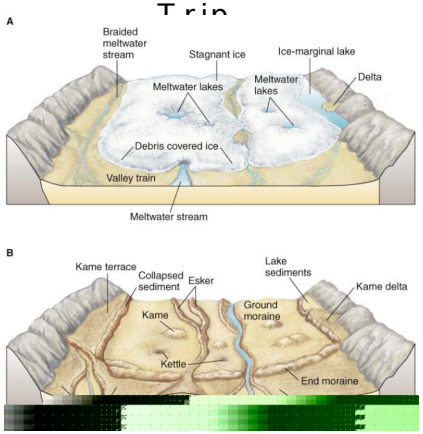
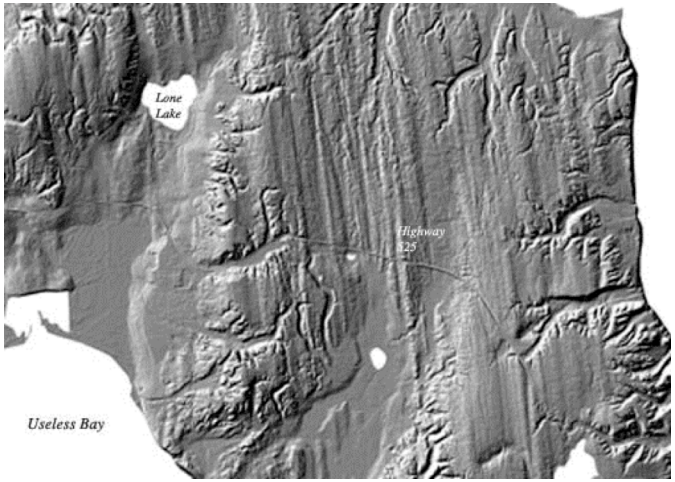
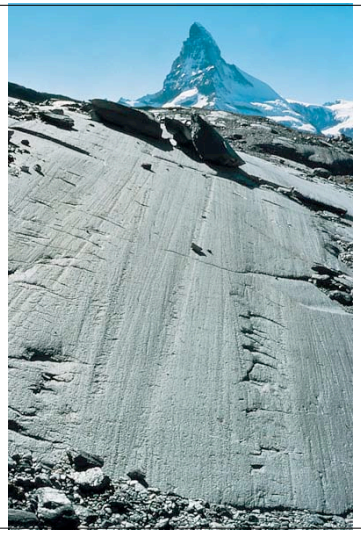
Glacial Features for Field Trip








Kettle
Photo Courtesy of
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Groundwater

Summary

- Groundwater is derived mostly from rainfall and occurs everywhere beneath the land surface.
- The water table is the top of the saturated zone. In humid regions, the form of the water table is a subdued imitation of the overlying land surface.
- Groundwater moves chiefly by percolation, at rates far slower than those of surface streams. In rock or sediment of constant permeability, the velocity of groundwater increases as the slope of the water table increases
- .In moist regions, groundwater in recharge areas percolates downward under the pull of gravity. It moves away from hills toward valleys, where it may emerge to supply streams (groundwater discharge areas). In dry regions, the groundwater is recharged by water percolating downward beneath surface streams.
- According to Darcyís Law, the discharge of water in a groundwater system is equal to the product of the cross-sectional area of flow, the coefficient of permeability, and the hydraulic gradient.

- Springs often occur at places where either the water table or an aquiclude intersects the land surface.
- Groundwater flows into most wells directly by gravity. Pumping of water from wells creates cones of depression in the water table.
- Major supplies of groundwater are found in aquifers, among the most productive of which are porous sand, gravel, and sandstone.
- If the top of a well that penetrates an artesian aquifer lies below the altitude of the water table in the recharge area, hydrostatic pressure will allow water to rise in the well and flow out at the surface without pumping.
- An unconfined aquifer is one that is not constrained above by an aquiclude, whereas a confined aquifer is bounded by aquicludes.
- Excessive withdrawal of groundwater can lead to lowering of the water table and to land subsidence.
- Water quality is influenced by the content of natural dissolved substances, seawater intrusion, and pollution by human and industrial wastes that percolate into groundwater reservoirs.
- Hazardous (toxic and radioactive) wastes should be stored underground only if geologic conditions imply little or no change in groundwater systems over geologically long intervals of time

