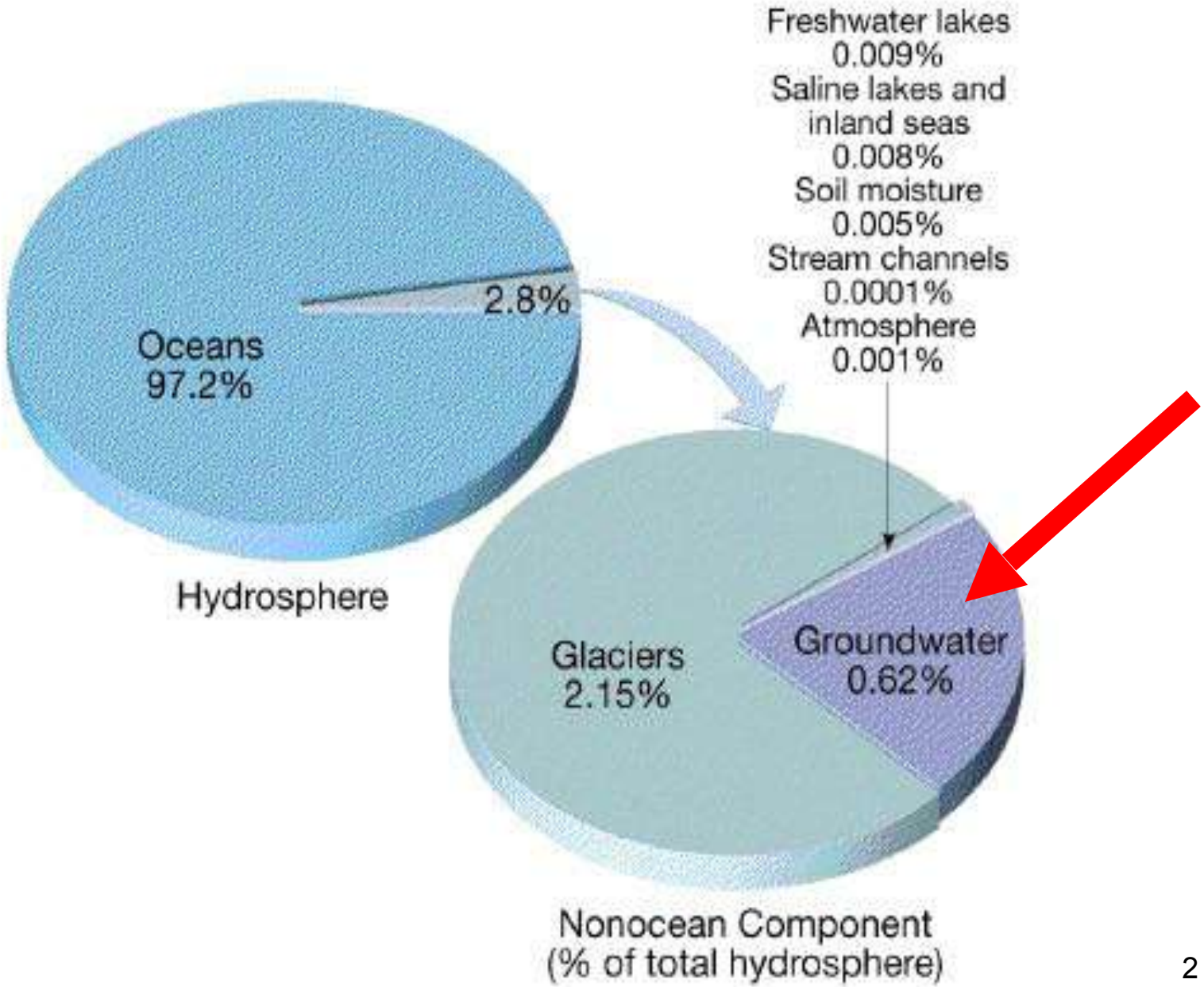
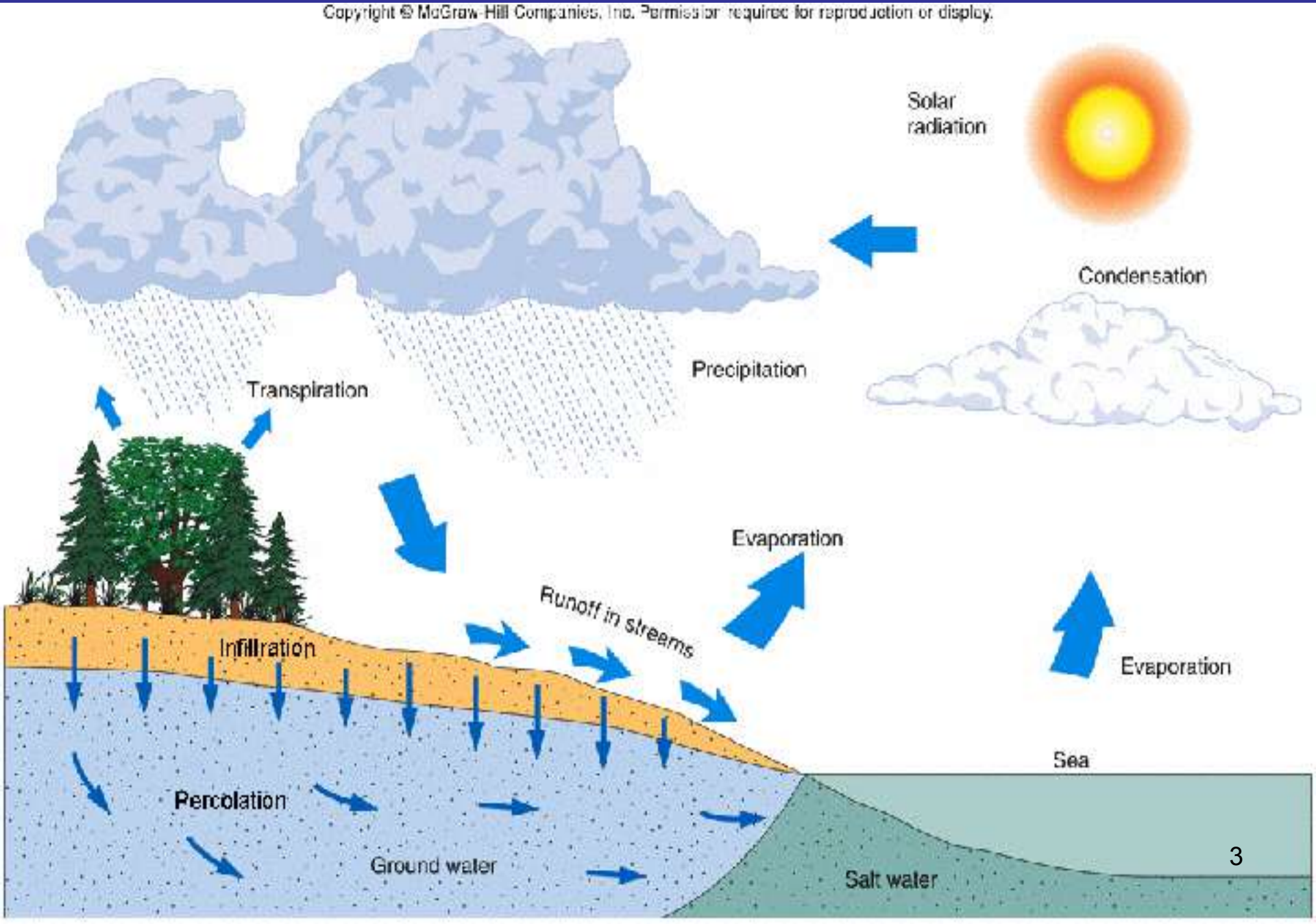
Module 17
Groundwater

Global Distribution of Water



The Hydrologic Cycle



Groundwater-Related Terms to Remember

- ***Aquifer:*** **a body of rock or soil that stores and easily transmits a significant quantity of groundwater**
  - **A confined aquifer is overlain by an aquitard**
  - **An unconfined aquifer is overlain by the water table**

- ***Aquitard:*** **an impermeable bed that hinders movement of groundwater**

- ***Artesian well:*** **a well in which the groundwater rises to a level higher than where it was first encountered**

- ***Cone of depression:*** **a cone-shaped depression in the water table surrounding a well from which water is pumped faster than it can move through the aquifer**

Groundwater-Related Terms to Remember

- ***Drawdown:*** **is the difference in elevation between the undisturbed water table and the bottom of a cone of depression**

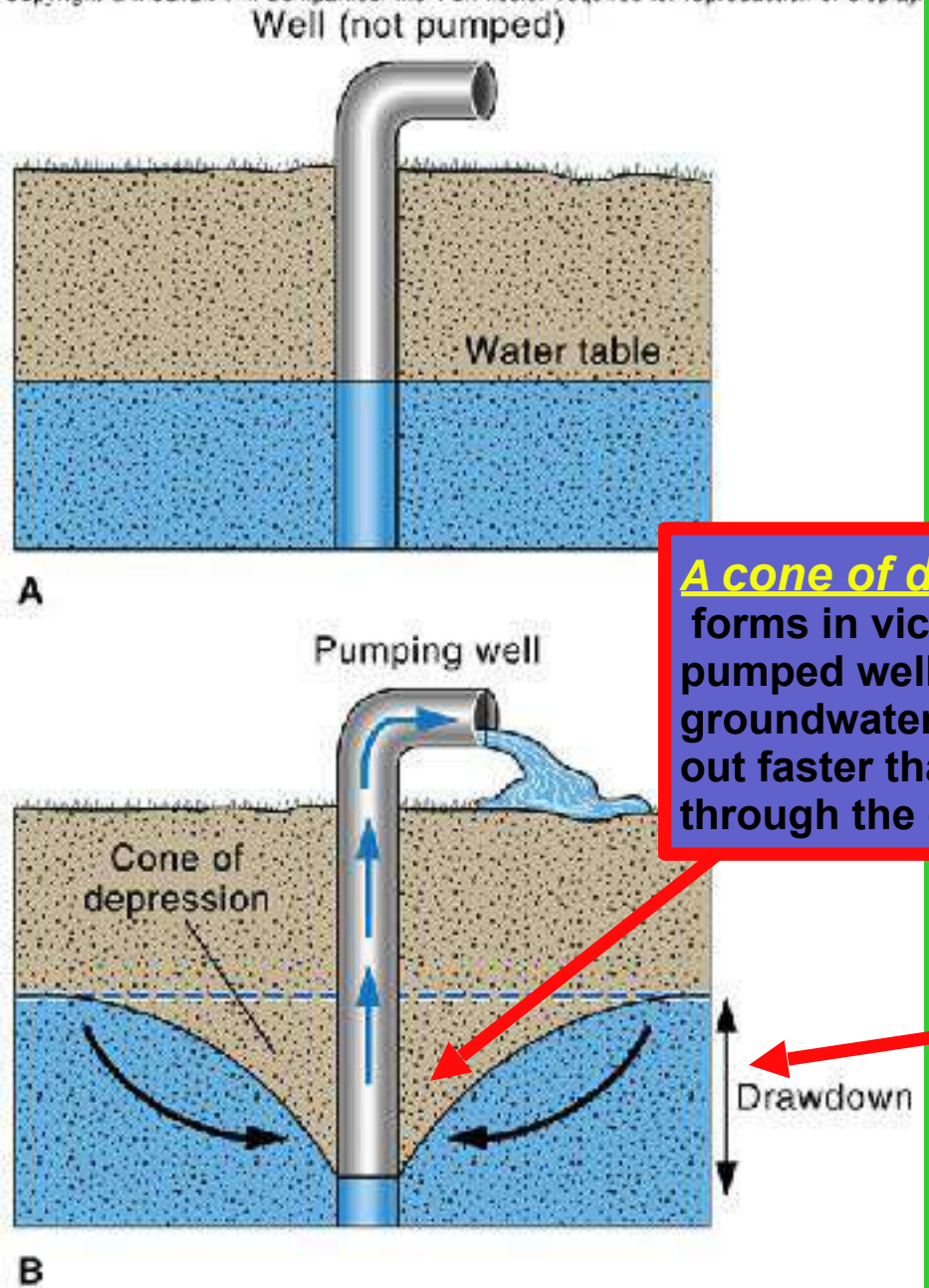
- ***Geyser:*** **a type of hydrothermal spring that intermittently erupts jets of hot water and steam**

- ***Groundwater:*** **water in the zone of saturation**

- ***Hard water:*** **does not lather readily with soap, due to high concentration(s) of Ca^{2+}, Mg^{2+}, Fe^{2+}, and/or Mn^{2+}**

- ***Karst topography:*** **formed in limestone bedrock in response to dissolution of the limestone by acidic water**
  - **Characterized by the presence of caves, sinkholes, disappearing streams, solution valleys, etc.**

Cone of Depression Produced by a Pumping Well



A cone of depression: **forms in vicinity of a pumped well because the groundwater is pumped out faster than it can move through the ground**

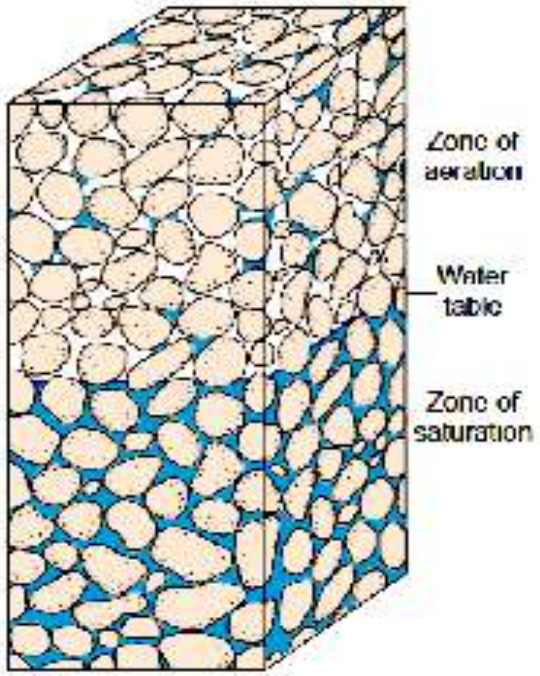


FIGURE 13.2 The water table is the upper surface of the zone of saturation. Water seeps into the ground through pore spaces in rock and soil. It passes first through the zone of aeration, in which the pore spaces are occupied by both air and water, and then into the zone of saturation, in which all of the pore spaces are filled with water. The depth of the water table varies with climate and amount of precipitation.

