Geologic Processes: A Ground-Water Perspective

GLY 414/514

MW Becker

Porosity and Permeability

- A hydrogeologist needs to understand geologic processes as they affect the porosity and permeability of geologic deposits and formations.
- We are differentiate:
  - Lithology: the mineralogy, grain size, and grain packing of the sediments or rocks
  - Stratigraphy: the geometric and age relationships between various geologic deposits or formation

Continental Environments

- Continental geologic environments are shaped by:
  - Weathering
  - Erosion
  - Transport
  - Deposition

Weathering

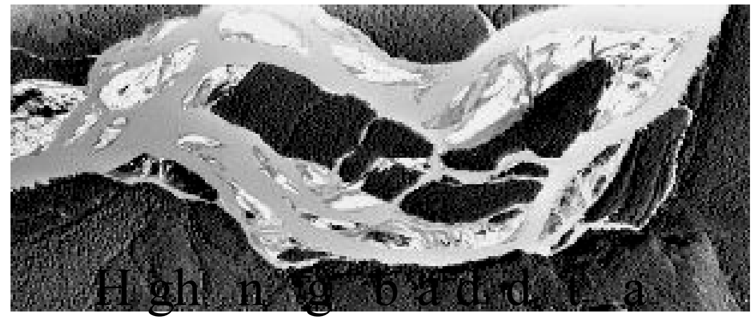
- Water is both ubiquitous and the perfect solvent, facilitating the chemical decomposition of rocks
- Moving and frozen water leads to physical decomposition of rocks.
- The overall affect is to transform consolidated material (rocks) in to unconsolidated material (soils and sediments)

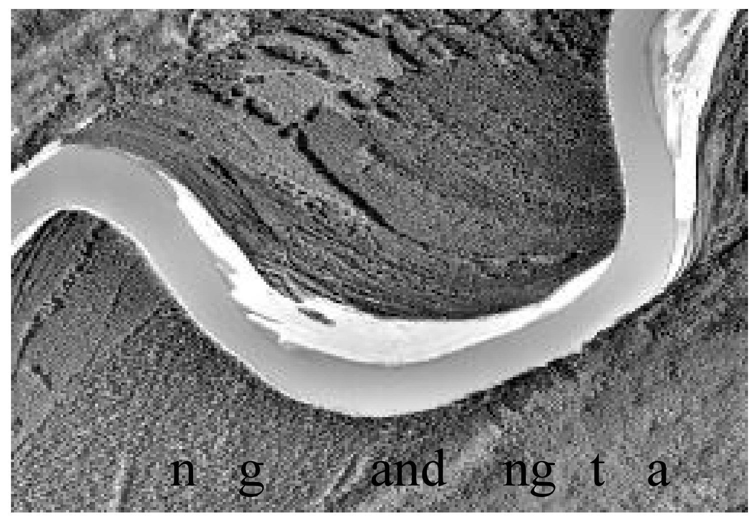
Fluvial Deposits

- Streams and rivers breakup rock material and redistribute them.
- Sediments deposited by moving water are called “fluvial”

Fluvial Deposits

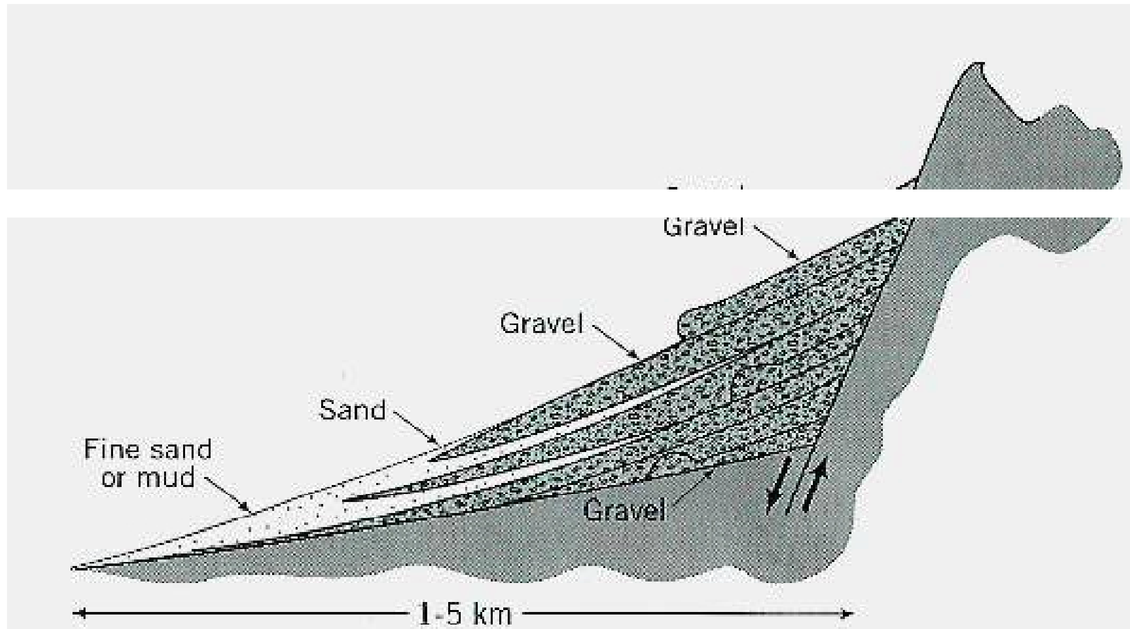
- High energy water movement leaves large grained deposits.
- Large-grained deposits are generally make permeable aquifers





