Dynamic Earth
EES 1000
Section: 601

Instructor: Deepak Mishra

Review

Exam 4 (May 7th; 5:30PM-6:45PM)

Syllabus: Chapters 14, 15, 16, 17

Sediment and Sedimentary Rocks

Chapter 14

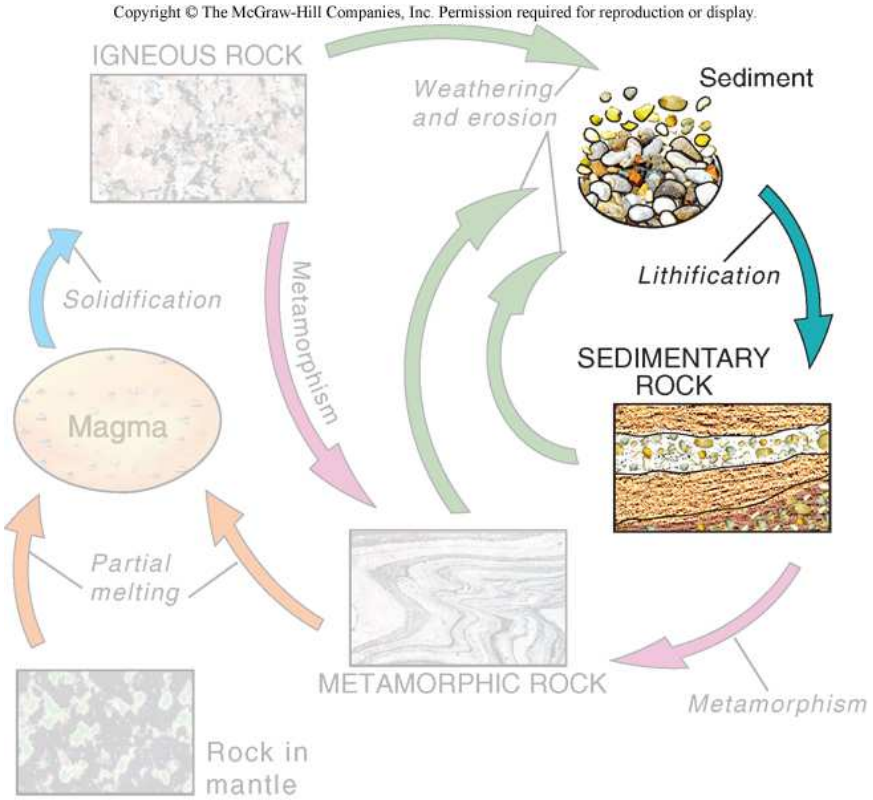
Sedimentary Rocks

- *Detrital or Clastic* rocks produced from rock fragments
- *Chemical* rocks produced by precipitation of dissolved ions in water
- *Organic* rocks produced by accumulation of biological debris, such as in swamps

Sediment

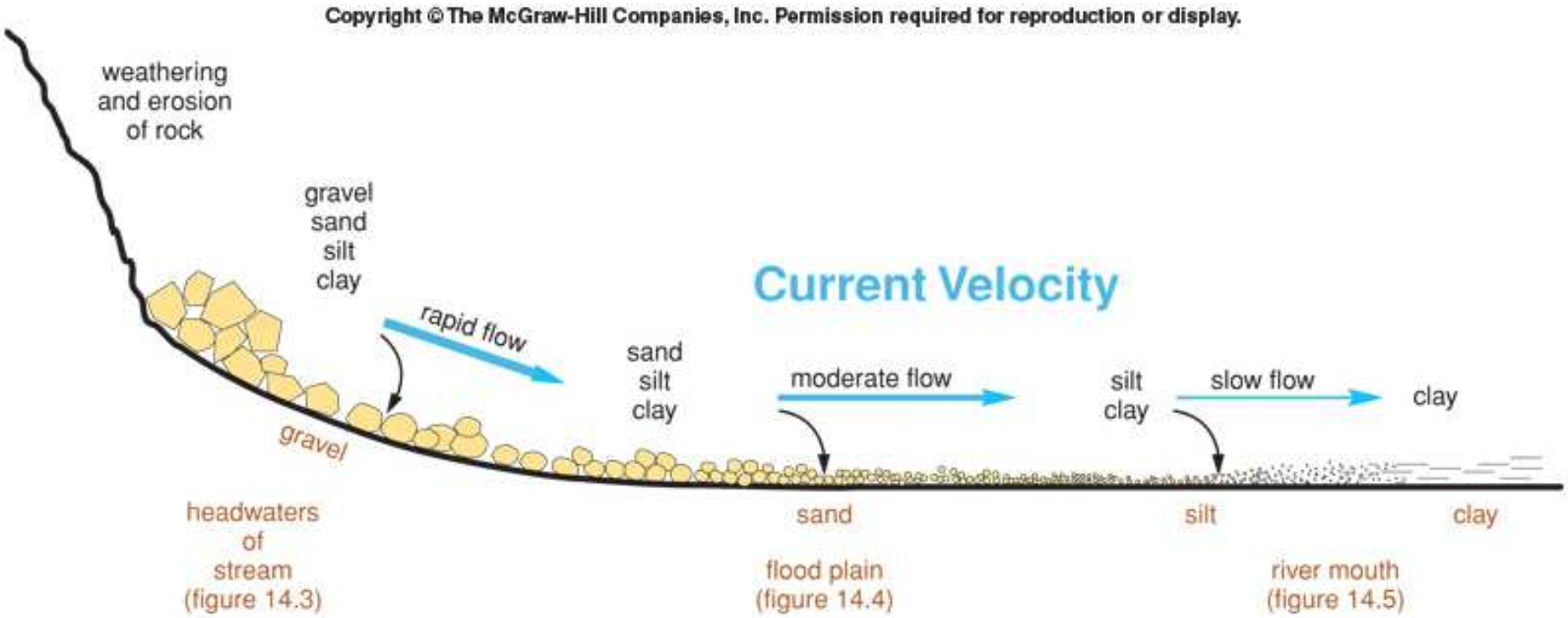
- Classified by *particle size*
  - Boulder - >256 mm
  - Cobble - 64 to 256 mm
  - Pebble - 2 to 64 mm

  Gravel
  - Sand - 1/16 to 2 mm
  - Silt - 1/256 to 1/16 mm
  - Clay - <1/256 mm



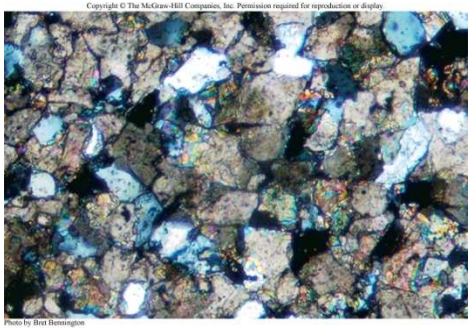
From Sediment to Sedimentary Rock

- *Transportation*



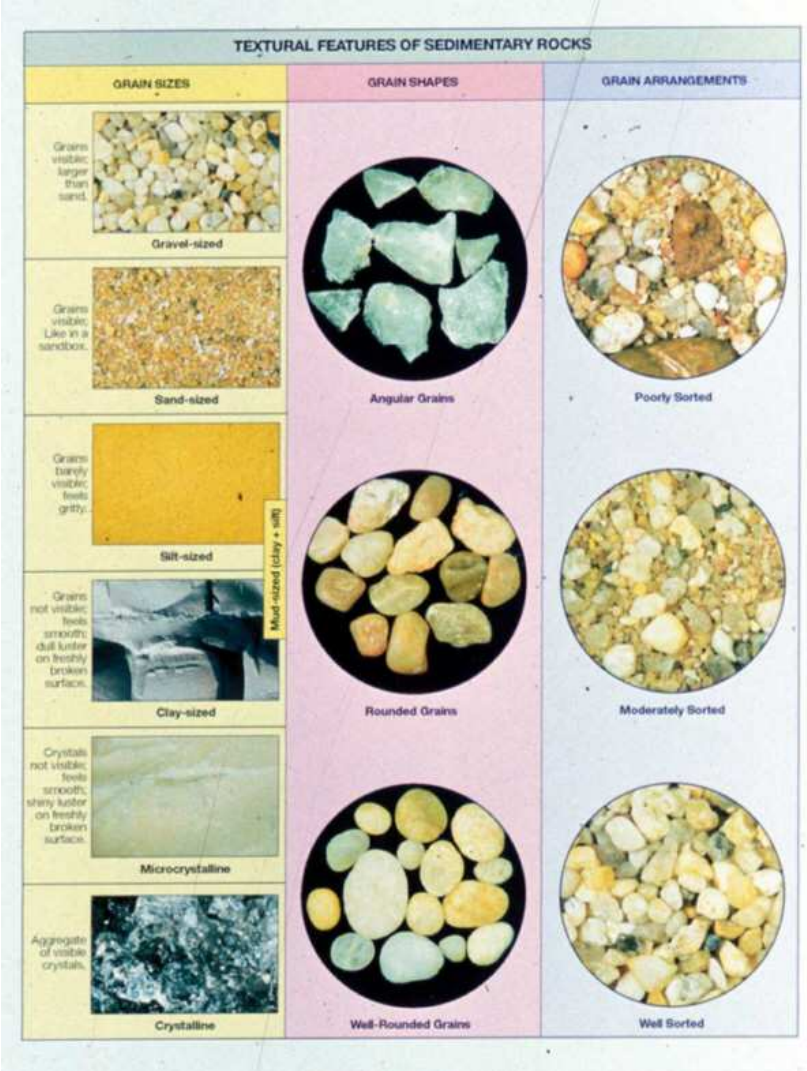
Types of Sedimentary Rocks

- *Detrital or clastic sedimentary rocks*
  - Most common sedimentary rock type
- *Chemical sedimentary rocks*
  - Have crystalline textures
  - Form by precipitation of minerals from solution
- *Organic sedimentary rocks*
  - Accumulate from remains of organisms



