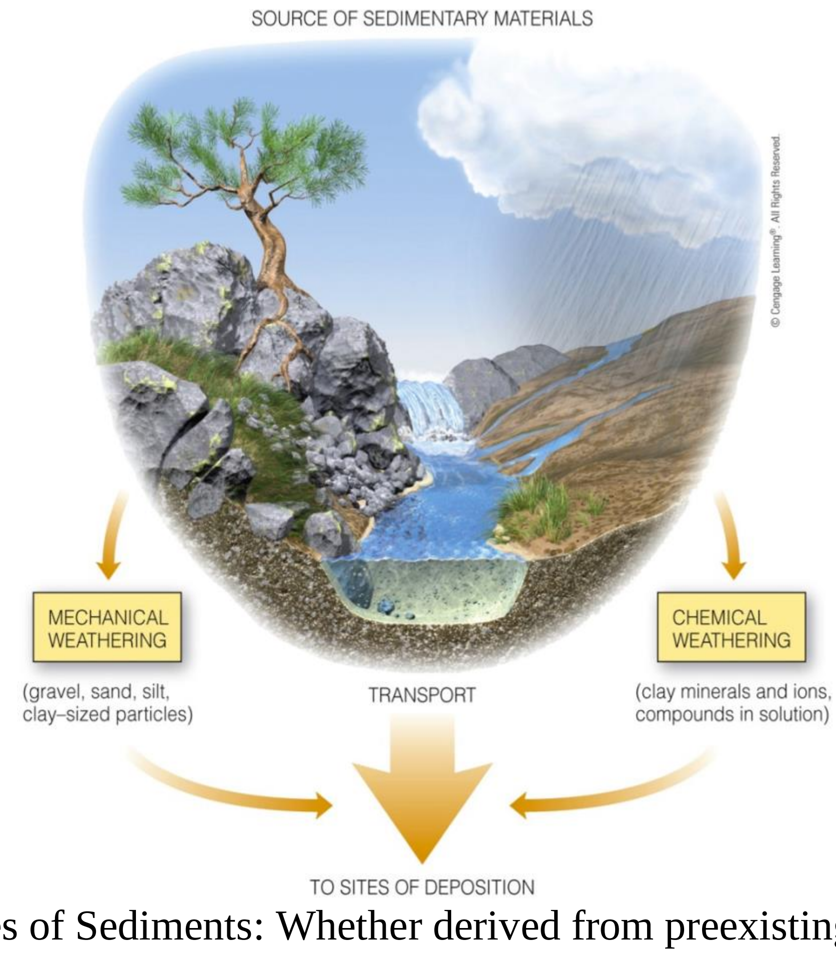
Sediment and Sedimentary Rocks

Some basic terminology

Weathering: mechanical and chemical decomposition and disintegration of rock and minerals at the surface

Erosion: removal of weathered rock and minerals from one place to another by water, wind, glaciers, and gravity

Transportation: moving of eroded material



Sources of Sediments: Whether derived from preexisting rocks by mechanical or chemical weathering, solid particles and ions and compounds in solution are transported and deposited elsewhere. If they are lithified, they become detrital and chemical sedimentary rocks.

Sedimentary rock: physically and/or chemically weathered rock that has been cemented together after being deposited

- makes up 5% of crust
- make up 75% of surface

Lithification: cementation/compaction of sediment

Sediment: all solid particles transported and deposited by wind, waters, glaciers, and gravity. Includes precipitates.

- Mechanical and chemical weathering produces the raw materials for soil and sedimentary rock
- Sediment may be **clastic** or **chemical**, and sedimentary rocks may form by the deposition of particles or by biologic activity
- **Clastic** sedimentary particles and the rocks they form are classified according to **size**

- Gravel/Rubble:	>2mm in diameter
- Sand:	1/16mm to 2 mm
- Silt:	1/256mm to 1/16mm
- Clay:	<1/256mm

Bioclastic sediment: remains of organisms, shells

Chemical sediment: deposits made from a precipitate

- ex. halite and limestone

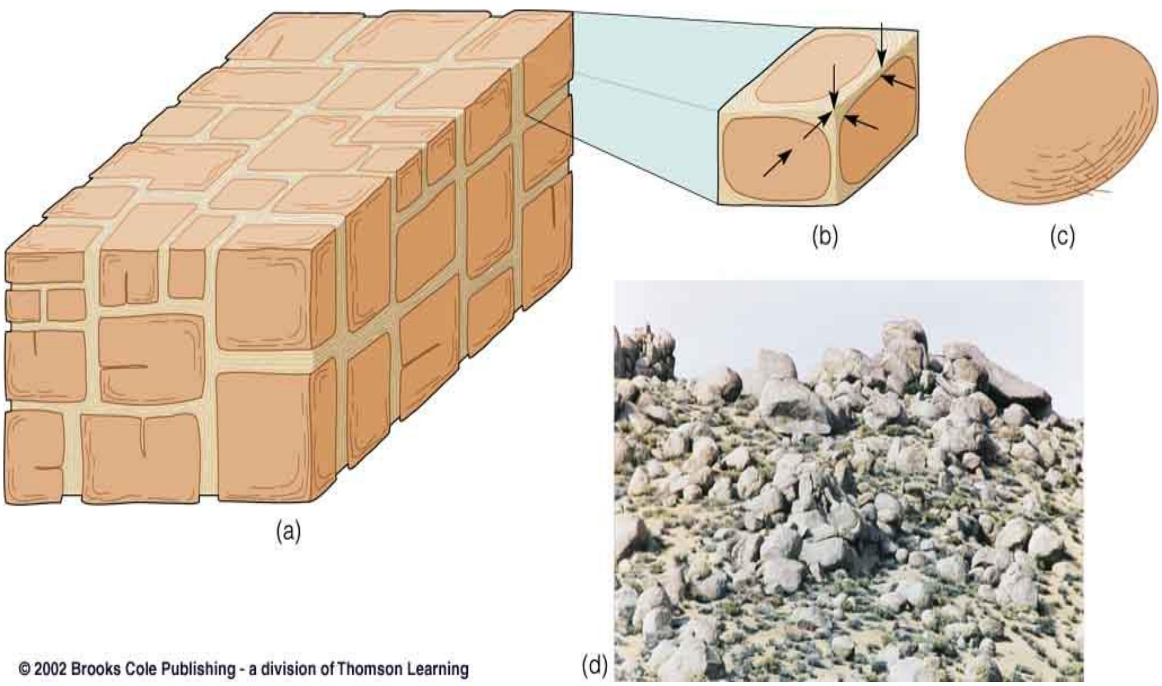
Clastic sediment: fragments of weathered rock or clasts