Alluvial Fans

- Alluvial fans are created where streams enter standing water



- Graded from coarse sediments upstream to fine sediments downstream

Alluvial Valleys and Basins

Alluvial Valleys

- Streams carve out valleys and leave them filled with sediments
- Sediments tend to be graded course to fine, from the center to the edge of the channel

Alluvial Basins

- In areas of mountain building (basin and range) basins are filled with eroded material
- Can result in very thick sequences of alluvium (e.g. Ogallala Aquifer)

Eolian Deposits

- Created by erosion and deposition by wind:
- Loess: unstratified fine-grained deposits (usually from glaciers)
- Dunes: stratified sand deposits (usually from deserts)

and h b a a d n
t n g a a d b
d d t th

Lacustrine Deposits

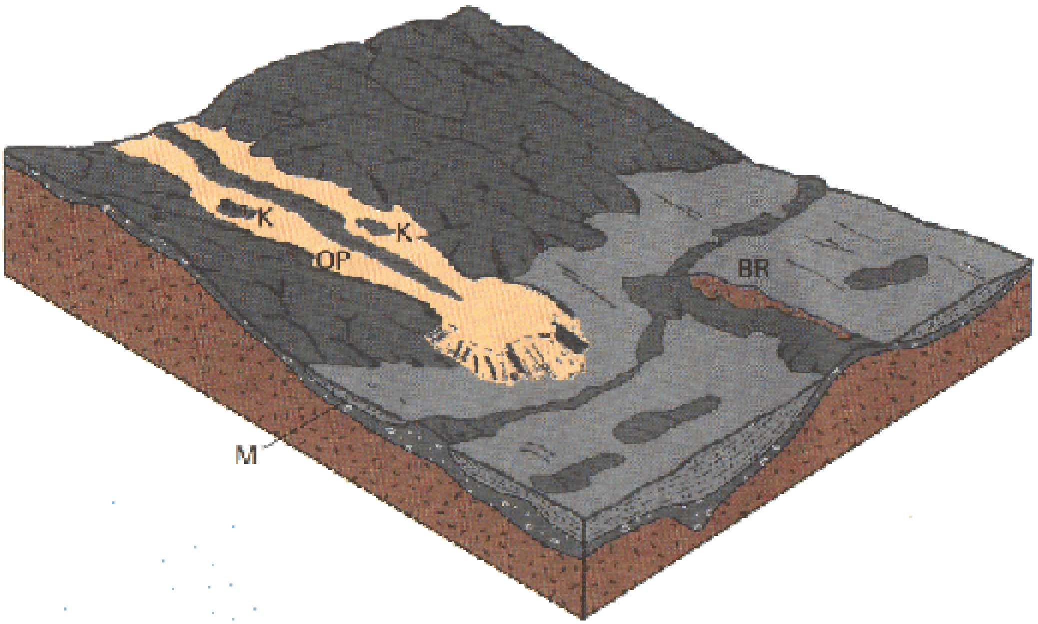
- Sediments deposited by lakes
- Because very low energy, tend to be very fine grained and produce low-permeability units.
- May also produce sequences of evaporites (e.g. gypsum).

Glacial Deposits

- Ice, water, wind, deposit glacial "drift". Water is everywhere near a glacier!

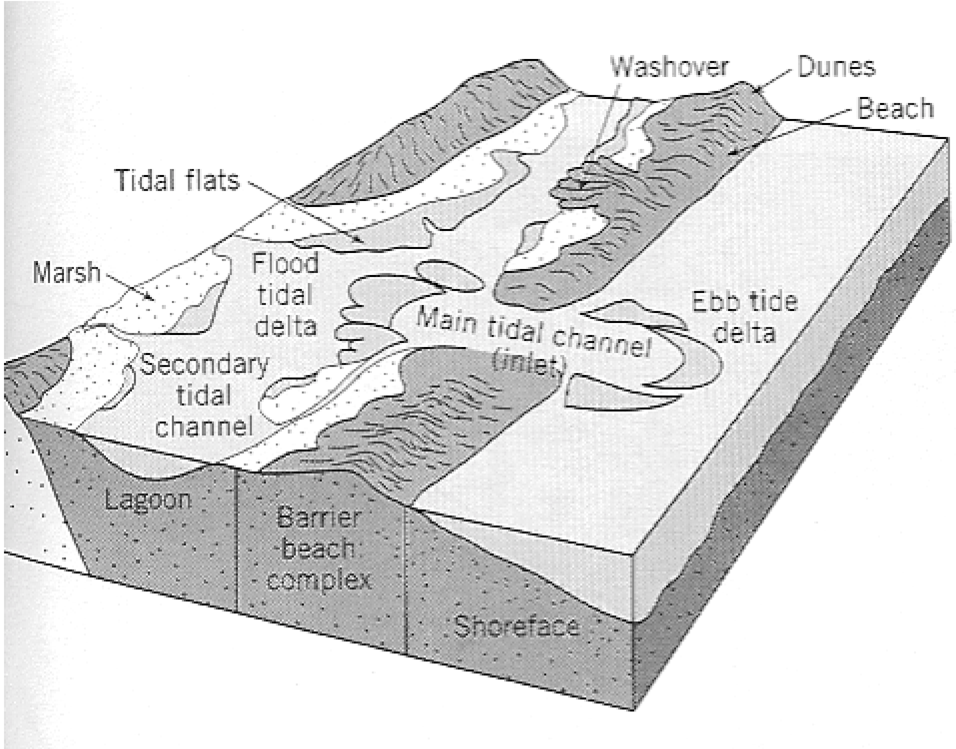
Glacial Deposits

- Glacial drift can be very thick and is typically extremely variable because of the variety of erosional and depositional mechanisms.