Clastic Sedimentary Rocks
Coarse-grained

- *Breccia and Conglomerate*



Clastic Sedimentary Rocks
Medium-grained

- *Sandstone*
  - Types determined by composition
    - *Quartz sandstone* - >90% quartz grains
    - *Arkose* - mostly feldspar and quartz grains
    - *Graywacke* - sand grains surrounded by dark, fine-grained matrix, often clay-rich

Clastic Sedimentary Rocks
Fine-grained

- *Shale*
  - Fine-grained clastic sedimentary rock
  - Splits into thin layers (*fissile*)
- *Siltstone*
  - Lacks fissility
- *Claystone*
  - Predominantly clay-sized grains
- *Mudstone*
  - Silt- and clay-sized grains; massive/blocky

Chemical Sedimentary Rocks

- *Carbonates*
  - Contain CO_3 as part of their chemical composition
  - *Limestone* is composed mainly of *calcite* (Ca-Rich)
    - Chemical alteration of limestone in Mg-rich water solutions can produce *dolomite*

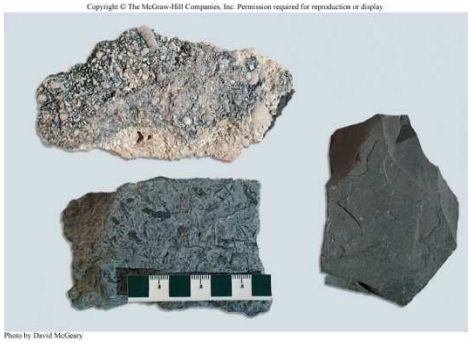
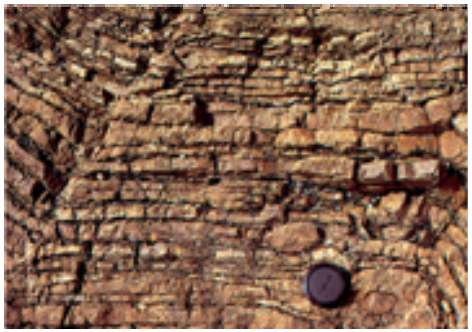


Photo by David McGeary.

- *Chert (inorganic)*
  - Hard, compact, fine-grained, formed almost entirely of silica
  - Can occur as layers or as lumpy nodules within other sedimentary rocks, especially limestones



- *Evaporites (inorganic)*
  - Form from evaporating saline waters (lake, ocean)
  - Common examples are rock gypsum, rock salt

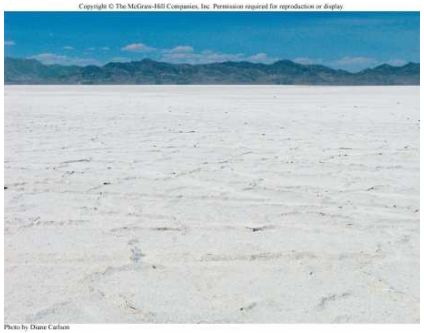


Photo by Diane Carlson

Inorganic Carbonate

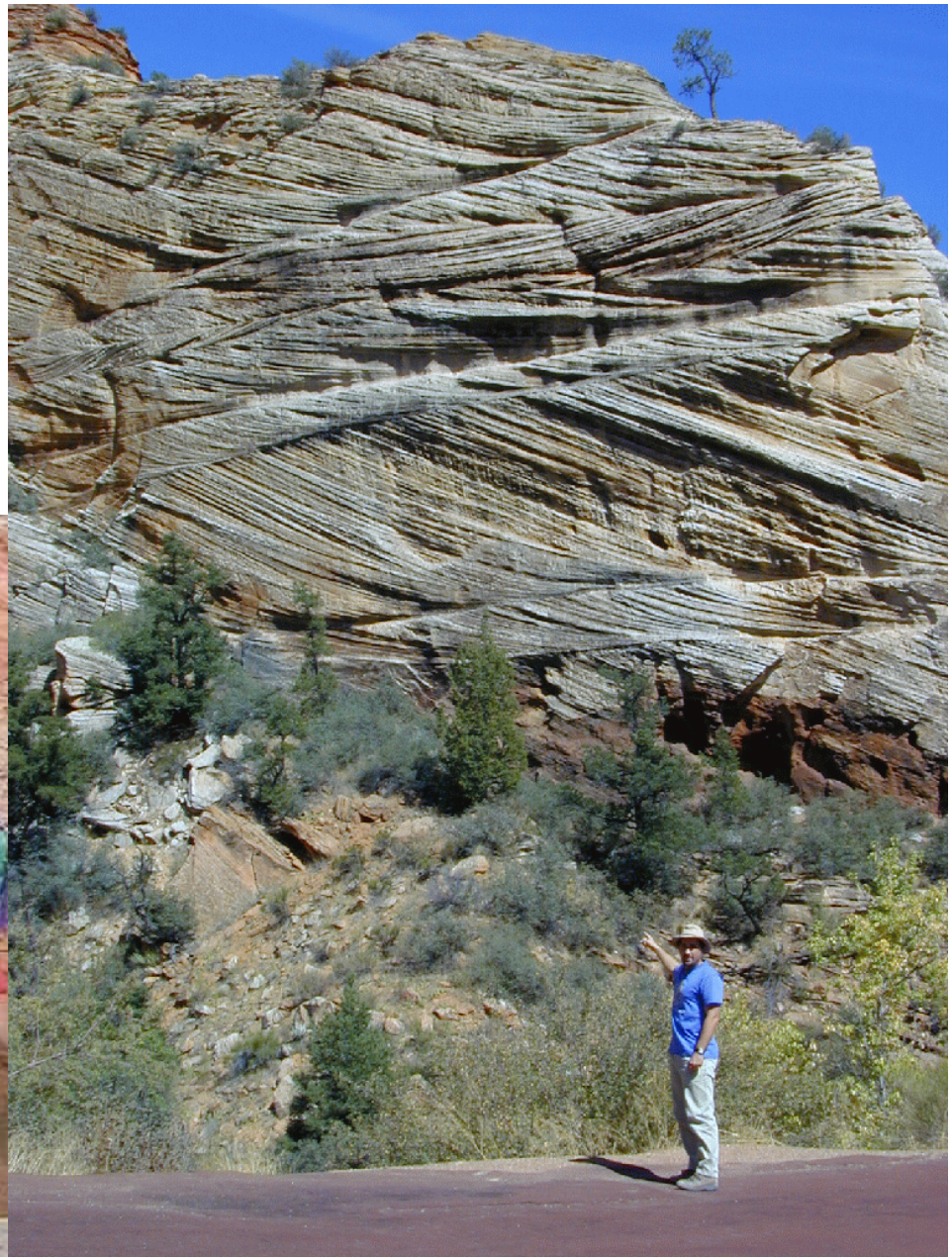
A

B

David McGeary

Aerial photo of underwater dunes of **“Ooids”** chemically precipitated from sea water on the shallow Bahamas Banks. An **Oolitic limestone** formed by the cementation of Ooids (small spheres)

Sedimentary Structures: Cross-bedding



Sedimentary Structures – graded beds

David McGeary

Metamorphism, Metamorphic Rocks, and Hydrothermal Rocks

Chapter 15

Metamorphism

Clay —Pressure→ Shale —Temp.→ Slate (mica)

(at equilibrium) (sedimentary) (metamorphic)

→

→

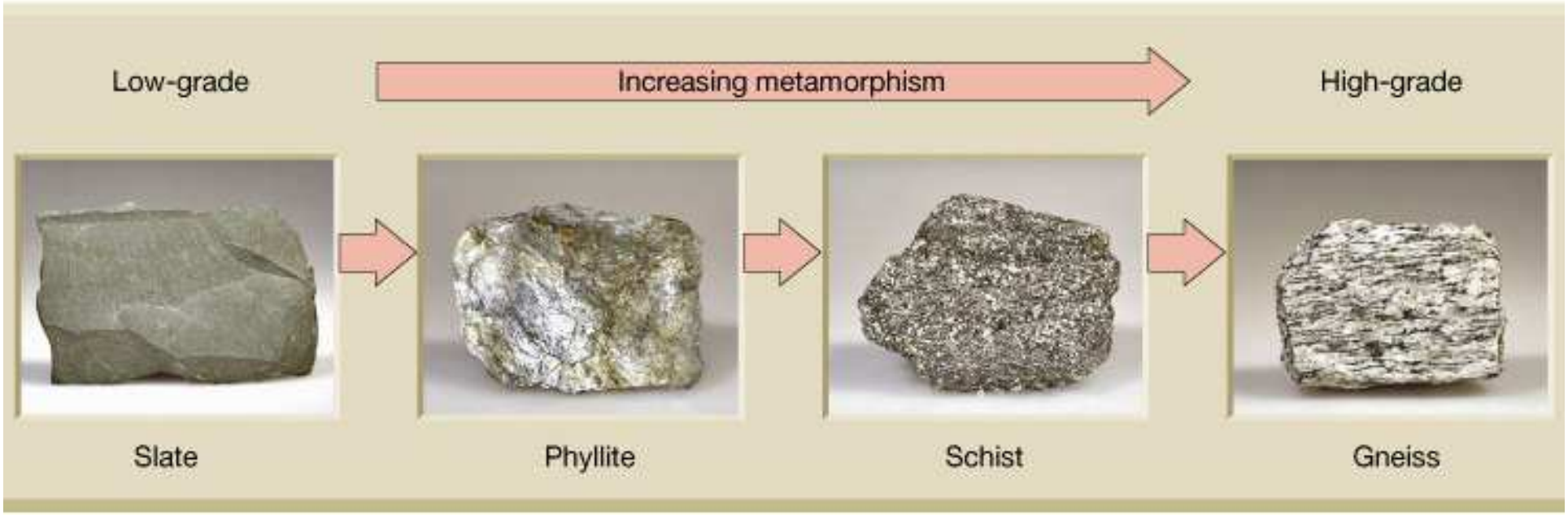
Factors Controlling Metamorphic Rock Characteristics

