Essentials of Geology, 11e

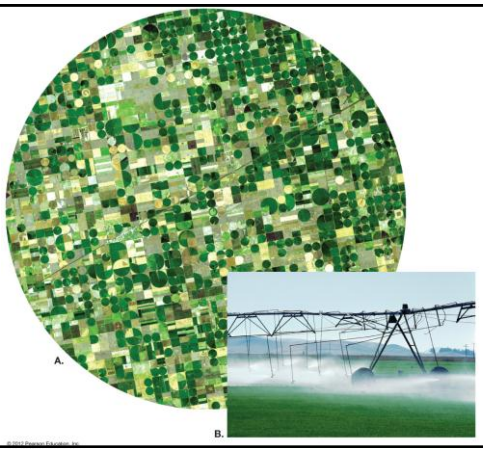
Groundwater

Chapter 10

Instructor – Jennifer Barson
Spokane Falls Community College
Geology 101

Stanley Hatfield
Southwestern Illinois C

Jennifer Cole
Northeastern University



Importance of Groundwater

- **Groundwater is water found in the pores of soil and sediment, plus narrow fractures in bedrock**
- **Groundwater is the largest reservoir of fresh water that is readily available to humans**

Importance of Groundwater

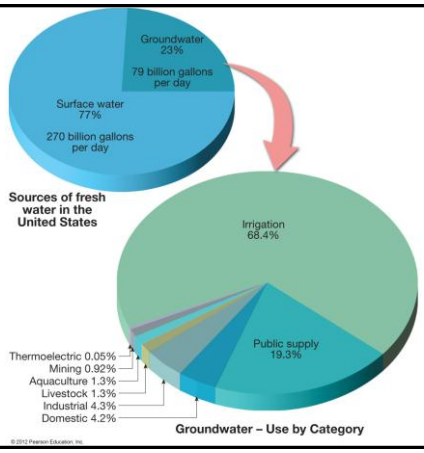
- **Geological role of groundwater**
  - **As an erosional agent, dissolving groundwater produces**
    - **Sinkholes**
    - **Caverns**
  - **Groundwater serves as an equalizer of streamflow**

TABLE 10.1
Fresh Water of the Hydrosphere

Parts of the Hydrosphere	Volume of Fresh Water (km^3)	Share of Total Volume of Fresh Water (percent)	Share of Total Volume of Liquid Fresh Water (percent)
Ice sheets and glaciers	24,000,000	84.945	0
Groundwater	4,000,000	14.158	94.05
Lakes and reservoirs	155,000	0.549	3.64
Soil moisture	83,000	0.294	1.95
Water vapor in the atmosphere	14,000	0.049	0.33
River water	1,200	0.004	0.03
Total	28,253,200	100.00	100.00

Source: U.S. Geological Survey Water Supply Paper 2220, 1987.

Table 10.1



Distribution of Groundwater

- **Belt of soil moisture** – water held by molecular attraction on soil particles in the near-surface zone
  - This soil water is used by plants
  - Some water directly evaporates back into the atmosphere

Distribution of Groundwater

- **Zone of aeration**
  - Area above the water table
  - Includes the **capillary fringe** and the belt of soil moisture
  - Water cannot be pumped by wells

Distribution of Groundwater

- **Capillary fringe**
  - Extends upward from the water table
  - Groundwater is held by surface tension in tiny passages between grains of soil or sediment

Distribution of Groundwater

- **Zone of saturation**
  - Formation
    - Water not held as soil moisture percolates downward
    - Water reaches a zone where all of the open spaces in sediment and rock are completely filled with water
    - Water within the pores is called **groundwater**
  - **Water table** – the upper limit of the zone of saturation

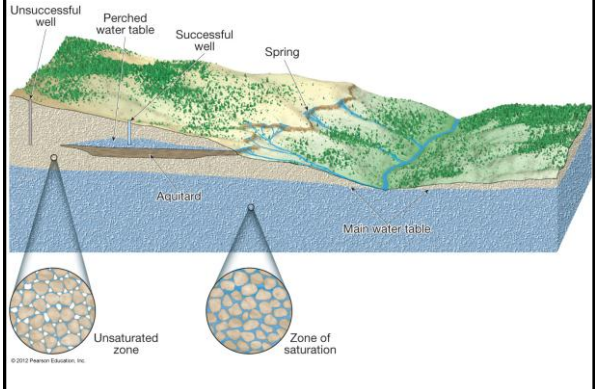


Figure 10.5

The Water Table

- The **water table** is the upper limit of the zone of saturation
- Variations in the water table
  - Depth is highly variable
    - Varies seasonably and from year to year
  - Shape is usually a subdued replica of the surface topography