Coastal Environments

- At margin of continents high-energy beach deposits develop next to low-energy tidal deposits



Marine Environments

- Marine sequences progress from sand to silt to limestone away from the coast. The resulting formations tend to be extensive.

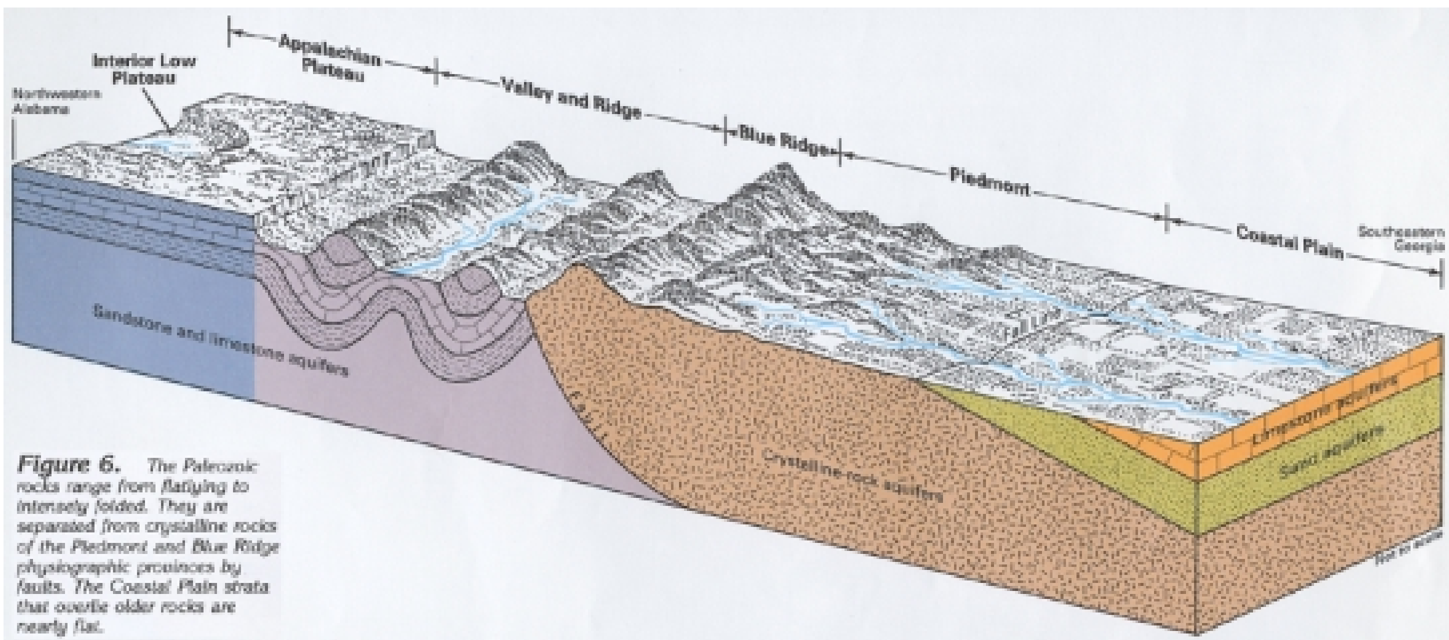
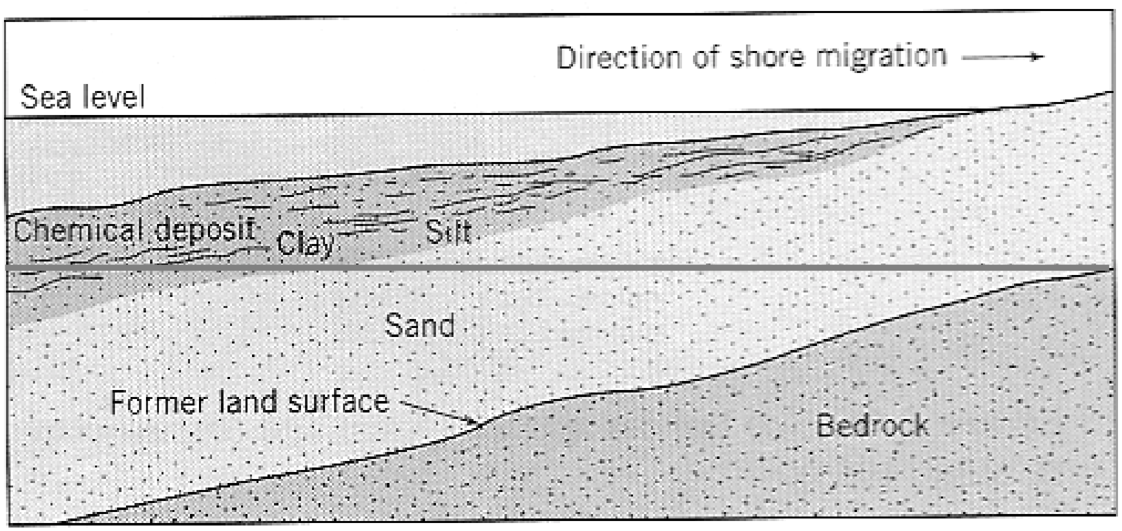


Figure 6. The Paleozoic rocks range from flatlying to intensely folded. They are separated from crystalline rocks of the Piedmont and Blue Ridge physiographic provinces by faults. The Coastal Plain strata that overlie older rocks are nearly flat.