Making Sediment Through Weathering 7.1

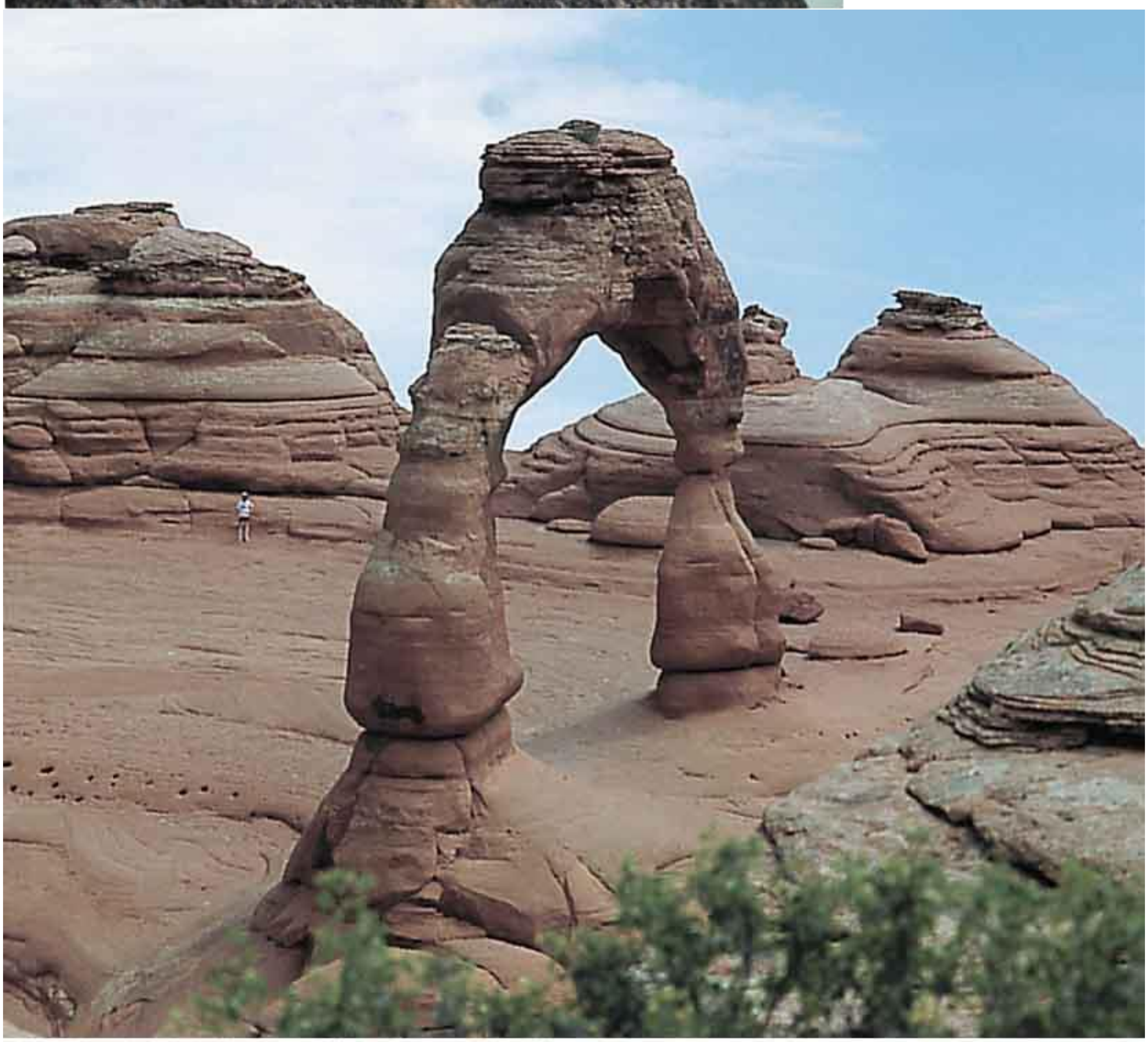
How are Earth Materials Altered?

Two Types of weathering: **Mechanical** and **Chemical** weathering
- decomposition and/or disintegration of rock and minerals at the surface

Why weathering occurs
- tectonic activity
- atmosphere
- Structural and chemical differences in rock can produce spectacular formations
- **Spheroidal weathering-** when the edges weather faster than the sides



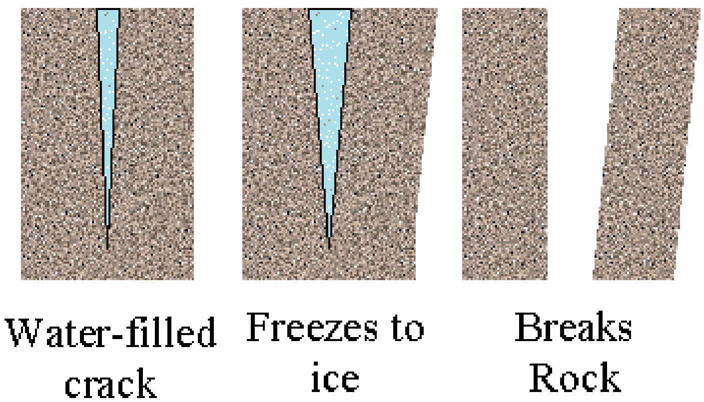
- **Differential weathering** – when certain rocks/minerals weather more rapidly than adjacent rocks/minerals



Mechanical Weathering: Physical forces break rocks into smaller pieces that retain the chemical composition of the parent material

- Types
  - Frost wedging
  - Pressure release
  - Thermal expansion/contraction
  - Salt crystal growth
  - Organic activity
  - Abrasion

- Frost wedging
  - water expands when freezes

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- Pressure Release
  - Cracking of rock due to a decrease in pressure
    - this occurs when a pluton is uplifted towards the surface
  - Exfoliation: when large sheets of rock splits of a larger rock mass like layers of an onion.
    - Granite behaves this way. Why?
      - Granite contains f-spar which chemically combines with water to form clay. Clay is bigger in size, therefore, rock expands and peels off in sheets

Slabs of granitic rock bounded by sheet joints in the Sierra Nevada of California. The slabs are inclined downward toward the roadway visible at the lower left.

Notice in this image that the sheet-joint bounded slabs have started moving down-slope toward the road.

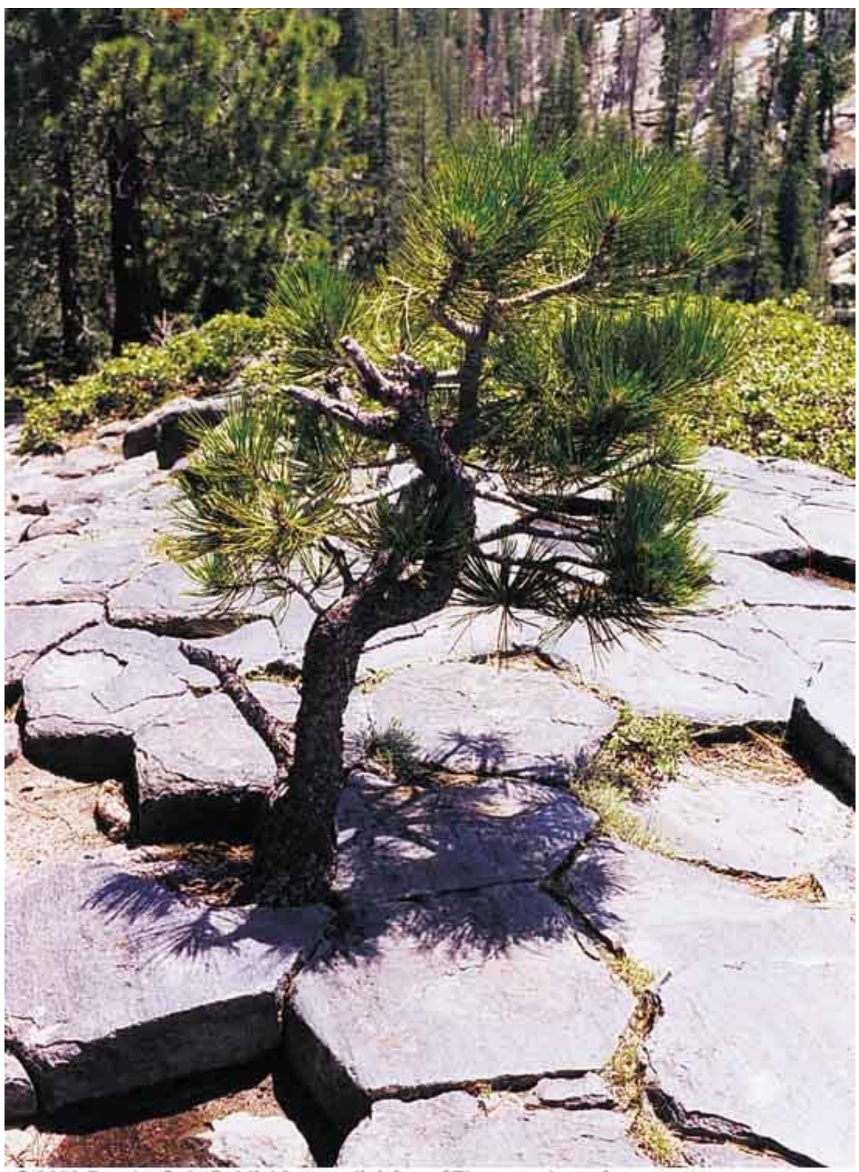
Exfoliation Domes North Dome and Basket Dome are two of many exfoliation domes in Yosemite National Park, California. In the distance you can see several other exfoliation domes.