Drawdown:
is the difference in elevation between the undisturbed water table and the bottom of the cone of depression

Groundwater-Related Terms to Remember

- ***Perched water table:*** **unconfined groundwater separated from the underlying main body of groundwater by an aquitard and a zone of aeration**

- ***Percolation:*** **slow movement of water through small openings within a porous material**

- ***Permeability:*** **a measure of the ability of a material to transmit groundwater. Dependent upon**
  - **How many conduits are present**
  - **How big the conduits are**
  - **How straight the conduits are**

- ***Pore space:*** **any open space within a body of sediment or rock**

Various types of pore spaces

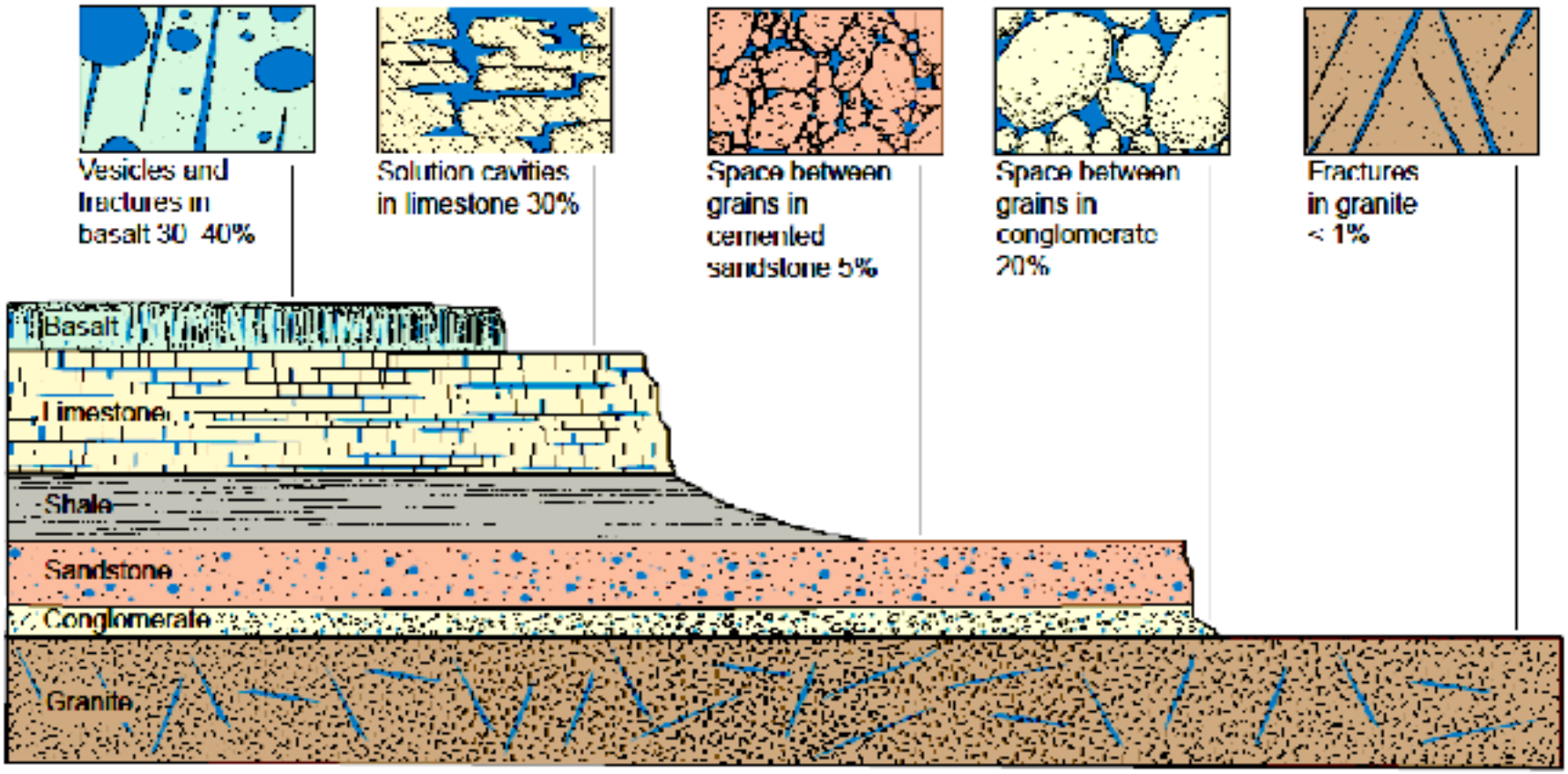


FIGURE 13.1 Various types of pore spaces in rocks permit the flow of groundwater.

Hamblin & Christiansen 2014

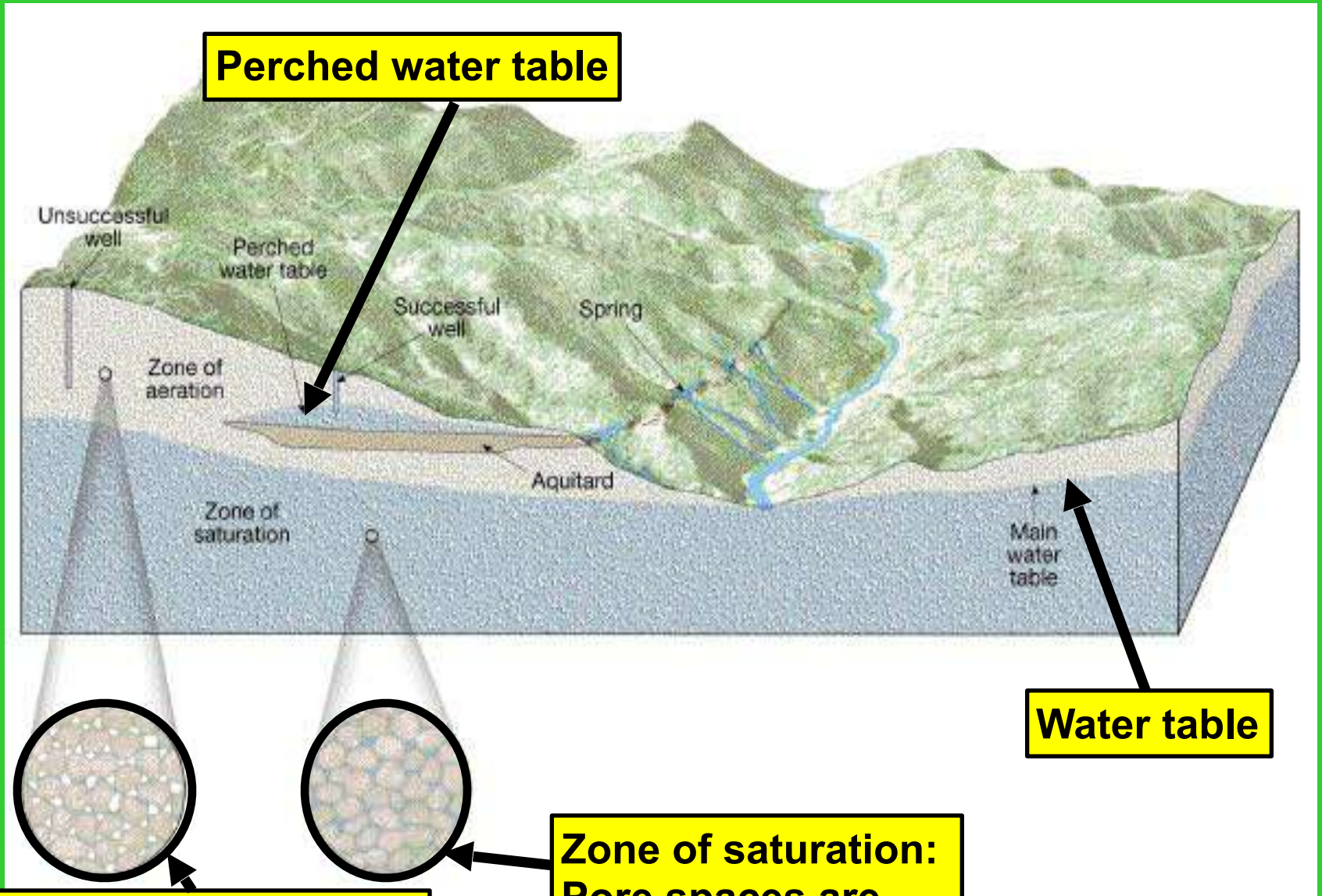
Groundwater-Related Terms to Remember

- ***Porosity***: **the percentage of a material occupied by pore spaces**
- ***Primary porosity***: **the spaces between grains composing the rock**
- ***Secondary porosity***: **cracks and caves produced by jointing, faulting, and dissolution of the bedrock**
- ***Sinkhole***: **a depression formed by collapse of the roof of a cave**
- ***Spring***: **a flow of groundwater naturally emerging at the Earth's surface**

Groundwater-Related Terms to Remember

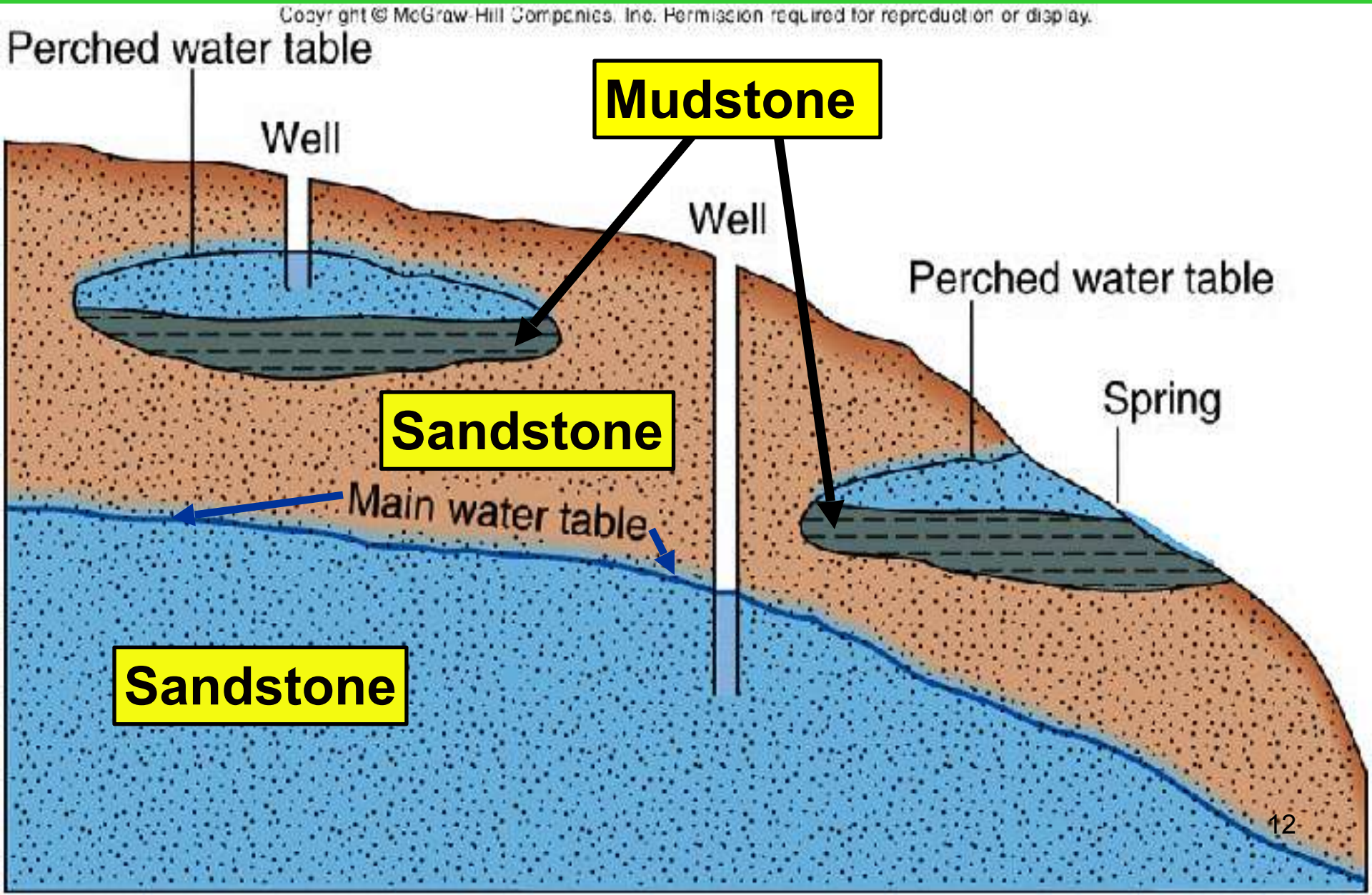
- ***Stalactite***: **an icicle-like structure attached to the ceiling of a cave**
- ***Stalagmite***: **a conical-shaped structure attached to the floor of a cave**
- ***Zone of aeration***: **the unsaturated region above the water table, the region where the pore spaces are filled partially with air and partially with water**
- ***Water table***: **the top of the zone of saturation**
- ***Zone of saturation***: **the region below the water table, the region where the pore spaces are completely filled with groundwater**

Features Associated with Subsurface Water



Perched Water Tables

(Plummer, McGeary, and Carlson, 2003, Physical Geology, 9th ed.)