Marine Environments

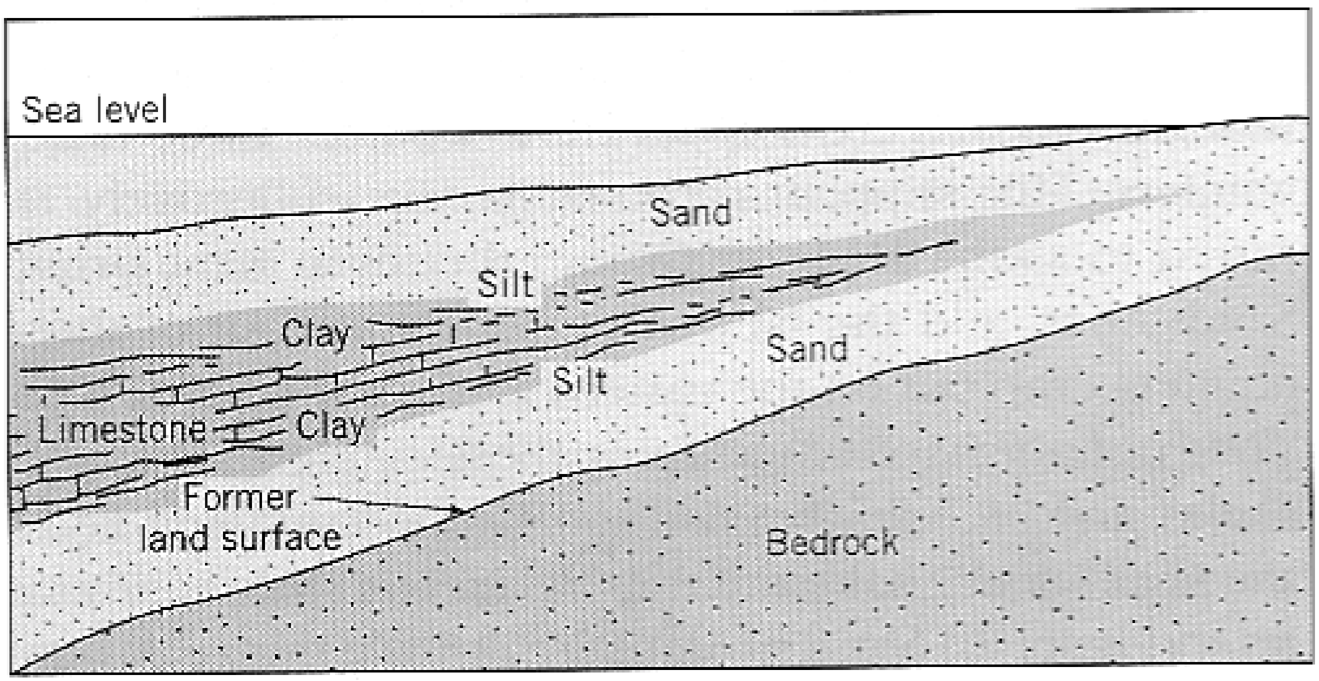
- Marine deposits are mapped with an understanding of transgression and regression of sea level



Ri in a l l
l in
an i
n

Marine Environments

- Repeated rising and lowering of sea level results in “transgressive-regressive” sequence



Diagenesis

- Means “re-making” of rock
- Can be physical or chemical change
- Usually occurs over long periods of time and under heat and pressure
- Can significantly alter the porosity and permeability of rock

Physical Porosity Reduction

- Compaction: rearrangement of grains and change in grain shape
- Pressure solution: grains dissolve at grain-grain contacts due to focused pressure

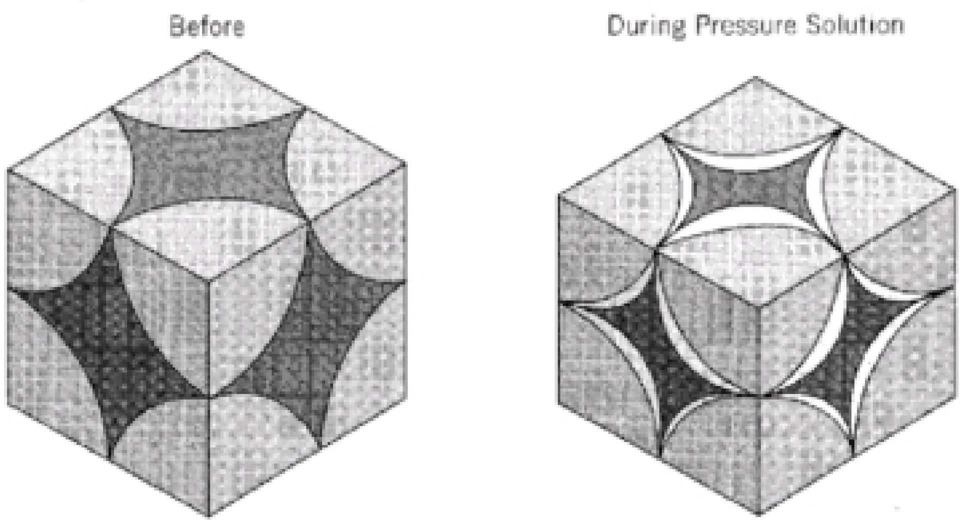


Figure 2.19 Pressure solution of identical spheres of simple cubic packing (from Weyl, J. Geophys. Res., v. 64, p. 2001–2025, 1959. Copyright by Amer. Geophys. Union).

Physical Porosity Reduction

The magnitude of porosity reduction is usually proportional to depth.