The Water Table

- Variations in the water table cont.
  - Factors that contribute to the irregular surface of the water table
    - Water tends to "pile up" beneath high areas
    - Variations in rainfall
    - Variations in permeability from place to place

The Water Table

- Interaction between groundwater and streams
  - Basic link in the hydrologic cycle
  - Three types of interactions
    - Gaining streams – gain water from the inflow of groundwater through the streambed
    - Losing streams – lose water to the ground-water system by outflow through the stream-bed
    - A combination of the two – streams can gain in some sections and lose in others

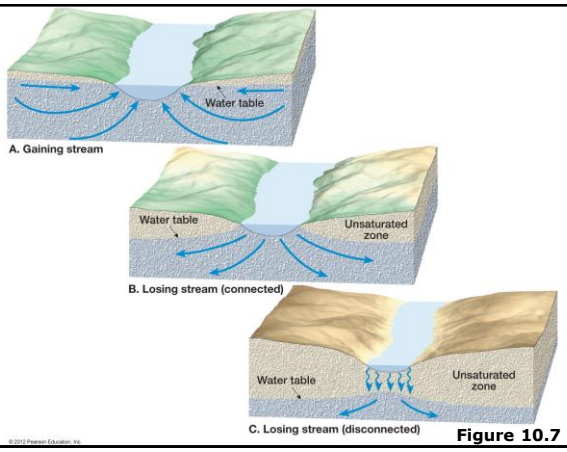


Figure 10.7

The Water Table

- Interaction between groundwater and streams
  - Interactions
    - A combination of the first two – a stream gains in some sections and loses in other areas
    - Flow direction may vary as a result of:
      - Storms adding water
      - Temporary flood peaks

Factors influencing the storage and movement of groundwater

- Porosity – percentage of total volume of rock or sediment that consists of pore spaces
  - Determines how much groundwater can be stored
  - Variations can be considerable over short distances
  - Depends on size and shape of grains, packing, sorting, and amount of cement

Factors influencing the storage and movement of groundwater

- Permeability - the ability of a material to transmit a fluid.
  - Pores must be ***connected*** to allow water flow
  - Groundwater moves by twisting and turning through the interconnected small openings
  - Rock or sediment might be porous yet still not allow water to move through it.

Factors influencing the storage and movement of groundwater

- **Aquitards and aquifers**
  - **Permeability – the ability of a material to transmit a fluid**
  - **Aquitard – an impermeable layer that hinders or prevents water movement (such as clay)**
  - **Aquifer – permeable rock strata or sediment that transmits groundwater freely (such as sands and gravels)**

Movement of Groundwater

- **Darcy's Law**
  - **Hydraulic gradient – the water table slope**
    - **determined by dividing the vertical difference between the recharge and discharge points by the length of flow between these points**
  - **Hydraulic head – the vertical difference between the recharge and discharge points**
  - **Hydraulic conductivity (K) – takes into account the permeability of the aquifer and the viscosity of the fluid**