]

- Thermal expansion and contraction
    - occurs during periods of differential heating and cooling, causing the rock to crack

- Salt cracking
    - salty water enters cracks
    - water evaporates leaving crystals that exert pressure on the rock (works just like frost wedging)

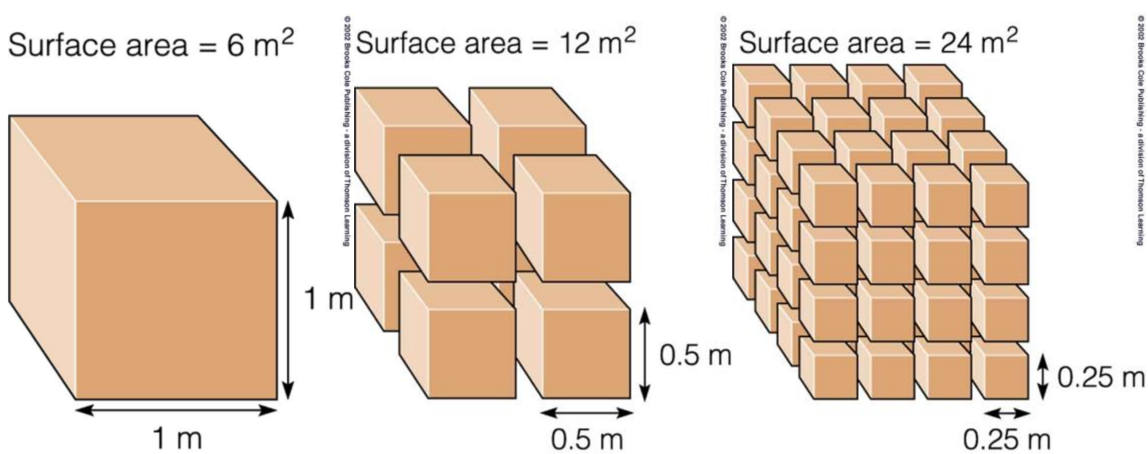
- Organic activity
    - plant roots grow into crack
    - roots expand and crack the rock (works just like frost wedging)



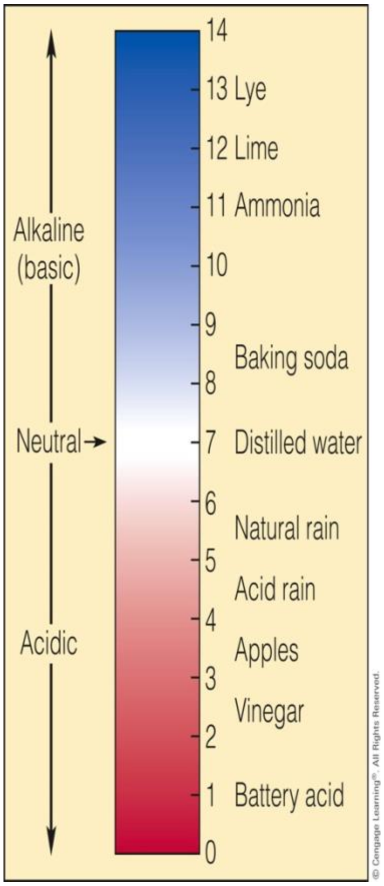
- Abrasion
  - grinding of rock surfaces by friction and impact.
    - produces rounded surfaces
  - agents of abrasion
    - water
    - wind
    - glaciers

Factors controlling the rate of mechanical weathering

- Mechanical weathering increases the surface area of parent rock, enabling mechanical processes to act more effectively



- Topography, particle size, climate, parent material, fractures
- Climate: High temperatures, rainfall, and lush vegetation will increase mechanical weathering



0 = most acidic
14 = most basic
7 = being neutral

Chemical Weathering: Decomposition of parent material to produce new minerals and ions. Agents include atmospheric gases, water, and acids.

- Other processes:
  - Solution
  - Oxidation
  - Hydrolysis

- **Air**: O_2, water, CO_2

  - **O_2**: Likes to react with many other elements. We refer to this process as <u>**oxidation**</u>
    ex. Rusting

$$4Fe + 3O_2 \longrightarrow 2Fe_2O_3 \text{ (hematite)}$$

- **CO_2**: Dissolves in water to form a weak acid called carbonic acid

$$CO_2 + H_2O \rightleftharpoons H_2CO_3 \rightleftharpoons H^+ + HCO_3^-$$

Carbon Dioxide | Water | Carbonic acid | Hydrogen Ion | Bicarbonate Ion

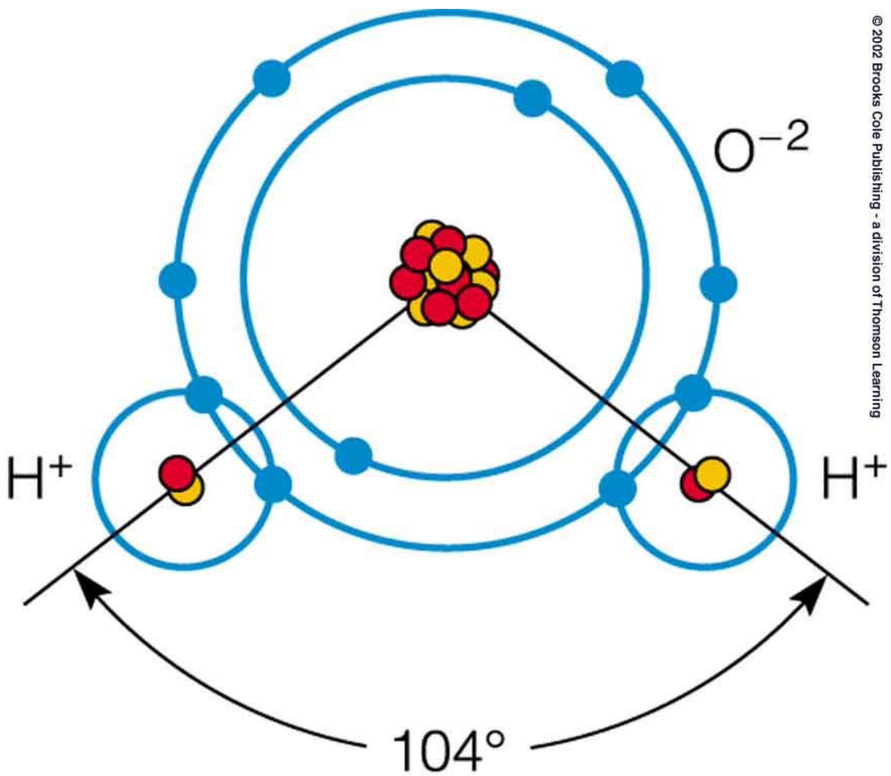
$$CaCO_3 + H^+ \rightleftharpoons H_2CO_3 + Ca^{++} \rightleftharpoons Ca^{++} + CO_2 + H_2O$$