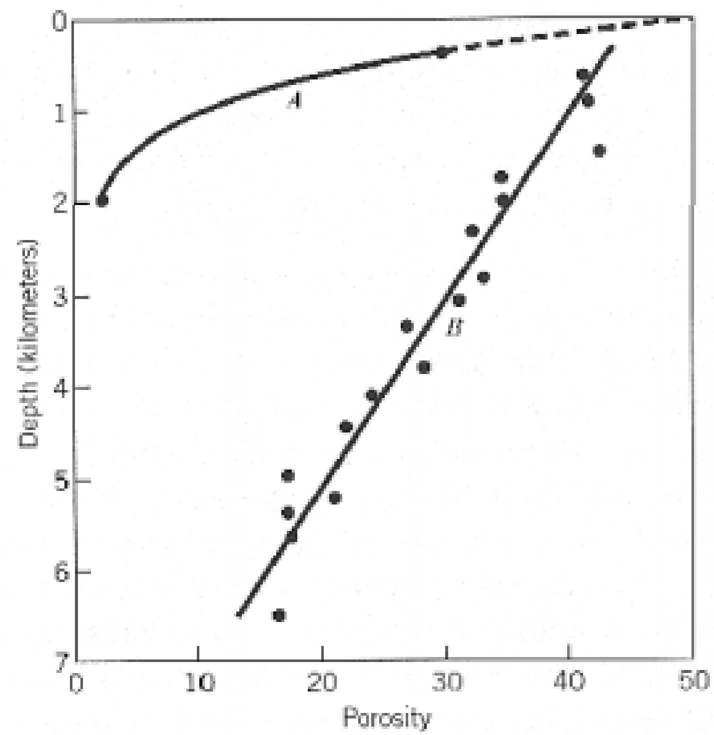


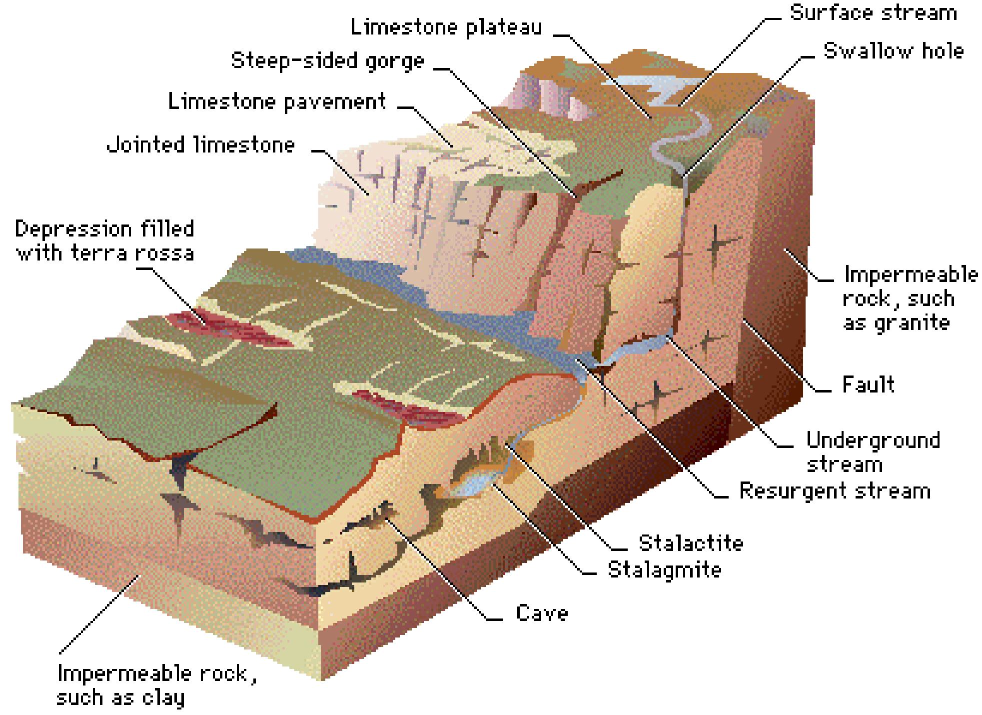
Figure 2.18 Porosity versus depth curves. Curve *A* from Athy (1930) for shales; curve *B* from Blatt (1979) for sandstones. Data for Blatt's curve represent 1000-ft averages of 17,367 porosity measurements (from an unpublished manuscript by Atwater and Miller).

Chemical Porosity Change

- Porosity can be reduced by:
  - Cementation
  - Mineral replacement
  - Recrystallization
- Porosity can be increased by:
  - Dissolution of grains
  - Dissolution of cement

Carbonate Dissolution

- Rain picks up CO_2 which percolates through the soil and picks up more CO_2 to form a weak solution of carbonic acid: **$H_2O + CO_2 = H_2CO_3$.**
- The infiltrating water naturally exploits any cracks or crevices in the rock.



Role of Pore Water in Diagenesis

- Compaction causes water to be displaced (volume of water forced out equals reduction in porosity)
- Under heat and pressure, pore fluid migration usually bring about chemical gradients
- Chemical gradients lead to cementation or dissolution