Q = (KA (h1-h2))/d

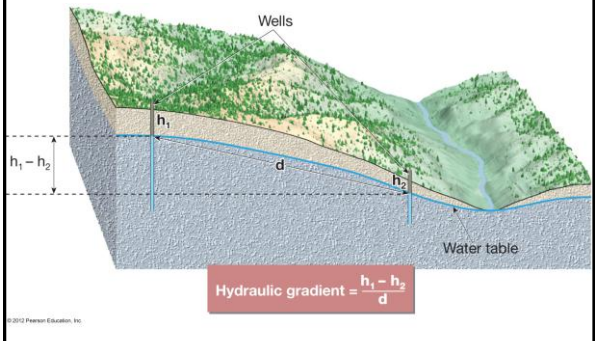


Figure 10.9

Flow System

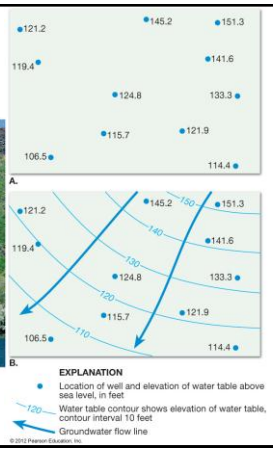


Figure 10.7 & 10.9

Movement of Groundwater

- **Exceedingly slow – typical rate of movement is a few centimeters per day**
- **Energy for the movement is provided by the force of gravity**
- **Darcy's Law – if permeability remains uniform, the velocity of groundwater will increase as the slope of the water table increases**

Features associated with Groundwater

- **Springs**
  - **Occur where the water table intersects Earth's surface**
  - **Natural outflow of groundwater**
  - **Can be caused by an aquitard creating a localized zone of saturation which is called a perched water table**

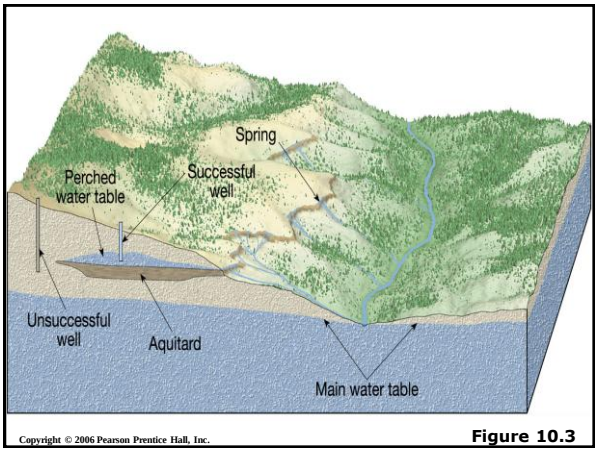


Figure 10.3

Figure 10.10

Features associated with Groundwater

- **Wells**
  - To ensure a continuous supply of water, a well must penetrate below the water table
  - Pumping of wells can cause
    - **Drawdown** (lowering) of the water table
    - **Cone of depression** in the water table

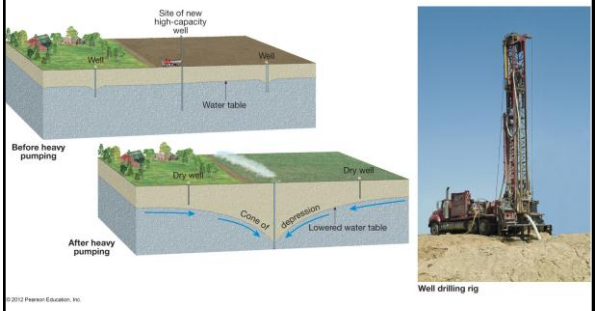


Figure 10.11

Features associated with Groundwater

- **Artesian well** – a situation in which groundwater under pressure rises above the level of the aquifer
  - Types of artesian wells
    - **Nonflowing** – pressure surface is below ground level
    - **Flowing** – pressure surface is above the ground
  - Not all artesian systems are wells, artesian springs also exist

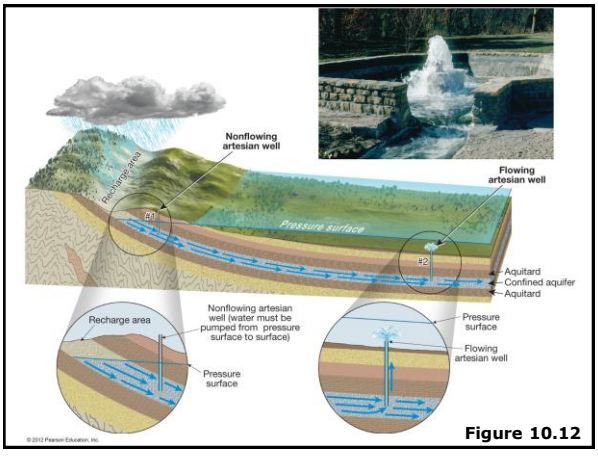


Figure 10.12

Problems associated with Groundwater Withdrawal

- **Treating groundwater as a nonrenewable resource**
  - **In many places the water available to recharge the aquifer falls significantly short of the amount being withdrawn**
- **Subsidence**
  - **Ground sinks when water is pumped from wells faster than natural recharge processes can replace it (San Joaquin Valley of California)**