Lime/Calcite | Carbonic acid

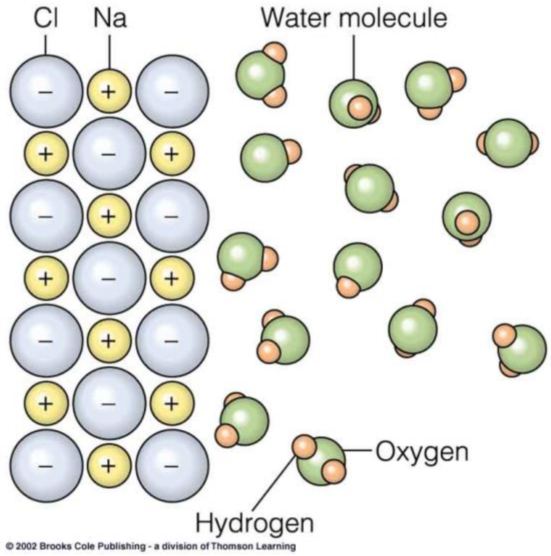
- Precipitate: when a solid "falls out" of solution

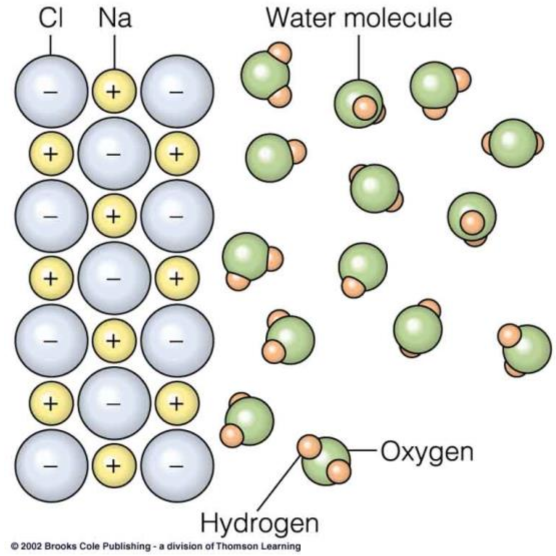
* These reactions are said to be reversible *

- **Water**: great solvent due to molecular structure and asymmetrical shape that makes the water bipolar.



- When some solids come into contact with water they will dissolve.





- Acid Rain
    - sulfur is released from burning fossil fuels
    - SO_2 is formed
    - SO_2 combines and reacts with H_2O and O_2 to form H_2SO_4 (sulfuric acid) a strong acid.
    - HNO_3 (Nitric acid) is very similar in how it reacts in the environment

- Hydrolysis: hydrogen ions (H^+) replace positive ions in minerals. Changes the composition of minerals.

    - cations$^+$
        1) K^{+1}, Ca^{+2}, Mg^{+2}, Na^{+1}: most soluble
        2) Fe^{+2}, Al^{+2}: intermediate
        3) Si^{+2}: least soluble

    - Weathering of feldspars
        - makes up 50% of crust
        - Granite = f-spar + quartz
        - f-spar weathers much more easily than quartz

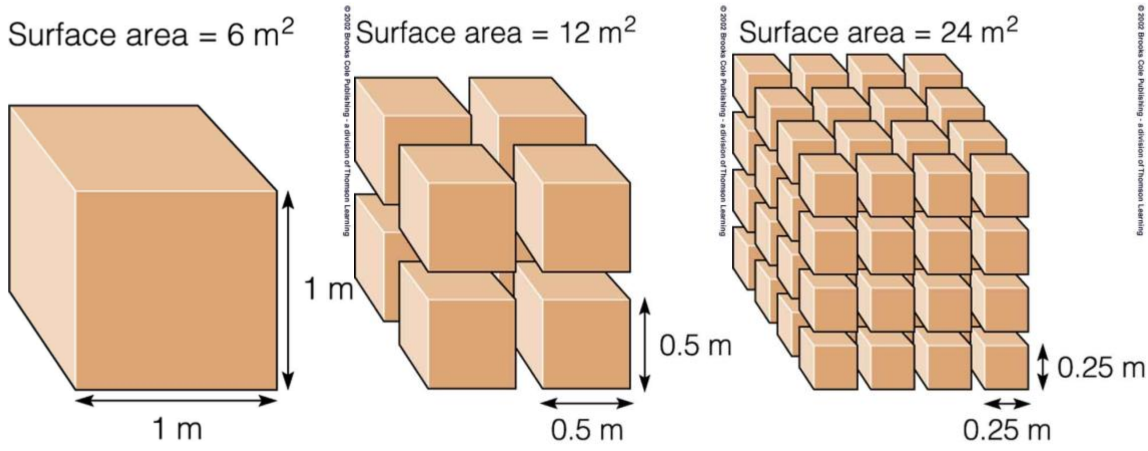
    - Example: Potassium f-spar (orthoclase) $KAlSi_3O_8$

- the K gets kicked out by the H^+ and forms clay

- F-spar weathers to clay
  - If weathers in dry environment all cations present: Smectite
  - If weather in moist environment K and some Silicon are removed: Kaolinite

- Factors controlling the rate of chemical weathering

  - Stability of minerals is opposite their order of crystallization
  - Mechanical weathering increases the surface area of parent rock, enabling chemical processes to act more effectively

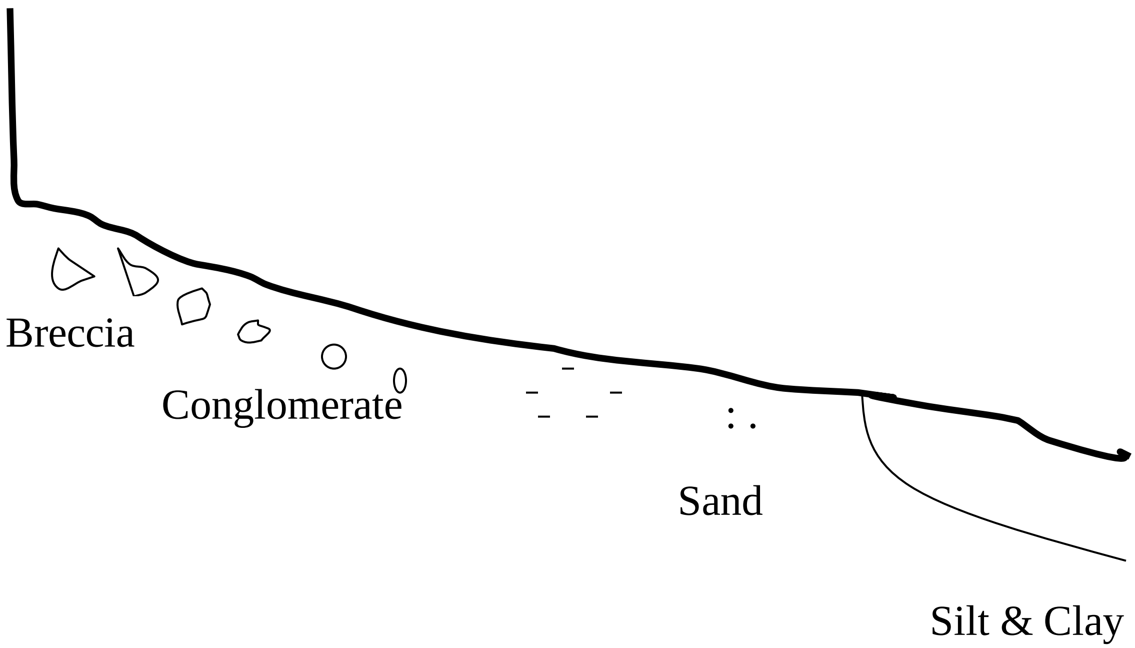


  - Presence of fractures, particle size, climate, parent material
  - Climate: High temperatures, rainfall, and lush vegetation will increase chemical weathering