Residual Pore Water

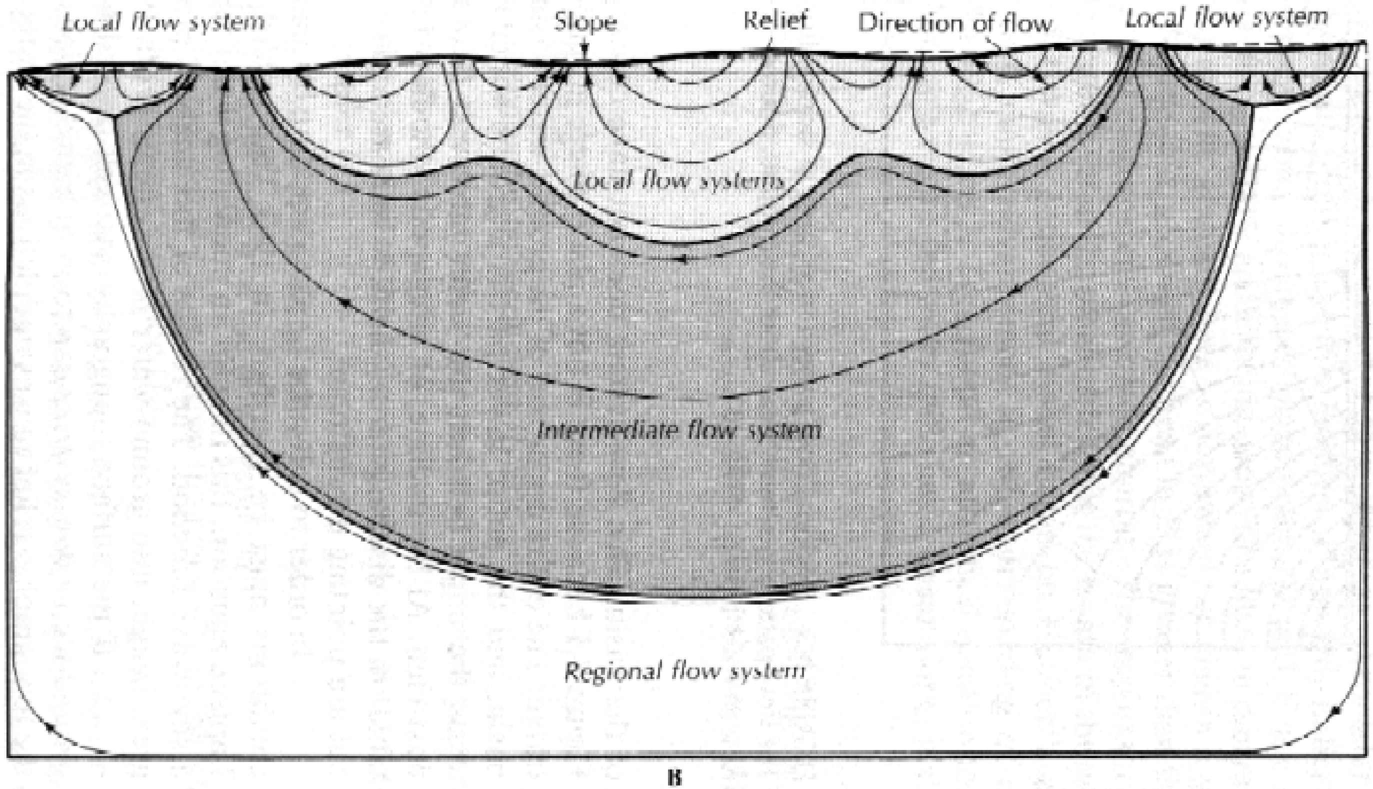
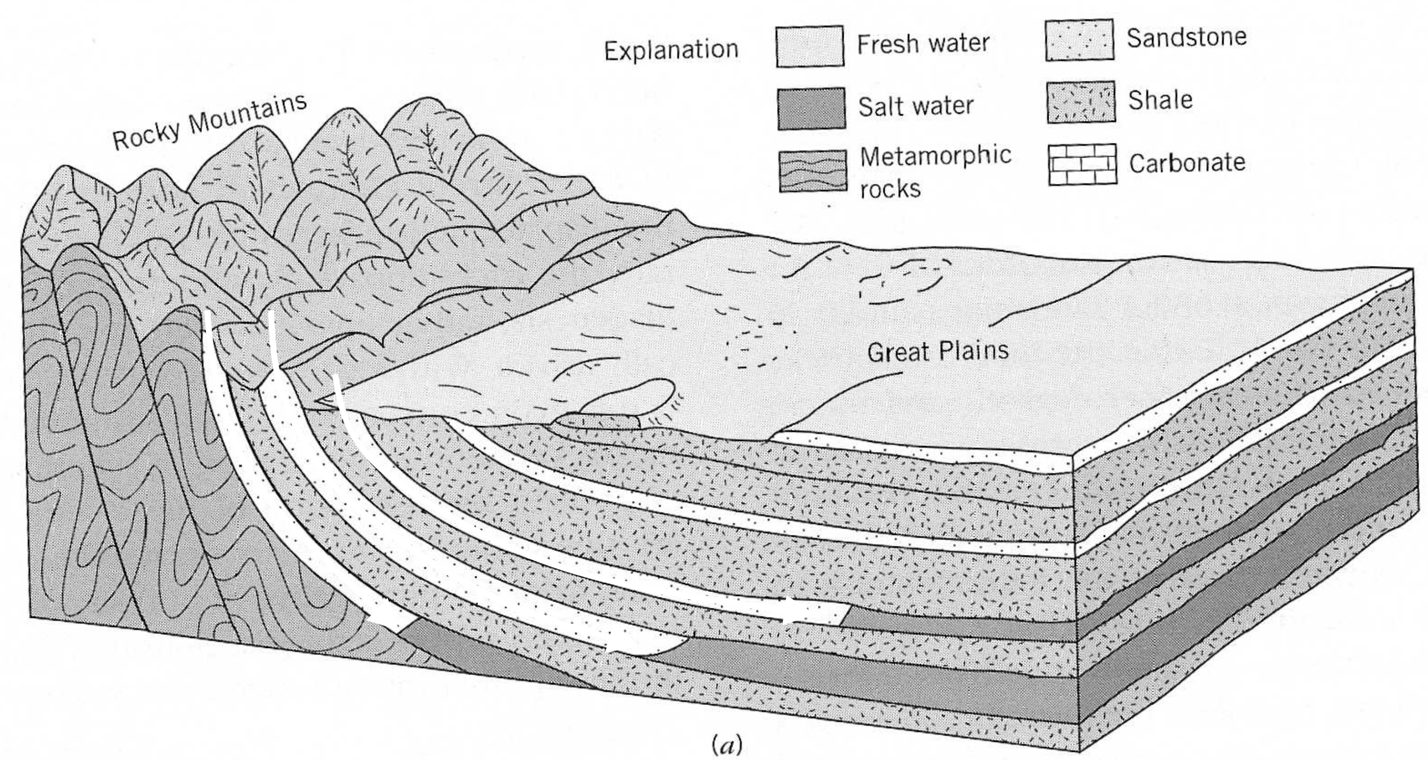