Figure 10.15

Groundwater Contamination

- **One common source is sewage**
  - **Extremely permeable aquifers, such as coarse gravel, have such large openings that groundwater may travel long distances without being cleaned**
  - **Sewage often becomes purified as it passes through a few dozen meters of an aquifer composed of sand or permeable sandstone**

Groundwater Contamination

- **Other sources and types of contamination include substances such as**
  - **Highway salt**
  - **Fertilizers**
  - **Pesticides**
  - **Chemical and industrial materials**

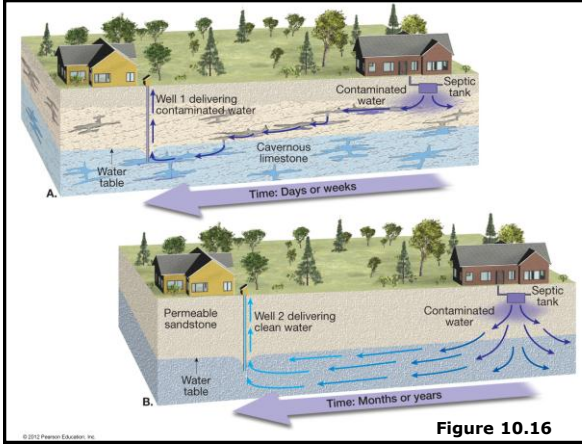


Figure 10.16

Hot Springs and Geysers

- **Hot springs**
  - **Water is 6-9°C warmer than the mean annual air temperature of the locality**
  - **The water for most hot springs is heated by cooling of igneous rock**
  - **Over 95% of the hot springs (and geysers) in the US are found in the west**
    - **Source of heat is cooling igneous rock, where the West was most recent volcanic activity**

Mammoth Hot Springs, Yellowstone National Park

Figure 10.20

Hot Springs and Geysers

- **Geysers**
  - Intermittent hot springs
  - Water erupts with great force
  - Occur where extensive underground chambers exist within hot igneous rock
  - Groundwater heats, expands, changes to steam, and erupts

Hot Springs and Geysers

- **Geysers**
  - Chemical sedimentary rock accumulates at the surface
  - Material reflects the chemical makeup of rock through which the water circulated
    - **Siliceous sinter** (from dissolved silica)
    - **Travertine** (from dissolved calcium car-bonate)

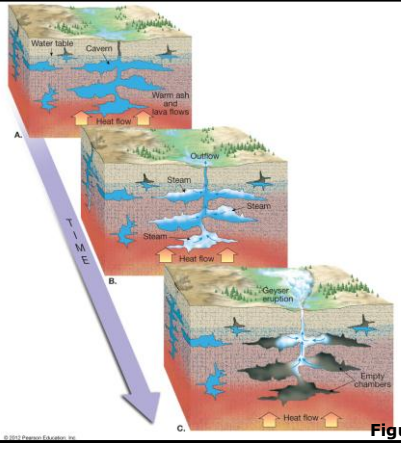


Figure 10.219

Copyright © 2006 Pearson Prentice Hall, Inc.

Geothermal Energy

- Tapping natural underground reservoirs of **steam** and **hot water**
- Favorable geologic factors include
  - A potent source of heat
  - Large and porous reservoirs with channels connected to the heat source
  - A cap of low permeability rocks
- Geothermal energy is not inexhaustible

