two plates whose edges consist of oceanic lithosphere collide.
- In this collision, the denser oceanic plate subducts beneath the other oceanic plate.

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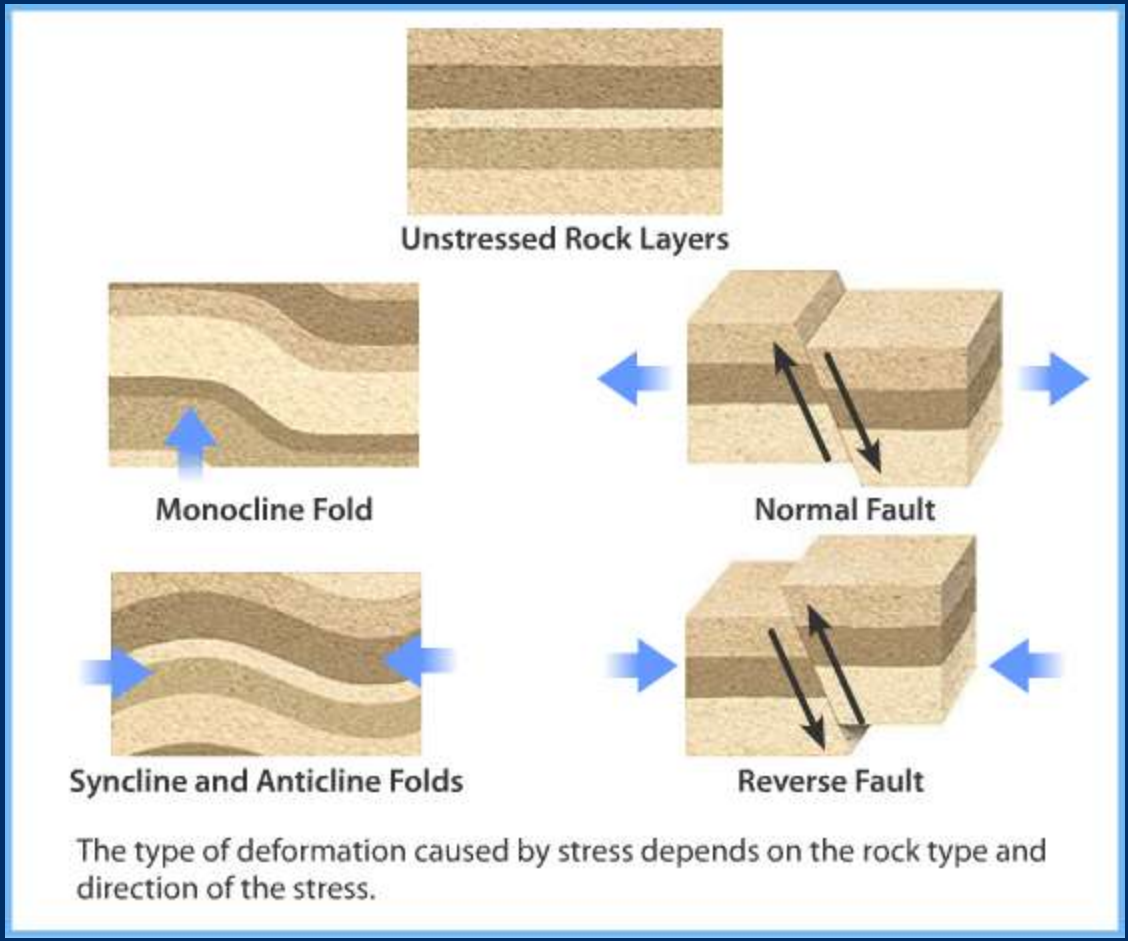
Volcano Formation at Convergent Boundaries



The type of deformation caused by stress depends on the rock type and direction of the stress.

End of Slide

Plate Tectonics and Mountains, *continued*

Collisions Between Oceanic Crust and Oceanic Crust

- As the denser oceanic plate subducts, fluids from the subducting lithosphere cause partial melting of the overlying mantle and crust.
- The resulting magma rises and breaks through the oceanic lithosphere.
- These eruptions of magma form an arc of volcanic mountains on the ocean floor.

End Of Slide

Plate Tectonics and Mountains, *continued*

Collisions Between Continents

- Mountains can form when two continents collide.
- An example of this type of collision is the formation of the Himalaya Mountains in which the oceanic lithosphere of the Indian plate subducted beneath the Eurasian plate.
- When the continental lithosphere of both plates collided, subduction stopped, but the collision continued.

End Of Slide

Plate Tectonics and Mountains, *continued*

Collisions Between Continents

- The intense deformation that resulted from the collision uplifted the Himalayas.
- Because the plates are still colliding, the Himalayas are still growing taller.

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Plate Tectonics and Mountains, *continued*

Reading Check

Why are the Himalayas growing taller today?

Plate Tectonics and Mountains, *continued*

Reading Check

Why are the Himalayas growing taller today?

The Himalayas are growing taller because the two plates are still colliding and causing further compression of the rock, which further uplifts the mountains.

Types of Mountains

Folded Mountains and Plateaus

folded mountain a mountain that forms when rock layers are squeezed together and uplifted

- The highest mountain ranges in the world consist of folded mountains that form when continents collide.
- The same stresses that form folded mountains also uplift plateaus, which are large, flat areas of rock high above sea level.

