Categories of Rocks

Igneous- cool and crystallize from molten (liquid) material (lava or magma)

Sedimentary- pieces of other rocks cemented together or rocks precipitated from water

Metamorphic- any type of rock heated without melting, squeezed and mixed with hot fluids

1. **Erosion** changes landscapes by wearing down mountains, filling in valleys, and making rivers appear and disappear.

2. **Deposition** is the process by which **sediments are laid down** in new locations.

3. **Weathering, erosion, and deposition act together in a cycle to wear down and build up Earth's surface.**

➢**Deltas** are formed as large amounts of sediments are **deposited at the mouth of a river.**

➢**Flood Plains** are **flat areas on both sides of a mature river or stream.** Fine sediments are deposited on flood plains after heavy rains or spring thaws. Larger sediments are deposited and form **ridge-like deposits called levees.**

➢The material deposited by a glacier is called **till.**

The till left behind after a glacier melts forms a ridge called **a moraine.**

- Deposition of sediment forms our **beaches.** Some of the sediments comes from surrounding shorelines, while others are carried by rivers from inland areas.

- Deposition by a longshore current (water moving parallel to the shoreline) creates sand **bars or barrier islands** (large semi-permanent bars) like the Outer Banks

The NC Outer Banks

➢The shape of a shoreline often results from changes in sea levels. Increased sea levels create **bays and harbors** while decreasing sea levels creates many sea **cliffs and terraces** (flat platforms at the base of a cliff).

Don't confuse weathering with erosion!

Weathering breaks up the Earth's surface into small pieces called sediment. Erosion is the process of moving sediments from one place to another.

Weathering causes rocks and earth materials to break down

The earth material is then moved through **erosion**

The earth material is finally dropped off through **deposition**

Erosion and Transport by Wind

Sedimentary rocks

Sediment: (sedimentum: settling)

- **fragments of solid material that settle and accumulate**
- **fragments settle in layers after being transported**

-fragments are products of weathering and erosion

- easy to see sedimentation in action!

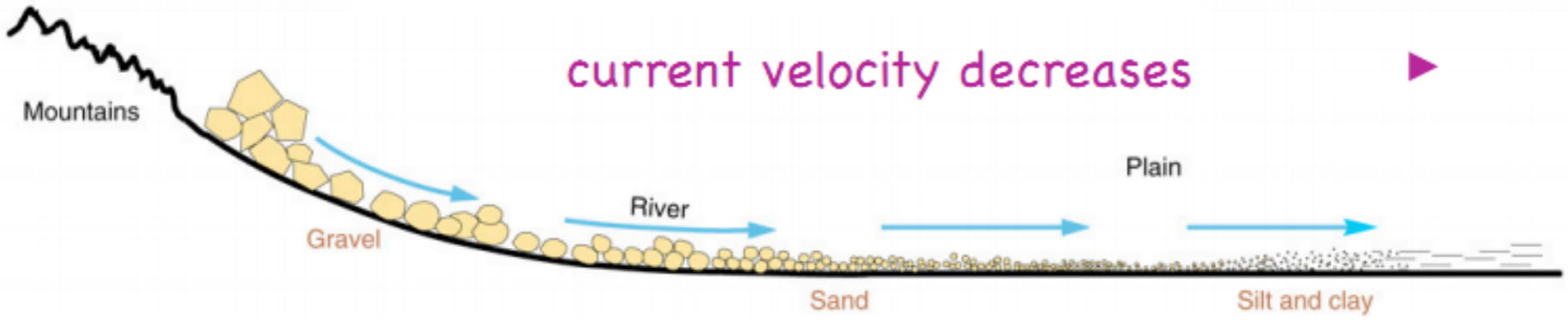
Sedimentary rock: **"lithified" sediment; "lithos" -- rock**

- **75% of all rock exposed on Earth's land surface**
- **composition is weathering products of rocks or biological matter**

- **principal source of coal, oil, natural gas, cement, Al, Fe, groundwater**

particle size sorting by rivers

as flow slows down, river can no longer carry larger particles

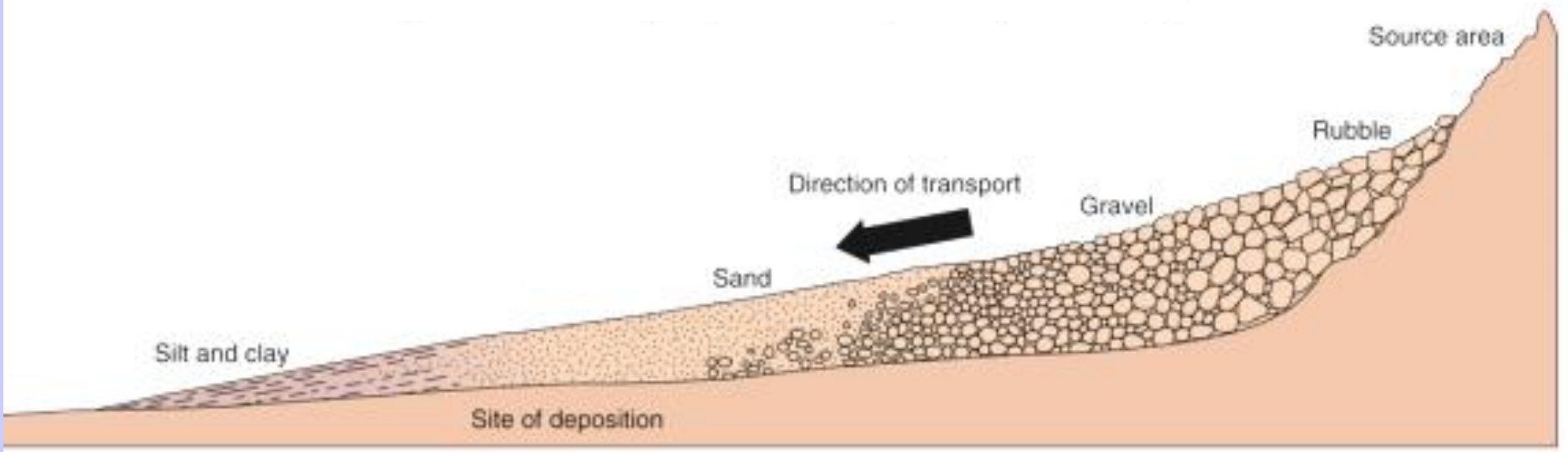


headwaters

mouth

grade = change in elevation/length

Distance from Source



turning sediment into sedimentary rock

transportation

movement of sediment away from its source, typically by water, wind or ice

rounding occurs by abrasion during transport
"particles knocking against each other"

sorting occurs as sediment is separated by size by transporting agents, such as water

--sediment size decreases with increased transport distance--

sediments may be *angular* or *rounded*

Photo by David McGeary

rounded beach boulders

angular fragments

sediment is classified by *particle size*

- boulder > 256 mm
- cobble: 64 to 256 mm
- pebble: 2 to 64 mm
- sand: 1/16 to 2 mm
- silt: 1/256 to 1/16 mm
- clay: < 1/256 mm

gravel/boulders at headwaters

normally deposited in or near steep mountains at river headwaters

Photo by David McGeary

sand/silt downstream, closer to mouth of river

Photo by David McGeary

turning sediment into sedimentary rock

deposition

- settling of transported material
- accumulation of chemical or organic sediments, particularly in water

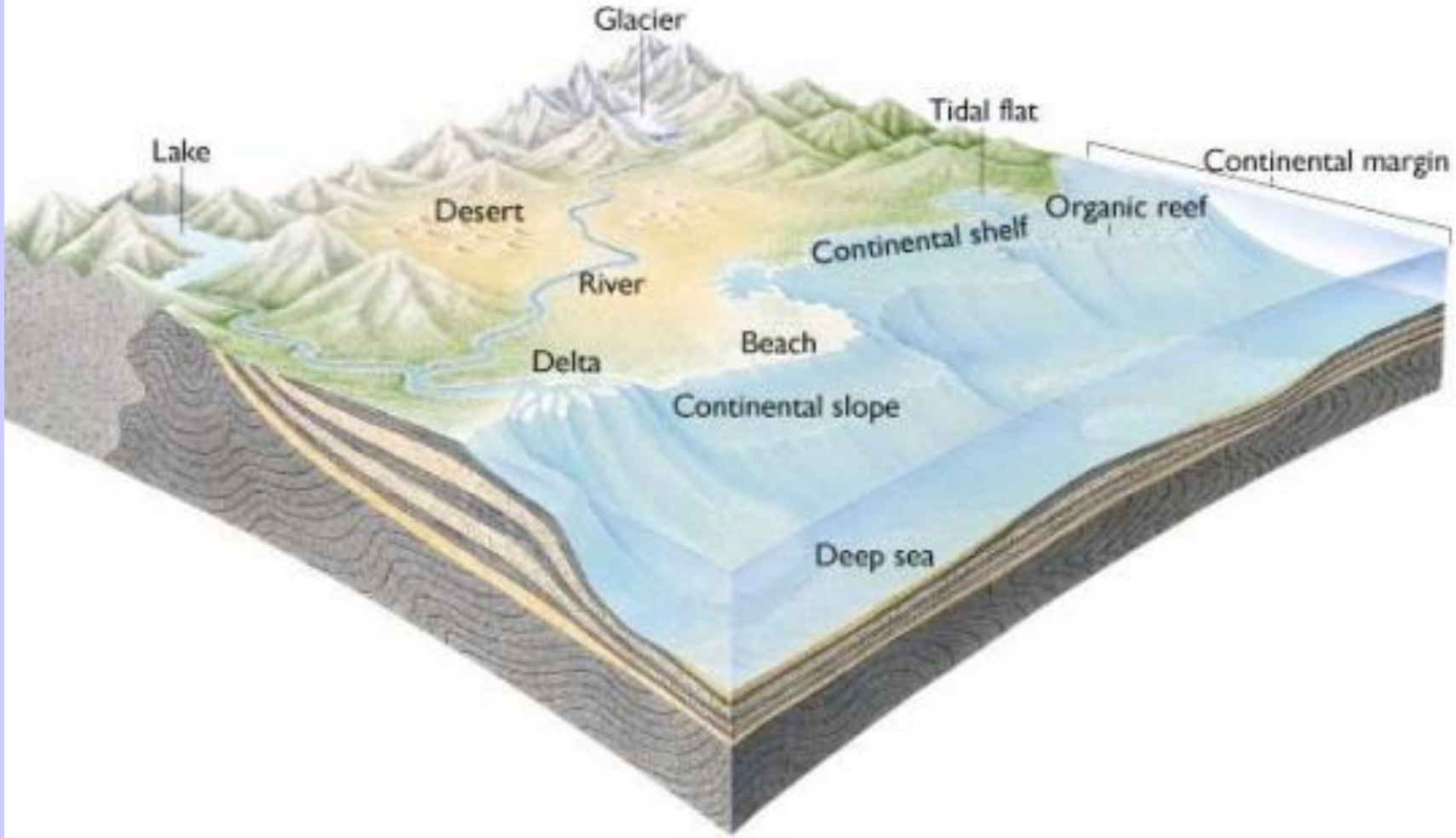
sediment transported from canyon and deposited at canyon mouth at the base of the slope