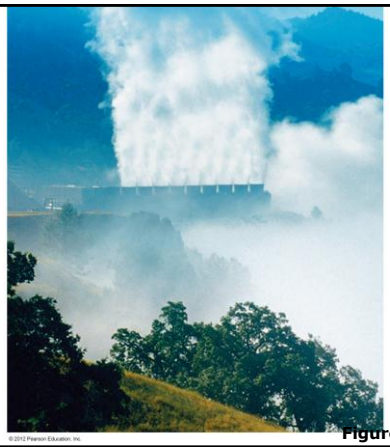


Figure 10.22

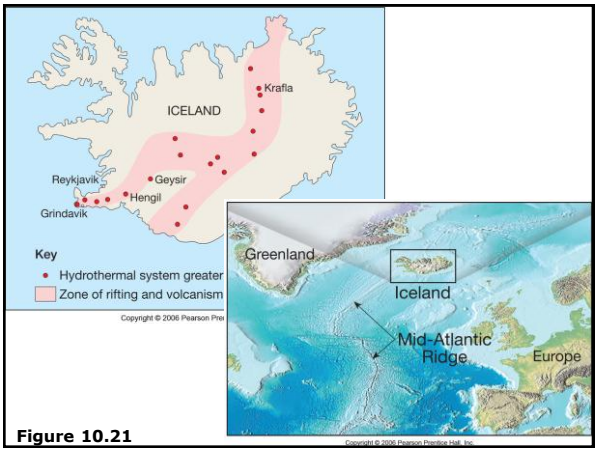


Figure 10.21

Geologic Work of Groundwater

- Groundwater **dissolves rock**
  - Groundwater is often mildly acidic
    - Contains weak carbonic acid
    - Forms when rainwater dissolves carbon dioxide from the air and from decaying plants
  - Carbonic acid reacts with calcite in limestone to form calcium bicarbonate, a soluble material

Geologic Work of Groundwater

- **Caverns**
  - Most caverns are created by acidic groundwater dissolving soluble rock at or just below the surface in the zone of saturation
  - Cave features found within caverns
    - Form in the zone of aeration
    - Groundwater percolation and deposition

Geologic Work of Groundwater

- **Caverns**
  - Features found within caverns
    - Composed of **dripstone** (**travertine**)
      - » Calcite deposited as dripping water evaporates
      - » Collectively, they are called **speleothems**
      - » Includes **stalactites** (hanging from the ceiling) and **stalagmites** (form on the floor of a cavern)

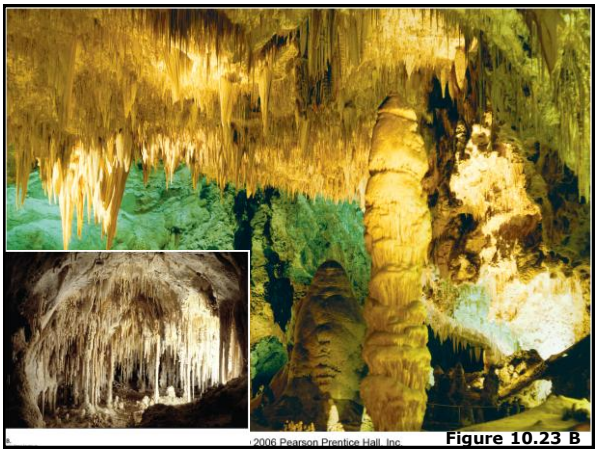


Figure 10.23 B

Geologic Work of Groundwater

- **Karst topography**
  - **Landscapes that have primarily been shaped by the dissolving power of groundwater**
  - **Some common features include**
    - **Irregular terrain**
    - **Sinkhole or sinks (formed by groundwater slowly dissolving the bedrock often accompanied by collapse)**
    - **Striking lack of surface drainage (streams)**

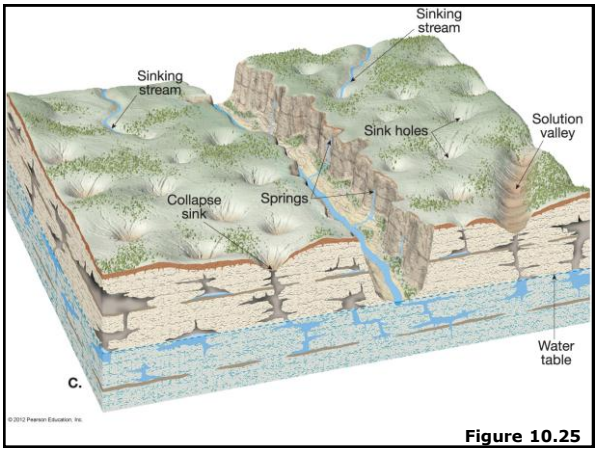


Figure 10.25

B.

Copyright © 2006 Pearson Prentice Hall, Inc.

Figure 10.26

End of Chapter 10