Formation of Sedimentary Rock 6.1

Erosion: Movement of Sediment

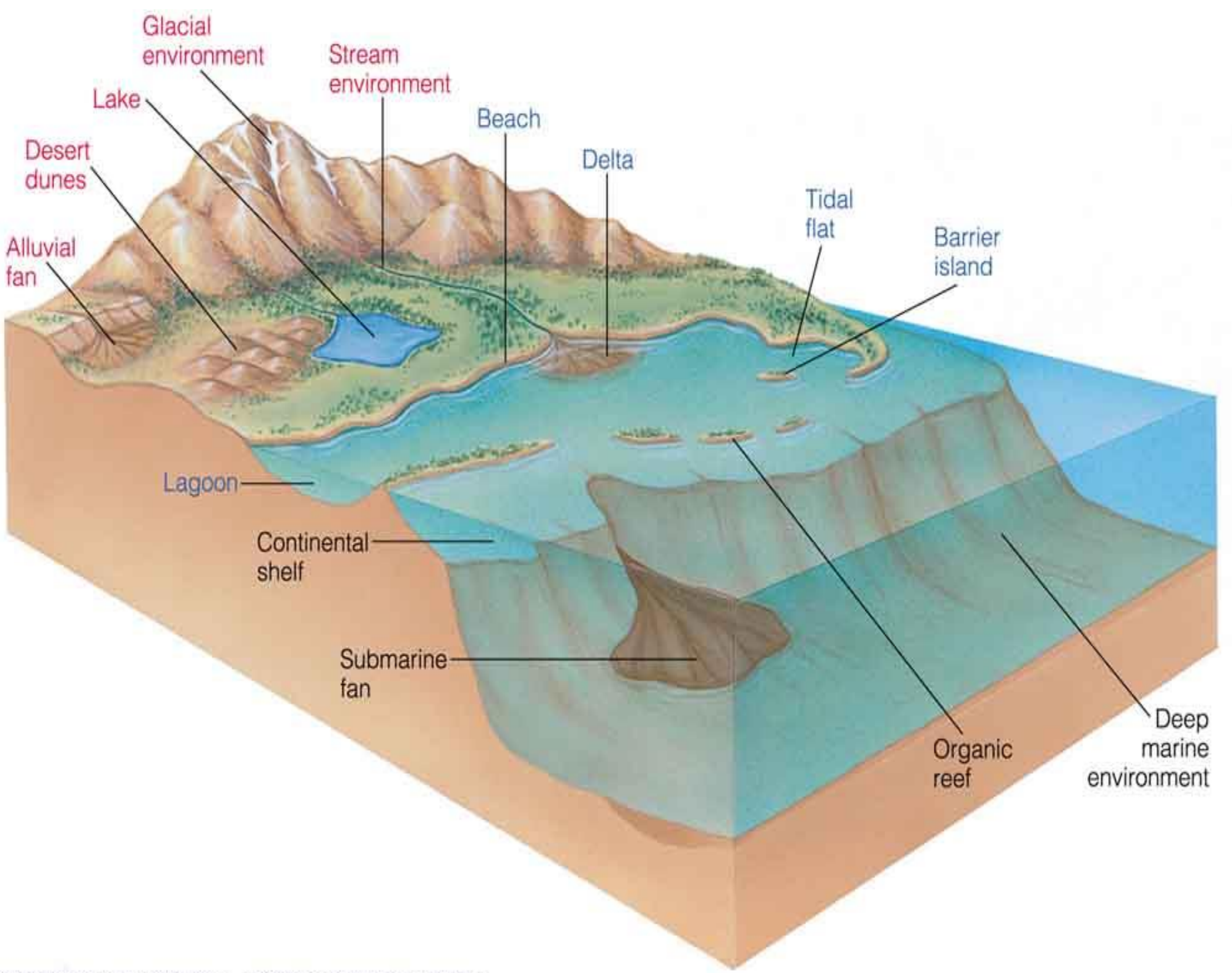
- Sediment is eroded/transported by wind, water, and glaciers, which is driven by gravity.
- As sediment moves it is weathered
    - rounding: angular edges → rounded
        - due to abrasion
- Sediment is sorted by size: Sorting
    - size decreases as you go downstream



Deposition of Sediment

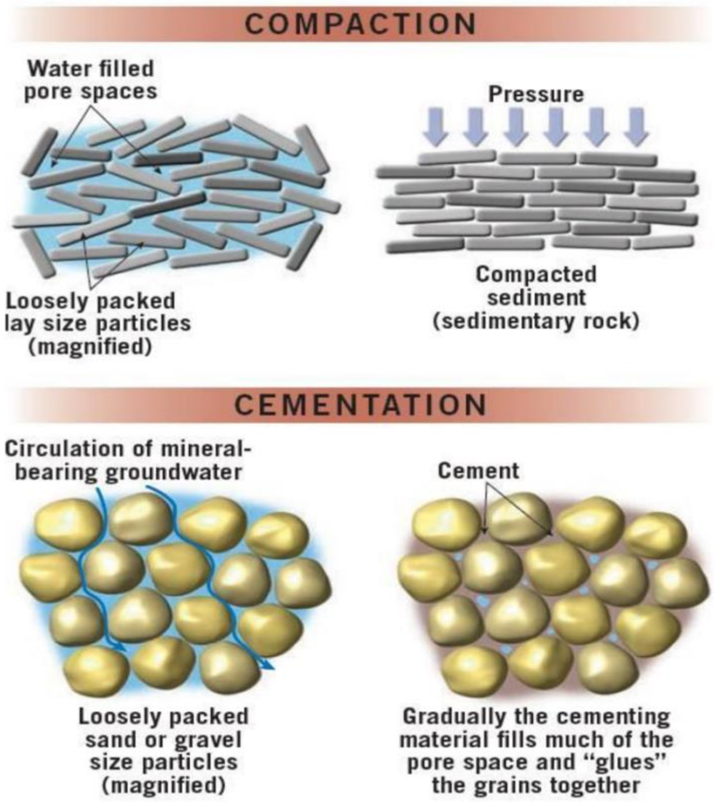
- Occurs when sediment **loses** energy
    - water or wind slows down
    - glacier melts
    - dissolved ions

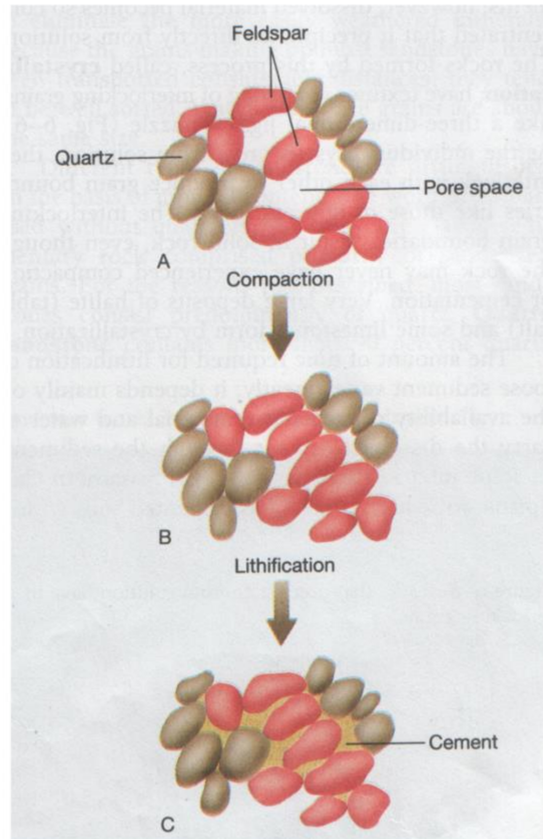
- Depositional environment: place where sediment is deposited
- Sediment can be carried a considerable distance from its source, eventually coming to rest in a depositional environment
    - Continental: dunes, alluvial fan
    - Transitional: beach, delta
    - Marine: submarine fan, deep marine environment