turning sediment into sedimentary rock

preservation

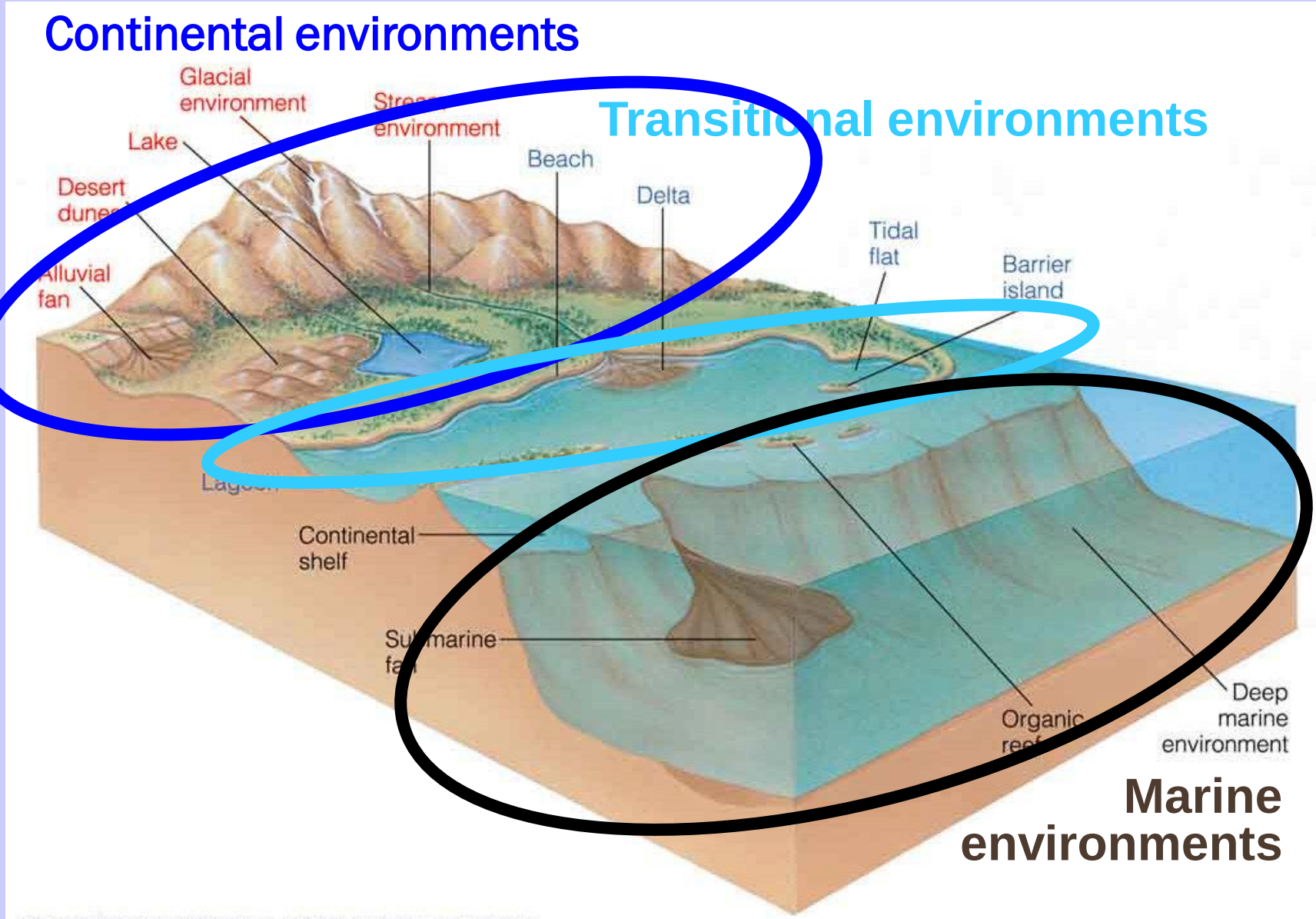
- sediments must be preserved to turn into rock
- burial by additional sediments deposited on top

environment of deposition is setting of deposition



sediments and sedimentary rocks form in many settings

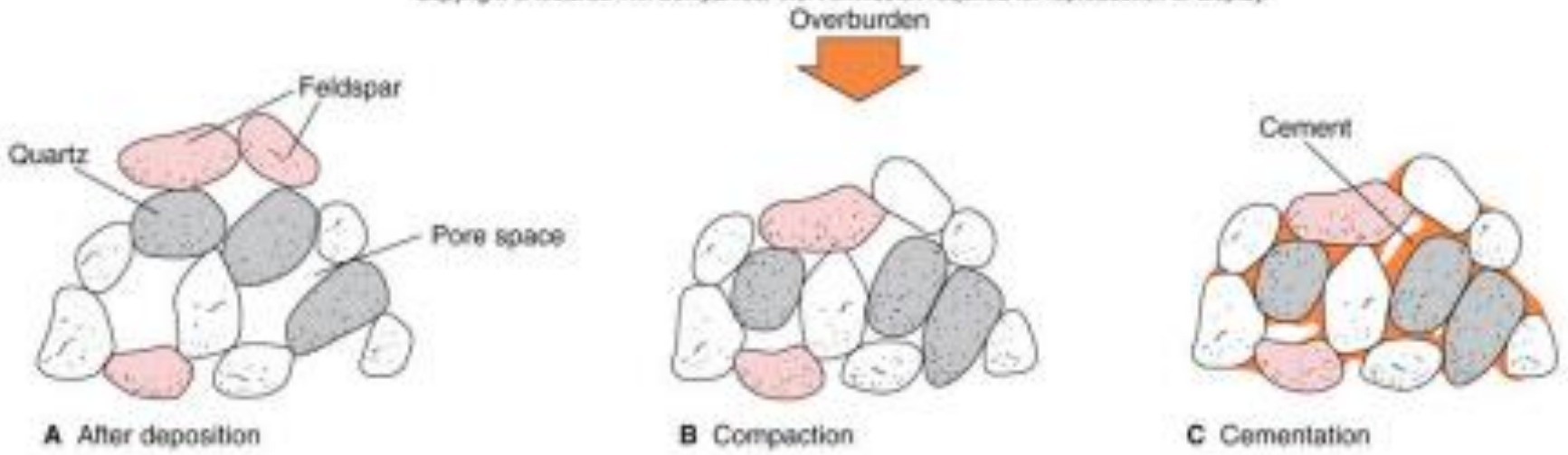
Depositional Environments



turning sediment into sedimentary rock

lithification

- sediments must be hardened into rock
- compaction and cementation occur



water is expelled from pore space

other fluids cement grains

Lithification and compaction of shale

NB volume loss during compaction

Sedimentary rocks Classified as-

Clastic, Chemical, or Organic

Clastic - made from small pieces of other rocks

--Conglomerate, Breccia, Sandstone, Siltstone, Shale all are common

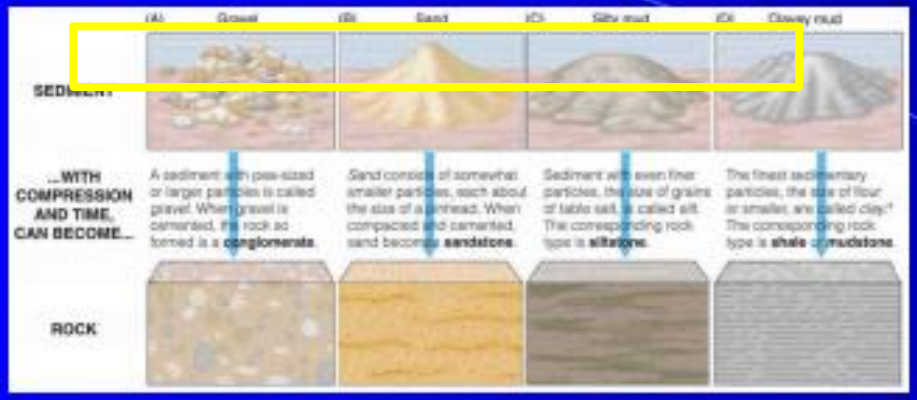
Chemical - precipitate from chemical reactions