- .Groundwater dissolves mineral matter from rock. It also deposits substances as cement between grains of sediment, thereby reducing porosity and converting the sediments to sedimentary rock.
- In carbonate rocks, groundwater not only creates caves and sinkholes by dissolution but also deposits calcium carbonate as dripstone and flowstone.
- Karst topography forms in areas of porous carbonate or other soluble rocks where the relief is great enough to permit gravitational flow of groundwater.

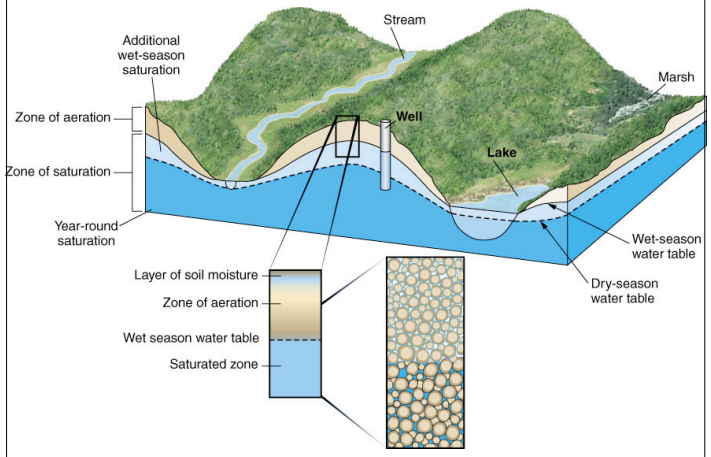
- water occupying pore spaces within bedrock and regolith
- Most originates as rainfall
  - Recharge
  - Discharge
- Most is shallow (<750 m)
  - Has been found as deep as 11 km

Hydrologic System

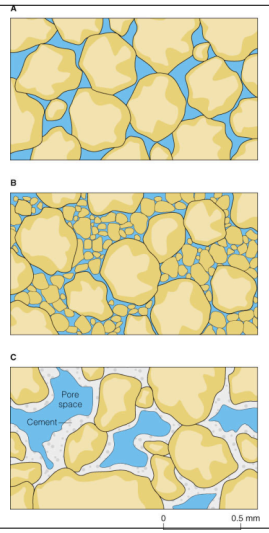
- ***97% in oceans***
- ***2% in glaciers***
- ***1% in surface and groundwater***
- 40 times more groundwater than surface water!

Water Table

- "Aeration zone" or "unsaturated zone"
  - Near surface regolith with mainly air filled voids
- "Saturated zone"
  - All openings filled with water
- "Water table"
  - Surface separating aeration zone from saturated zone



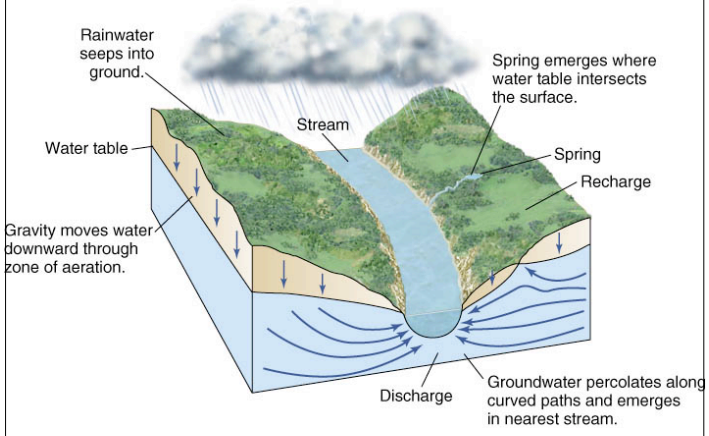
- "Porosity"
  - Amount of open space in soil or rock
  - Controlled by:
    - Size and shape of particles
    - Compaction
    - Overburden
    - Degree of cementation
  - 10%-50% in gravels
  - less in bedrock
    - Very low in igneous/metamorphic
    - Limestone can have caves with large volumes