End Of Slide

Types of Mountains, *continued*

Folded Mountains and Plateaus, *continued*

- Most plateaus form when thick, horizontal layers of rock are slowly uplifted so that the layers remain flat instead of faulting and folding.
- Most plateaus are located near mountain ranges.
- Plateaus can also form when layers of molten rock harden and pile up on Earth's surface or when large areas of rock are eroded.

End Of Slide

Types of Mountains, *continued*

Fault-Block Mountains and Grabens

fault-block mountain a mountain that forms where faults break Earth's crust into large blocks and some blocks drop down relative to other blocks

- Where parts of Earth's crust have been stretched and broken into large blocks, faulting may cause the blocks to tilt and drop relative to other blocks.

Types of Mountains, *continued*

Fault-Block Mountains and Grabens

- The same type of faulting that forms fault-block mountains also forms long, narrow valleys called grabens.
- Grabens develop when steep faults break the crust into blocks and one block slips downward relative to the surrounding blocks.
- Grabens and fault-block mountains commonly occur together.

End Of Slide

Types of Mountains, *continued*

Dome Mountains

dome mountain a circular or elliptical, almost symmetrical elevation or structure in which the stratified rock slopes downward gently from the central point of folding

- Dome mountains are rare, and form when magma rises through the crust and pushes up the rock layers above the magma.

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Types of Mountains, *continued*

Reading Check

Name three types of mountains found in the United States.

End Of Slide

Types of Mountains, *continued*

Reading Check

Name three types of mountains found in the United States.

Your answer may include three of the following: folded mountains, fault-block mountains, dome mountains, and volcanic mountains.

End Of Slide

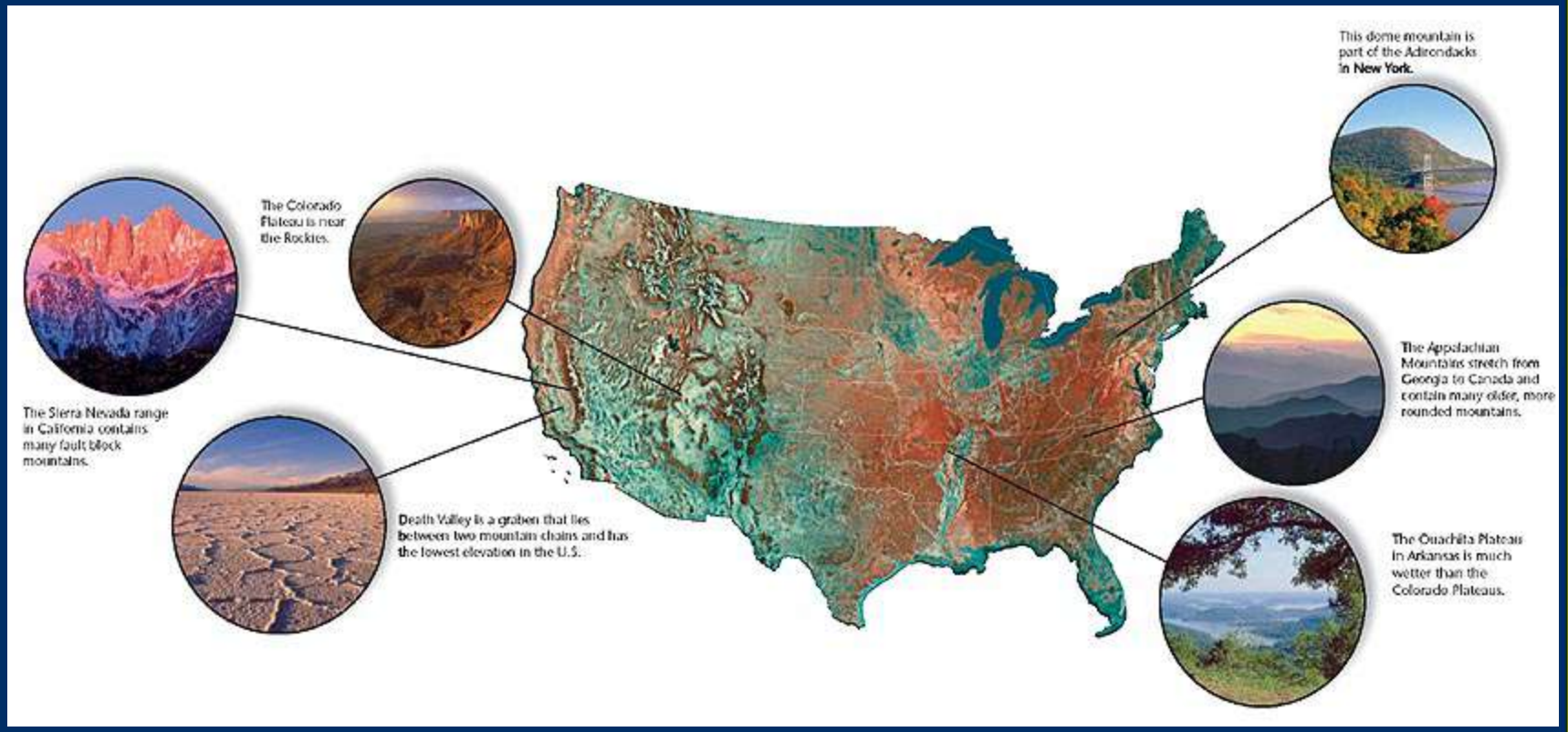
Types of Mountains, *continued*

Volcanic Mountains

- Mountains that form when magma erupts onto Earth's surface are called *volcanic mountains*, which commonly form along convergent plate boundaries.
- Some of the largest volcanic mountains are part of the mid-ocean ridges along divergent plate boundaries.
- Other large volcanic mountains form on the ocean floor at hot spots.