---Limestone, chert, rock salt, gyprock

Organic-Made from compressed altered plant materials

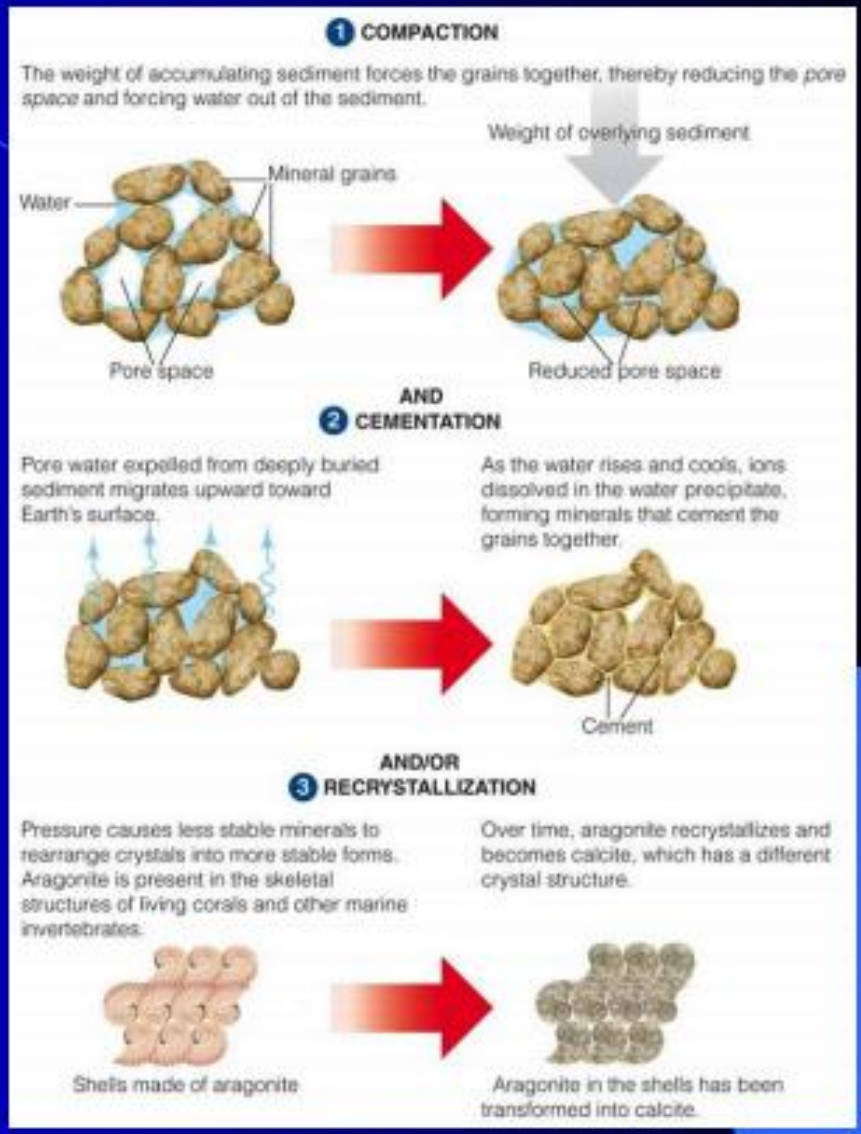
--Coal

Clastic Sediments ⟶ Lithification



When clastic sediment is lithified, the result is clastic sedimentary rock

- **Conglomerate:** rounded clasts > 2 mm
- **Breccia:** angular clasts > 2 mm
- **Sandstone:** clasts 0.5 - 2 mm
- **Siltstone:** silt and clay-szied particles
- **Shale:** mostly clay-sized particles in a rock that easily splits into sheets
- **Mudstone:** shale that does not split



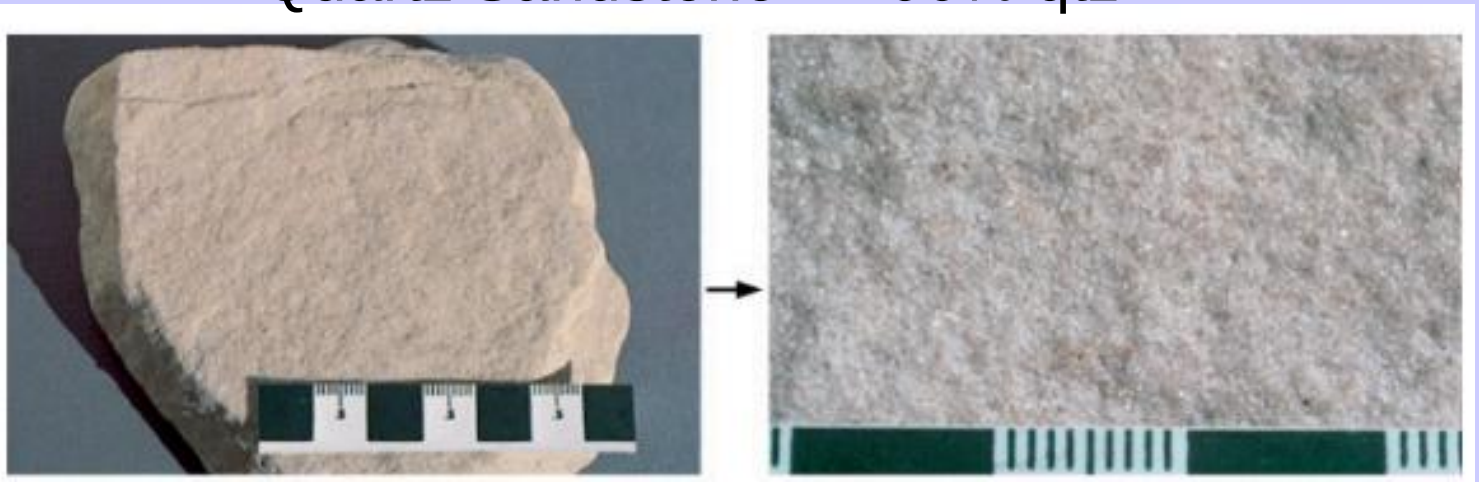
Basic Clastic Rock Types

- Breccias: angular particles
- Conglomerates: rounded particles
- Sandstones
  - Quartz sandstone: dominated by quartz grains
  - Arkose sandstone: composed of qtz & fsp grains
  - Graywacke: dominated by lithic (rock) fragments
- Shales: mud and silt particles