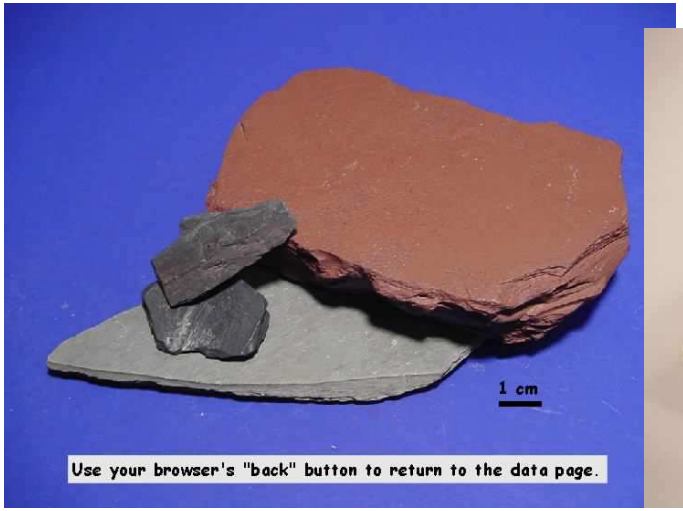
- Texture and mineral content of metamorphic rocks depend on:
  - Parent rock *composition*
  - *Temperature* during metamorphism
  - *Pressure* during metamorphism
  - Effects of *fluids*, such as water
  - *Time*

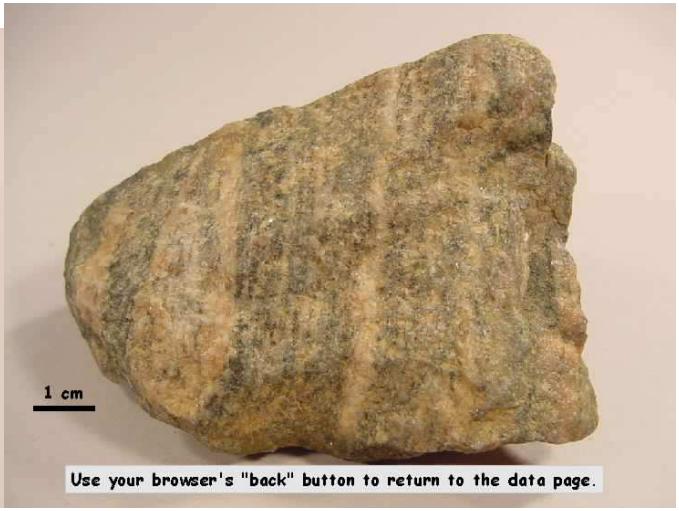
Foliation

- When a rock has a planar texture, it is said to be ***foliated***.
- There are three very different textures (from lowest to highest degree of metamorphism) are all variation of foliation and are important in classifying metamorphic rocks.
- **Slaty texture**: If the rock splits easily along flat and parallel planes
- **Schistose**: If needle-shaped minerals have grown parallel to a plane
- **Gneissic**: If the new minerals separated into distinct (light and dark) bands.

Foliated Rocks







Metamorphic grades as indicators of the pressure and temperature where the rock formed, and of the tectonic setting

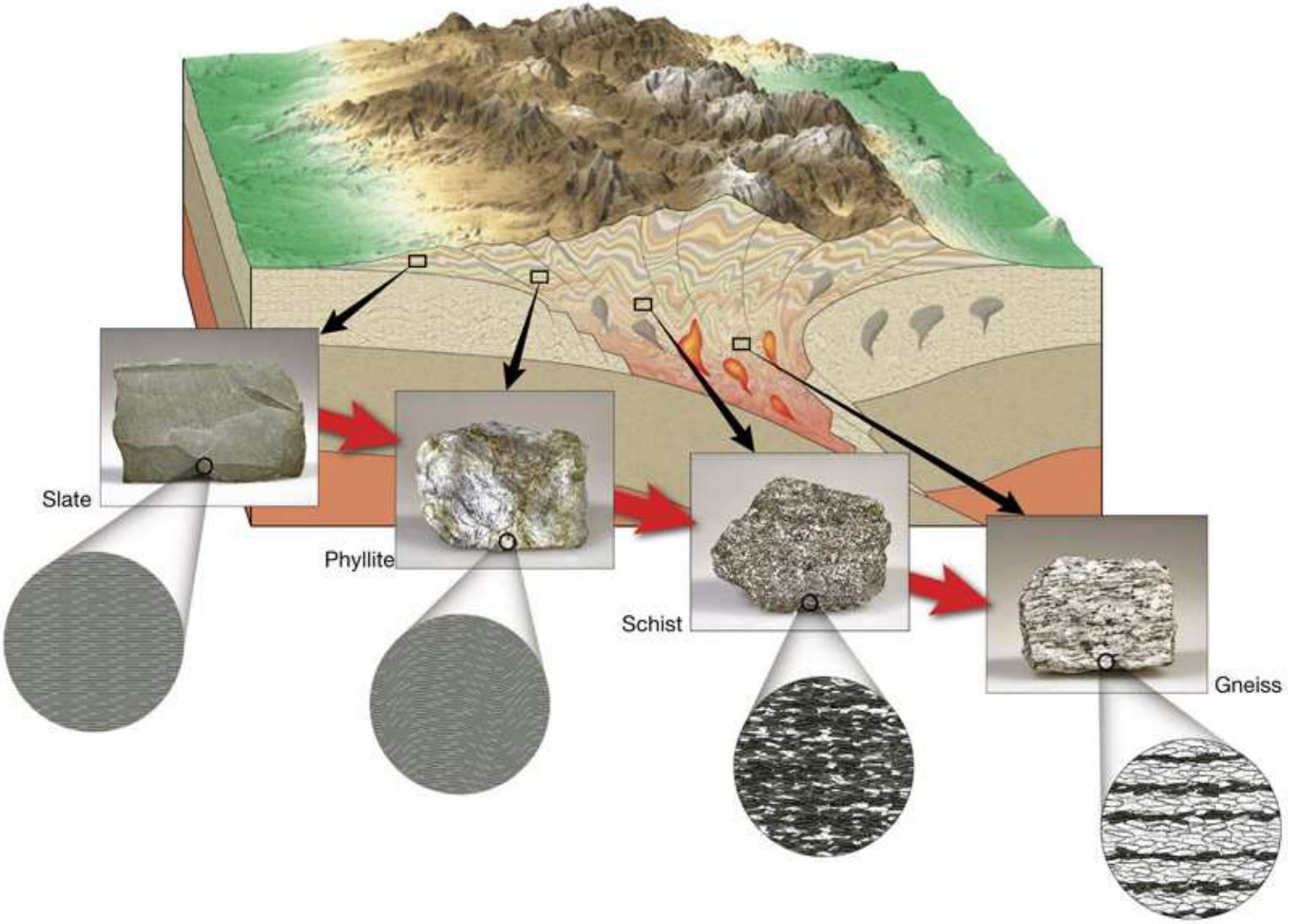


TABLE 15.1 Classification and Naming of Metamorphic Rocks (Based Primarily on Texture)

Nonfoliated

Name Based on Mineral Content of Rock

Usual Parent Rock	Rock Name	Predominant Minerals	Identifying Characteristics
Limestone	Marble	Calcite	Coarse interlocking grains of calcite (or, less commonly, dolomite)
Dolomite	Dolomite marble	Dolomite	Calcite (or dolomite) has rhombohedral cleavage; hardness intermediate between glass and fingernail. Calcite effervesces in weak acid
Quartz sandstone	Quartzite	Quartz	Rock composed of interlocking small granules of quartz. Has a sugary appearance and vitreous luster; scratches glass
Shale	Hornfels	Fine-grained micas	A fine-grained, dark rock that generally will scratch glass. May have a few coarser minerals present
Basalt	Hornfels	Fine-grained ferromagnesian minerals, plagioclase	

Foliated

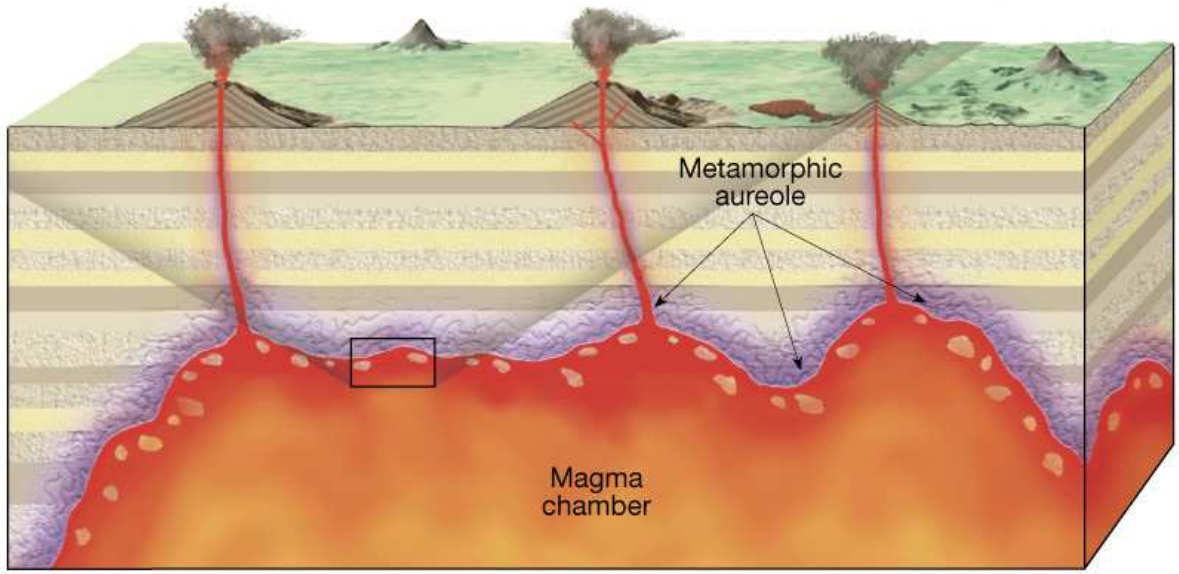
Name Based Principally on Kind of Foliation Regardless of Parent Rock. Adjectives Describe the Composition (e.g., biotite-garnet schist)