End Of Slide

Types of Mountains, *continued*



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Types of Mountains

Click a thumbnail image to learn more.

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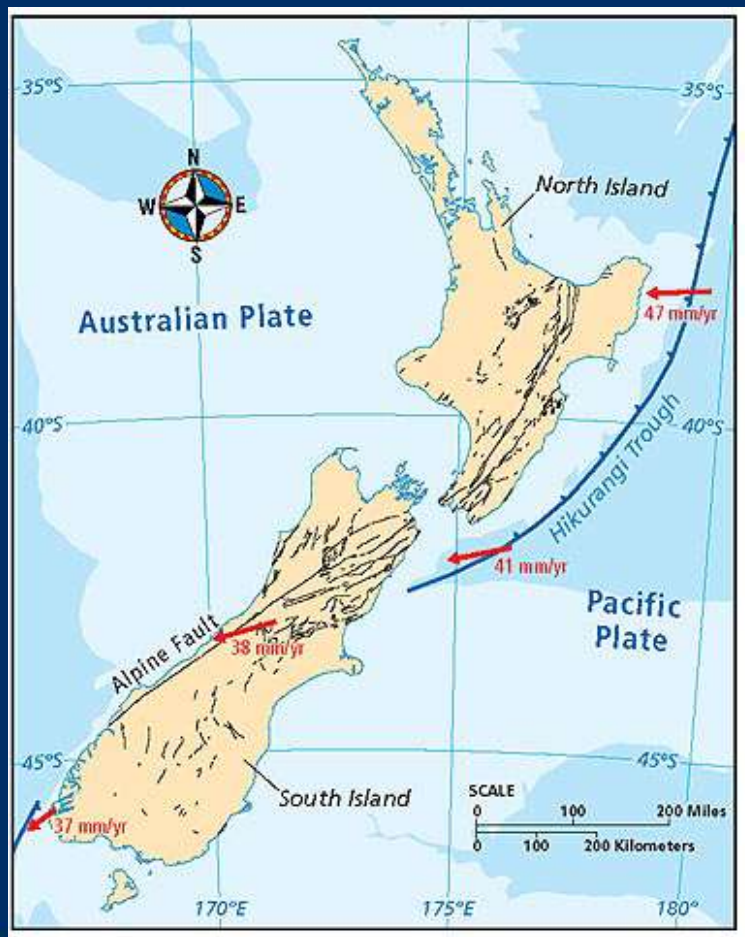
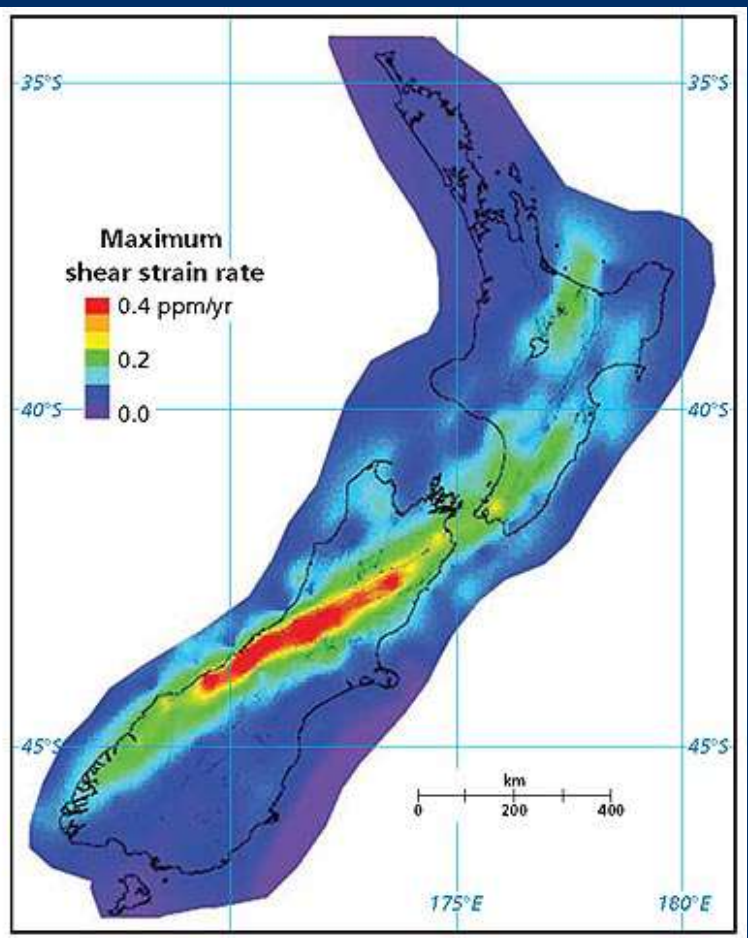
Maps in Action





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Brain Food Video Quiz

Multiple Choice

1.Where are most plateaus located?