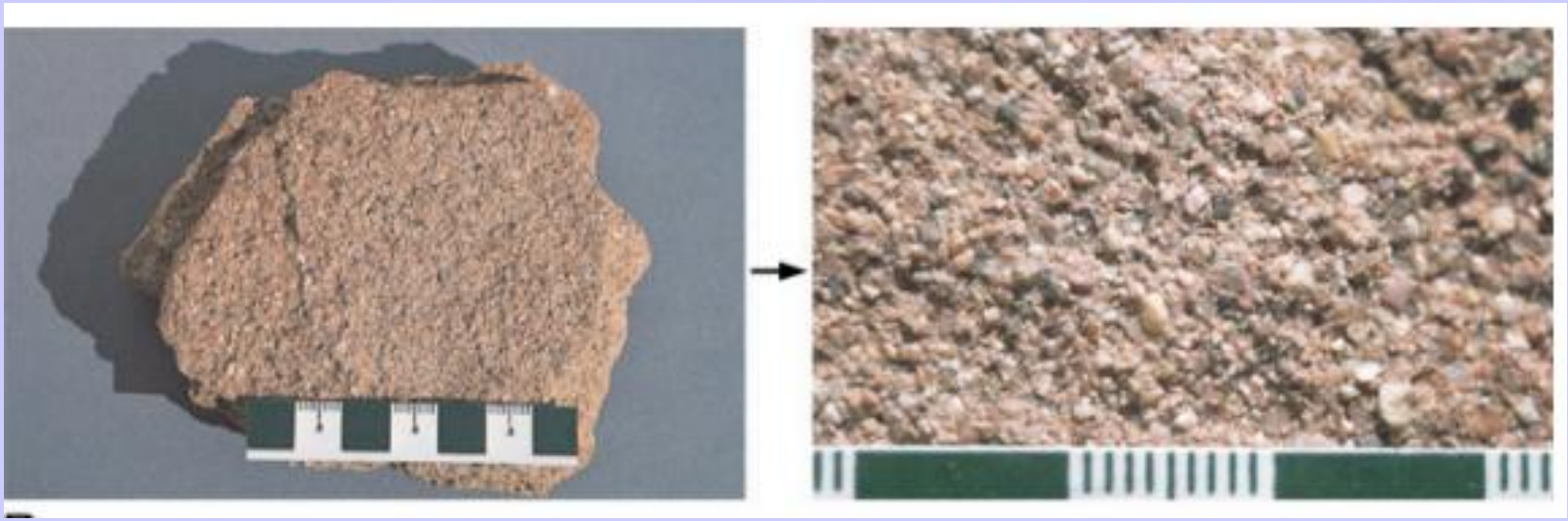
Coarse Breccia

Conglomerate

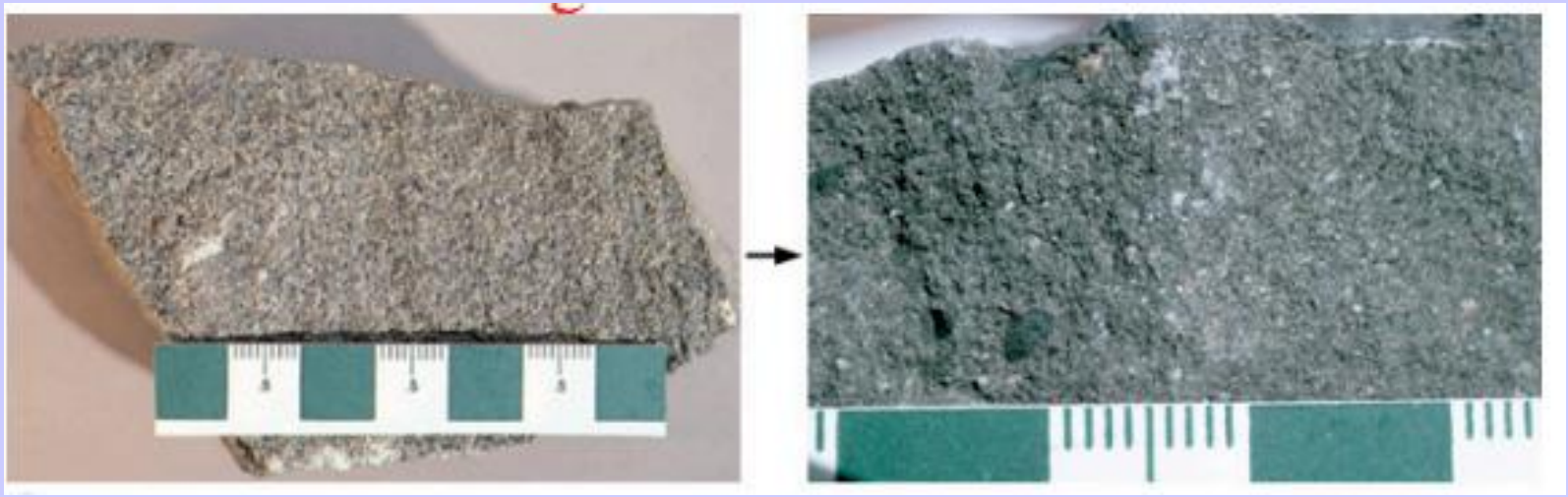
Quartz Sandstone - > 90% qtz



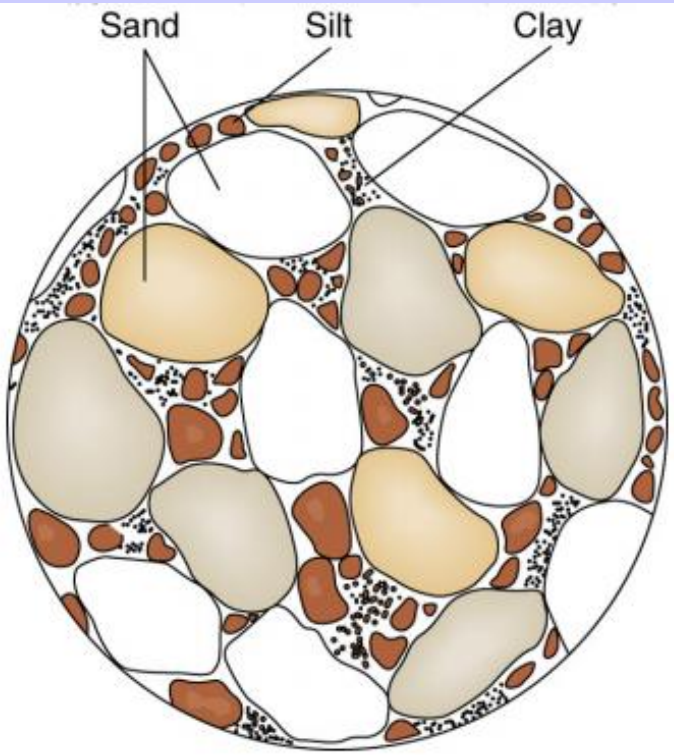
Arkose Sandstone - Feldspar + Qtz



Graywacke - lithic fragments in dark fine grained matrix



Poorly sorted, “dirty” sandstone



Sorting can be based on particle size and/or composition; It yields important constraints on provenance of the clastic particles.

Shale hand specimens

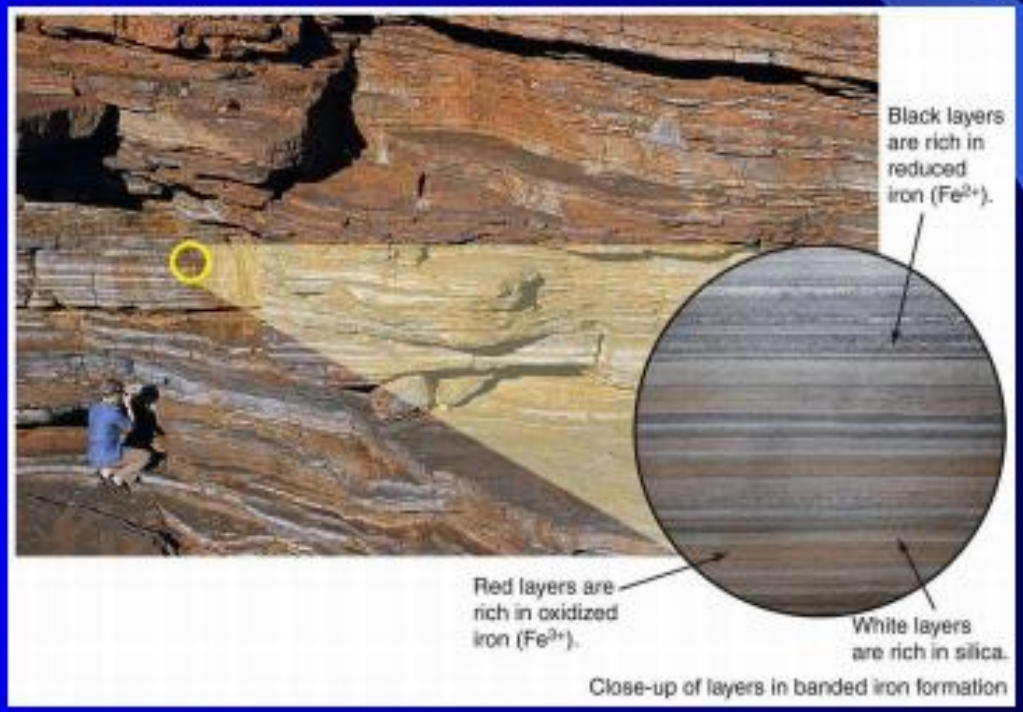
NB very fine grained and thin laminations

Chemical Sedimentary Rocks

- Carbonate Rocks (*e.g.* $CaCO_3$)
- Chert (*e.g.* SiO_2)
- Evaporites (*e.g.* NaCl; $CaSO_4 \bullet 2H_2O$)

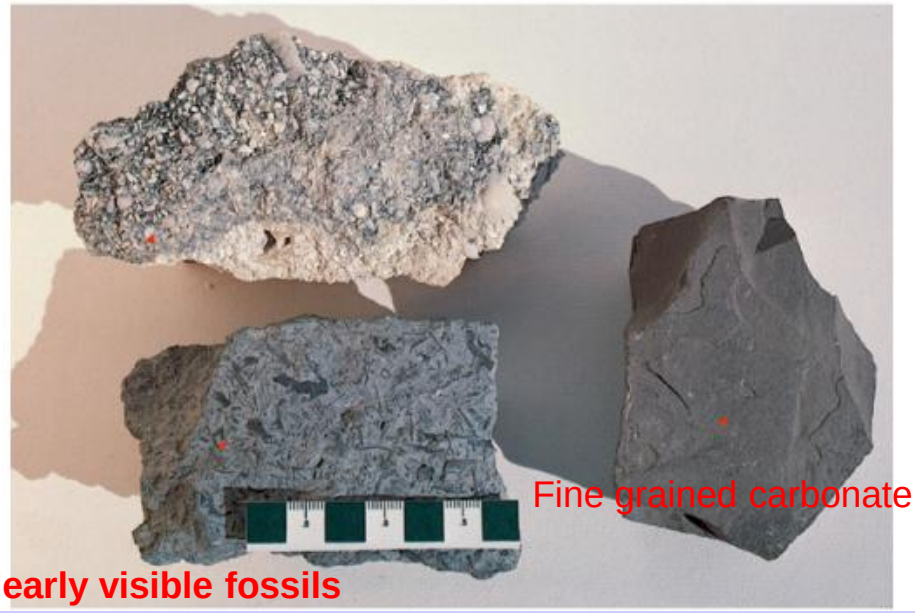
Chemical sedimentary rock results from lithification of chemical sediment formed by precipitation of minerals from water

- Evaporite: formed by evaporation
- Banded iron formation: formed during an atmospheric change from O_2-poor to O_2-rich
- Limestone: lithified shells and other skeletal material from marine organisms
- Chert: tiny particles of quartz from siliceous skeletons of microscopic sea creatures