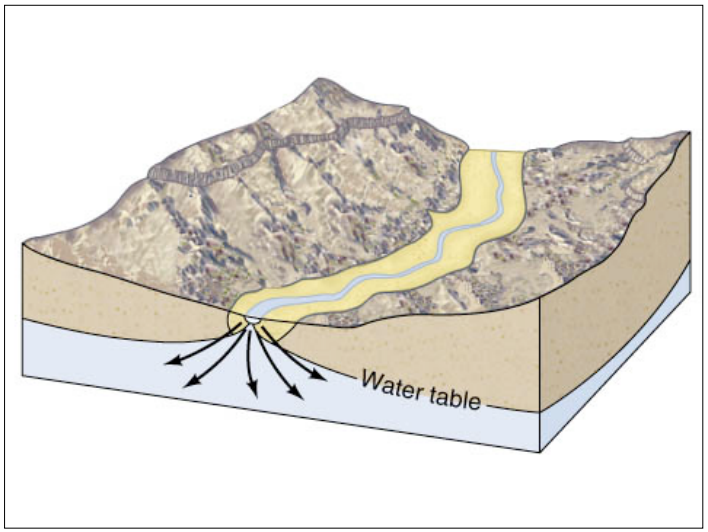


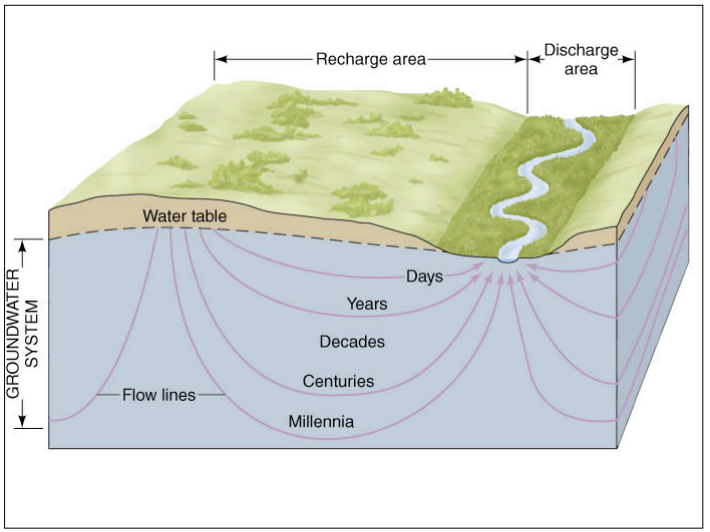
- Permeability
  - Connectivity of voids in porous material
  - High permeability -> easier flow of water
  - High porosity does not always mean high permeability
    - examples

Groundwater movement

- Most groundwater is in constant motion
  - From cm/year to several hundred meters/year
- From "recharge" area to "discharge" region
  - Days (shallow) to millennium (deep)
- Generally slow rate:
  - Time required to remove pollution or to recharge
- "Percolation" in saturation zone
  - Gravity driven, threadlike paths,





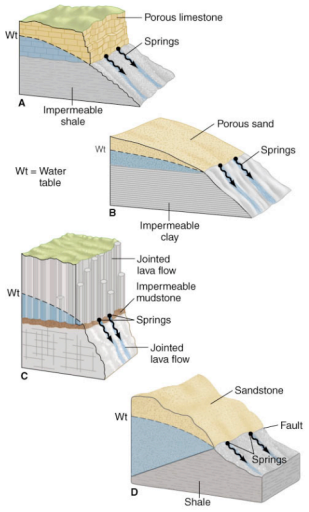


Darcy's Law

- Groundwater "flux" is proportional to "hydraulic gradient"
- "Flux" is volume of water moving through an area in a period of time
- "Hydraulic Gradient" is slope of water table
- Constant of proportionality is "permeability"