Lithification of sediment

- Clastic material contains spaces between them: pore space
  - the spaces are filled with a cement, bonding the material together ⟶ *cementation*
  - If the material gets compressed, the space shrinks ⟶ compaction





- Common cementing agents include: calcite, silica, iron oxide
  - Rock formed from dissolved ions that have precipitated ⟶ *crystallization*

<u>Sedimentary Rock</u>

- *<u>Detrital/Clastic Sedimentary rock</u>*: formed from fragments of weathered rock

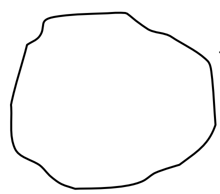
- *Organic Sedimentary rock*: lithified remains of plants and animals

- *Chemical Sedimentary rock*: rock formed from crystallization

* Limestone and Dolomite can form by all 3 processes*

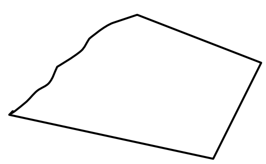
- **Detrital/Clastic Sedimentary Rock**: 80% of all sedimentary rock

  - **Conglomerate** and **Breccia**
    - conglomerate: formed from gravel



rounded

    - breccia: formed from rubble



angular

  - **Sandstone**
    - Lithified sand
    - consists predominantly of quartz

    ex. *Quartz sandstone* = 90% quartz
    Arkose = 25% feldspar
    - course & angular; why would this be?
    Graywacke = poorly sorted, contains silt & clay as a cement, resulting in a dark color.
    - grains = quartz, feldspar, other

Sandstone Types

Quartz Sandstone

Arkose Sandstone

Graywacke

- **Fine-Grained** (mudrocks)

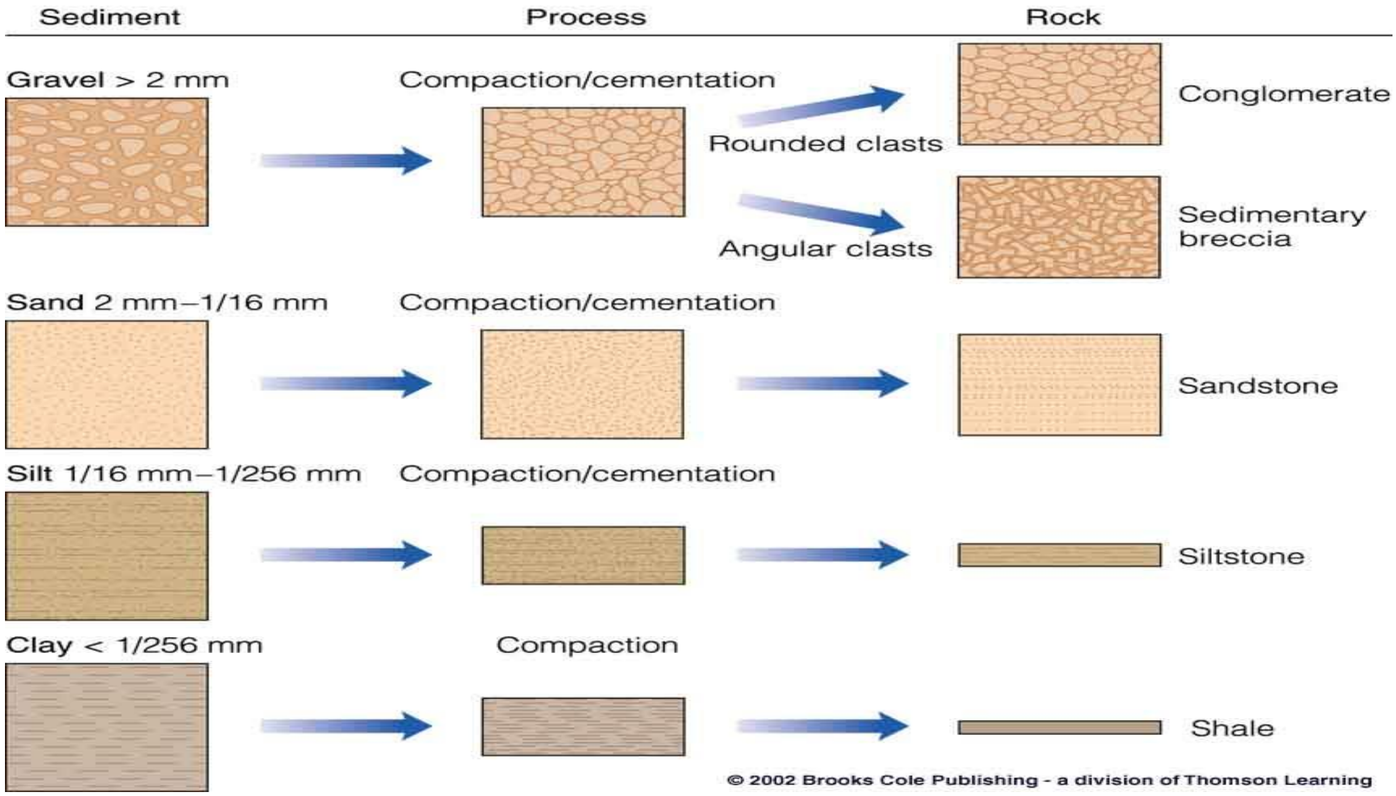
  - Sedimentary rock made from silt and clay

  ex. *Claystone* = predominately made of clay

Siltstone = predominately made of silt
- mostly consists of quartz
- may or may not show layering

Mudstone = mixture of clay and silt
- not layered

Shale = compacted Claystone, 75% of all clastic rock
- has rock layers that split easily
- color: gray to black
- source of oil and natural gas
- Why so much shale in the world?



Sizes and Names of Clastic Sediment and Clastic Rocks

Diameter (mm)	Sediment		Clastic Sedimentary Rock
256— 64 — 4—	Boulders Cobbles Pebbles Granules	Gravel (rounded) or Rubble (angular)	Conglomerate (rounded particles) or Breccia (angular particles)
2—	Sand		Sandstone
1/16—	Silt	Mud	Siltstone } Mudstone
1/256—	Clay		Claystone or Shale

- **Organic Sedimentary Rock**

  - *Chert* = rock made of pure quartz. Found as irregular nodules (precipitated ions) in other rock (limestone) or as bedded chert - rock made of tiny marine organisms that make their shell of silica

    - *Flint*: black chert due to organic inclusions
    - *Jasper*: red or brown due to iron oxides

  - *Peat* = decaying plant material that has not been converted into coal: 50% carbon

  - *Coal* = lithified plant material

    - *Lignite*- brown coal: 70% carbon
    - *Bituminous* – soft coal: 80% carbon
    - *Anthracite*- hard coal; metamorphic: 98% carbon

- **Chemical Sedimentary Rocks**

  - Evaporites: when water evaporates leaving the dissolved ions.
    - *Gypsum*: $CaSO_4 \cdot 2H_2O$
    - *Halite*: NaCl, rock salt