Close-up of layers in banded iron formation

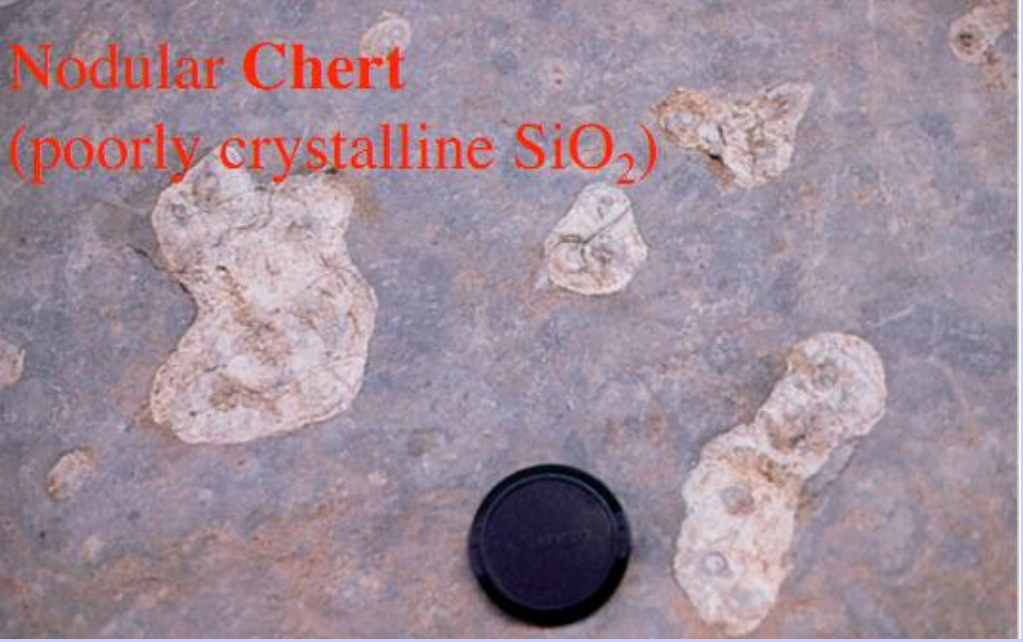
Bioclastic Limestones



Fine grained carbonate mud

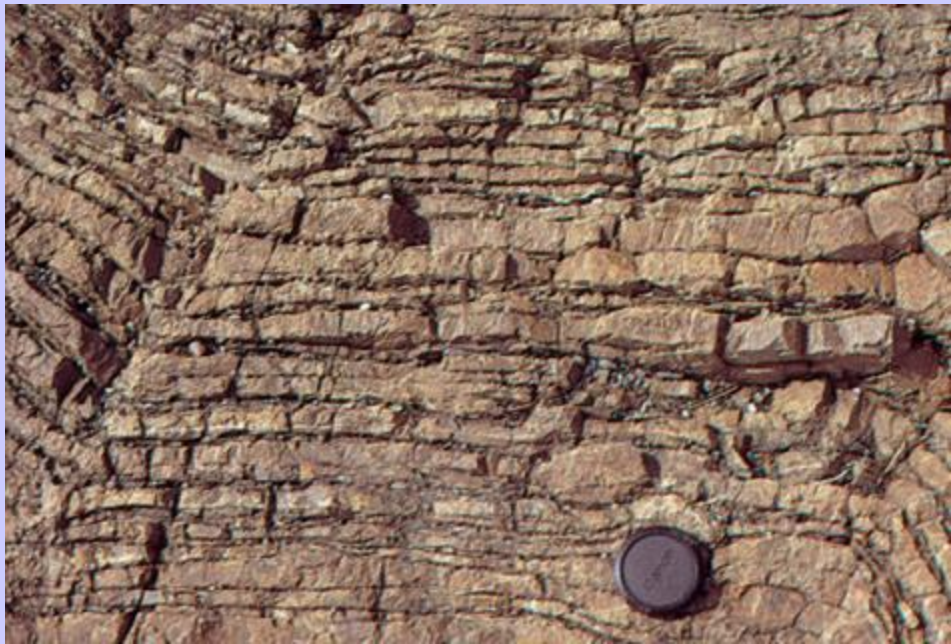
Clearly visible fossils

Fossil Rich Limestone - Coquina



Redwall limestone, Grand Canyon, AZ

Bedded Chert



Bonneville salt flats

Coal Bed - Trinidad, CO

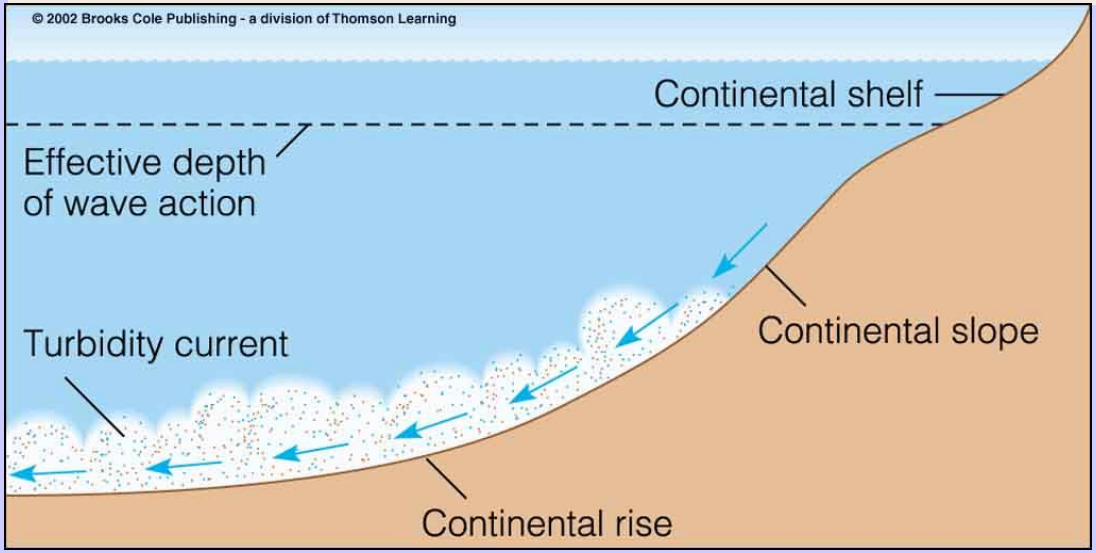
Bedding

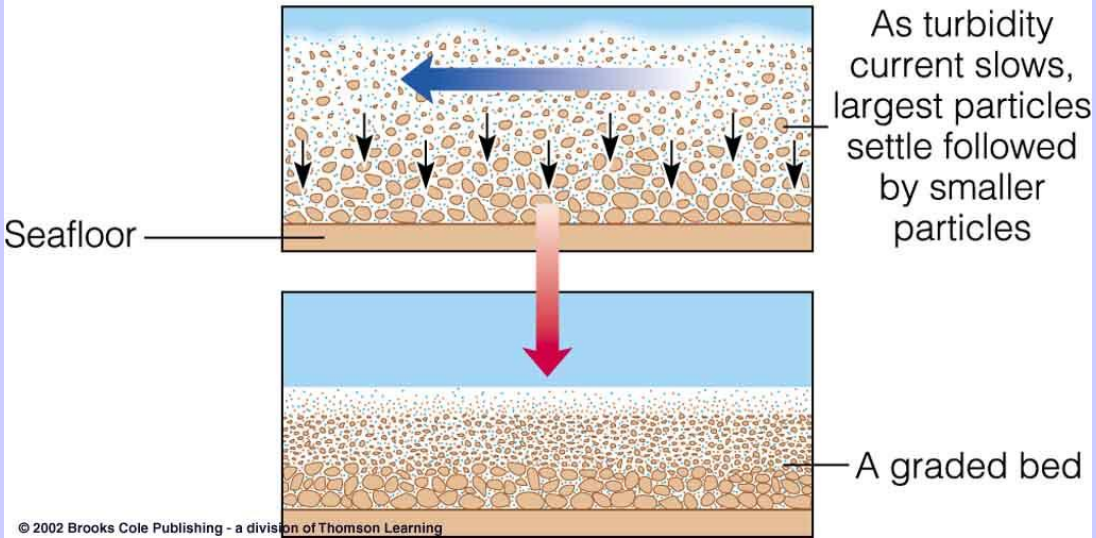
- **Sedimentary rocks generally have bedding or stratification**
  - Individual layers less than 1 cm thick are **laminations**
    - common in mudrocks
  - **Beds** are thicker than 1 cm
    - common in rocks with coarser grains

Sedimentary Structures

Graded Bedding

- Some beds show an upward gradual decrease in grain size, known as **graded bedding**

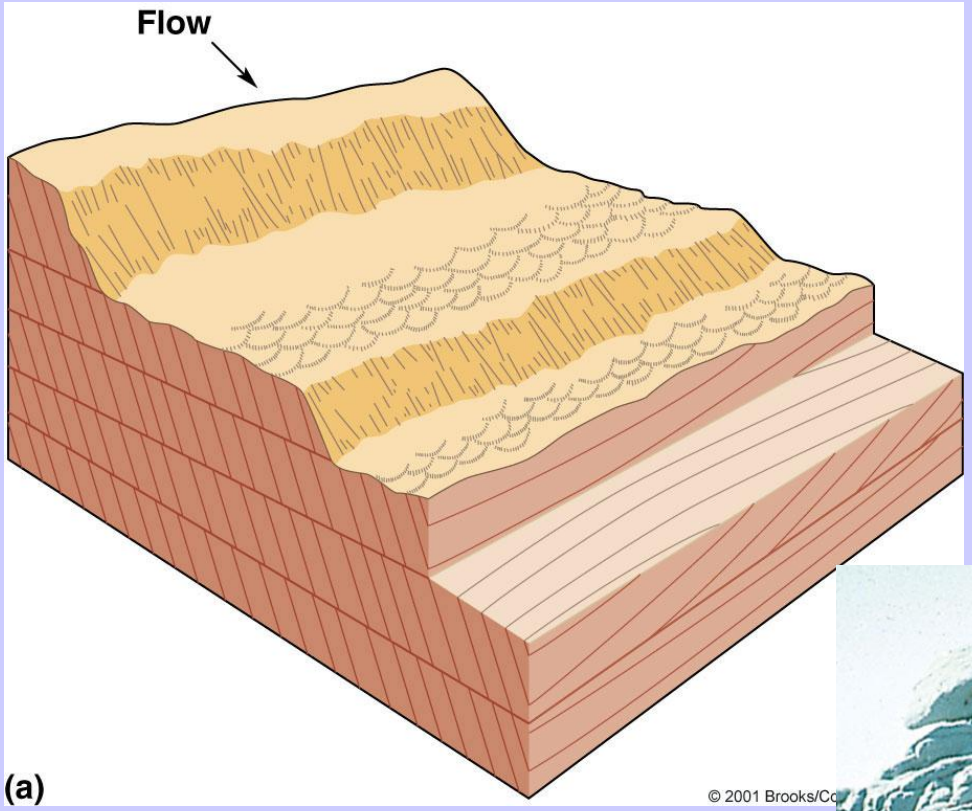




- Graded bedding is common in turbidity current deposits
  - which form when sediment-water mixtures flow along the seafloor
  - As they slow,
  - the largest particles settle out then smaller ones