FIGURE 8.4 The effect of increased basin depth is shown on these two figures. In Part A, the basin depth/length ratio is 1:20; in Part B, it is 1:2. The shallow basin has only local flow systems, whereas the deep basin has local, intermediate, and regional flow systems. The water table configuration is the same for both basins. Source: J. A. Tóth, *Journal of Geophysical Research* 68 (1963): 4795–4811.

Uplift and Erosion

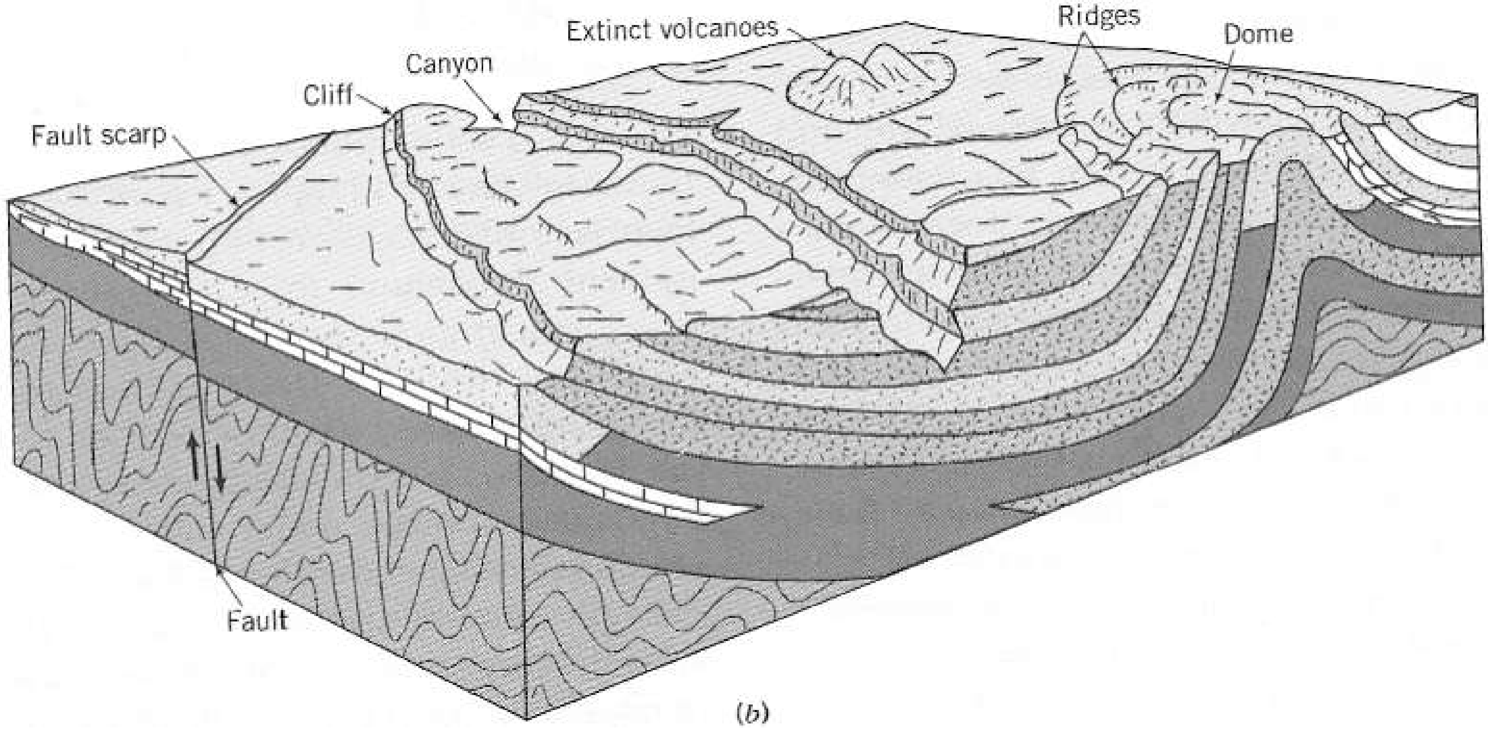
Uplifted Range



Colorado Front Range (after Heath, 1984)