  - Carbonates: rock made of carbonate minerals; containing CO_3

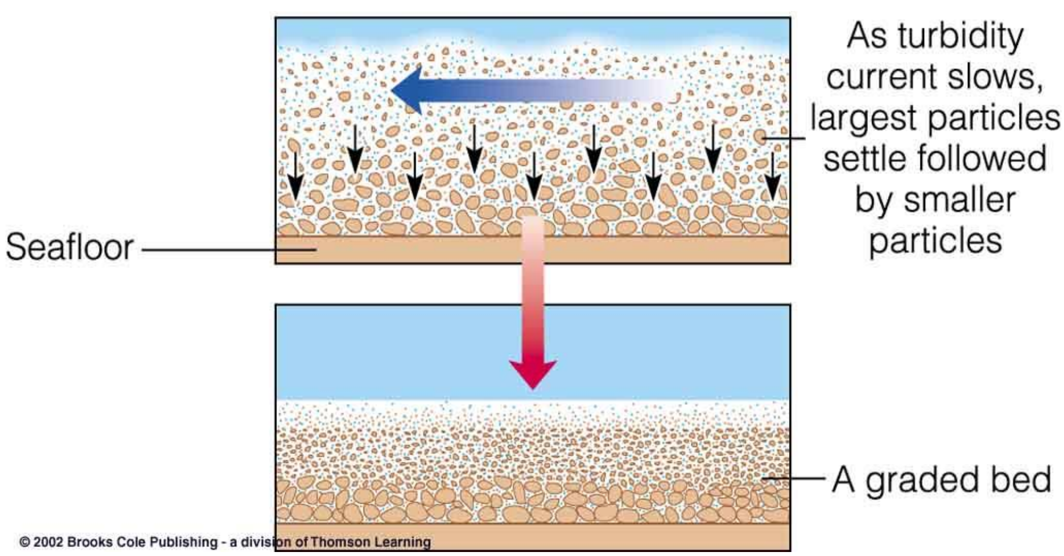
    - *Limestone*: calcite rich
      - can form from precipitating out of water
      - *Bioclastic Limestone*: lithified remains of animals
      - types of limestone
        - *Coquina*: coarse shell fragments cemented together
        - *Chalk*: shells and skeletons of microorganisms

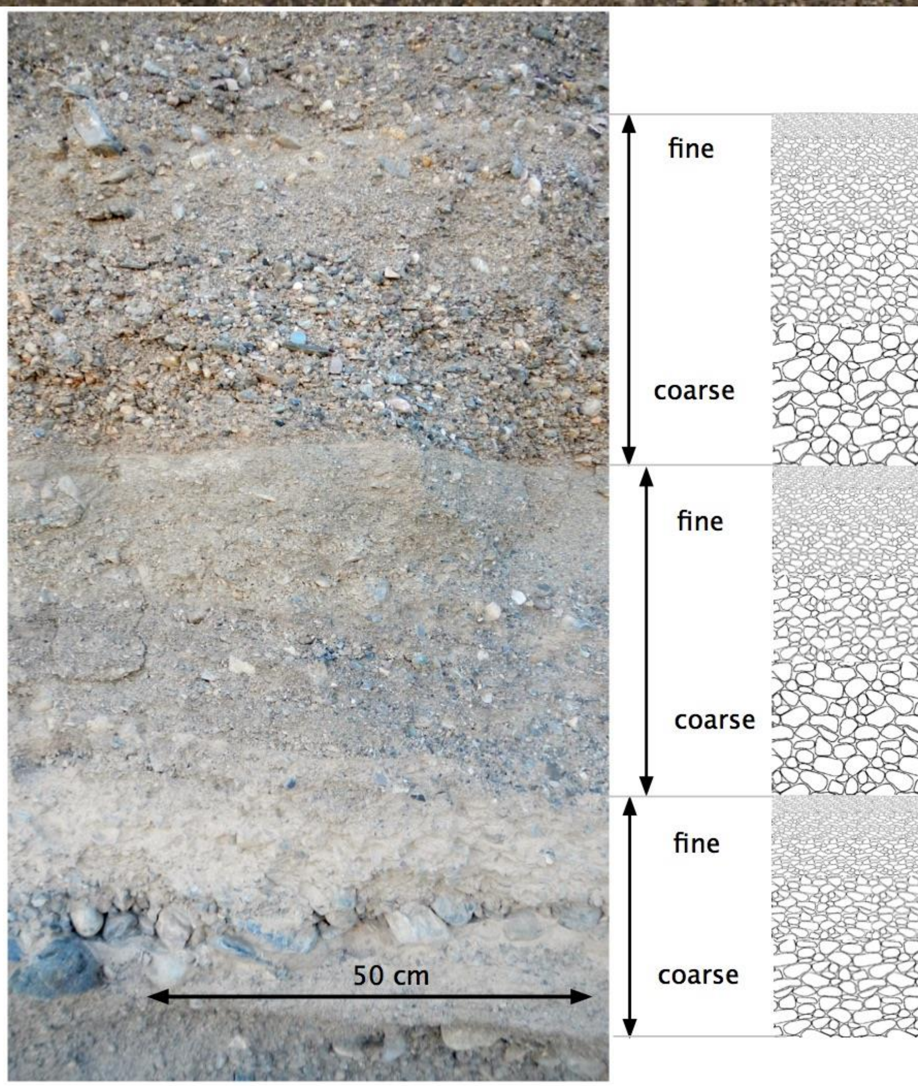
    - *Dolostone*: calcium magnesium carbonate
      - forms from the mineral dolomite

Sedimentary structures: features that develop as sediment is deposited

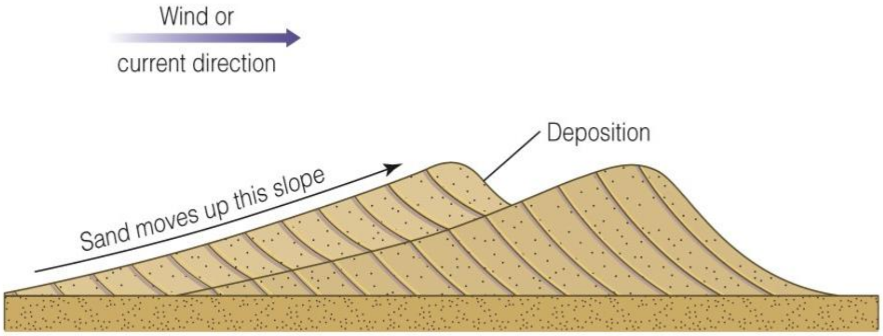
- Bedding: horizontal layering of sediment in rock

Graded Bedding: large clastic material at bottom – smaller clastic material at top

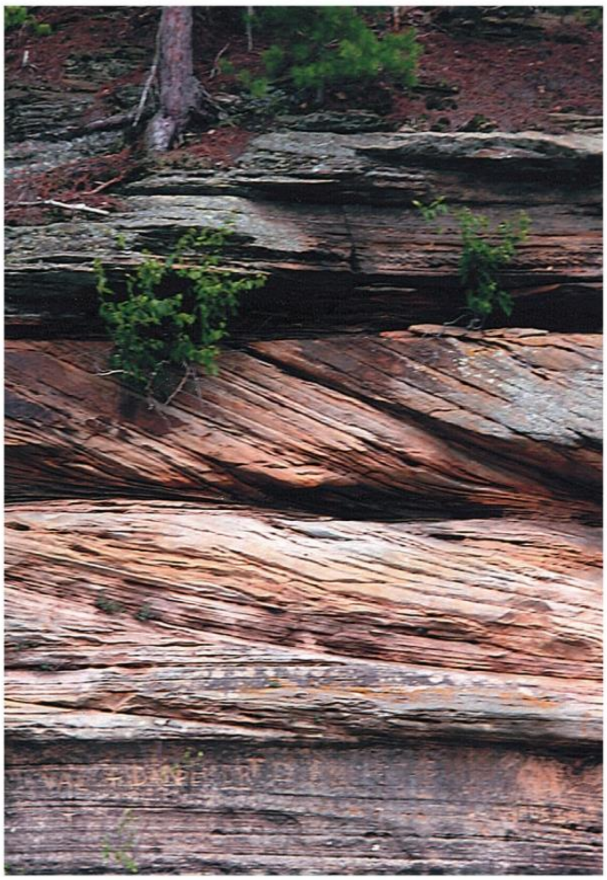



fine
coarse
fine
coarse
fine
coarse
50 cm

Cross-bedding: Beds at an angle to the main sedimentary layer

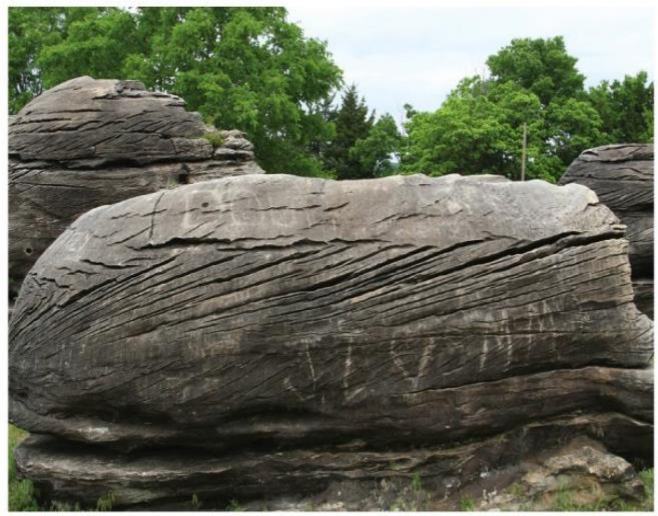


a Origin of cross-bedding by deposition on the sloping surface of a desert dune. Cross-bedding also forms in dunelike structures in stream and river channels and on the continental shelf.