A.near mountain ranges

B.bordering ocean basins

C.beneath grabens

D.alongside diverging boundaries

Multiple Choice, *continued*

1. Where are most plateaus located?

A. near mountain ranges

B. bordering ocean basins

C. beneath grabens

D. alongside diverging boundaries

Multiple Choice, *continued*

2. Which of the following features form where parts of the crust have been broken by faults.

F. monoclines

G. plateaus

H. synclines

I. grabens

Multiple Choice, *continued*

2. Which of the following features form where parts of the crust have been broken by faults.

F. monoclines

G. plateaus

H. synclines

I. grabens

Multiple Choice, *continued*

3. Which of the following statements describes the formation of rock along strike-slip faults?

A. Rock on either side of the fault plane slides vertically.

B. Rock on either side of the fault plane slides horizontally.

C. Rock in the hanging wall is pushed up and over the rock of the footwall.

D. Rock in the hanging wall moves down relative to the footwall.

Multiple Choice, *continued*

3. Which of the following statements describes the formation of rock along strike-slip faults?

A. Rock on either side of the fault plane slides vertically.

B. Rock on either side of the fault plane slides horizontally.

C. Rock in the hanging wall is pushed up and over the rock of the footwall.

D. Rock in the hanging wall moves down relative to the footwall.

Multiple Choice, *continued*

4. Which does not result in mountain formation?

F. collisions between continental and oceanic crust

G. subduction of one oceanic plate beneath another oceanic plate

H. deposition and isostasy

I. deformation caused by collisions between two or more continents

Multiple Choice, *continued*

4. Which does not result in mountain formation?

F. collisions between continental and oceanic crust

G. subduction of one oceanic plate beneath another oceanic plate

H. deposition and isostasy

I. deformation caused by collisions between two or more continents

Short Response

5. What is the term for a condition of gravitational equilibrium in Earth's crust?

Short Response, *continued*

5. What is the term for a condition of gravitational equilibrium in Earth's crust?

isostasy

Short Response, *continued*

6. What is the term for a type of stress that squeezes and shortens a body?

Short Response, *continued*

6. What is the term for a type of stress that squeezes and shortens a body?

compression

Short Response, *continued*

7. As a volcanic mountain range is built, isostatic adjustment will cause the crust beneath the mountain range to do what?

Short Response, *continued*

7. As a volcanic mountain range is built, isostatic adjustment will cause the crust beneath the mountain range to do what?

sink

Reading Skills

Read the passage below. Then, answer questions 8–10.

Stress and Strain

Stress is defined as the amount of force per unit area on a rock. When enough stress is placed on a rock, the rock becomes strained. This strain causes the rock to deform, usually by bending and breaking. For example, if you put a small amount of pressure on the ends of a drinking straw, the straw may not bend—even though you have put stress on it. However, when you have put enough pressure on it, the straw bends, or becomes strained.

One example of stress is when tectonic plates collide. When plates collide, a large amount of stress is placed on the rocks that make up the plate, especially the rocks that make up the plates involved in the collision. Because of the stress, these rocks become extremely strained. In fact, even the shapes of the tectonic plates can changes as a result of these powerful collisions.