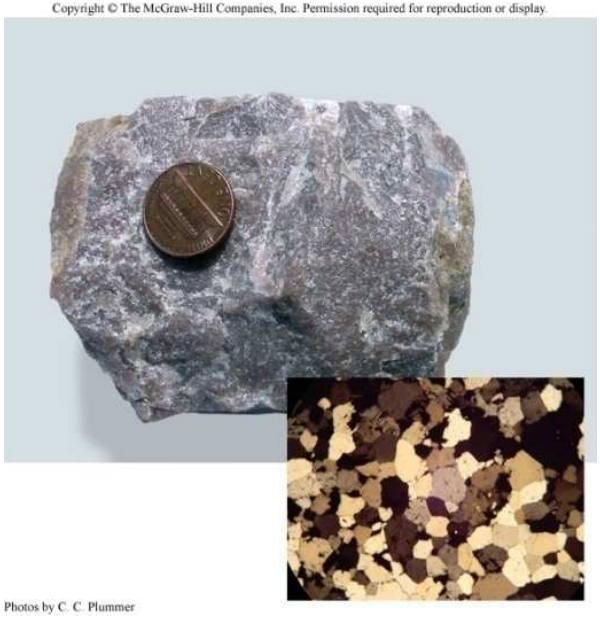
Texture	Rock Name	Typical Characteristic Minerals	Identifying Characteristics
Slaty	Slate	Clay and other sheet silicates	A very fine-grained rock with an earthy luster. Splits easily into thin, flat sheets
Intermediate between slaty and schistose	Phyllite	Mica	Fine-grained rock with a silky luster. Generally splits along wavy surfaces
Schistose	Schist	Biotite and muscovite amphibole	Composed of visible platy or elongated minerals that show planar alignment. A wide variety of minerals can be found in various types of schist (e.g., garnet-mica schist, hornblende schist, etc.).
Gneissic	Gneiss	Feldspar	Light and dark minerals are found in separate, parallel layers or lenses. Commonly, the dark layers include biotite and hornblende; the light-colored layers are composed of feldspars and quartz. The layers may be folded or appear contorted

Types of Metamorphism

- ***Contact metamorphism***
  - *High temperature* is dominant factor
  - Produces *non-foliated* rocks
  - Occurs adjacent to magma bodies intruding cooler country rock
  - Occurs in narrow zone (~1-100 m wide) known as contact *aureole*
  - Rocks may be fine- (e.g., hornfels) or coarse-grained (e.g., marble, quartzite)

Photo A by C. C. Plummer





Photos by C. C. Plummer

Types of Metamorphism

- *Regional metamorphism*
  - *High pressure* is dominant factor
  - Results in rocks with *foliated* textures
  - Prevalent in intensely deformed mountain ranges
  - May occur over wide temperature range
  - Higher pressure and temperature will produce increased *metamorphic grade*
  - Prograde metamorphism of shale produces:
    - *slate*
    - *phyllite*
    - *schist*
    - *gneiss*

Types of Metamorphism

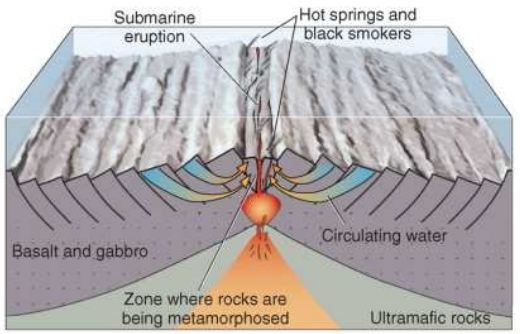
- *Partial melting* during metamorphism produces *migmatites*
  - *Migmatites* exhibit both intrusive igneous and metamorphic textures
- *Shock metamorphism* is produced by rapid application of extreme pressure
  - Meteor impacts produce this
  - Shocked rocks are found around and beneath *impact craters*

Photo by C. C. Plummer

Photo by Frank M. Hanna

Hydrothermal Processes

- Rocks precipitated from or altered by hot water are referred to as *hydrothermal*
  - Common at *divergent plate boundaries*
- Hydrothermal processes:
  - *Metamorphism*
    - Water transmits *pre-existing ions* between grains
  - *Metasomatism*
    - Water adds *new ions* to the rock



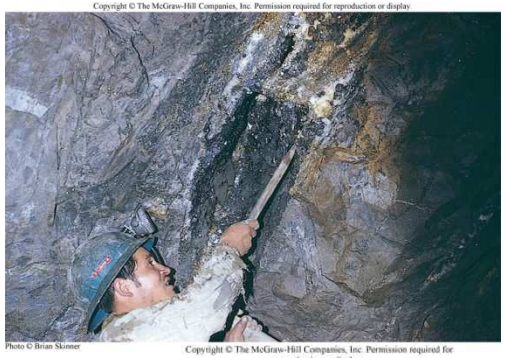
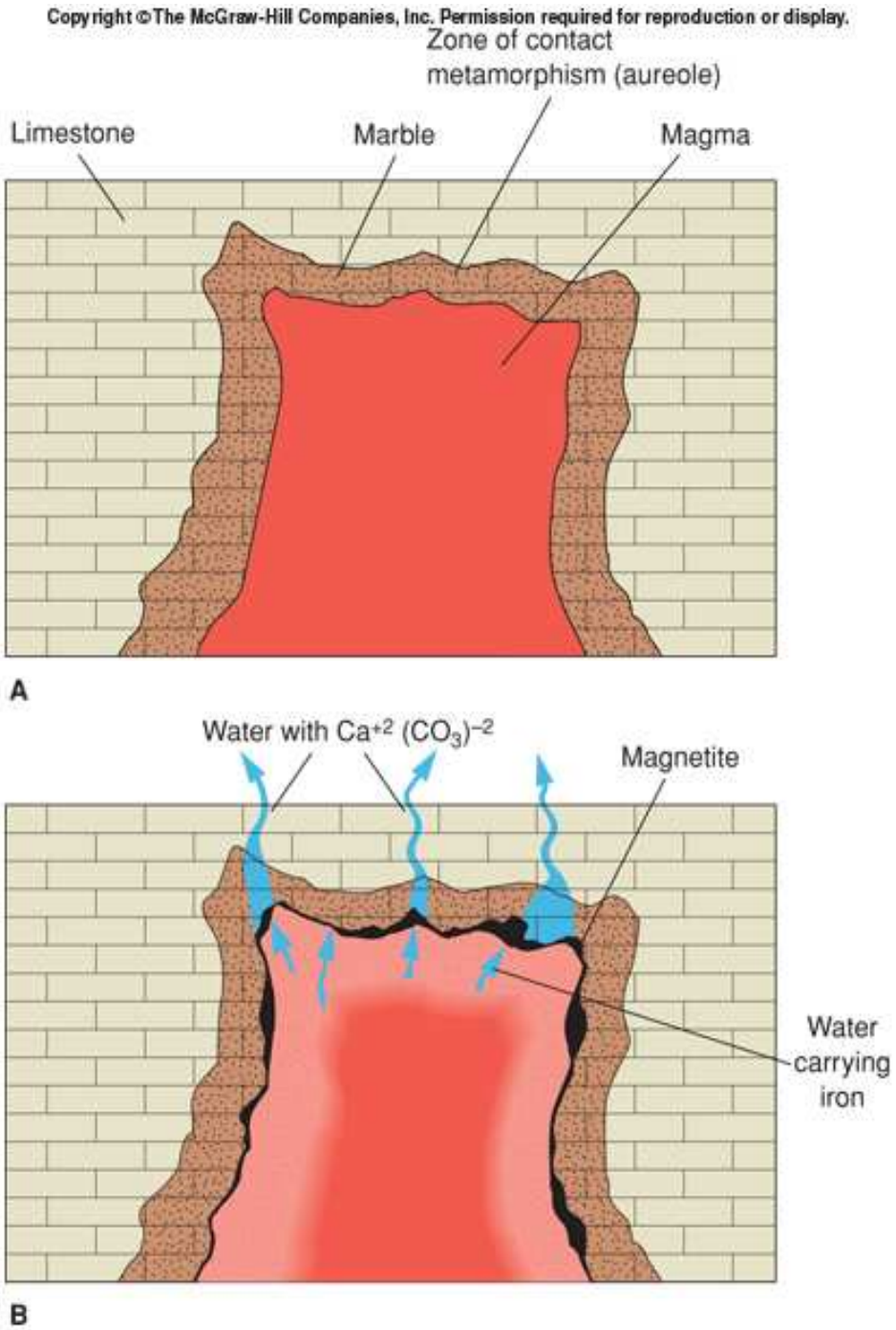