Surface Exposure of the Water Table

The surface of any sea, lake, pond, stream, or spring is the water table

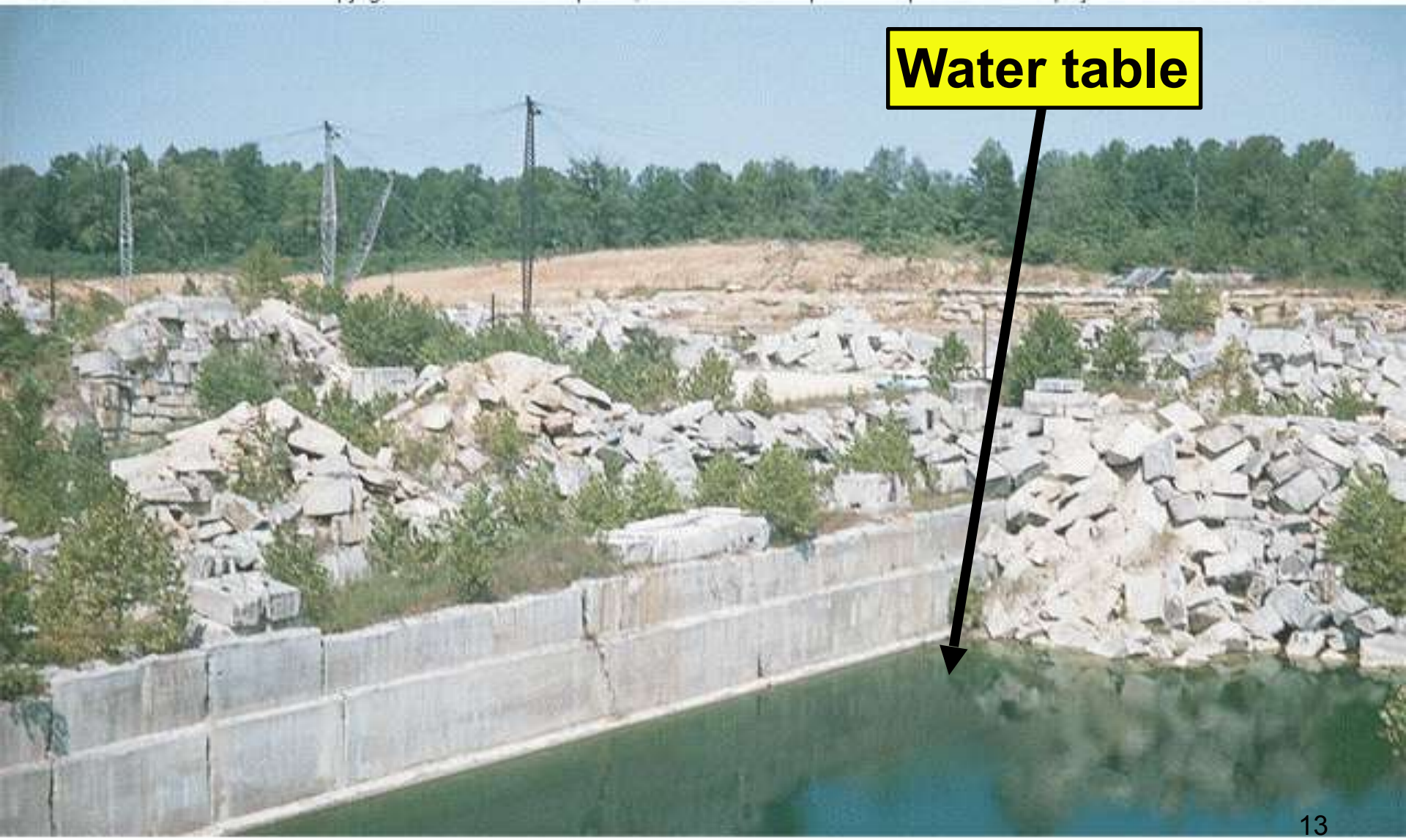
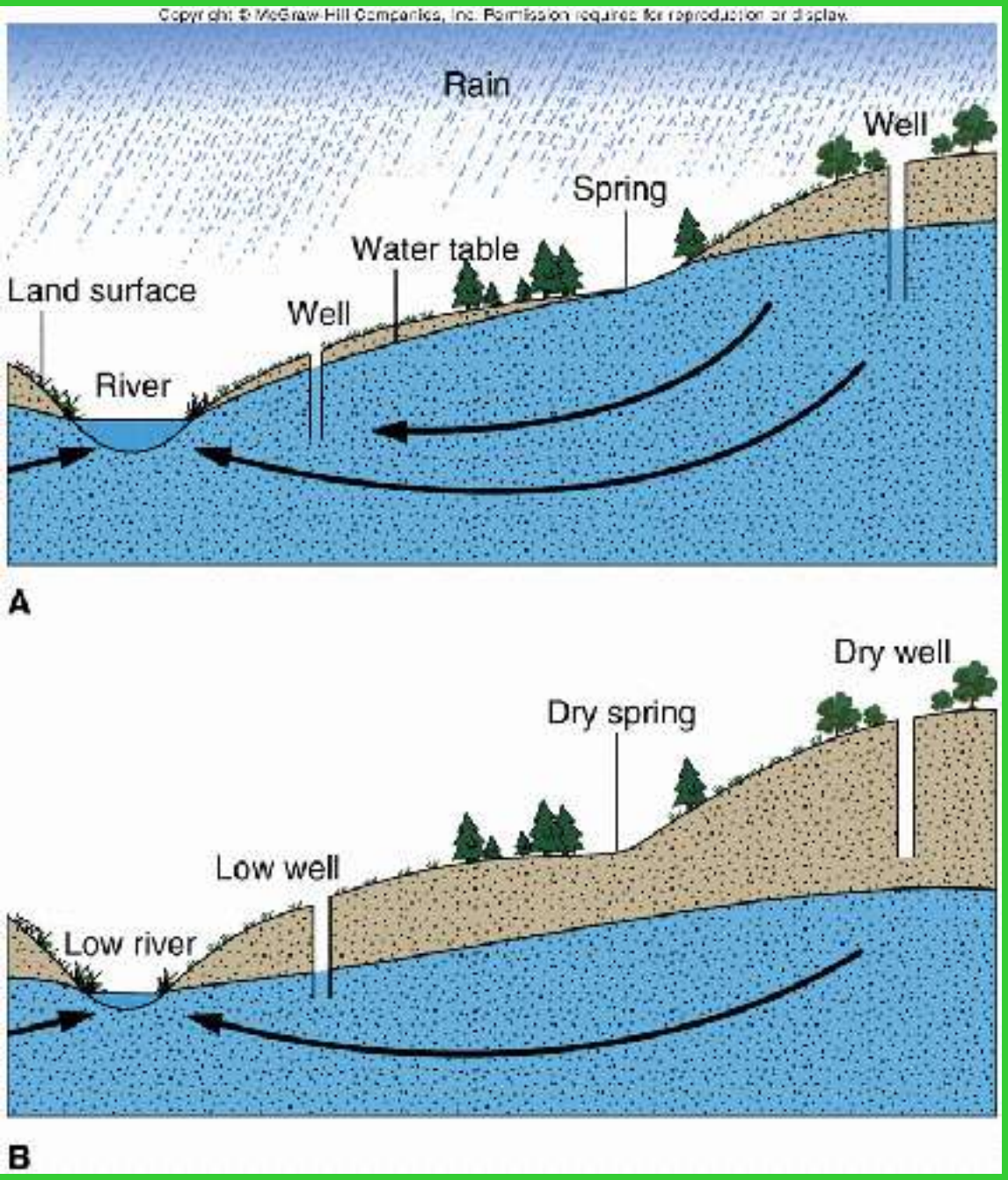


Photo by David McGeary



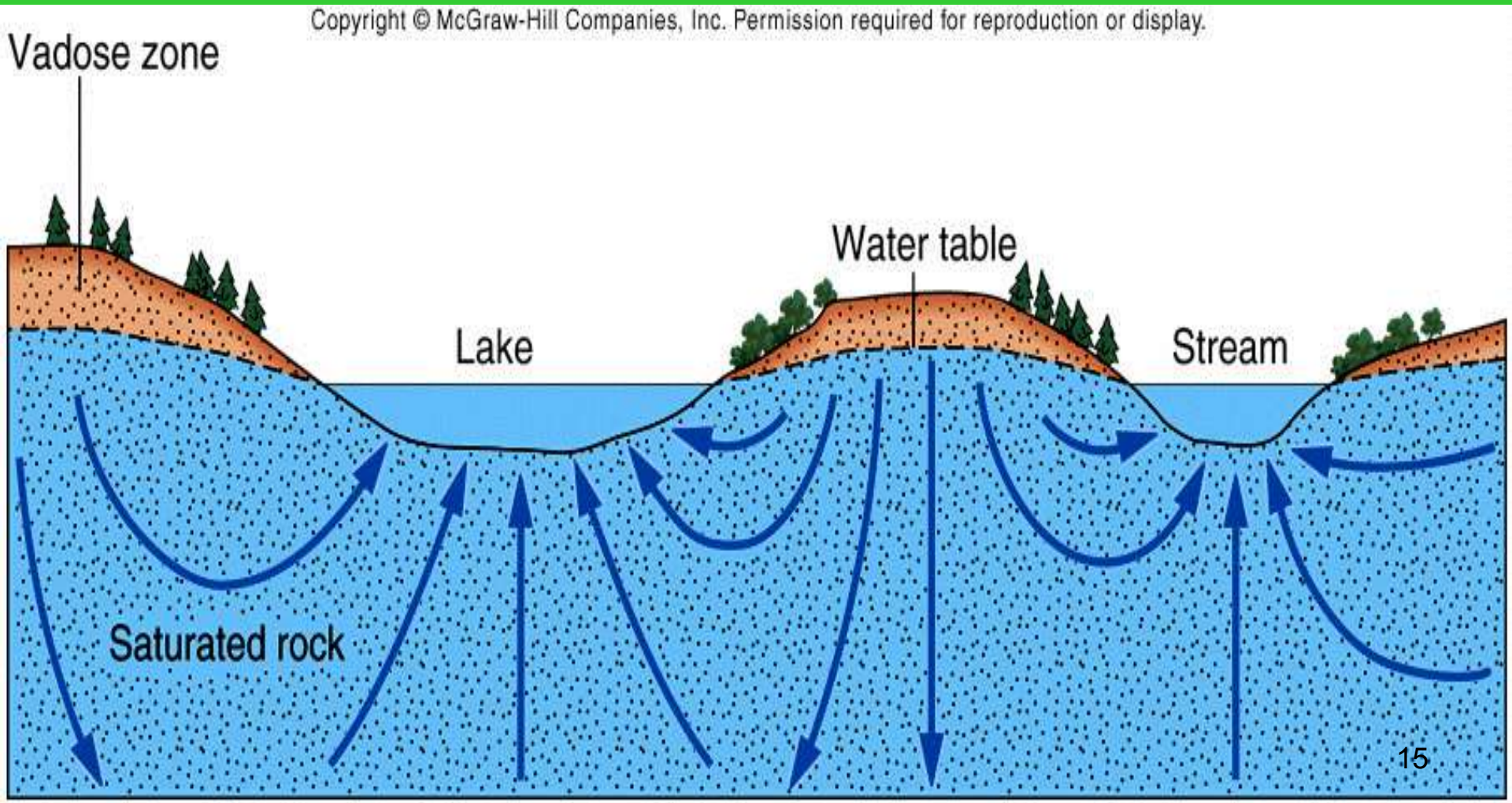
Movement of Groundwater

During wet weather the water table rises, is recharged

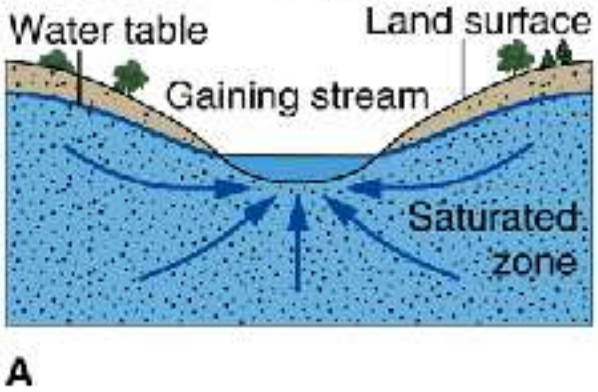
During drought the water table falls

Movement of Groundwater

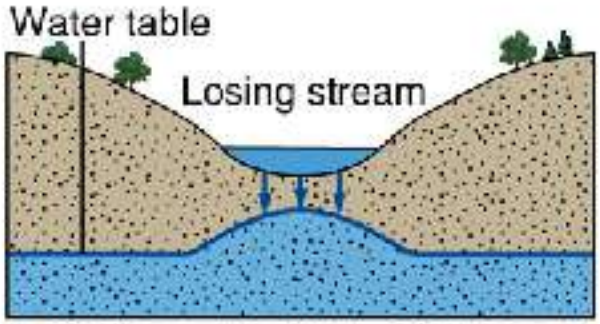
Note that the topography of the water table usually mimics the topography of the land



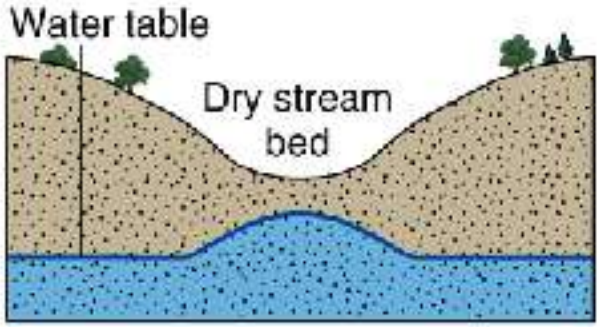
Gaining and Losing Streams



A



B



C

<u>A gaining stream</u>:
During rainy seasons ***<u>streams gain water</u>*** from the saturated zone

<u>A losing stream</u>:
During droughts ***<u>streams lose water</u>*** to the saturated zone

<u>In arid regions</u>:
The topography of the water table does not mimic the topography of the land

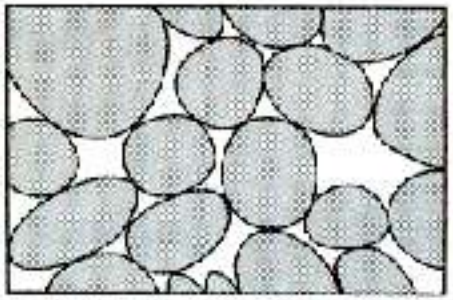
Porosity and Permeability of Sediments and Rocks

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, mudstone	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

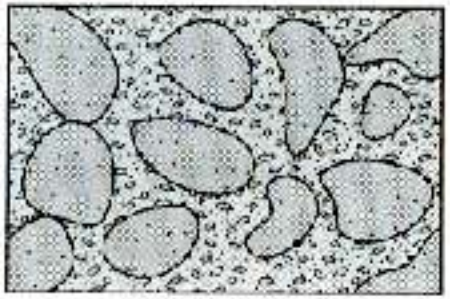
Primary Porosity

***Porosity*: the percent of a material occupied by pore spaces**



(*a*) Well-sorted sedimentary deposit deposit having high porosity

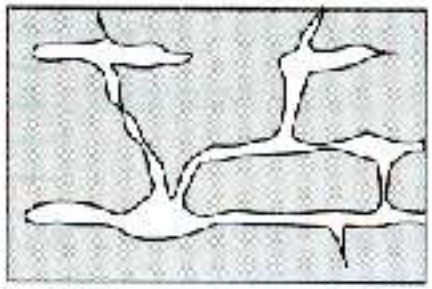
***Primary porosity*: the spaces between the grains composing the rock**