Reading Skills, *continued*

8. Based on the passage, which of the following statements is not true?

A. Strain ca cause a rock to deform by bending or breaking.

B. Rocks, like drinking straws, will not bend when pressure is applied to them.

C. Stress is defined as amount of force per unit area that is put on a rock.

D. A large amount of stress is placed on the rocks involved in tectonic plate collisions.

Reading Skills, *continued*

8. Based on the passage, which of the following statements is not true?

A. Strain ca cause a rock to deform by bending or breaking.

B. Rocks, like drinking straws, will not bend when pressure is applied to them.

C. Stress is defined as amount of force per unit area that is put on a rock.

D. A large amount of stress is placed on the rocks involved in tectonic plate collisions.

Reading Skills, *continued*

9. Which of the following statements can be inferred from the information in the passage?

F. The stress of tectonic plate collisions often creates large, smooth plains of rock.

G. The stress of tectonic plate collisions often creates large mountain chains.

H. Bending a drinking straw requires the same amount of pressure that is needed to bend a rock.

I. The only time a rock has stress is when the rock is involved in a tectonic collision.

Reading Skills, *continued*

9. Which of the following statements can be inferred from the information in the passage?

F. The stress of tectonic plate collisions often creates large, smooth plains of rock.

G. The stress of tectonic plate collisions often creates large mountain chains.

H. Bending a drinking straw requires the same amount of pressure that is needed to bend a rock.

I. The only time a rock has stress is when the rock is involved in a tectonic collision.

Reading Skills, *continued*

10. What happens to rocks when plates collide?

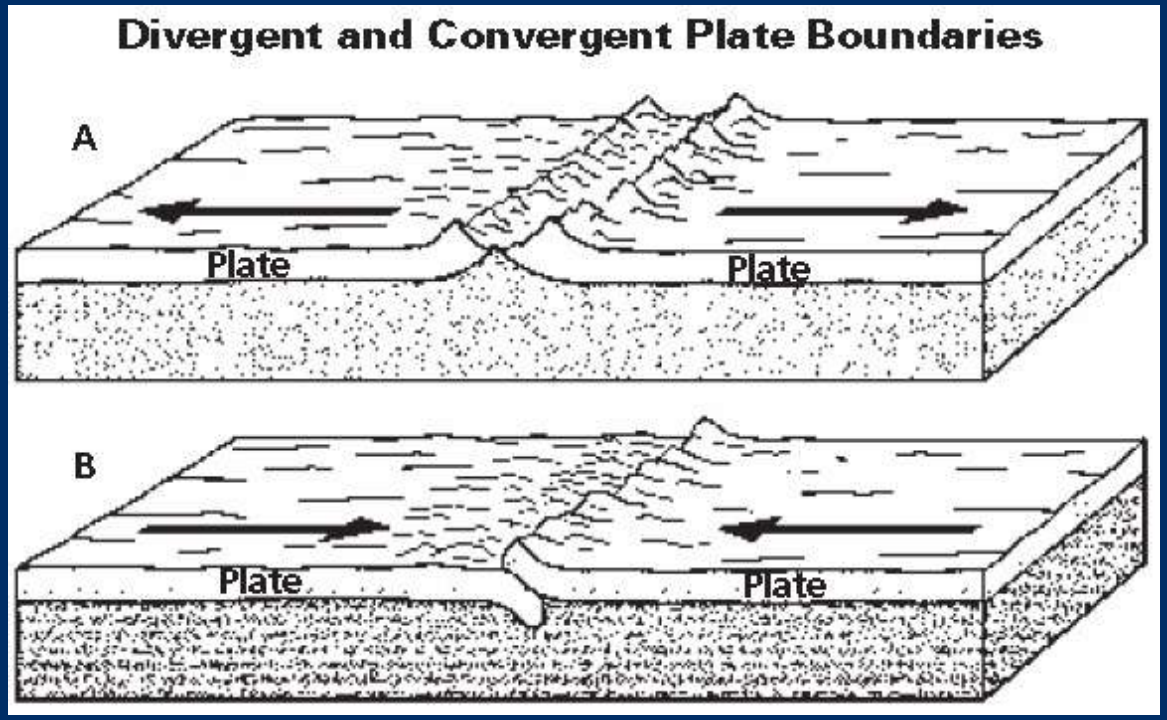
Reading Skills, *continued*

10. What happens to rocks when plates collide?

Rocks suffer severe stress in a tectonic collision, and they are usually deformed by the extremely high amounts of pressure.

Interpreting Graphics

Use the figure below to answer questions 11 -12. The diagrams show a divergent and a convergent plate boundary.



Interpreting Graphics, *continued*

11. Which of the following is not likely to be found at or occur at the boundary found in diagram A?

A. volcanoes

B.lava flows

C. earthquakes

D. subduction

Interpreting Graphics, *continued*

11. Which of the following is not likely to be found at or occur at the boundary found in diagram A?

A. volcanoes

B. lava flows

C. earthquakes

D. subduction

Interpreting Graphics, *continued*

12. How does the subduction of the oceanic crust shown in diagram B produce volcanic mountains?

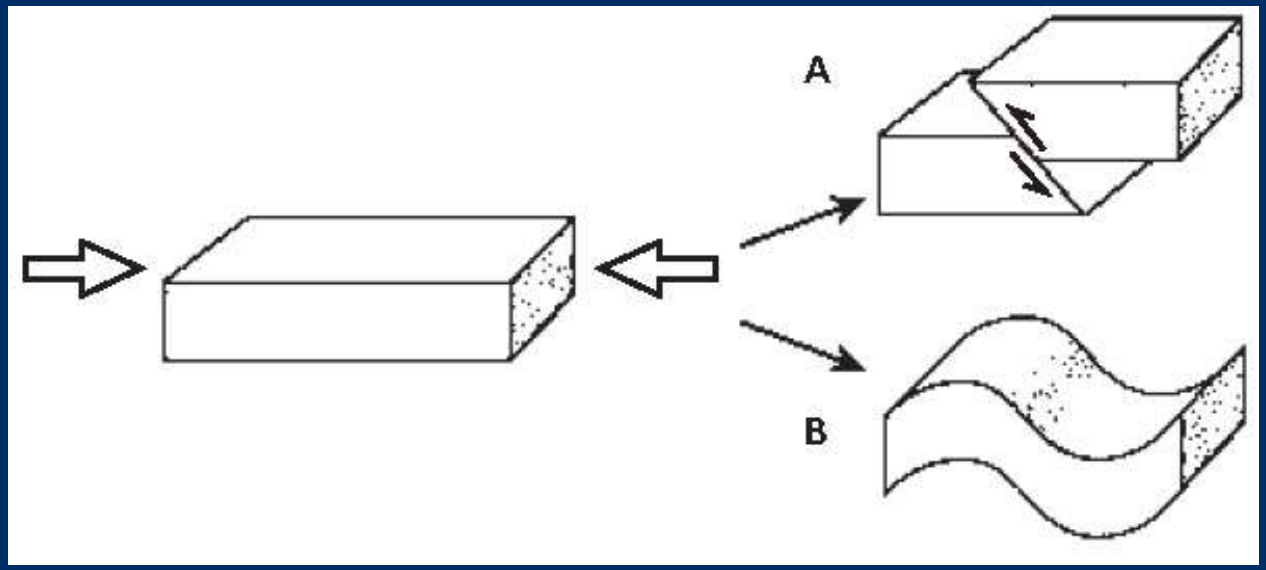
Interpreting Graphics, *continued*

12. How does the subduction of the oceanic crust shown in diagram B produce volcanic mountains?

Answer should include the following points: subduction causes partial melting of the overlying mantle, which produces magma that may erupt to form volcanic mountains; as the oceanic plate is subducted by the denser continental plate, the oceanic plate heats up and releases water; the water causes a partial melting of the mantle, which changes rock into magma; this magma rises to the surface and forms volcanic mountains.