Photo © Brian Skinner

Photo courtesy of Kennecott Copper Company

Contact Metasomatism

Metamorphism coupled with the introduction of ions from an external source

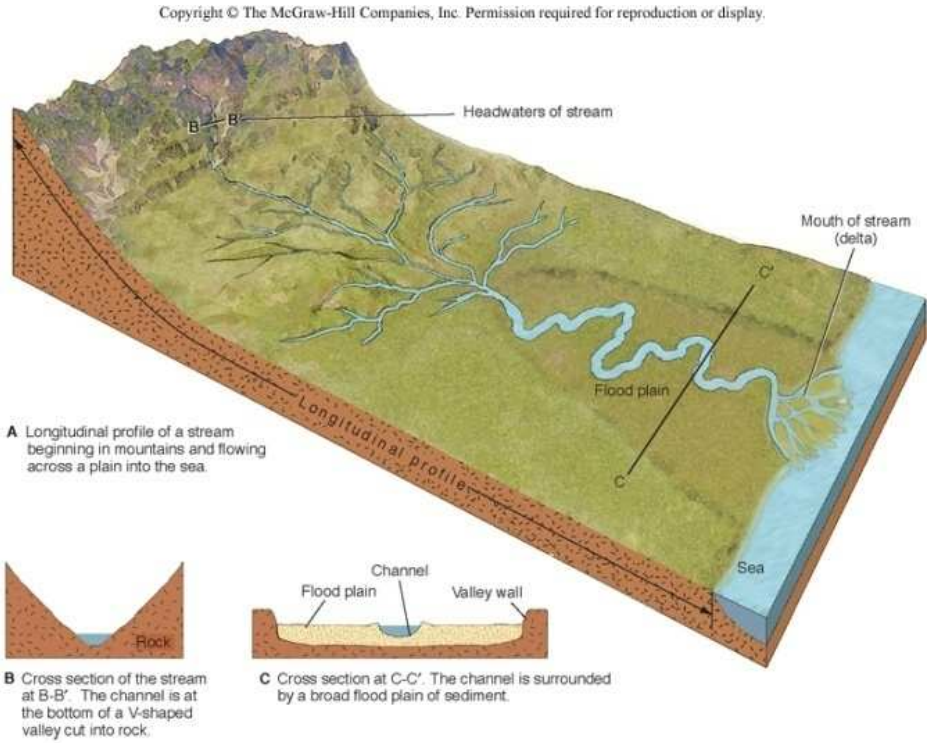


Streams and Floods

Chapter 16

Running Water

- *Stream* - a body of running water, confined to a channel, that runs downhill under the influence of gravity
  - *Headwaters* - upper part of stream near its source in the mountains
  - *Mouth* - place where a stream enters sea, lake or larger stream

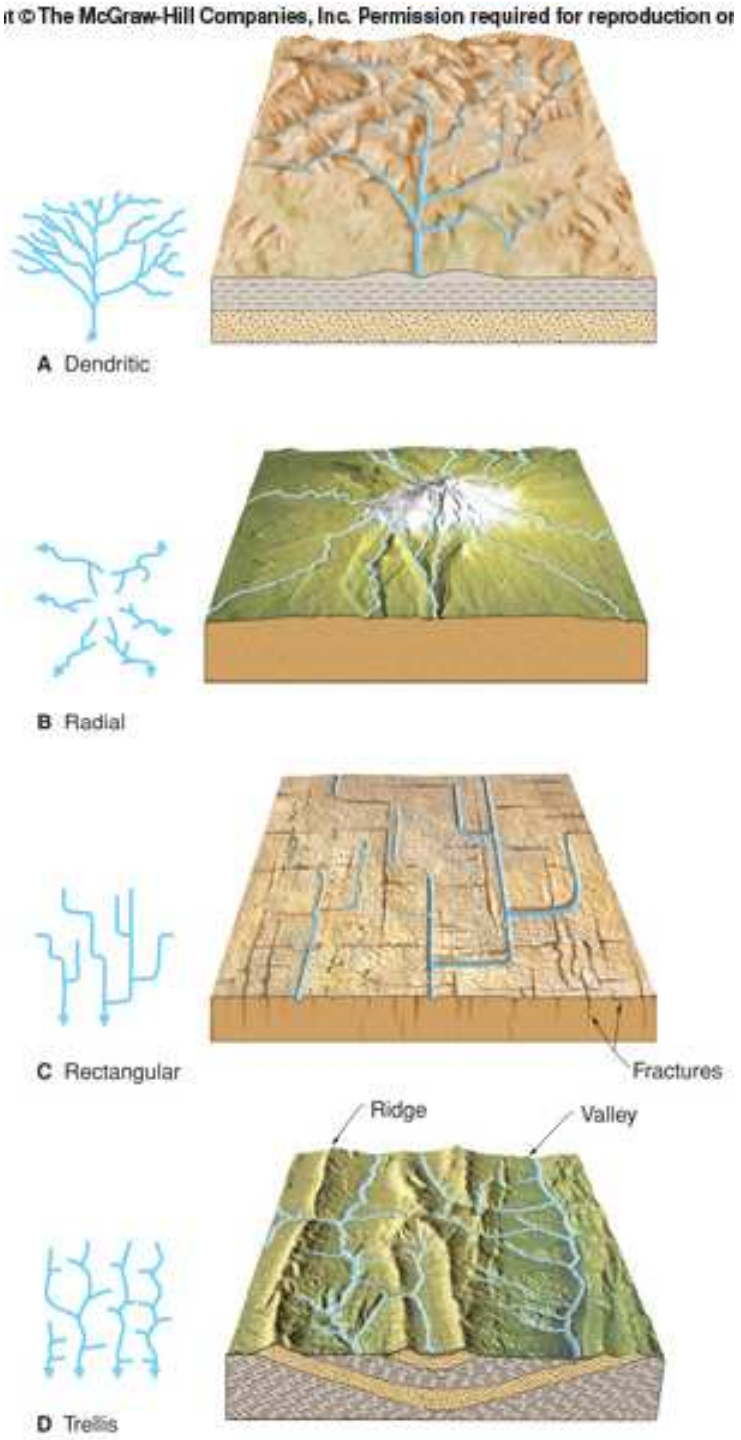


- **Tributaries:** drain into larger streams

- **Distributaries:** drain away from larger streams

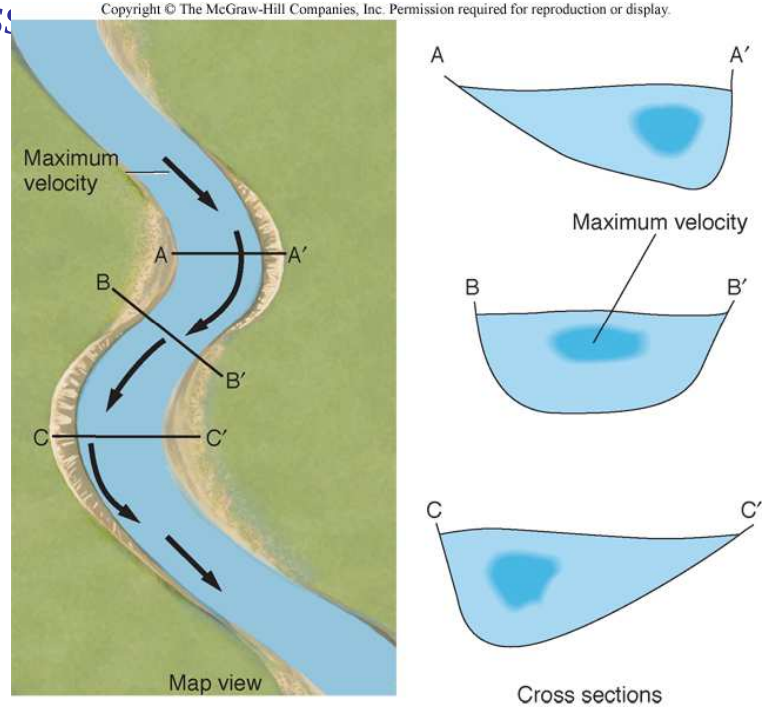
Drainage Patterns

- Dendritic – uniformly erodible
- Radial – high conical mountains/volcanoes
- Rectangular – regularly fractured rock
- Trellis – alternating resistant vs. nonresistant bed rock (e.g. limestone and shale)



Stream Erosion

- Stream erosion (and deposition) controlled by flow *velocity* and *discharge*
  - *Stream velocity* controlled by stream *gradient* (slope), *channel shape* and *channel roughness*
    - Maximum velocity near *center* of channel
  - Floods involve increased velocity and *discharge* (volume of water passing a particular point in a stream over time)
- Higher stream velocities promote erosion and transport of coarser sediments



Sediment Transportation

- Sediment load transported by a stream can be subdivided into *bed load*, *suspended load*, and *dissolved load*

- *Bed load* - large or heavy particles that travel on the streambed
  - *Traction load* - large particles that travel along the streambed by rolling, sliding or dragging
  - *Saltation load* - medium particles (typically sand-sized) that travel downstream by bouncing along - sometimes in contact with the streambed and sometimes suspended in the flowing water

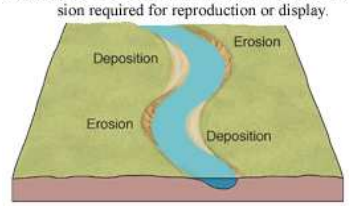
- *Suspended load* - sediment that is small/light enough to remain above the stream bottom by turbulent flow for an indefinite period of time

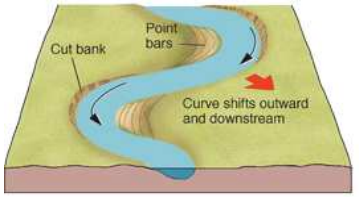
- *Dissolved load* - dissolved ions produced by chemical weathering of soluble minerals upstream

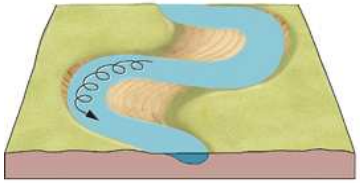
Sediment Deposition

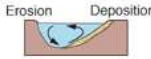
- *Meandering streams* flow faster along the outside of bends and more slowly along the inside, depositing *point bars* on the insides of the meanders

- *Meander cutoffs (Oxbow lake)* may form when a new, shorter channel is cut through the narrow neck of a meander (as during a flood)