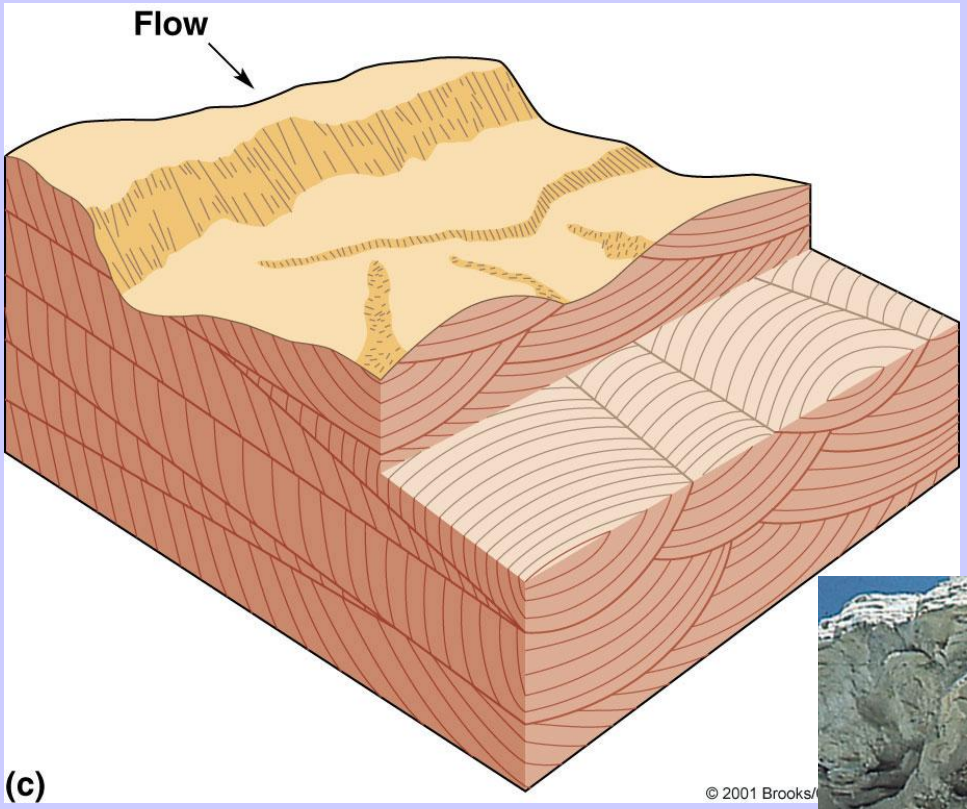
Cross-Bedding

- Tabular cross-bedding forms by deposition on sand waves

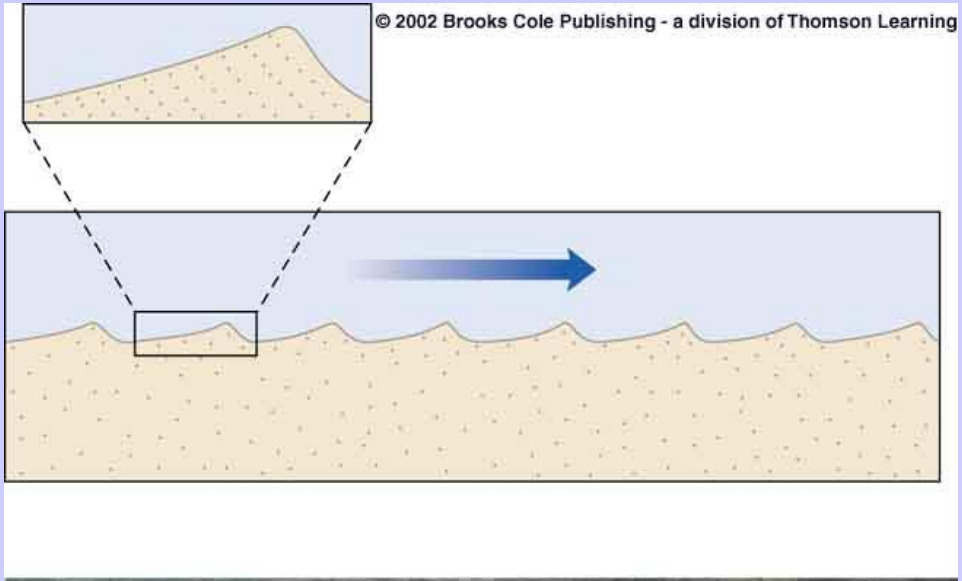


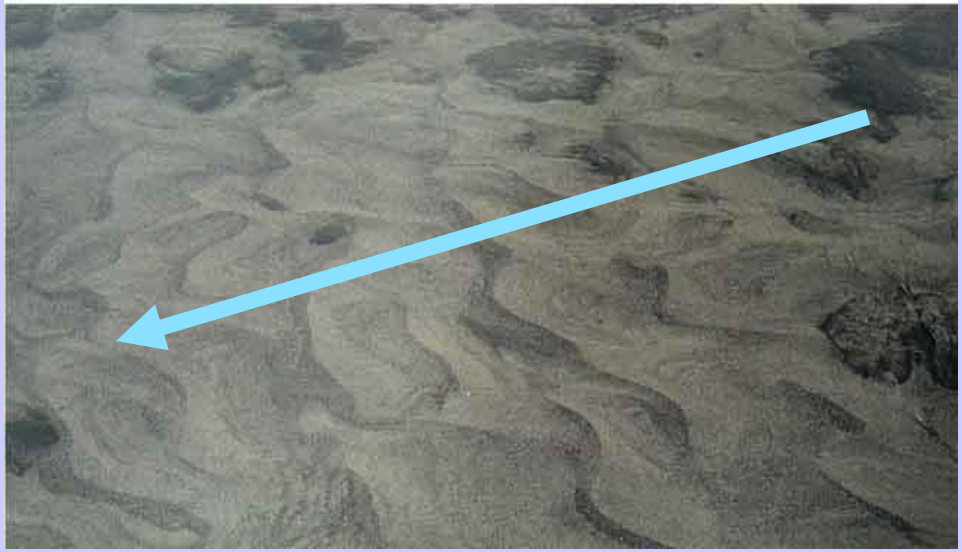
Cross-Bedding

- Trough cross-bedding formed by migrating dunes



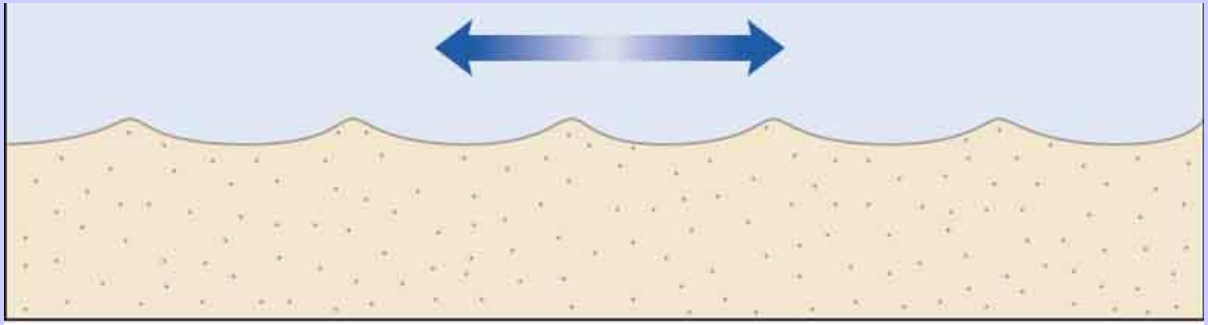
Current Ripple Marks





- **Ripples with an asymmetrical shape**
- In the close-up of one ripple,
  - the internal structure
  - shows small-scale cross-bedding
- The photo shows current ripples
  - that formed in a small stream channel
  - with flow from right to left

Wave-Formed Ripples



- As the waves wash back and forth,
  - + symmetrical ripples form
- The photo shows wave-formed ripple marks
  - + in shallow seawater

Mud Cracks

- When clay-rich sediments dry, they shrink
  - + and crack into polygonal patterns
  - + bounded by fractures called mud cracks
- Mud cracks require wetting and drying to form,

- as along a lakeshore
- or a river flood plain
- or where mud is exposed at low tide along a seashore