(*b*) poorly sorted sedimentary deposit having low porosity

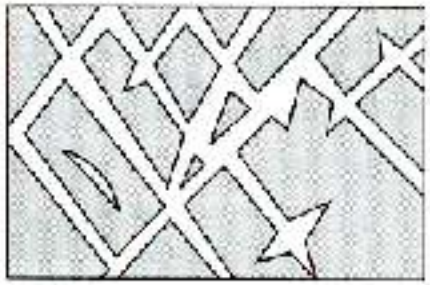
Secondary Porosity

***Porosity*: the percent of a material occupied by pore spaces**



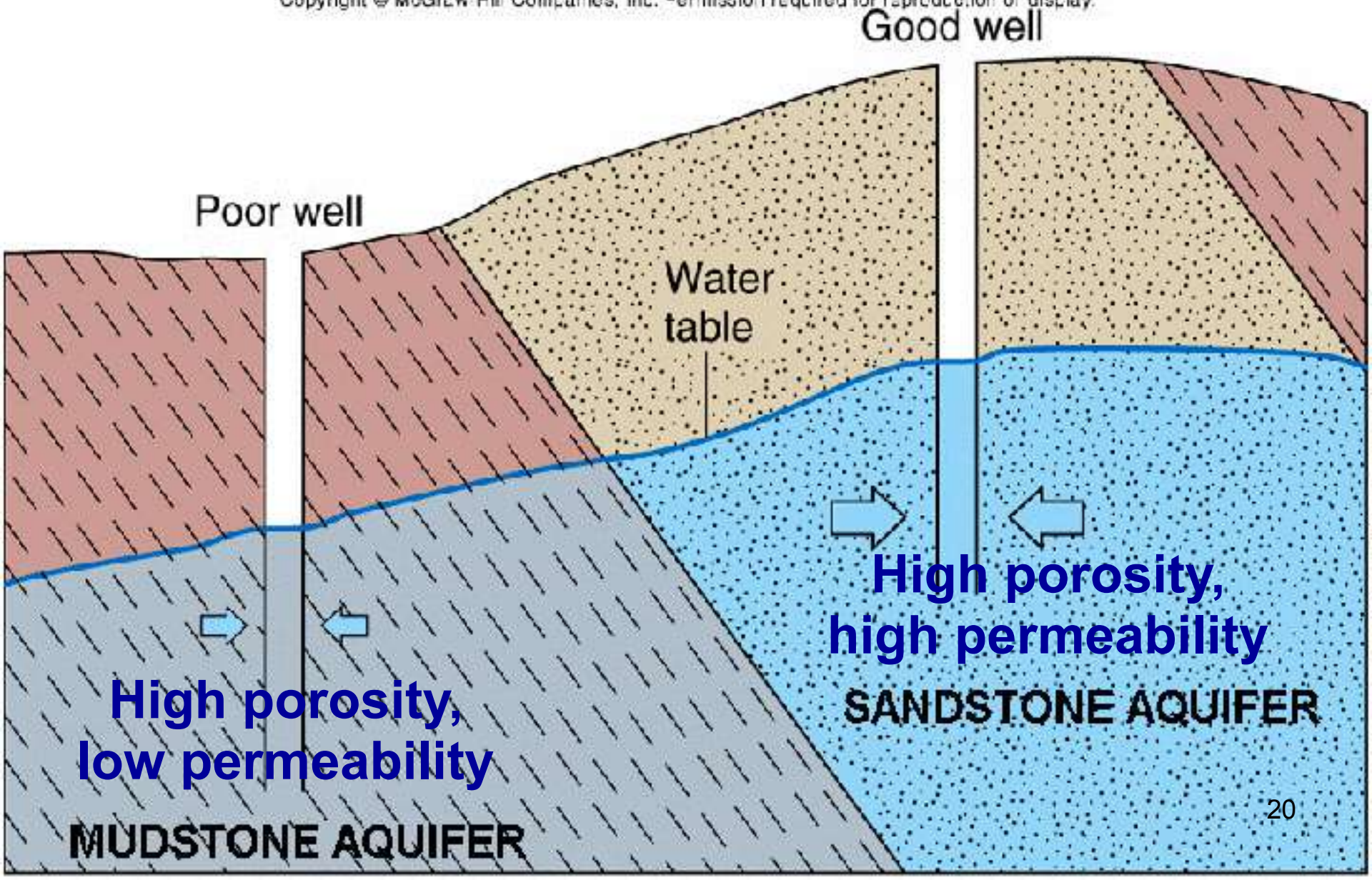
(*e*) rock rendered porous by solution

***Secondary porosity*: the cracks and caves produced by jointing, faulting, and dissolution of the bedrock**

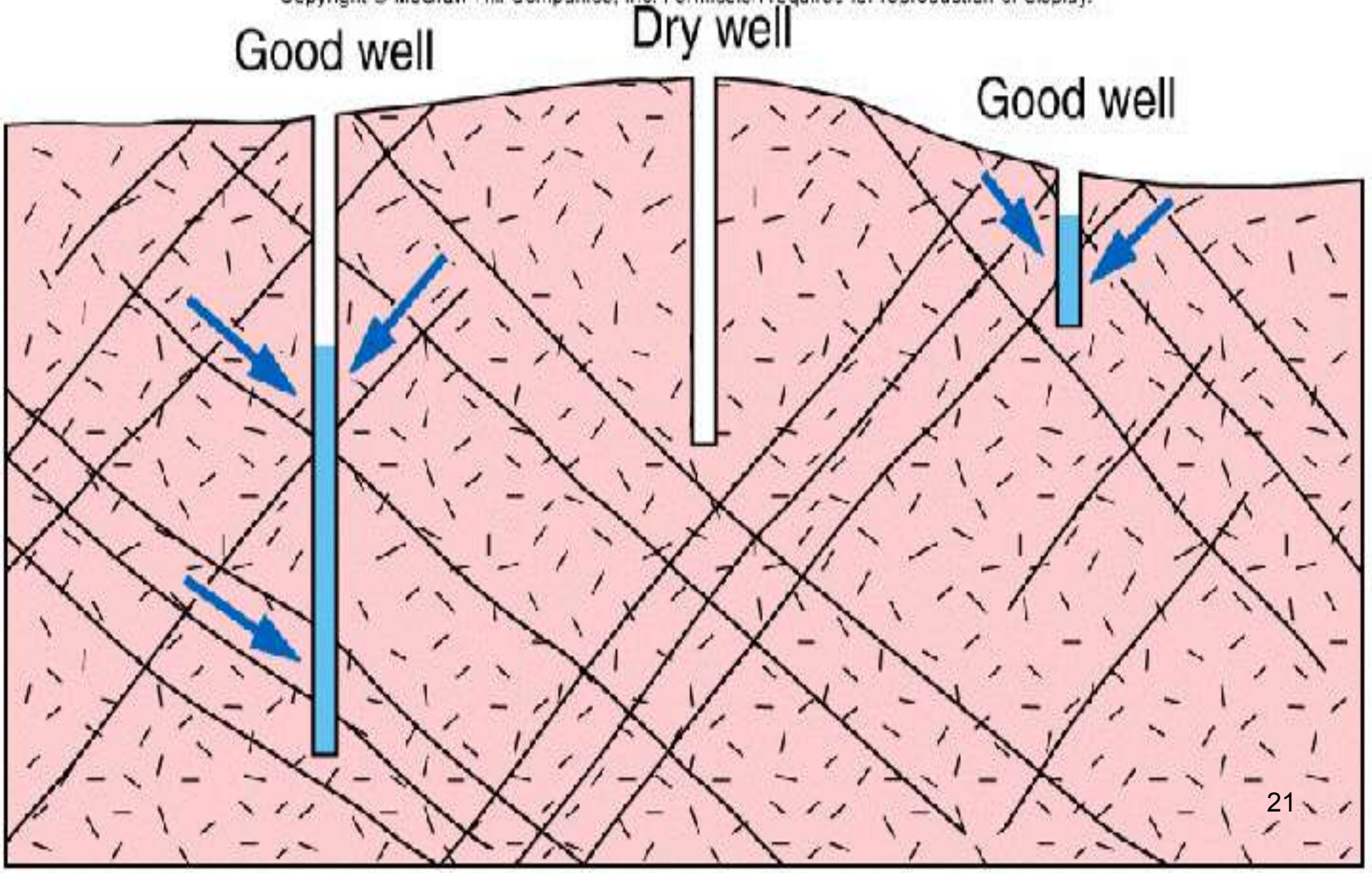


(*f*) rock rendered porous by fracturing

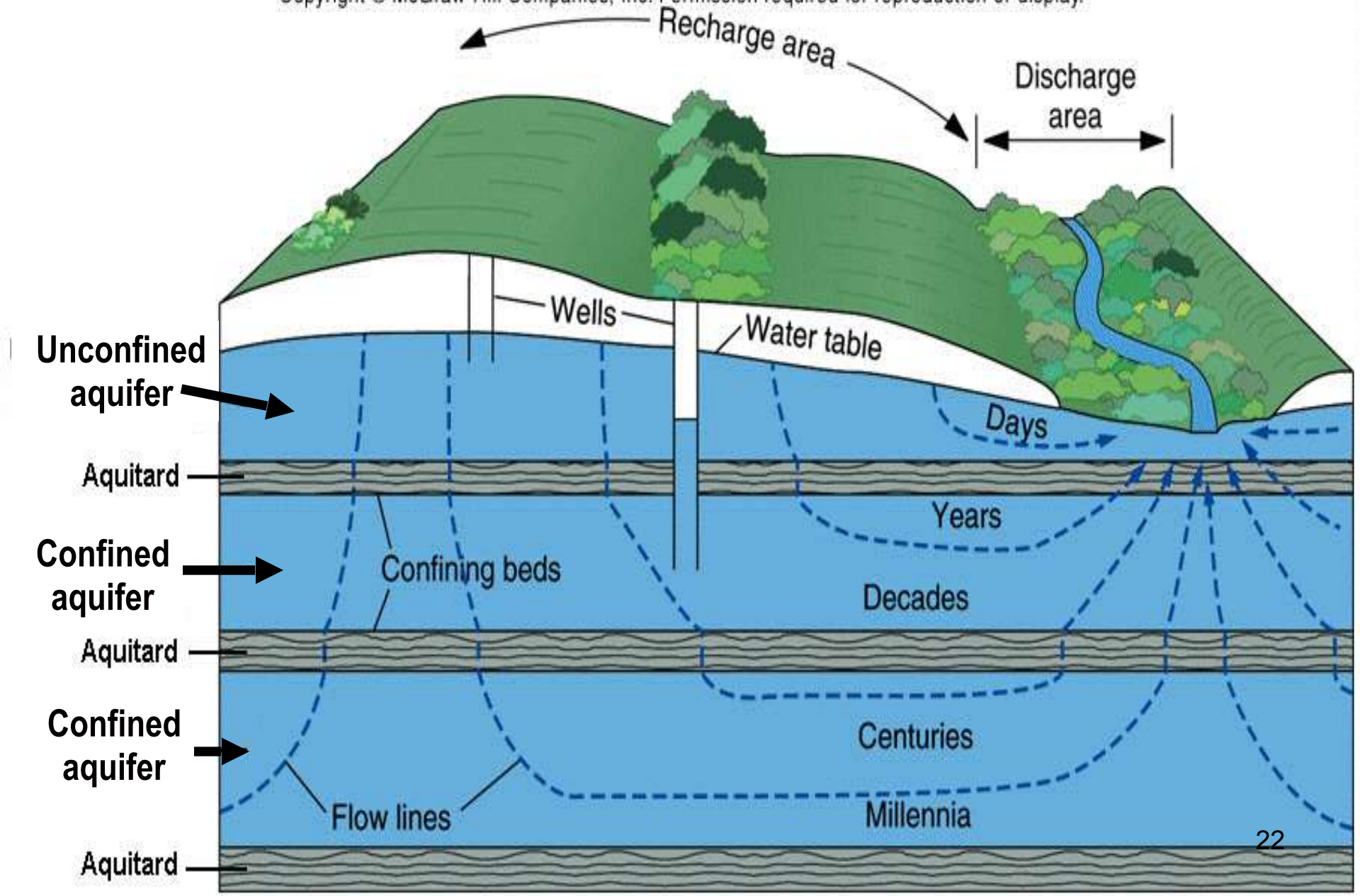
Effect of Porosity and Permeability on Wells: Mudstone versus Sandstone



Effect of Porosity and Permeability on Wells: Fractured versus Un-fractured Bedrock