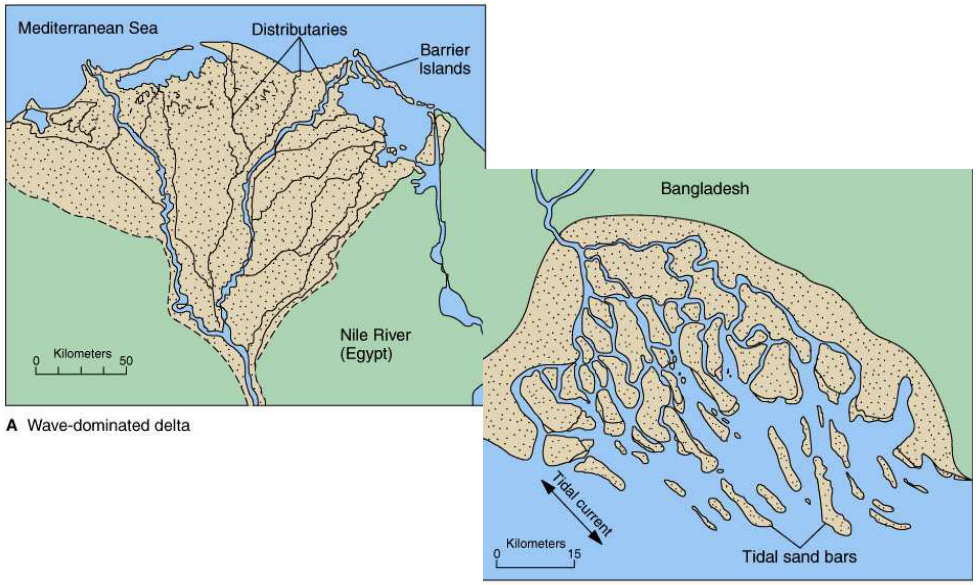




Corkscrew water motion on a curve helps cause erosion and deposition

Sediment Deposition

- *Delta* - body of sediment deposited at the mouth of a river when flow velocity decreases
  - Surface marked by shifting *distributary* channels
  - Shape of a delta depends on whether its *wave-dominated*, *tide-dominated*, or *stream-dominated*



Ground Water

Chapter 17

Ground Water

- *Ground Water* lies beneath the ground surface, filling pores in sediments and sedimentary rocks and fractures in other rock types
- Represents *0.6%* of the hydrosphere (35x the water in all lakes and rivers combined)
  - Resupplied by slow *infiltration of precipitation*
  - Generally cleaner than surface water
  - Accessed by *wells*

Porosity and Permeability

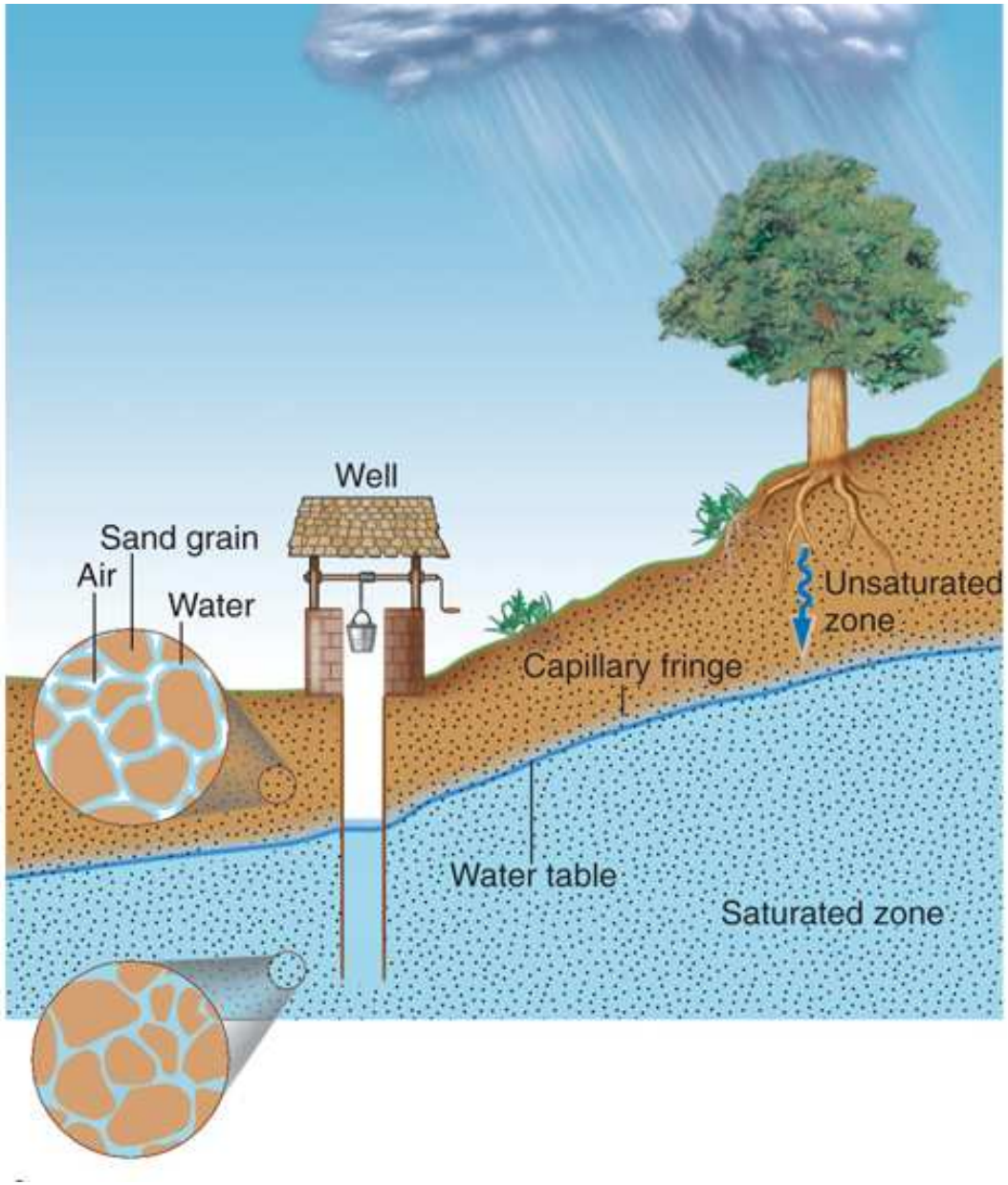
- *Porosity* - the percentage of rock or sediment that consists of voids or openings
  - Measurement of a rock's ability to hold water
  - Loose sand has ~30-50% porosity
  - Compacted sandstone may have only 10-20% porosity

- *Permeability* - the capacity of a rock to transmit fluid through pores and fractures
  - Interconnectedness of pore spaces
  - Most sandstones and conglomerates are porous *and* permeable
  - Granites, schists, unfractured limestones are *impermeable*

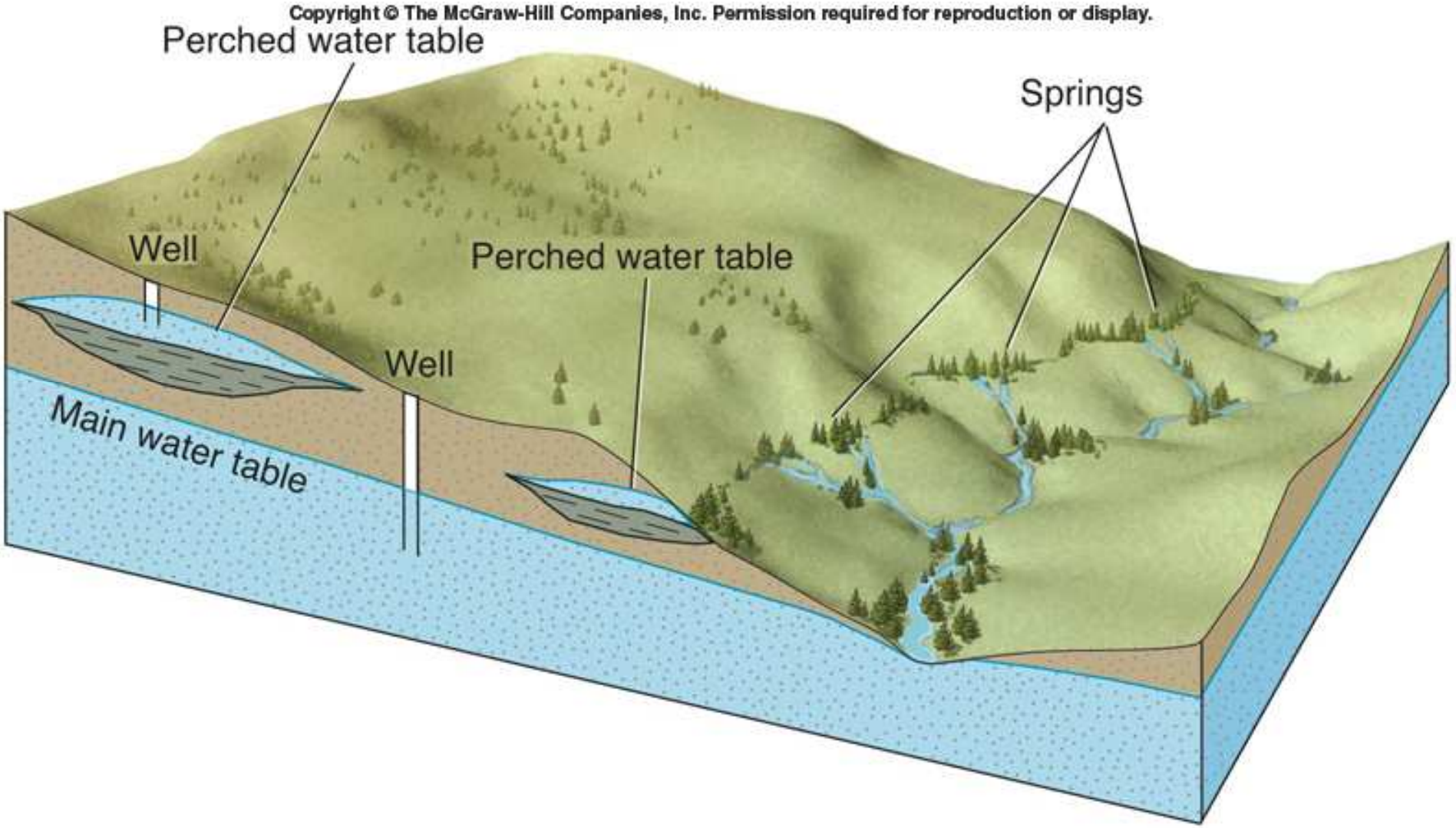
TABLE 17.1 Porosity and Permeability of Sediments and Rocks