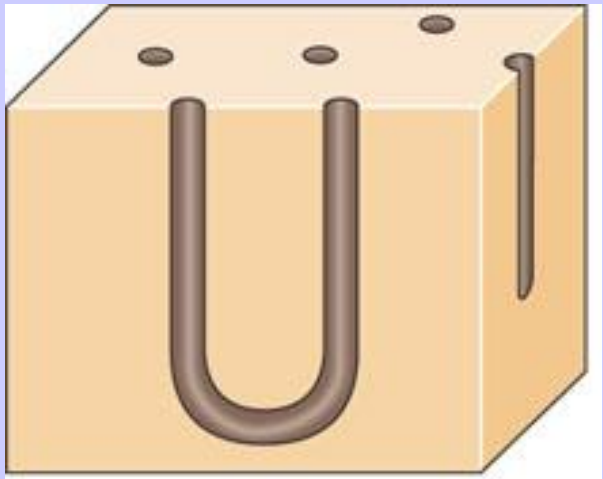
Ancient Mud Cracks

- Mud cracks in ancient rocks
- Mud cracks typically fill in
  - with sediment
  - when they are preserved
  - as seen here

Biogenic Sedimentary Structures

- Biogenic sedimentary structures include
  - -tracks
  - -burrows
  - -trails
- called ***trace fossils***
- Extensive burrowing by organisms
  is called *bioturbation*
- It may alter sediments so thoroughly
  that other structures are disrupted or destroyed

Bioturbation



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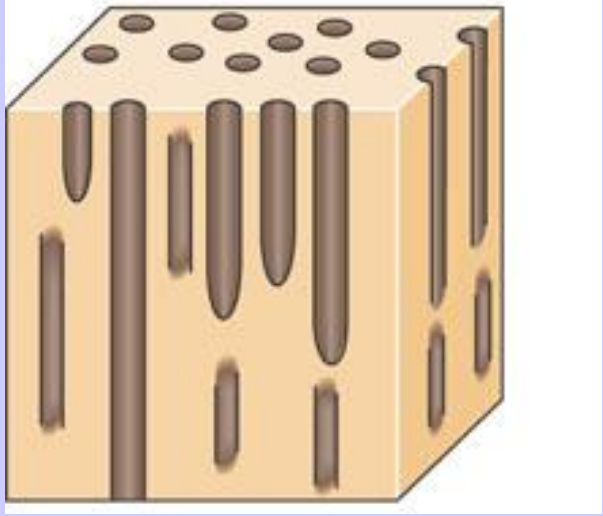


- U-shaped burrows

- Vertical burrows

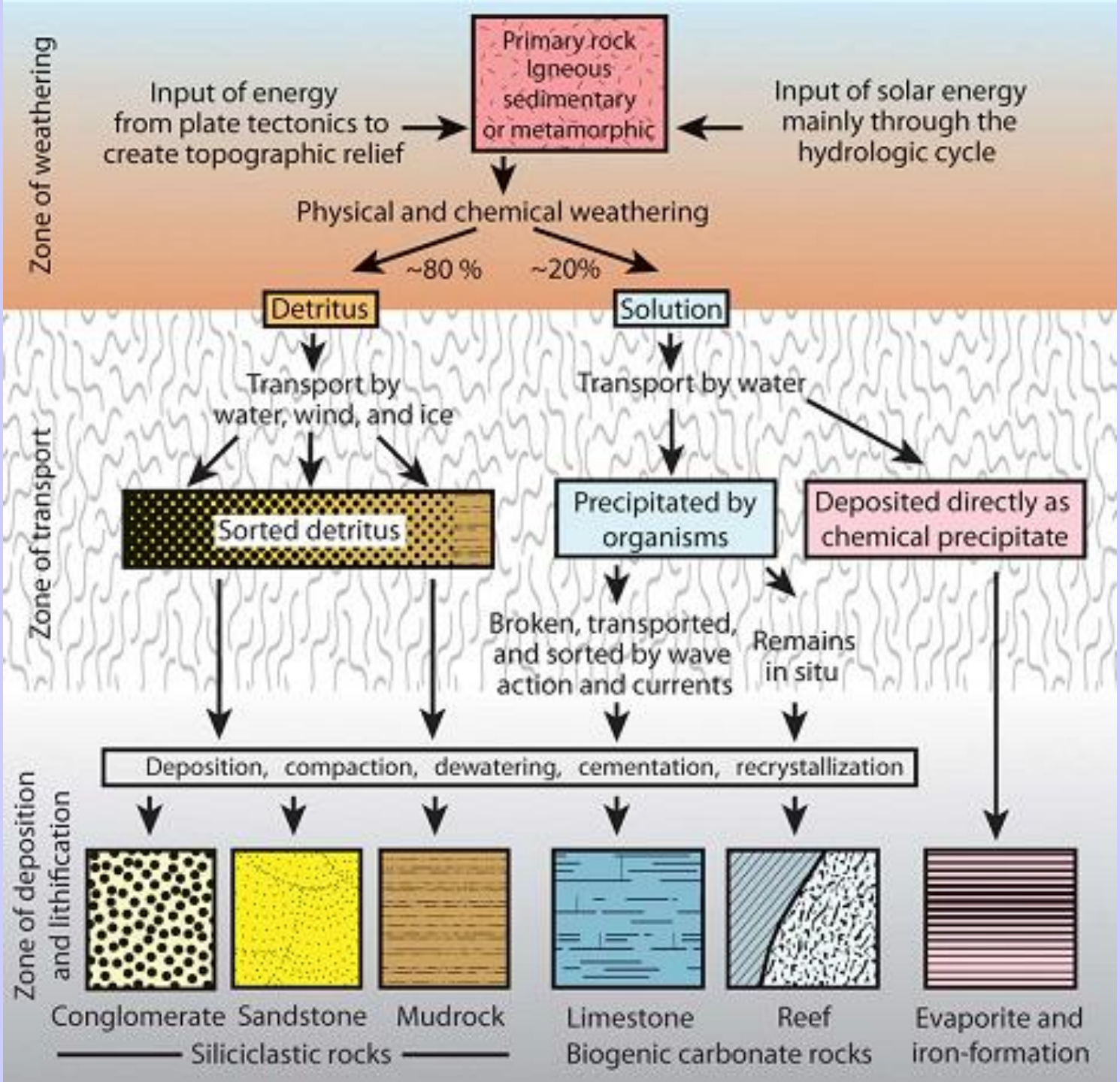
Bioturbation

- **Vertical, dark-colored areas in this rock are sediment-filled burrows**

Fossils Are Constituents of Sedimentary Rocks

- This variety of limestone,
  - + known as **coquina**,
  - + is made entirely of **shell fragments**

Summary


Zone of weathering
Primary rock
Igneous
sedimentary
or metamorphic
Input of energy
from plate tectonics to
create topographic relief
Input of solar energy
mainly through the
hydrologic cycle
Physical and chemical weathering
~80 %
~20%
Detritus
Solution
Zone of transport
Transport by
water, wind, and ice
Transport by water
Sorted detritus
Precipitated by
organisms
Deposited directly as
chemical precipitate
Broken, transported,
and sorted by wave
action and currents
Remains
in situ
Deposition, compaction, dewatering, cementation, recrystallization
Zone of deposition
and lithification
Conglomerate
Sandstone
Mudrock
Limestone
Reef
Evaporite and
iron-formation
Siliciclastic rocks
Biogenic carbonate rocks

SANDSTONE

- **Sandstone rocks are composed almost entirely of sand-sized quartz grains (0.063 – 2 mm) cemented together through lithification.**
- Sandstone rocks are generally classified as quartz sandstone, arkose (quartz with feldspars), or graywacke (quartz with feldspar, clay, and other coarse-grained mineral fragments).
- **Sandstones comprise about 20% of all sedimentary rocks and are formed in a variety of different environments including fluvial (rivers), marine, coastal (oceans and beaches), aeolian (wind blown), and glacial (ice).**
- The differences in texture, sorting, and rounding help geologists decipher the environmental conditions that formed the sandstone.

Courtesy: Florida Department of Environmental Protection

SHALE

- **Shale is a fine-grained, moderately to well-sorted rock formed by the compaction of well rounded silt-and clay-sized grains.**
- Shales often contain fine laminations which helps impart fissility to the rock. Fissility is a term used to describe layered laminations formed by compression forces exerted over long-time periods.
- **Shale usually contains about 50% silt, 35% clay, and 15% chemical materials, many shales may also contain organic plant materials and fossils.**
- Shale is characterized by thinly, laminated layers, representing successive deposition of sediments.
- **Shale accounts for about 50% of all sedimentary rocks deposited on the Earth's surface.**
- The sediments that form shale are most likely deposited very gradually in non-turbulent, environments such as a lakes, lagoons, flood plains, and deep-ocean basins.

Siltstone

- **Siltstone is finer grained than sandstone, but coarser grained than mudstone, and it consists primarily of well-sorted, rounded grains ranging between 3.9 - 62.5 μm.**
- Siltstone is similar to shale except that it lacks fissility.

MUDSTONE

- **Mudstone consists of very silt-sized and clay-sized grains (<0.0625 mm) and are often well consolidated with little pore space.**
- **Mudstones do not contain laminations or fissility, but they may contain bedding-plane features such as mud cracks or ripples.** Mud cracks are formed by subaerial drying conditions. Ripples suggest gentle wave activity or water movement during deposition.

http://www.auckland.ac.nz/

CONGLOMERATE

- **Conglomerates are poorly-sorted composites of a wide range of rounded grain sizes ranging from sand to cobbles (< 0.062 to > 2 mm).**
- **Conglomerates usually contain a framework of large grains held together by a matrix of sands, silt, and clay-sized particles.**
- The combination of poorly-sorted, predominantly coarse, rounded grains suggests that conglomerates form in high-energy environments such as steep-gradient streams.