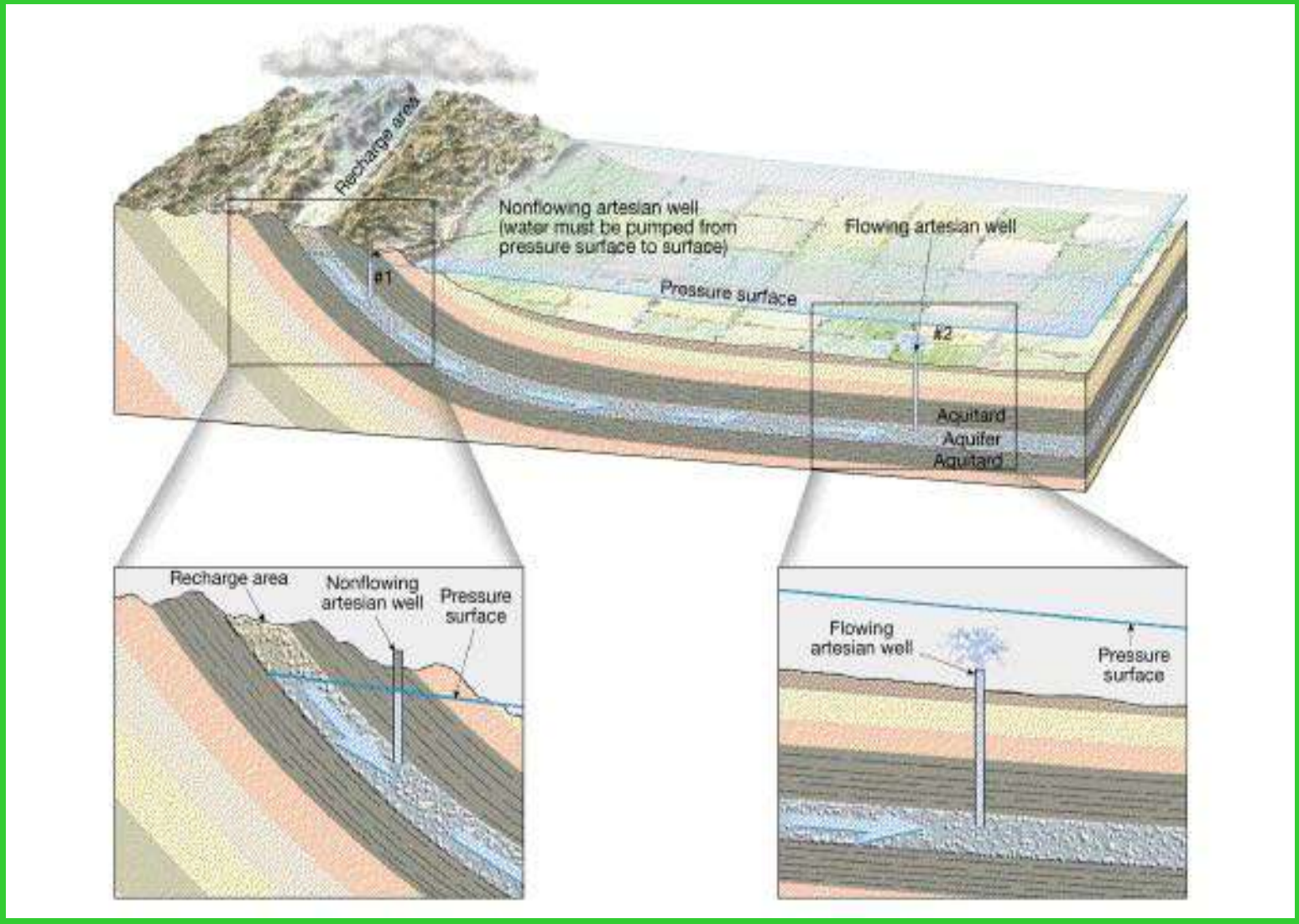


Unconfined and Confined Aquifers

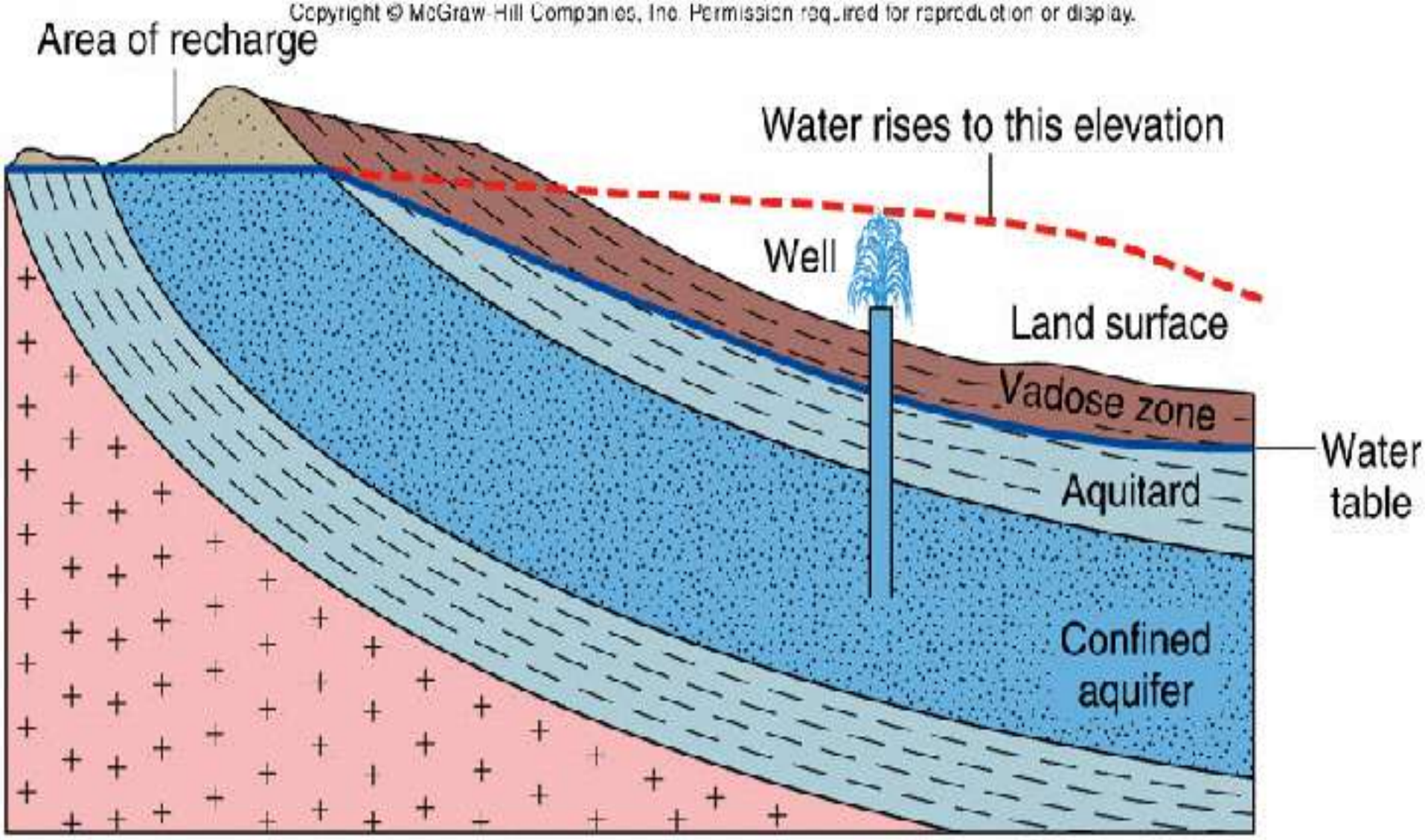


Artesian Systems

Artesian systems are systems in which groundwater rises higher than the elevation at which it was first encountered



Flowing Artesian Well



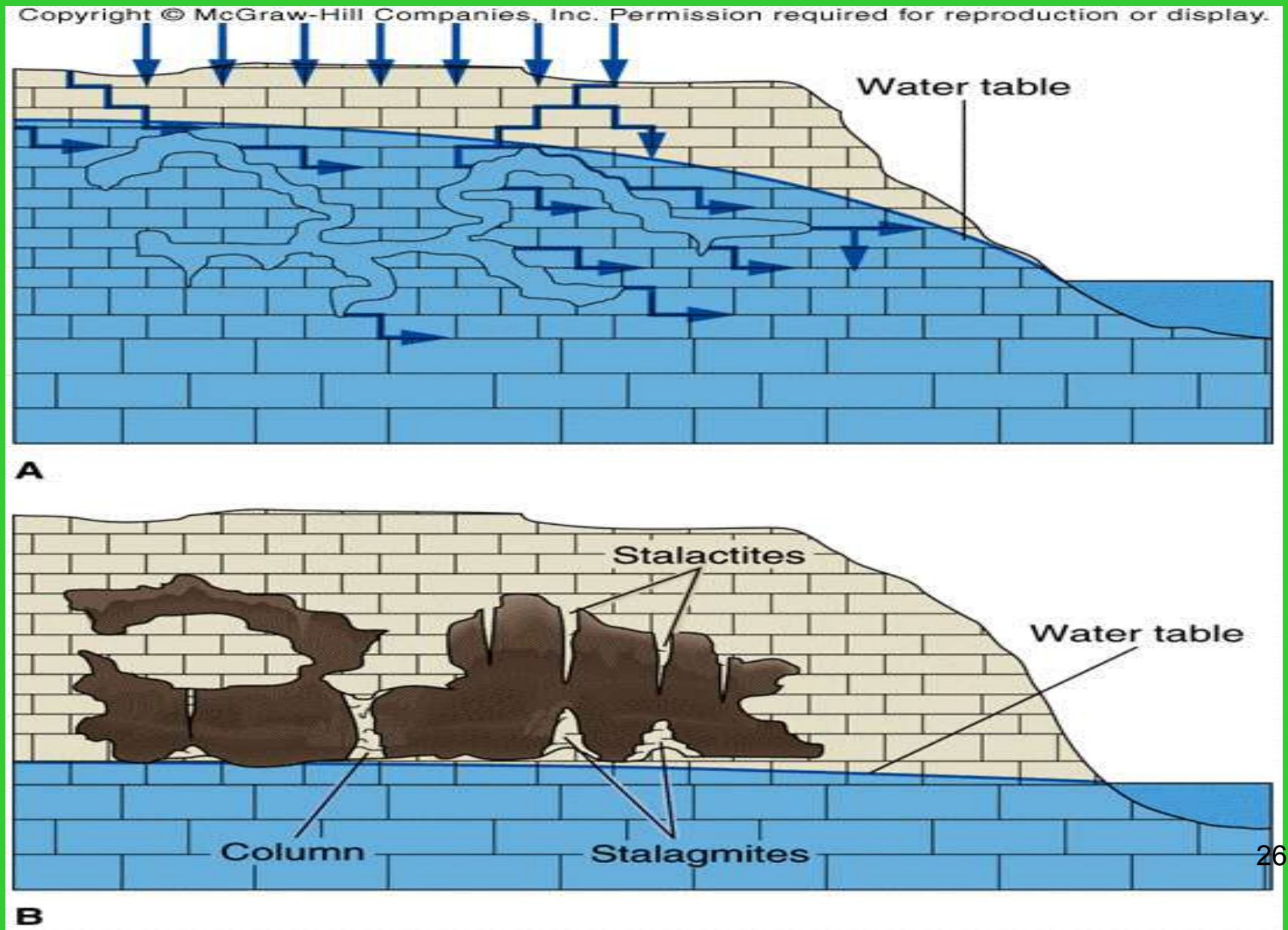
Karst Topography

- **Is named after where it was first recognized, in Karst Yugoslovia**

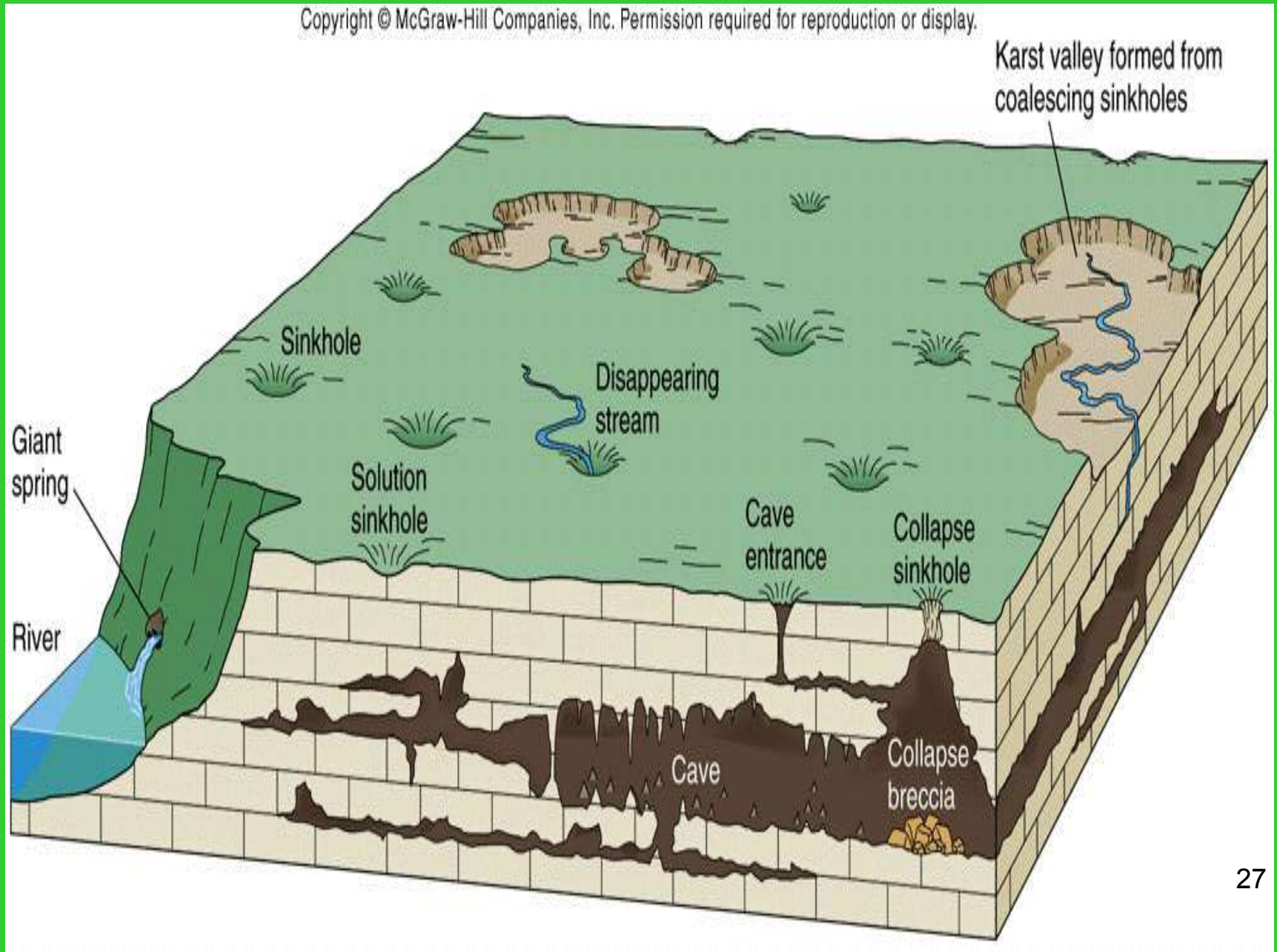
- ***Karst topography is formed by dissolution of limestone bedrock by acidic groundwater***

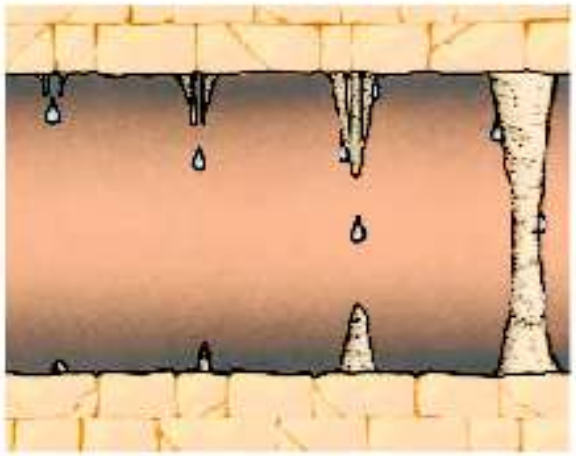
- **The features of karst topography are:**
  - **Caves**
  - **Stalactites and stalagmites**
  - **Sinkholes**
  - **Dissolution valleys**
  - **Disappearing streams**
  - **Reappearing streams**

Features Associated with Karst Topography



Features Associated with Karst Topography





(A) Diagram showing, left to right, the evolution of stalactites, stalagmites, and columns.