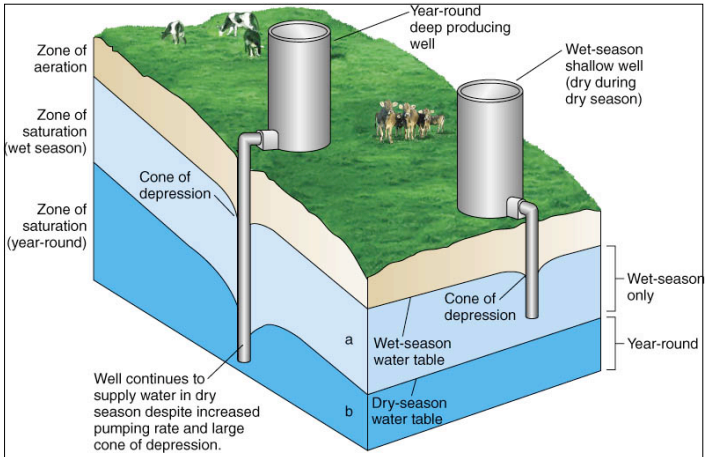
Aquifers & Springs

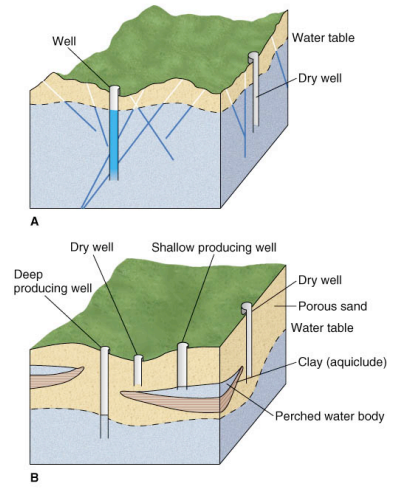
- ***Aquifer: Body of permeable rock saturated with water***
  - Sufficient porosity and permeability to supply wells
  - can be regionally extensive
  - confined aquifers create artesian wells and springs
- ***Springs: Groundwater emerging at the surface***
  - aquiclude
  - seasonally variable
  - cold springs most common
  - hot springs require either volcanic heat or deep circulation on faults



Wells

- Cone of depression
- Perched water table
- Subsidence
- Water "mining"





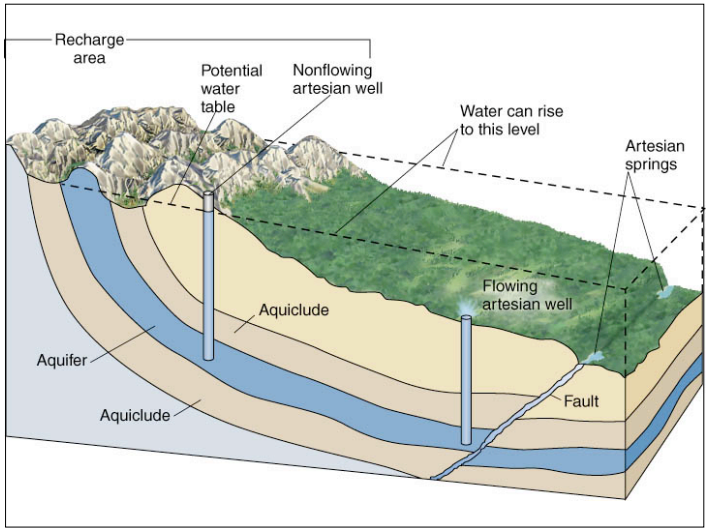
Aquifers

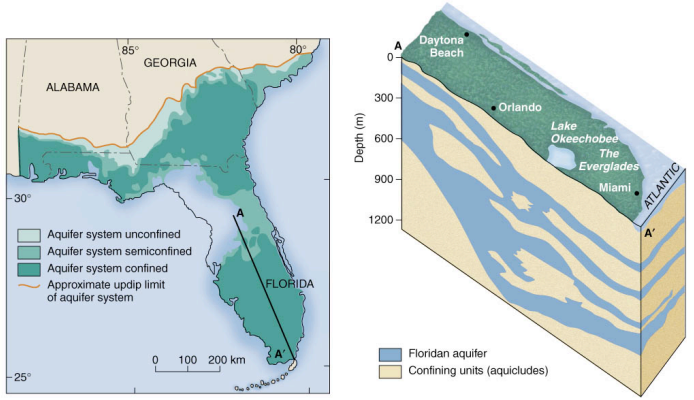
- Sand/gravel are good prospects
- Sandstones may be good
- Special case: limestone
- Confined
  - bounded by aquicludes.
- Unconfined
  - an aquifer that is not overlain