Interpreting Graphics, *continued*

Use the figure below to answer questions 13-14. The diagram shows two possible outcomes when pressure, which is represented by the large arrows, is applied to the rock on the left.



Interpreting Graphics, *continued*

13. What type of deformation is seen in the rock labeled A?

F. Brittle

G. Ductile

H. Folding

I. monocline

Interpreting Graphics, *continued*

13. What type of deformation is seen in the rock labeled A?

F. Brittle

G. Ductile

H. Folding

I. monocline

Interpreting Graphics, *continued*

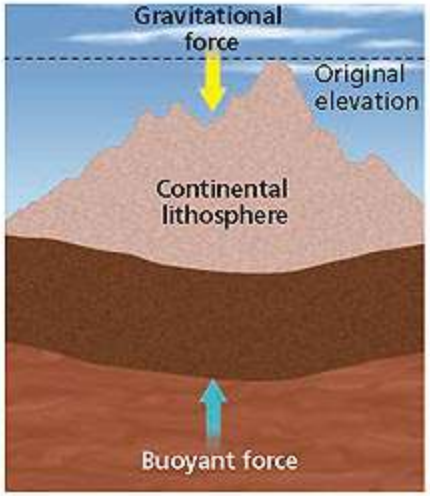
14. Describe the type of rock deformation shown Figure B. Under what conditions is this type of deformation likely to occur?

Interpreting Graphics, *continued*

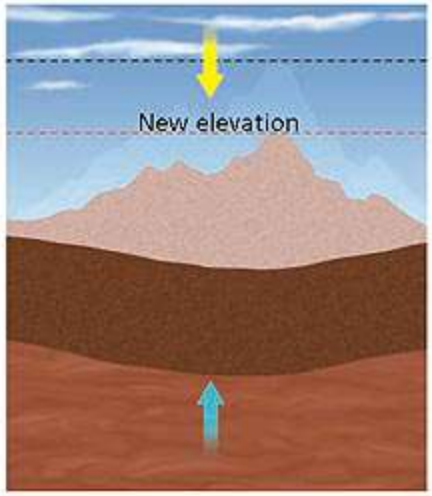
14. Describe the type of rock deformation shown Figure B. Under what conditions is this type of deformation likely to occur?

Answer should include the following points: when stress is applied, a rock can respond with brittle or ductile strain; ductile strain is common in rock that is hot or has pressure evenly exerted; ductile strain may be a change in volume or shape without breaking; ductile strain is usually bending or folding.

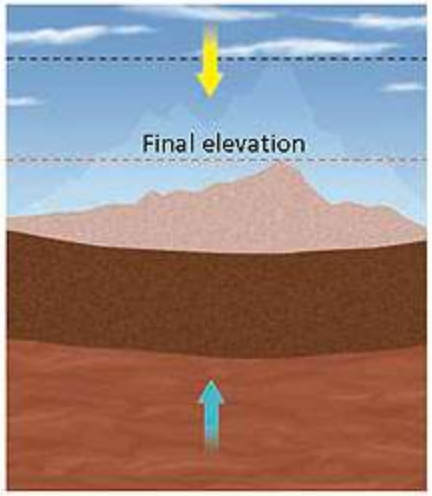
Isostatic Adjustment



When the gravitational force equals the buoyant force, the lithosphere and asthenosphere are in isostasy.



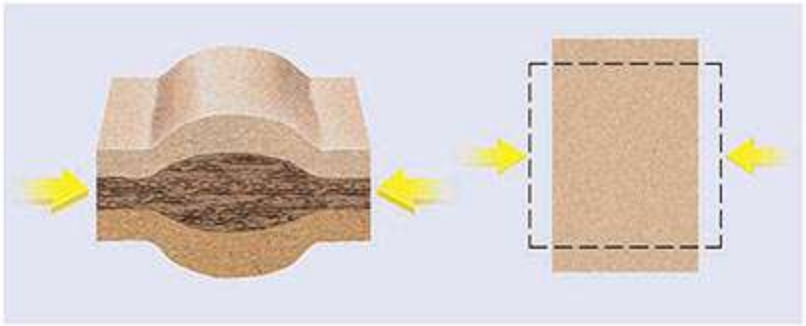
As erosion wears away the crust, the lithosphere becomes lighter and is pushed up by the asthenosphere.



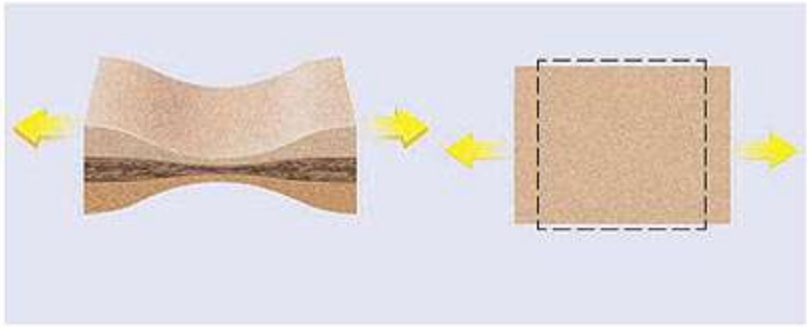
As erosion continues, the isostatic adjustment also continues.