(B) Long, slender stalactites (soda straws) grow as a drop of water suspended at the end loses carbon dioxide and evaporates. *(Courtesy of David Herron)*

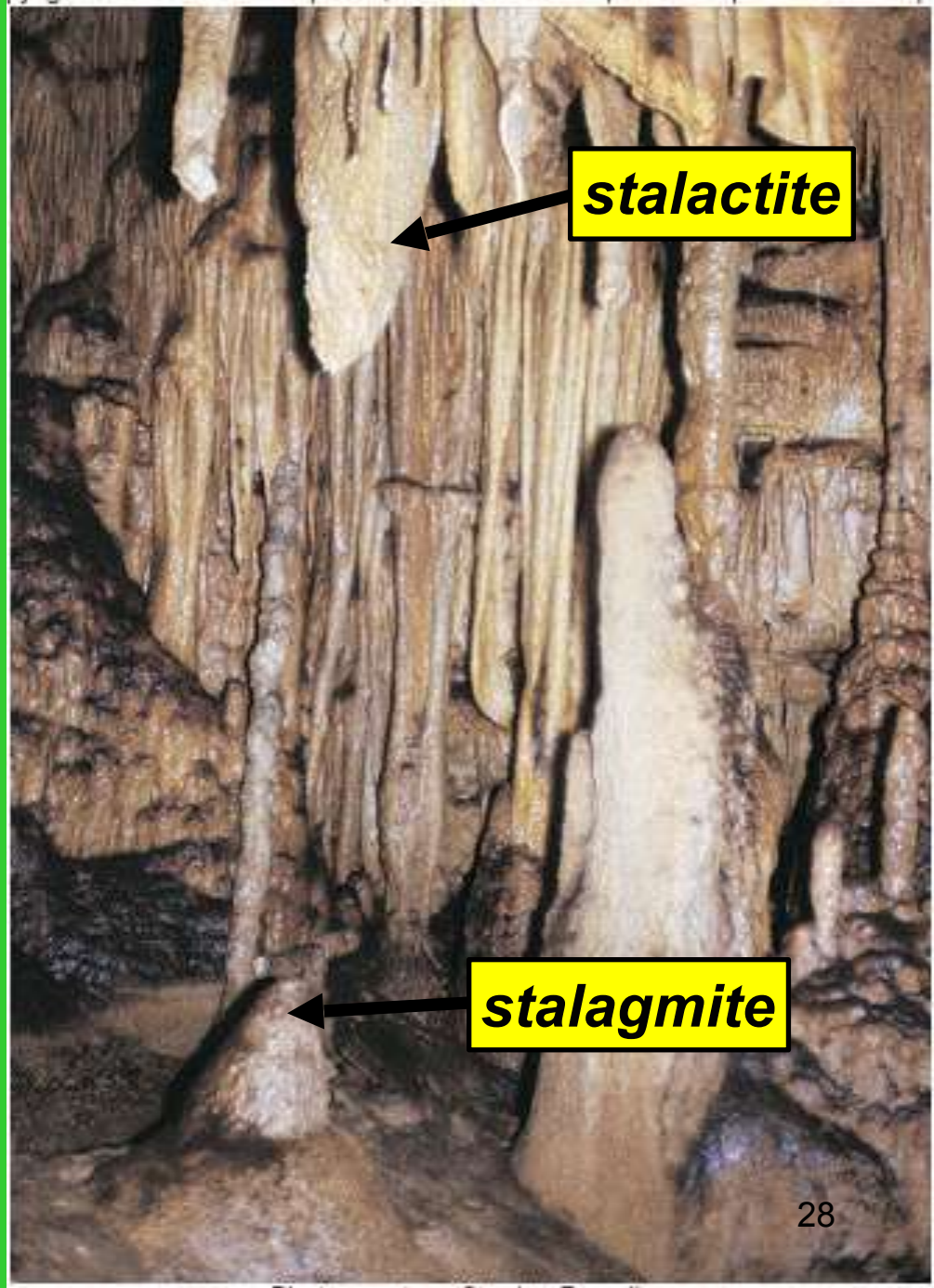
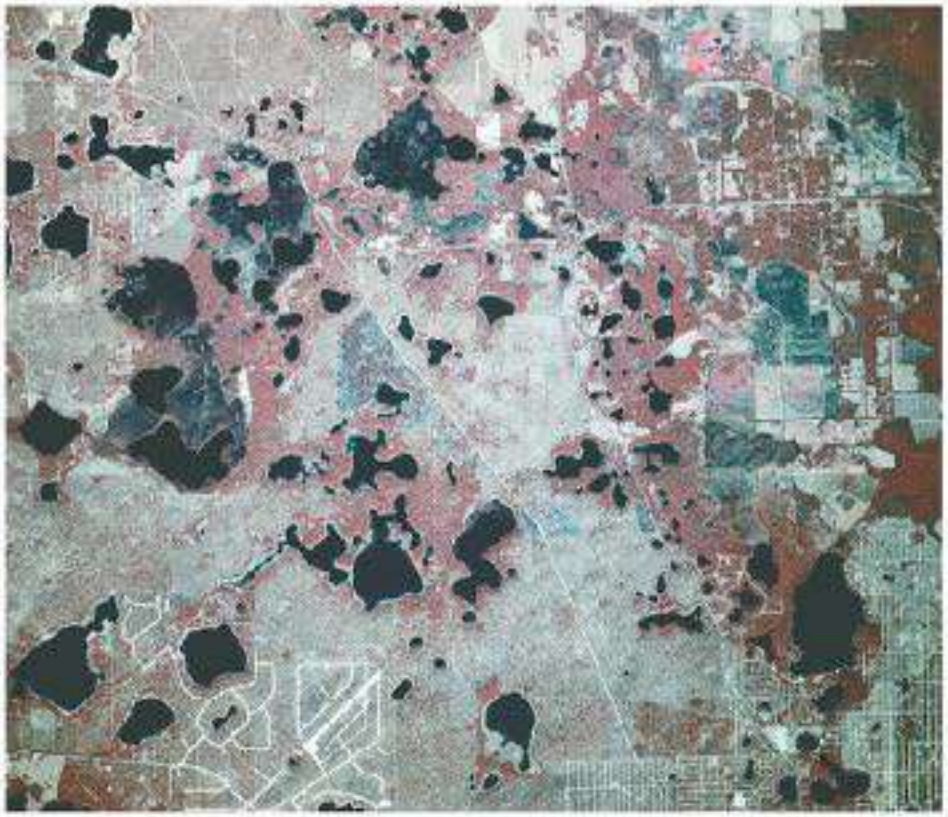


Photo courtesy Stanley Fagerline

Sinkholes

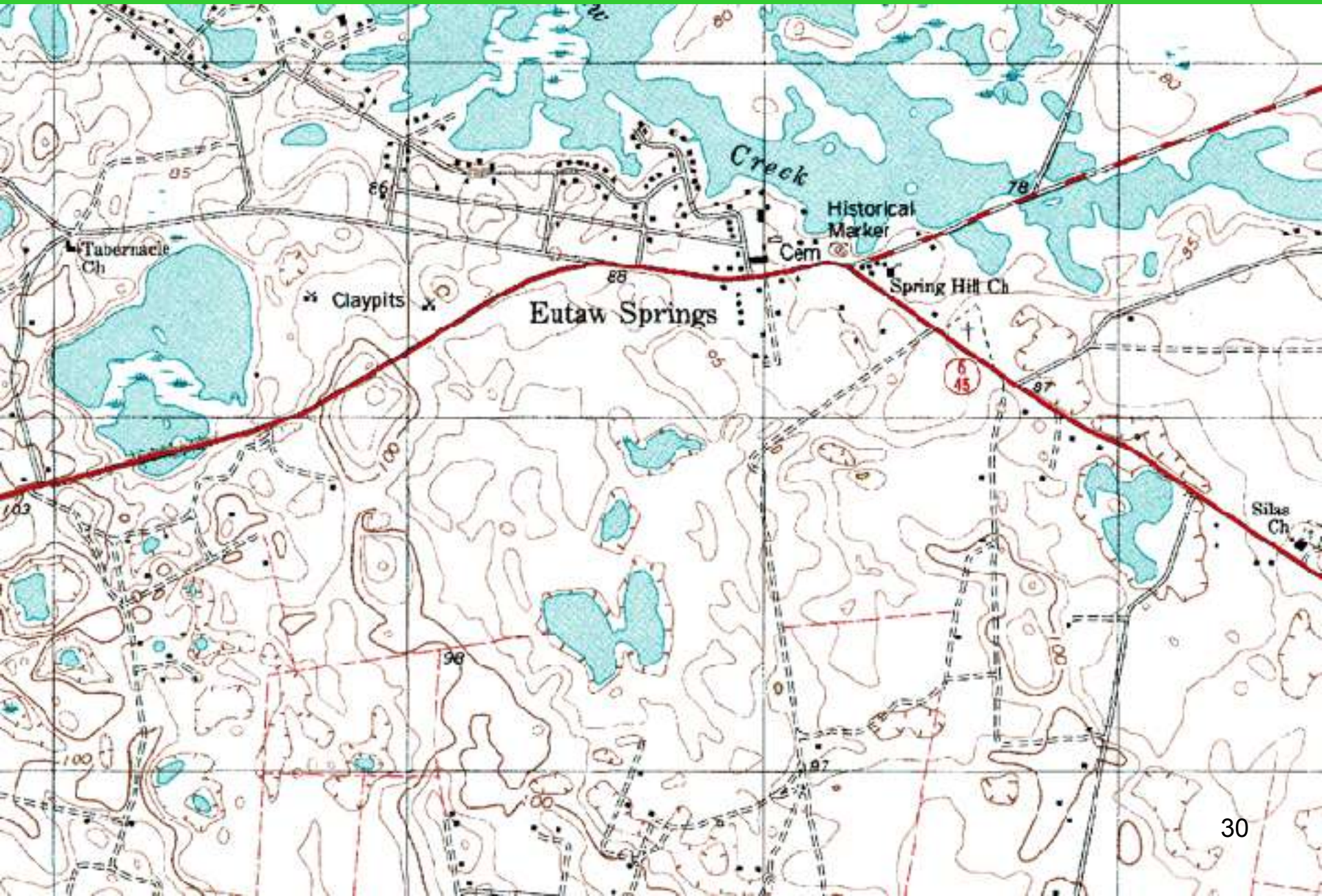


A

B

Sinkholes Developed in Santee Limestone

(the Atlantic Coastal Plain, near Eutaw Springs, SC)



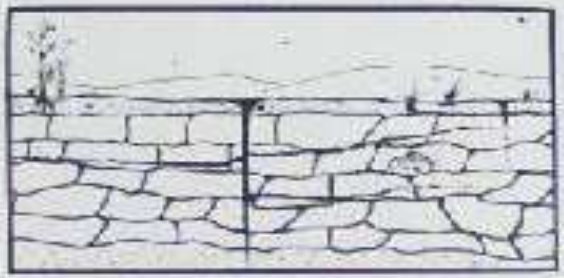
Sinkhole Formed in Santee Limestone
(the Atlantic Coastal Plain, Santee State Park, SC)

Water from recent heavy rains flowing into a sinkhole in a lake bed at Santee State Park. All the water in the lake rapidly drained into the cave when this sinkhole formed in 1999.

LIMESTONE SINKHOLES

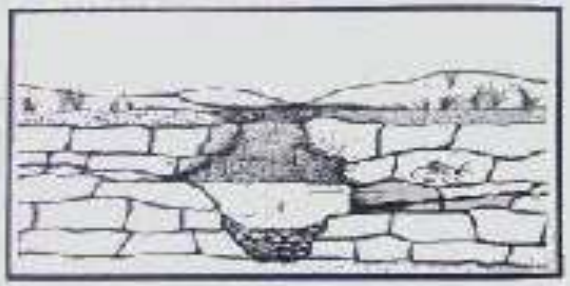
Santee Limestone is a geological formation that occurs in an east-west belt across South Carolina's Coastal Plain. A common geological feature which occurs here on the park and in many other areas of the world containing limestone subsoils, is the "sinkhole". Sinkholes are found in various stages of development from small hidden underground caverns to large open depressions.

1. During the Eocene Epoch forty to fifty million years ago, a shallow subtropical sea covered the coast of the planet. The shells of countless millions of tiny creatures were deposited on the sea bottom, forming the basis of sedimentary limestone rock.

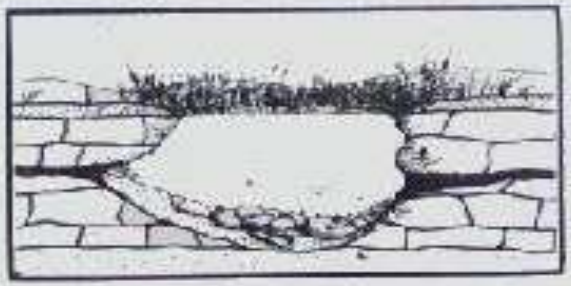


2. Over millions of years the massive sediment was transformed into limestone under the influence of extreme pressure. During this period the sea advanced and receded many times. In more recent times, several thousand years ago, cracks in the rock admitted rain and ground water.

3. Limestone, being mostly composed of calcium carbonate, is slowly dissolved by the slightly acidic flowing water. Rainwater becomes acidic by its contact with atmospheric gases such as carbon dioxide.



4. The roof of the underground cavern, once sufficiently enlarged, collapses. The subterranean stream continues to flow through the now exposed cave. Exposure to the atmosphere may speed the erosion of the opening.



5. Further erosion has widened the opening of the cave. Soil and material falling into the structure have blocked the openings of the stream. Deprived of these outlet channels, the sinkhole fills with rainwater. Aquatic plants and animals eventually colonize the pond.