Uplift and Erosion

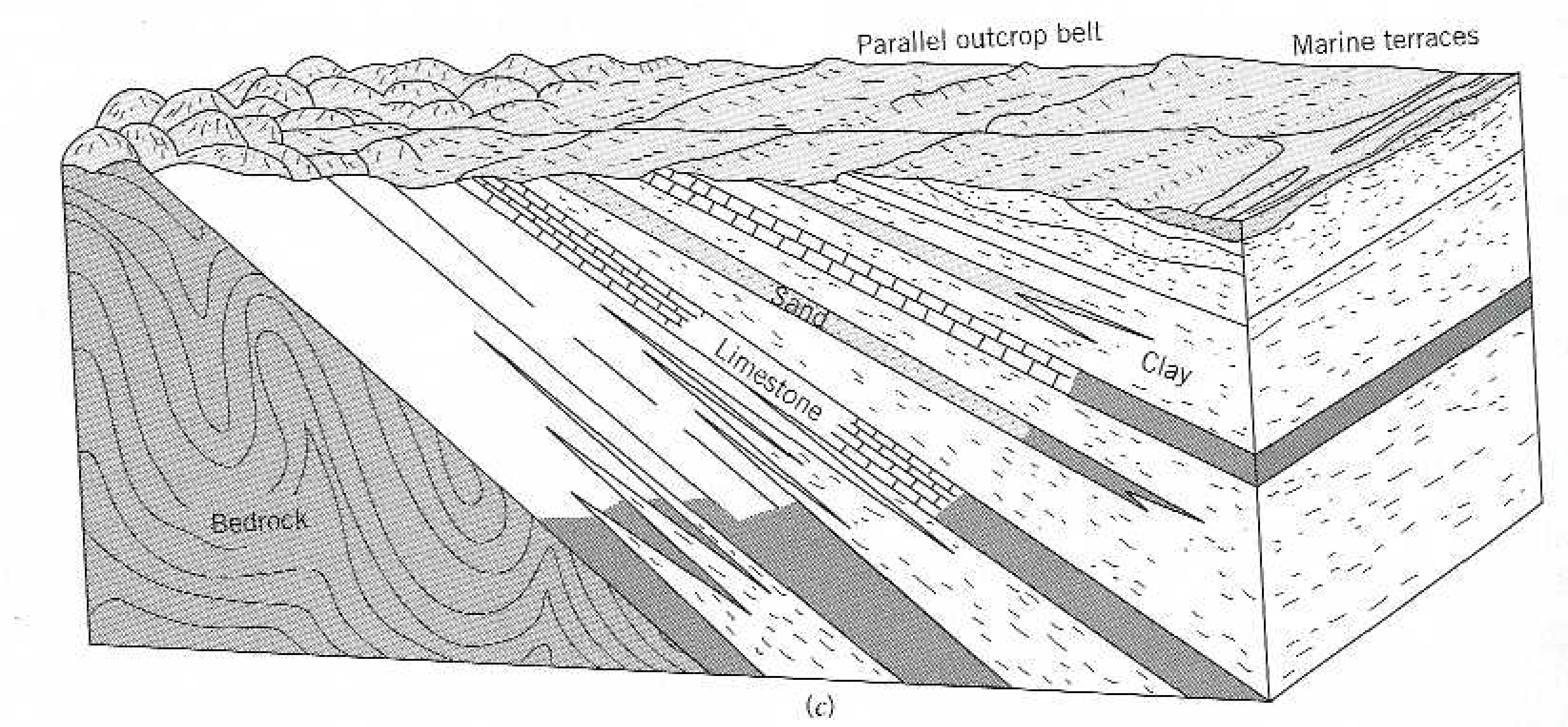
Uplifted Basin



Colorado Plateau (after Heath, 1984)

Uplift and Erosion

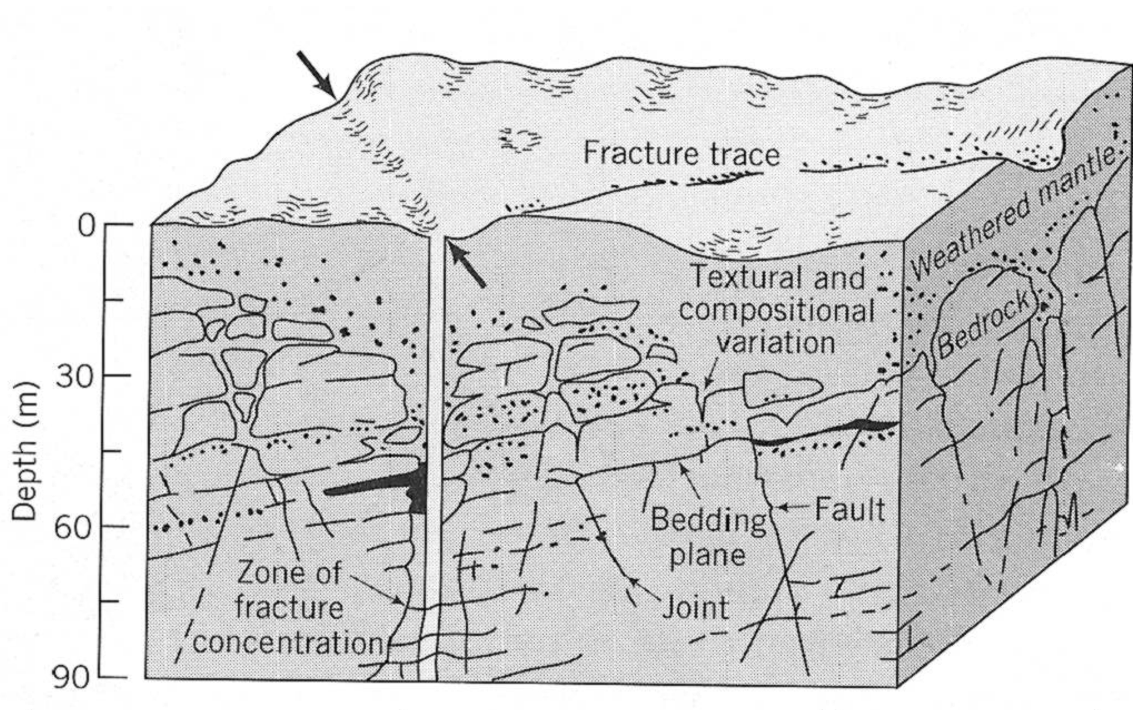
Erosion without Uplift



Atlantic Coastal Plain (after Heath, 1984)

Stress and Strain

- Tectonic and Loading stresses result in fracturing of stiff geologic material (rocks and clays)



(after Lattman and Parizek, 1964)