Types of Stress

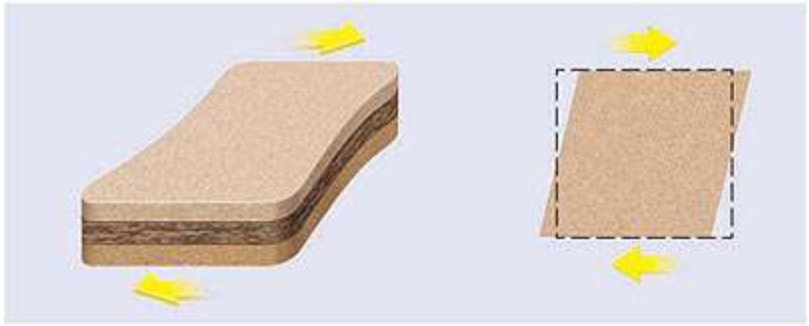
Compression



Tension

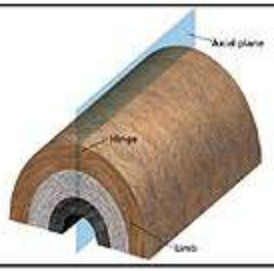


Shear stress



Folds

Anatomy of a Fold



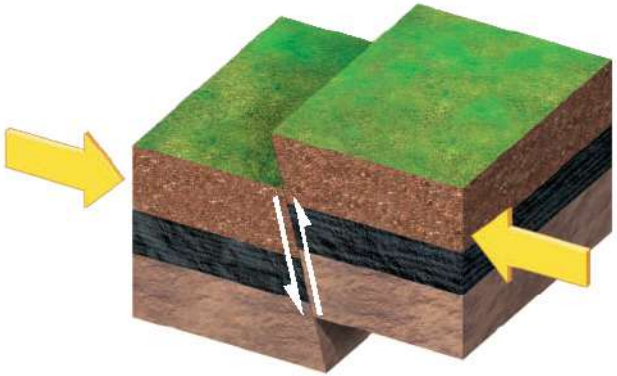
Syncline

Anticline

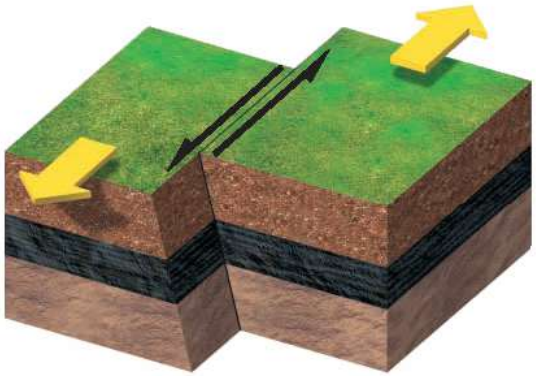
Monocline

Faults

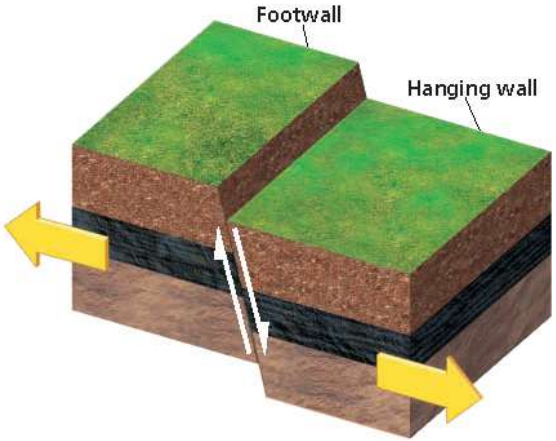
Reverse Fault



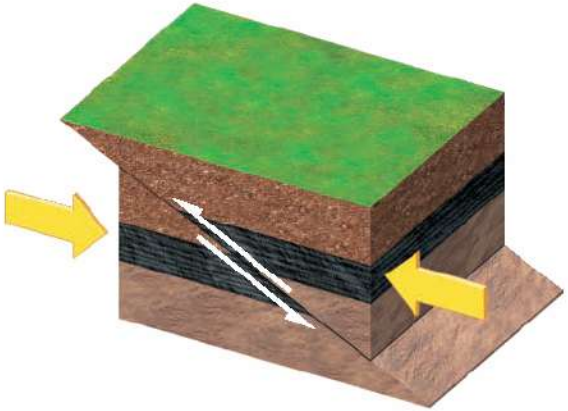
Strike-Slip Fault