South Carolina Geological Survey

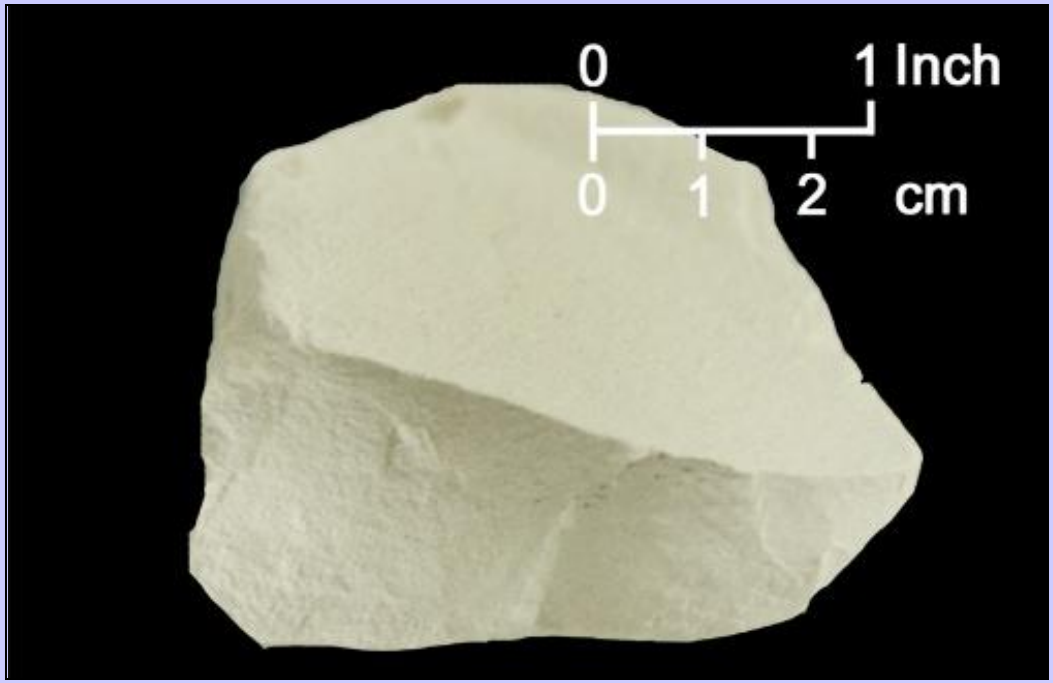
BRECCIA

- **Breccia is a poorly-sorted composite of a wide range of grain sizes ranging from clays to gravels (< 0.062 to > 2 mm).**
- Breccias usually contain a framework of gravel-sized grains held together by a matrix of sands, silts, and clay.
- **Breccia is similar to a conglomerate except that it consists of angular grains, as opposed to rounded grains.**
- The combination of poorly-sorted, predominantly coarse, angular grains suggests that breccias form from rapid deposition in high energy environments such as steep-gradient streams, glacial flood deposits, landslides, talus, alluvial fans, or in association with faulting.

South Carolina Geological Survey

KAOLIN

- **Kaolin consists of very fine-grained kaolinite clay weathered from feldspar minerals in metamorphic and igneous rocks.**
- **Kaolin is generally very light colored to off-white.**
- Kaolin is mined in several counties of South Carolina, including Aiken, Lexington, Richland, Kershaw, and Chesterfield Counties.



Florida Department of Environmental Protection, Florida Geological Survey

DOLOSTONE

- **Dolostone is composed of Dolomite, a calcium-magnesium carbonate mineral.**
- **Dolostone forms when magnesium in pore water replaces some of the calcium present in limestone.** For this reason, dolostone is often preceded by the formation of limestone deposits. Dolostone forms very slowly and is rarely observed forming in modern environments.
- Dolostone abundance increases with age. There are more older than younger dolostones.

EVAPORITES

- **Evaporites are chemical deposits formed when restricted bodies of saline water evaporate, precipitating out a range of minerals.**
- Evaporite deposits do not involve a single chemical precipitate, instead they consist of chlorides, sulfides, carbonates, and borates.
- **Halite and gypsum are two common examples of mineral precipitates**.

Utah's Bonneville Salt Flats

LIMESTONE

- **Limestone consists almost entirely of the mineral calcite ($CaCO_3$) and can form by either inorganic or biochemical processes.**
- Limestones form under a variety of environmental conditions and for this reason several types of limestone exist.
- **Limestone accounts for about 10% of all sedimentary rocks, and of those, limestones with marine biochemical origin are the most common.**

State Park in Glen Rose, Texas.

CORAL REEFS

- Coral Reefs are limestone formations created by marine organisms.
- Corals are invertebrate animals which secrete a calcareous (calcite-rich) external skeleton . Over long periods of time coral colonies form massive reef formations. Some of which surround entire islands or extend along the shoreline **for 100's of miles.**
- The Florida Keys were once an underwater coral reef rich in biodiversity of sea life. Today the Keys are lithified limestone deposits exposed above modern sea level. Living coral reefs exist offshore along the Atlantic Coast of the Keys.

South Carolina Geological Survey

This is an example of a fossilized brain coral from the Key Largo Limestone formation in the Florida Keys.

TRAVERTINE

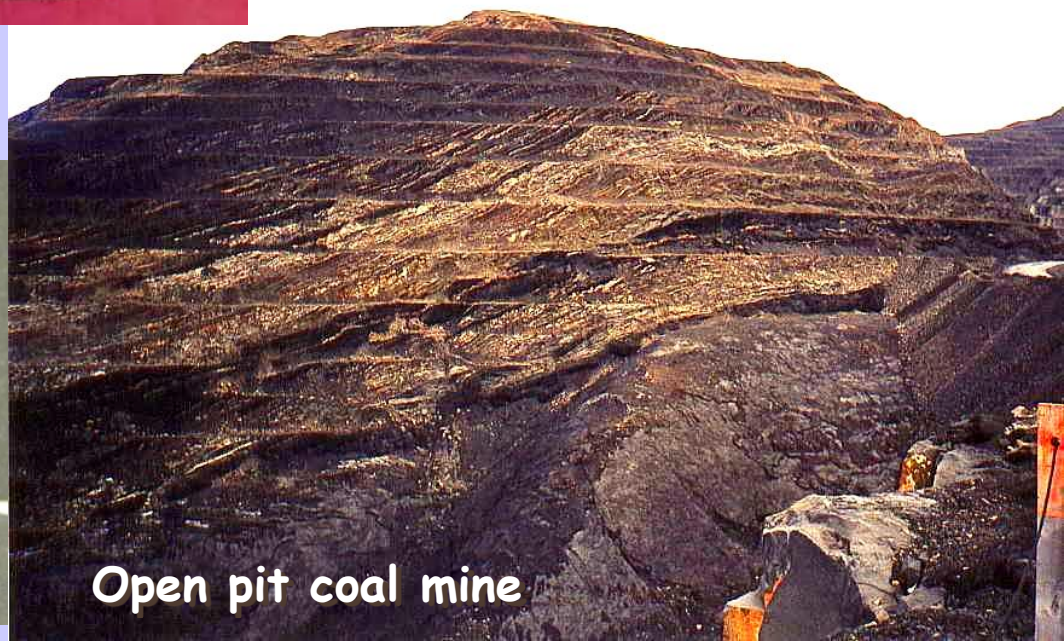
- **Travertine is an inorganic limestone that forms when calcium carbonate precipitates out of ground water that discharges from seeps, caves, grottos, springs, or along faults.**
- When the ground water becomes exposed to the atmosphere carbon dioxide dissolved in the water escapes, causing calcium carbonate to precipitate out of the solution.
- Travertine also forms where water emerges from hot springs. The picture below is of a hot spring in Yellowstone National Park.

COAL

- **Coal is made almost entirely of plant material and other organic deposits that have been buried for millions of years under elevated conditions of heat and pressure.**
- **Although the chemical composition of coal changes from its organic origins, it often retains fossilized imprints of plant leaves, bark, wood, and organisms that lived during the time the organic materials were deposited.**
- It requires very specific environmental conditions for plant material to become coal. The organic material must be deposited in an anoxic (oxygen free) environment to prevent it from decomposing. Most coal beds originated in swampy, saturated, environments.
- Deposited organic material goes through four main phase of coal formation, which are related to increasing heat and pressure :
- 1. Peat
- 2. Lignite
- 3. Bituminous
- 4. Anthracite

Coal- organic textured sedimentary rock

Lignite



CHERT

- **Chert represent a group of hard rocks made from micro- and cryptocrystalline silica (SiO_2). Chert can develop as a nodules inside other rocks or as rock layers.**

- **Most cherts are hypothesized to originate from silica derived from one of three sources: solution in water, biochemical sediments, or lava flows and volcanic ash.**

- Chert occurs in a variety of forms including flint, jasper, and agate.

- Chert is a very hard rock that generally breaks along conchoidal fractures, this characteristic makes it possible to carve sharp-pointed edges onto the rock. Native American's used chert to create arrowheads that were attached to primitive spears, arrows, and knives.

CHERT

- **Flint is the most common form of chert. It is often a dark, glassy, colored rock that forms as nodules embedded in limestone. The dark color of the chert comes from the organic matter it contains.**

- Jasper is a red variety of chert that gets its color from iron oxide.

- Agate is a banded form of chert that may contain several different colors layered throughout the rock.

Jaspe
r

Agate forming inside a coral