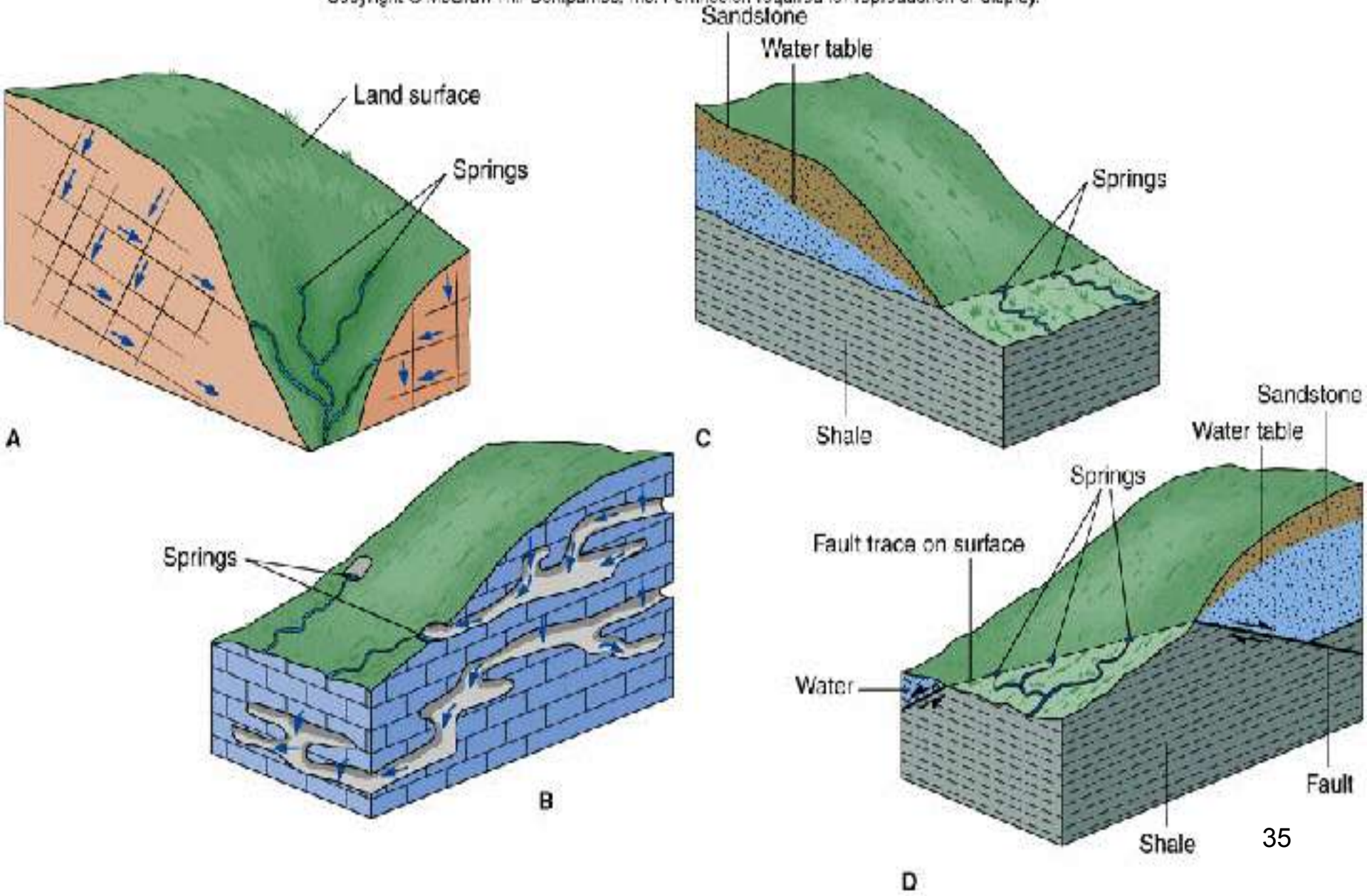
6. Continuing erosion and the collection of organic material gradually fill the depression. The old underground channel is now completely sealed. Over thousands of years, different successional trees and plants move in to replace upland species as the wetland disappears.

In case you still haven't caught on to how and why caves and sinkholes form in limestone bedrock, here is a display at Santee State Park illustrating their formation.

Springs

- **A spring is a flow of groundwater naturally emerging at Earth's surface**
- **Springs are formed where:**
  - **a prominent joint system intersects the ground surface**
  - **a perched water table intersects the ground surface**
  - **a cave system intersects the ground surface**
  - **a fault intersects the ground surface**

Springs

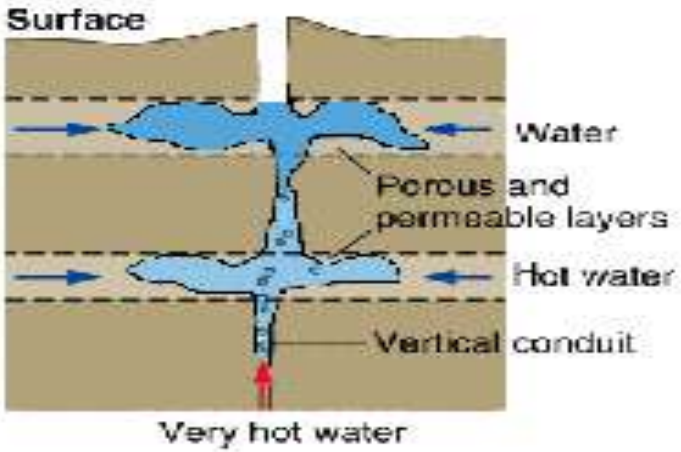


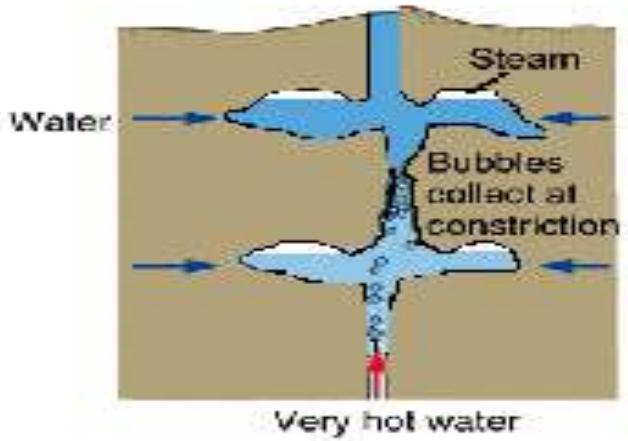
Geysers and Travertine Terraces

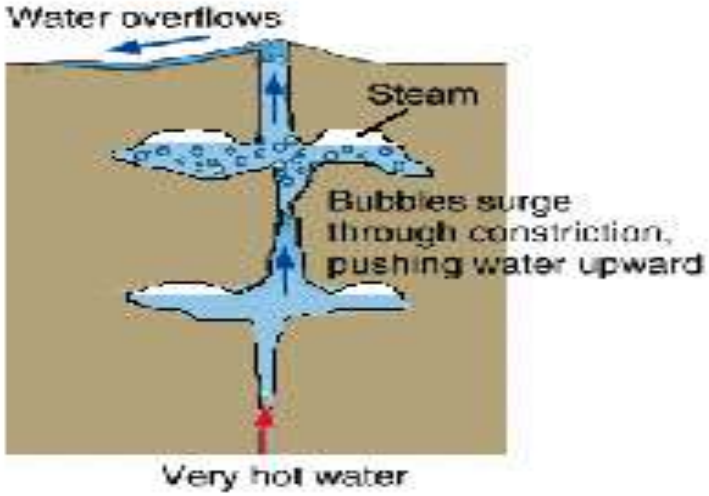
- **Geysers occur in hydrothermal areas where groundwater is heated by hot rock and erupted at the ground surface**

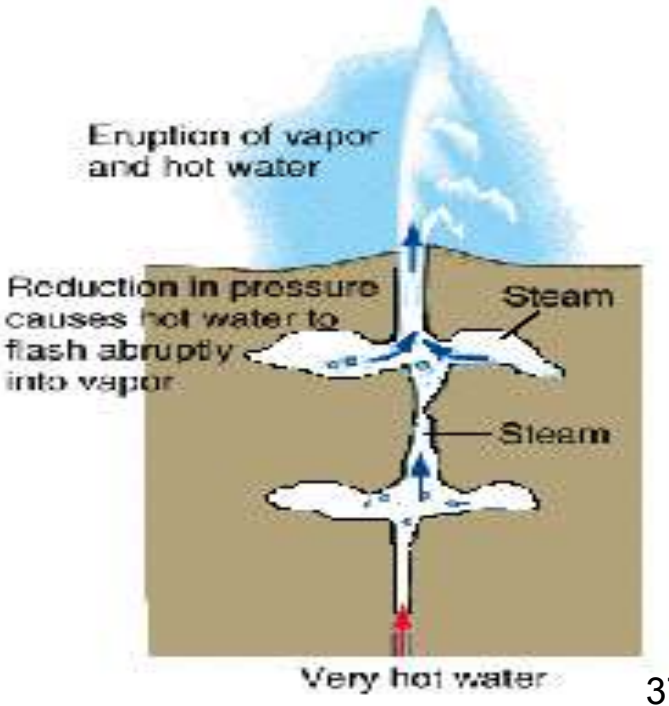
- **Travertine terraces form at the ground surface where calcium carbonate is precipitated from hydrothermal water percolating through limestone bedrock**

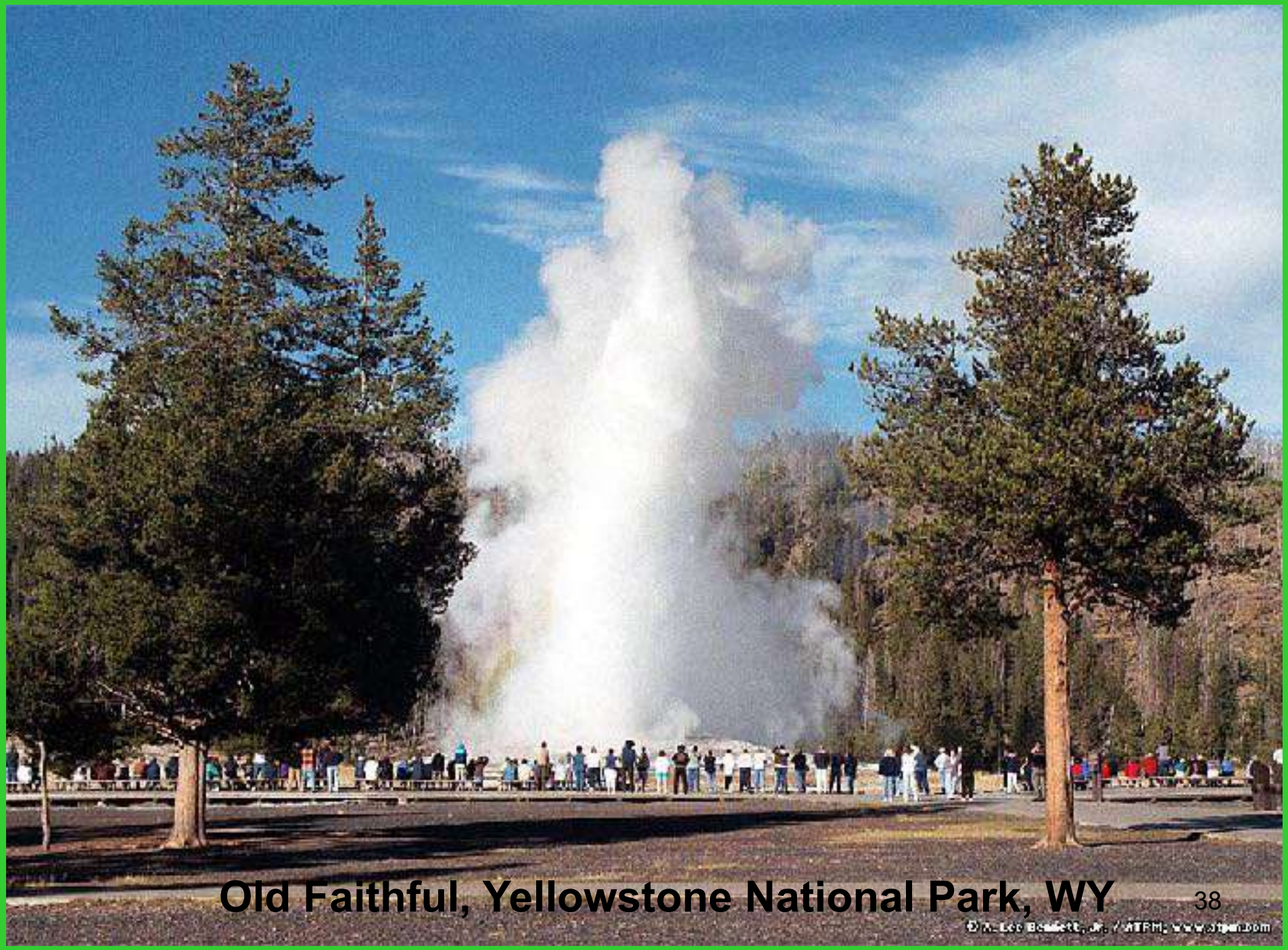
Geysers


Surface
Water
Porous and permeable layers
Hot water
Vertical conduit
Very hot water


Steam
Water
Bubbles collect at constriction
Very hot water


Water overflows
Steam
Bubbles surge through constriction, pushing water upward
Very hot water


Eruption of vapor and hot water
Reduction in pressure causes hot water to flash abruptly into vapor
Steam
Steam
Very hot water



Old Faithful, Yellowstone National Park, WY

Travertine Terraces, Mammoth Hot Springs, Yellowstone

Photo by Diane Carlson

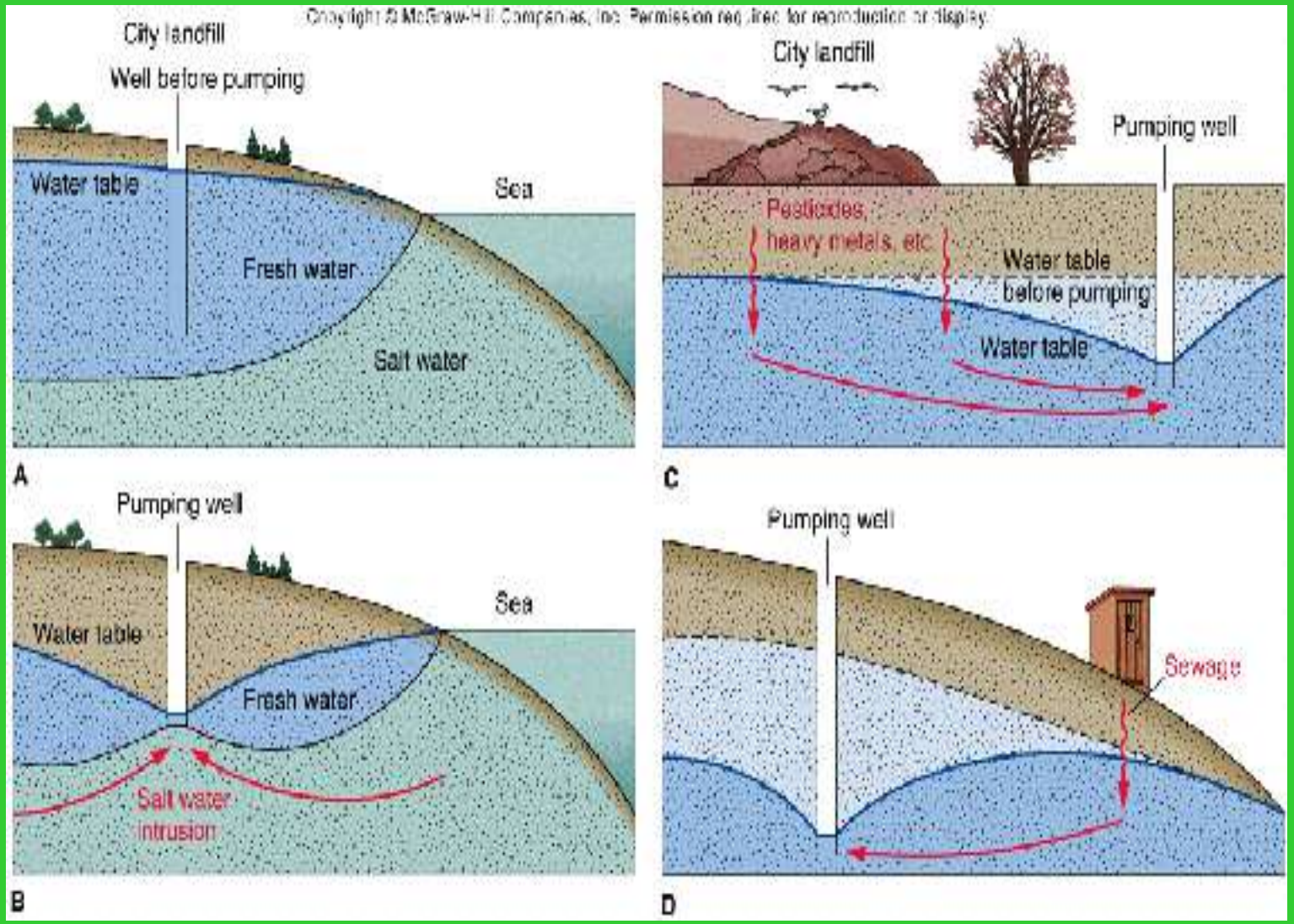
Problems Affecting the Water Table and Groundwater