Normal Fault

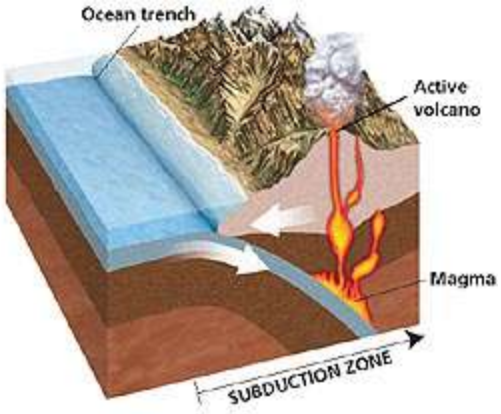


Thrust Fault

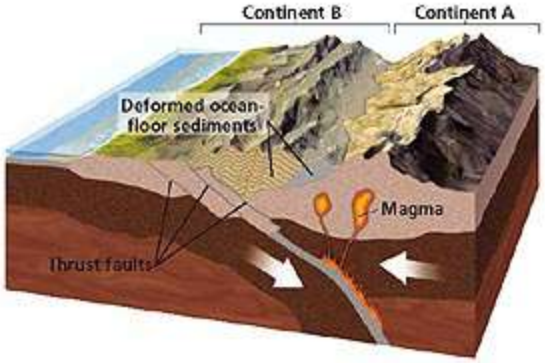


How Mountains Form

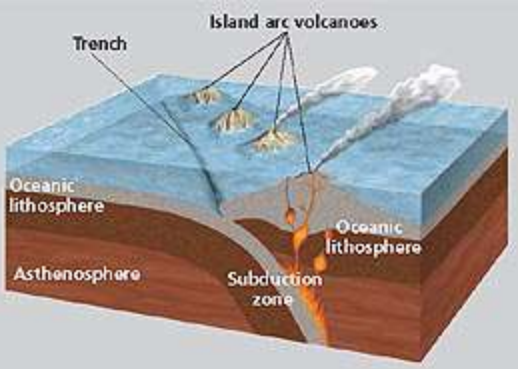
Collisions Between Continental and Oceanic Crust



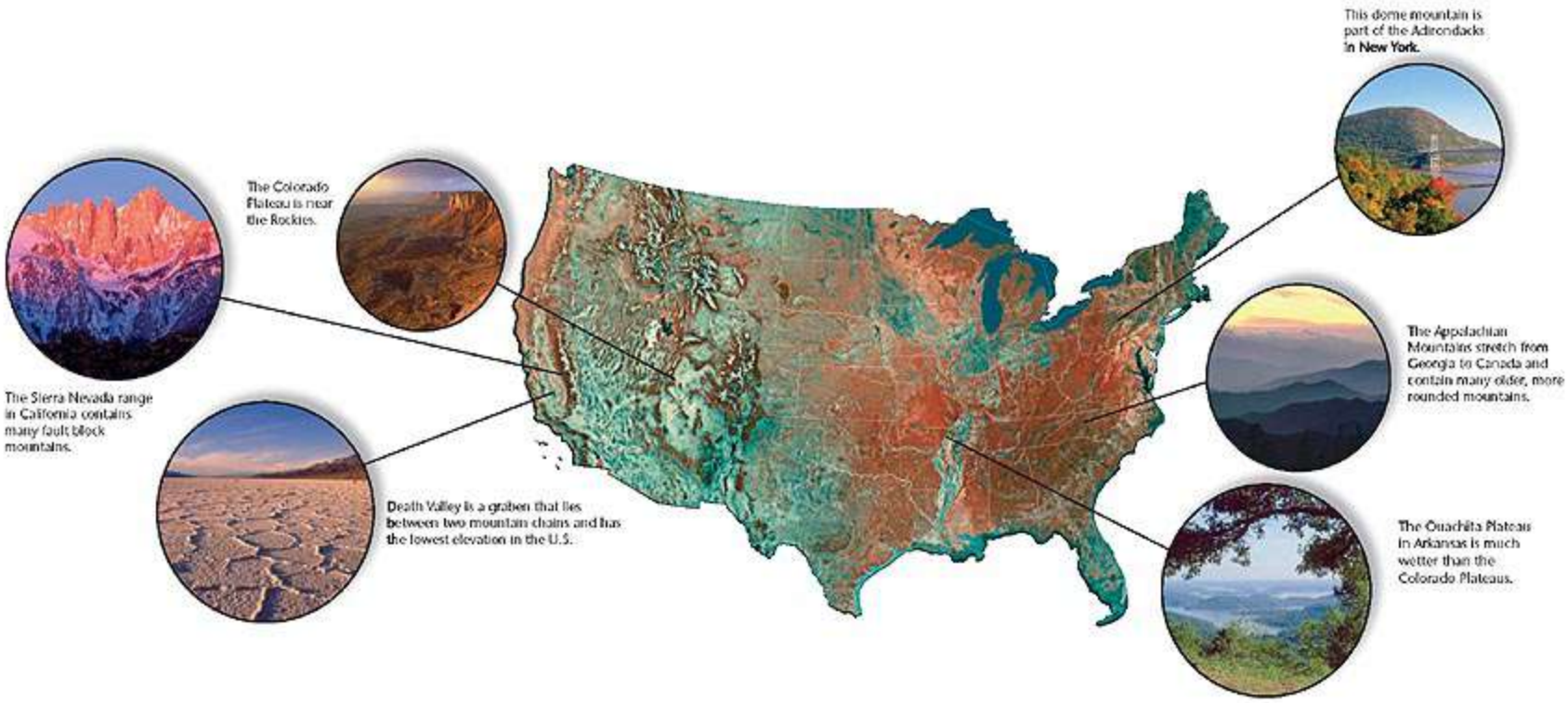
Collisions Between Continents



Collisions Between Oceanic Crust and Oceanic Crust



Types of Mountains in the United States



Shear Strain in New Zealand