Sediment	Porosity (%)	Permeability
Gravel	25 to 40	Excellent
Sand (clean)	30 to 50	Good to excellent
Silt	35 to 50	Moderate
Clay	35 to 80	Poor
Glacial till	10 to 20	Poor to moderate
Rock		
Conglomerate	10 to 30	Moderate to excellent
Sandstone		
Well-sorted, little cement	20 to 30	Good to very good
Average	10 to 20	Moderate to good
Poorly sorted, well-cemented	0 to 10	Poor to moderate
Shale	0 to 30	Very poor to poor
Limestone, dolomite	0 to 20	Poor to good
Cavernous limestone	up to 50	Excellent
Crystalline rock		
Unfractured	0 to 5	Very poor
Fractured	5 to 10	Poor
Volcanic rocks	0 to 50	Poor to excellent

Water Table


Well
Sand grain
Air
Water
Unsaturated zone
Capillary fringe
Water table
Saturated zone

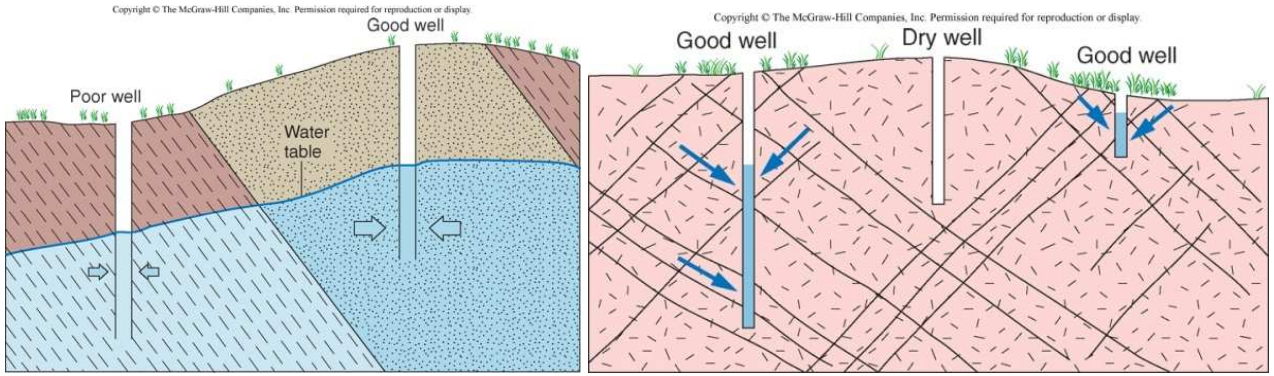
Perched Water Table



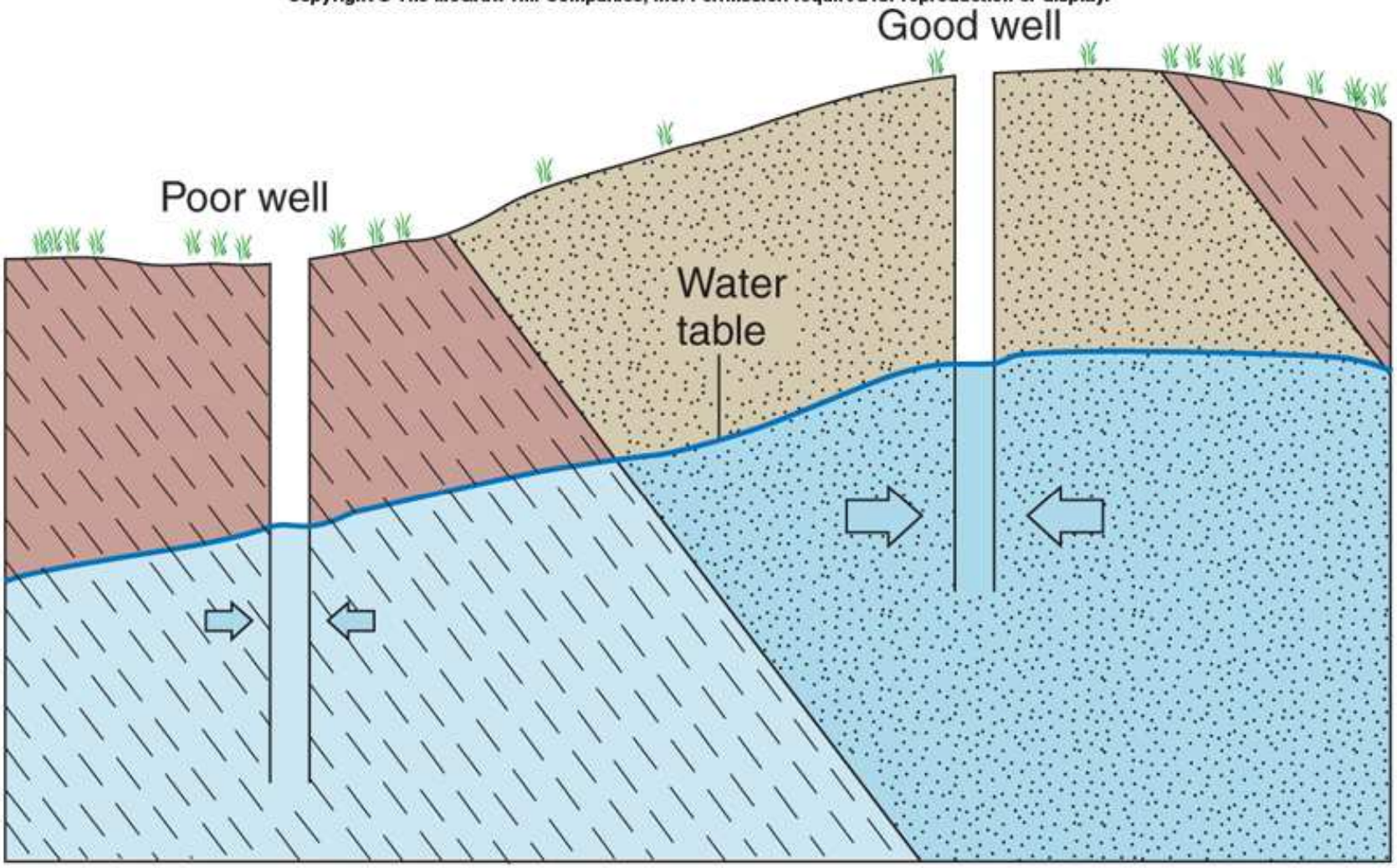
Perched water tables above lenses of less permeable shale within a large body of sandstone. Downward percolation of water is impeded by the less permeable shale.

Aquifers and Aquitards

- *Aquifer* - body of saturated rock or sediment through which water can move easily
  - Sandstone
  - Conglomerate
  - Well-jointed limestone
  - Sand and gravel
  - Highly fractured rocks



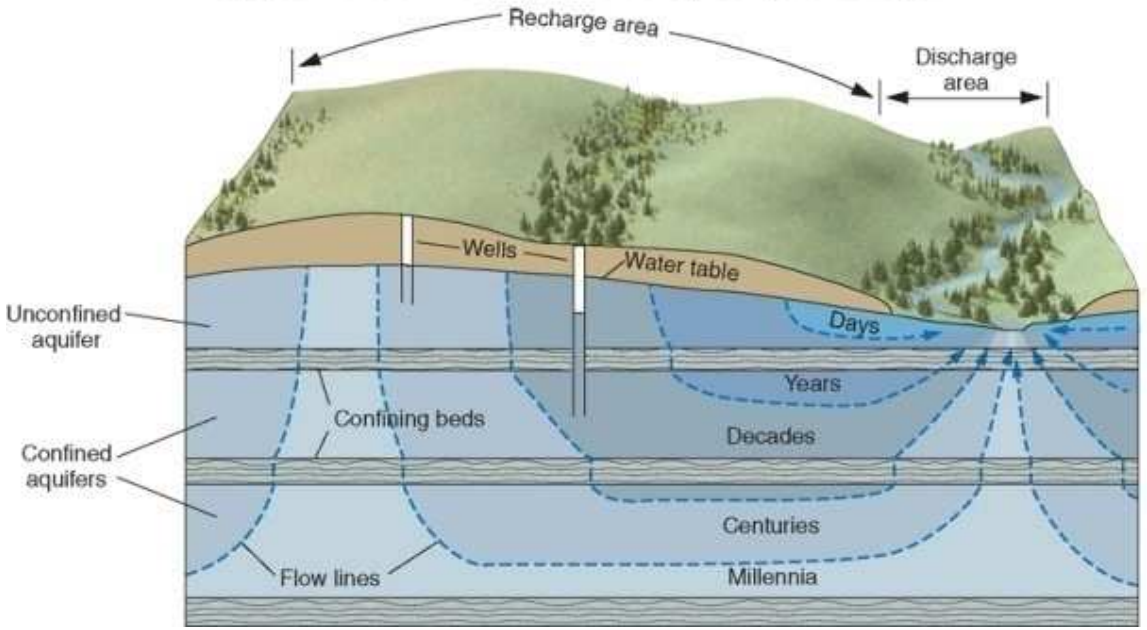
- *Aquitard* - rock/sediment that retards ground water flow due to low porosity and/or permeability
  - Shale, clay, unfractured crystalline rocks



A well must be installed in an aquifer to obtain water. The saturated part of the highly permeable sandstone is an aquifer, but the less permeable shale is not. Although shale is saturated, it will not readily transmit water.