Subsidence

Photo by Richard C. Ireland, U.S. Geological Survey

Problems Affecting the Water Table and Groundwater

Salt Water Intrusion ***Contamination***

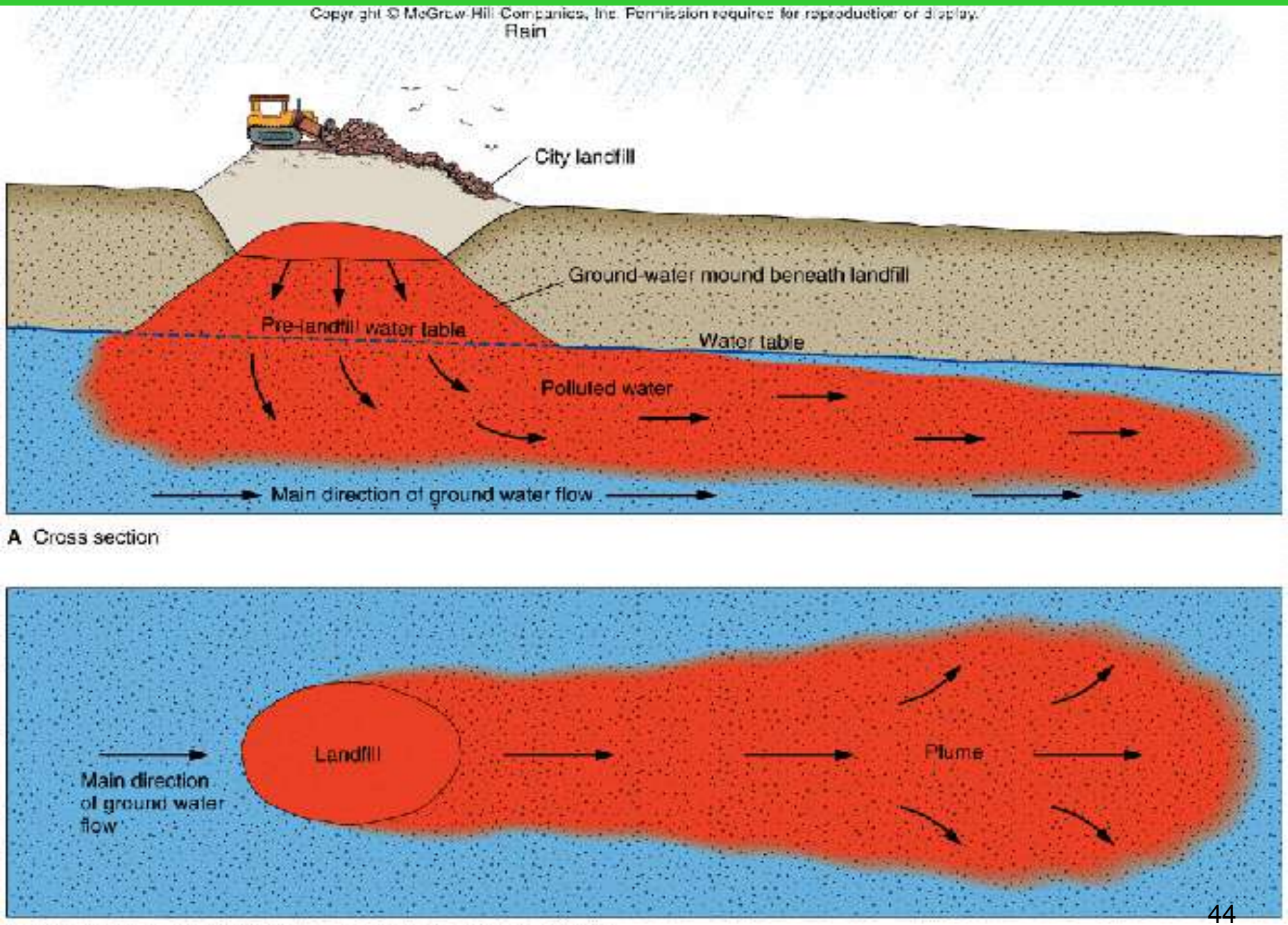


C

USDA-Soil Conservation Service

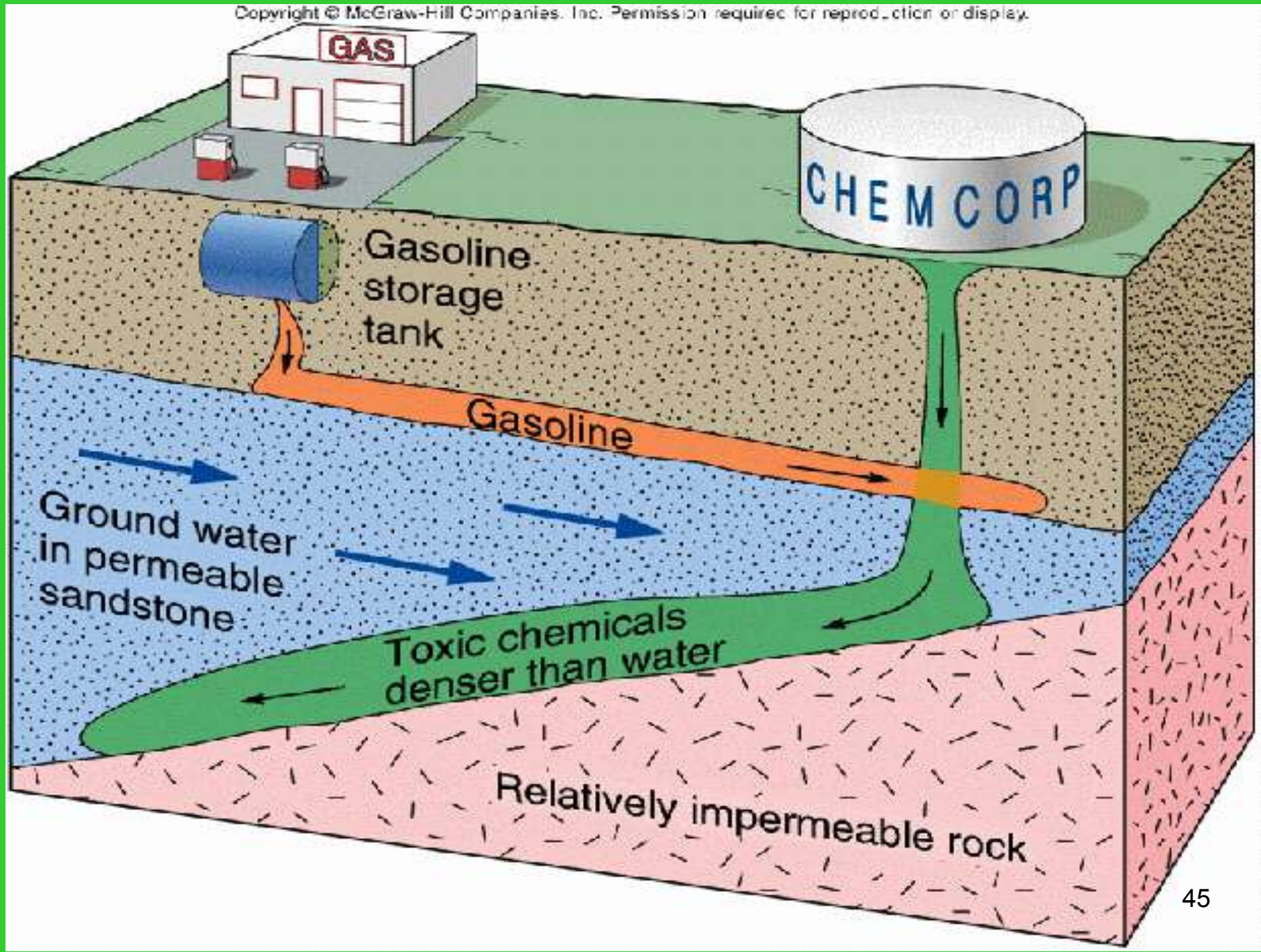
D

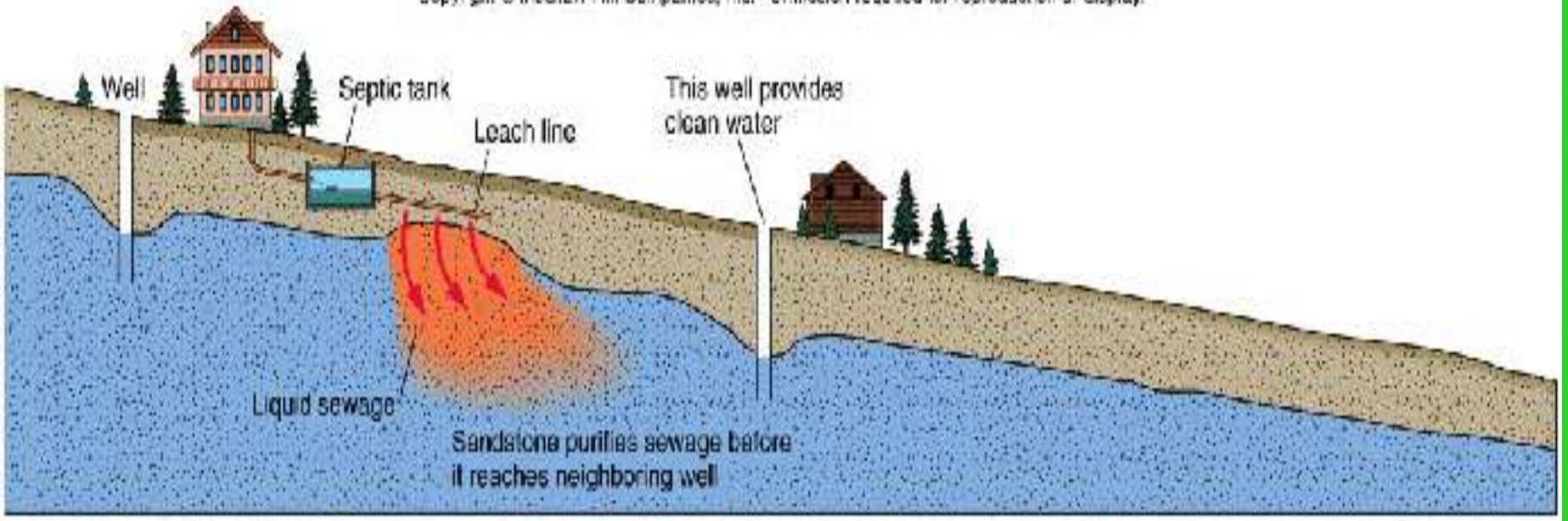
USDA-Soil Conservation Service



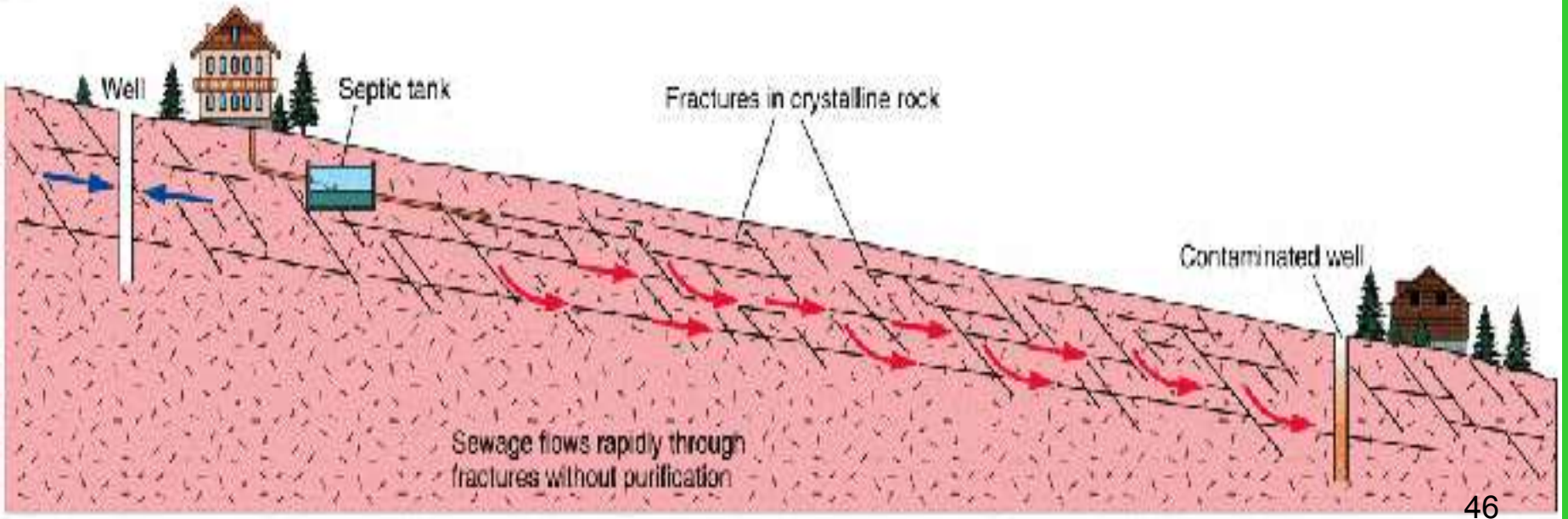
A Cross section

B Map view of contaminant plume. Note how it grows in size with distance from the pollution source.





A



B

Thank you