High Plains Aquifer

- Provides 30% of irrigation in US
- Water table has dropped by 50%

- The Dakota aquifer : confined aquifer.
- **artesian aquifer**, and the well is called an **artesian well.**





Puget Sound Aquifers

Groundwater "Mining"

- In the dry regions of western North America, groundwater is a major source of water for human consumption
- In many of these dry regions, withdrawal exceeds natural recharge.
- Groundwater: a nonrenewable resource

- Natural recharge takes so long to replenish a depleted aquifer that vast underground water supplies have been lost to future generations.
- When groundwater withdrawal exceeds recharge, the water table falls.
  - It can cause shallow wells to run dry and necessitate the drilling of still

- The water pressure in the pores of an aquifer helps support the weight of the overlying rocks or sediments.
- When groundwater is withdrawn, the pressure is reduced, and the particles of the aquifer shift and settle slightly.
- As a result, the land surface subsides.
  - widespread in the south-western United States.
  - It has caused structural damage to buildings, roads, cables, pipes, and drains.

- **Chemical weathering by ground water**
- ***chemical species: chlorides, sulfates, bicarbonates, magnesium, calcium, sodium, iron, etc.***
- ***"Hard Water" is rich in bicarbonates of calcium and magnesium***
- ***transports cements***

Caves

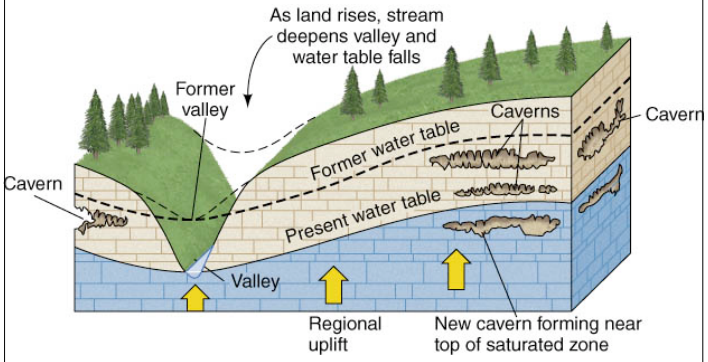
- **Result of extensive chemical weathering of subsurface**
- **An issue of Chemical Equilibrium**
  - *variables: temperature, pressure, and concentration*
    - *T decrease - more limestone dissolves in H_2O*
    - *Increase concentration by evaporation - limestone precipitates*
    - *Increase acidity - limestone dissolves*

Chemical precipitates

- ***dripstone***
- ***flowstone***
- ***stalactites***
- ***stalagmites***

Caves

- **Sinkholes**
  - *large solution cavity open to the sky*
- **Karst Topography**
  - *regionally pervasive dissolution yielding closely spaced sinkholes*



Underground Storage of Hazardous Wastes

- Most studies concerning disposal of hazardous wastes— both toxic and radioactive— have concluded that underground storage is appropriate, provided safe sites can be found.
- Safe sites for disposing of radioactive wastes must not be affected chemically by groundwater, physically by earthquakes or other disruptive events, or accidentally by people.

- Geologists generally agree that the ideal underground storage site for radioactive wastes should possess the following characteristics:
  - The enclosing rock should have few fractures and low permeability.
  - The enclosing rock should have no present or future economic mineral potential.
  - Local groundwater flow should be away from plant and animal life.

  - Only very long paths of groundwater flow should be directed toward places accessible to humans.
  - The area should have low rainfall.
  - The zone of aeration should be thick.
  - The rate of erosion should be very low.
  - The probability of earthquakes or volcanic activity should be very low.
  - Future climate change should be unlikely to affect groundwater conditions substantially.