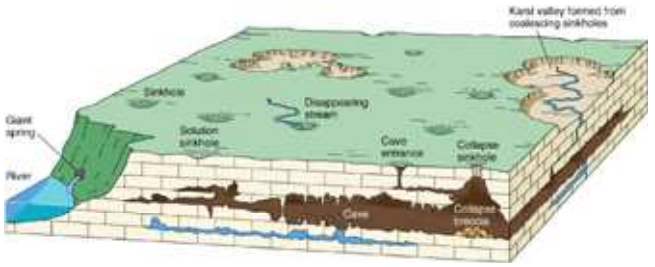
Unconfined vs. Confined Aquifers

- *Unconfined Aquifer*
  - Has a water table, and is only partly filled with water
  - Rapidly *recharged* by precipitation infiltrating down to the saturated zone
- *Confined Aquifer*
  - Completely filled with water under pressure
  - Separated from surface by impermeable *confining layer/aquitard*
  - *Very slowly* recharged



Caves, Sinkholes, and Karst

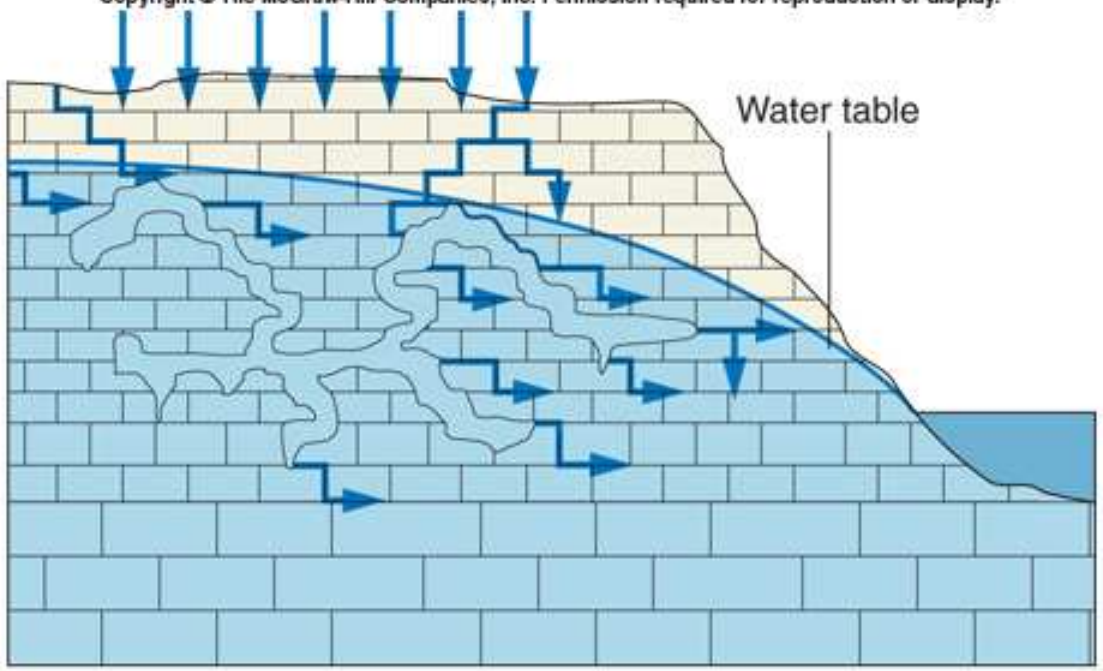
- *Caves (Caverns)* - naturally-formed underground chambers
  - Acidic ground water dissolves limestone along joints and bedding planes



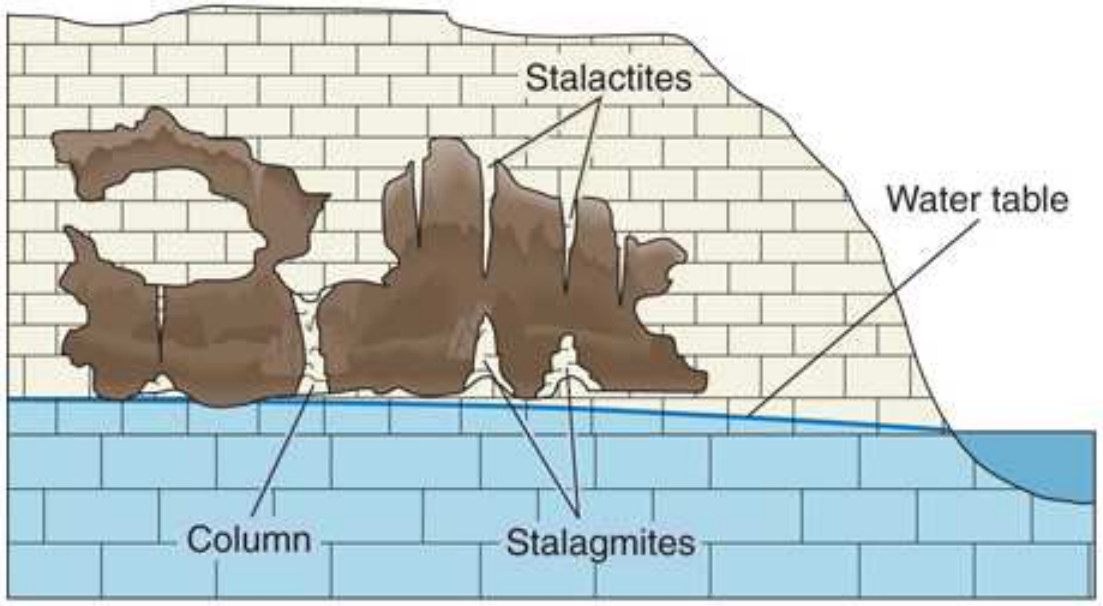
- Caves near the surface may collapse and produce *sinkholes*

- Rolling hills, disappearing streams, and sinkholes are common in areas with *karst topography*

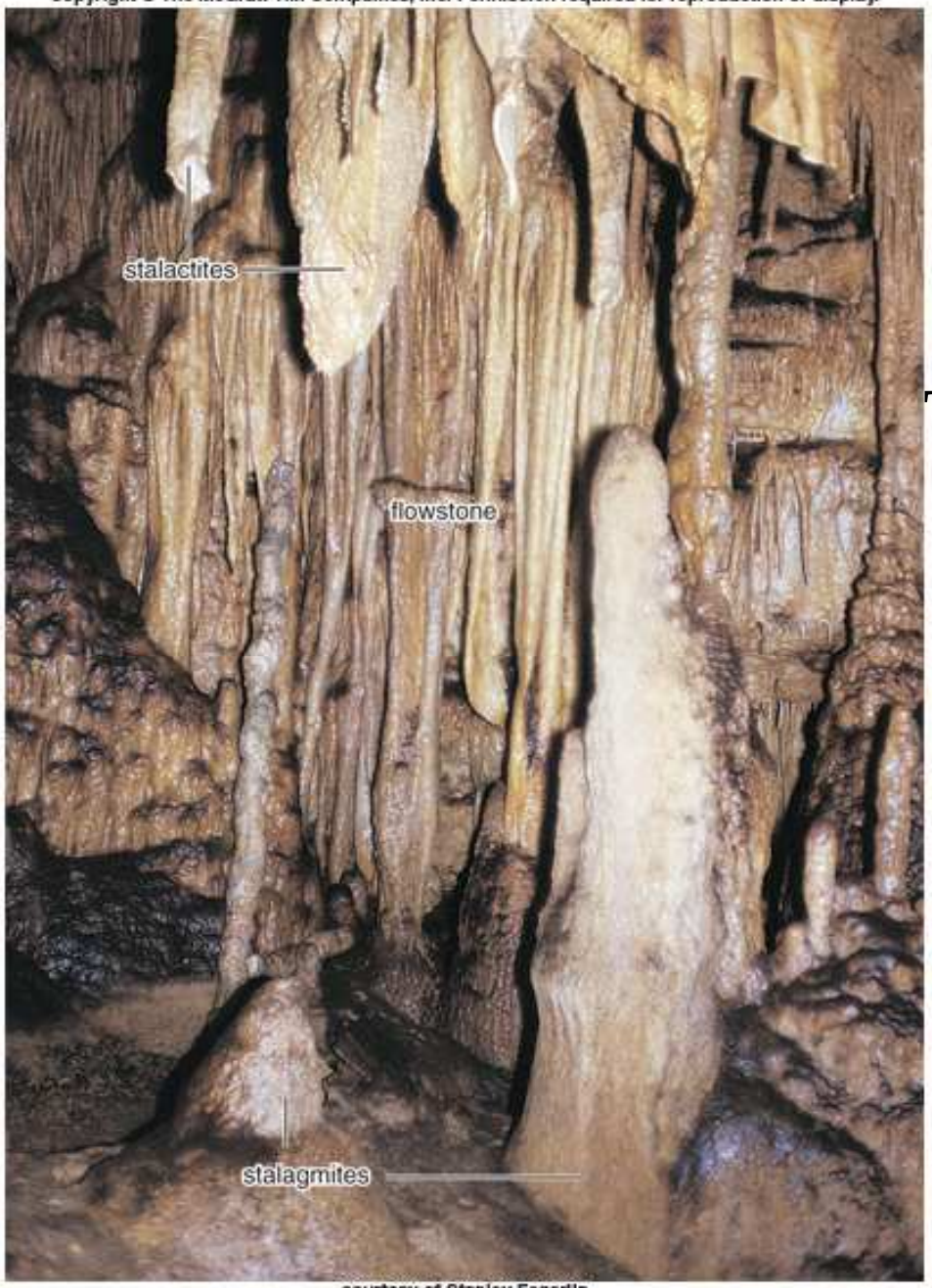
Cave Formation



A



B



courtesy of Stanley Fagerlin

Stalactites : hanging from cave ceiling

Stalagmites : formed on the cave floor

Together they are called as

Dripstone

or

Speleothems

Good Luck!