Sue Monroe

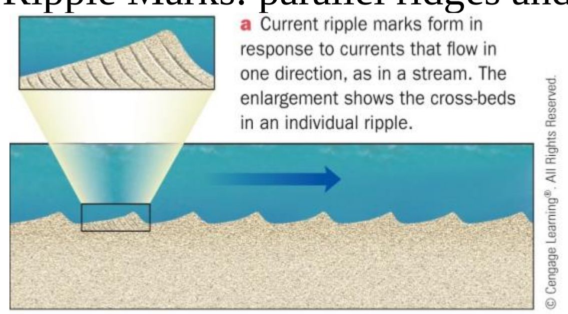
b Horizontal bedding and cross-bedding in sandstone at Wisconsin Dells, Wisconsin. About 10 m of strata are visible in this image.



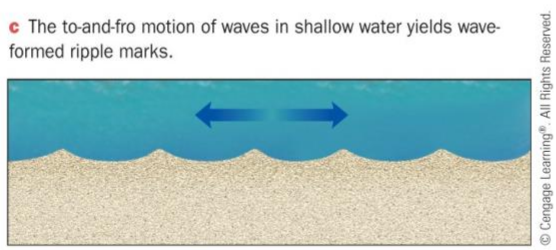
James S. Monroe

c Outcrop of cross-bedding at Rock City, Kansas. These cross-beds are about 45 cm high.

- Ripple Marks: parallel ridges and troughs formed by loose sediment



a Current ripple marks form in response to currents that flow in one direction, as in a stream. The enlargement shows the cross-beds in an individual ripple.



c The to-and-fro motion of waves in shallow water yields wave-formed ripple marks.

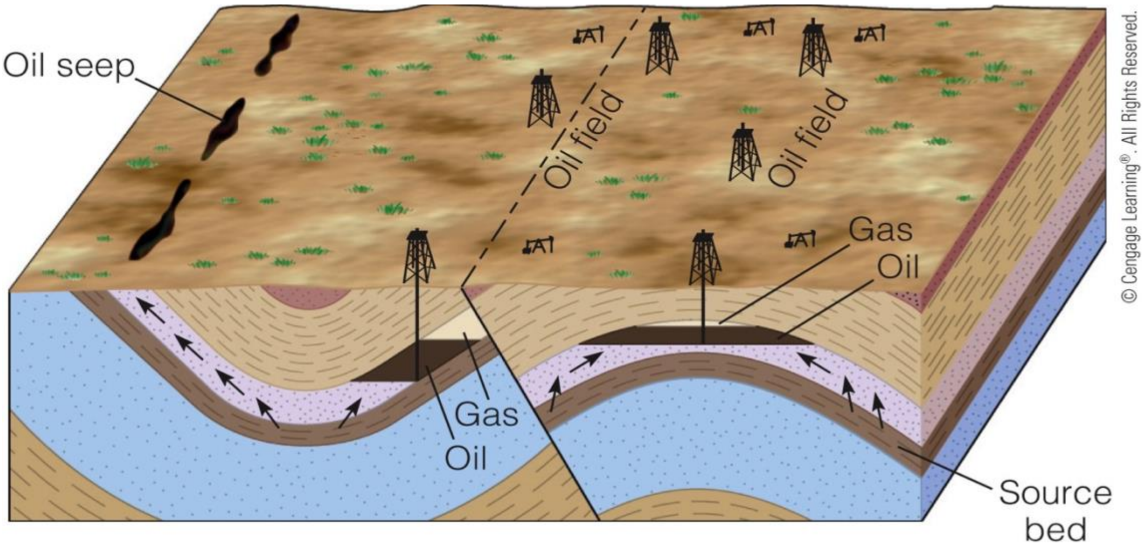
b Current ripple marks that formed in a stream channel.

d Wave-formed ripple marks in sand in shallow seawater.

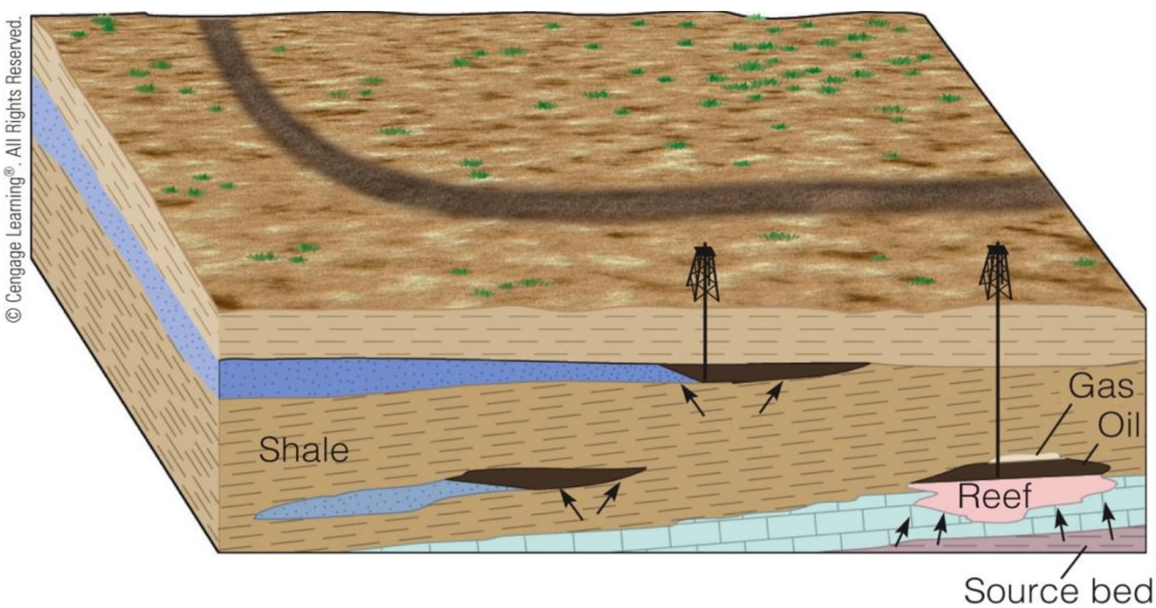
Current ripple marks *Wave-formed ripple marks*

Important Resources in Sedimentary Rocks

- Petroleum and Natural Gas: *Hydrocarbons*
    - *Source rock*: rock in which hydrocarbons form
    - *Reservoir rock*: rock that holds the hydrocarbon
    - *Cap rock*: prevents the hydrocarbon from reaching the surface.



Two examples of structural traps: one formed by folding and the other by faulting.



Two examples of stratigraphic traps: one in sand within shale and the other in a buried reef.

The sedimentary rock oil shale (left) and oil extracted from it. The United States has vast oil shale deposits.