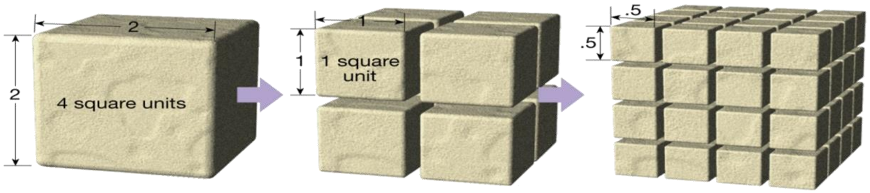
Weathering

- Weathering is physical breakdown and chemical decomposition of rocks
- Everything on the surface of Earth undergoes weathering

Weathering 1: mechanical

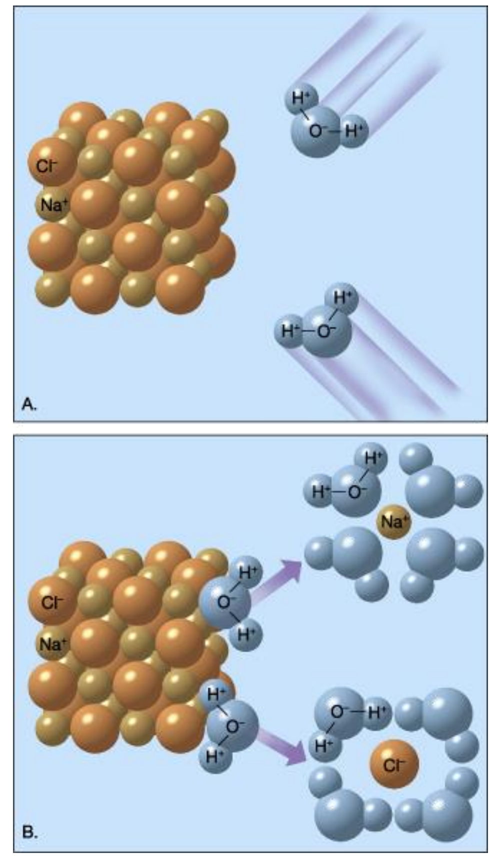
- Breaking of rocks into smaller pieces



- Among the types of mechanical weathering frost wedging is the most common
  - alternating freezing and thawing of water in fractures and cracks promotes the disintegration of rocks

Weathering 2: chemical weathering

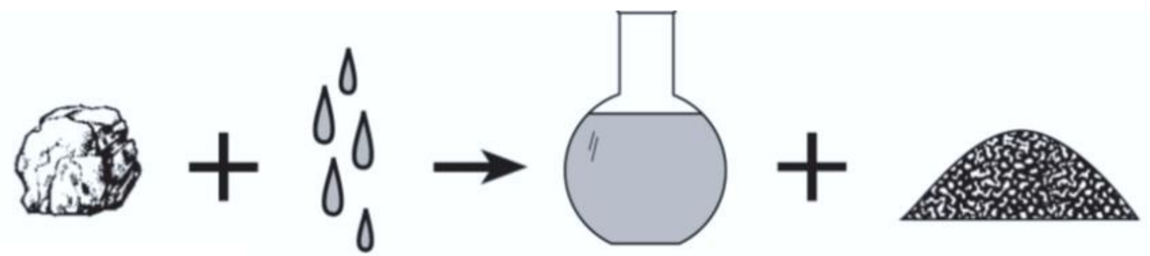
- Breaks down components and structures of minerals
- The most effective agent of chemical weathering is water.
    - water transport ions and molecules
- Chemical weathering is present everywhere BUT it is most effective at tropical latitudes (hot and humid)



Example of salt crystal dissolving in water

Chemical Weathering of silicates

- Minerals that are unstable at surface conditions break into more stable minerals
  - Most silicates experience chemical weathering transforming into clay minerals
  - Oxides and ions go into solution (e.g. acid rain dissolves carbonates)
- Quartz undergoes only mechanical weathering.
  - Quartz fragments become smaller and smaller



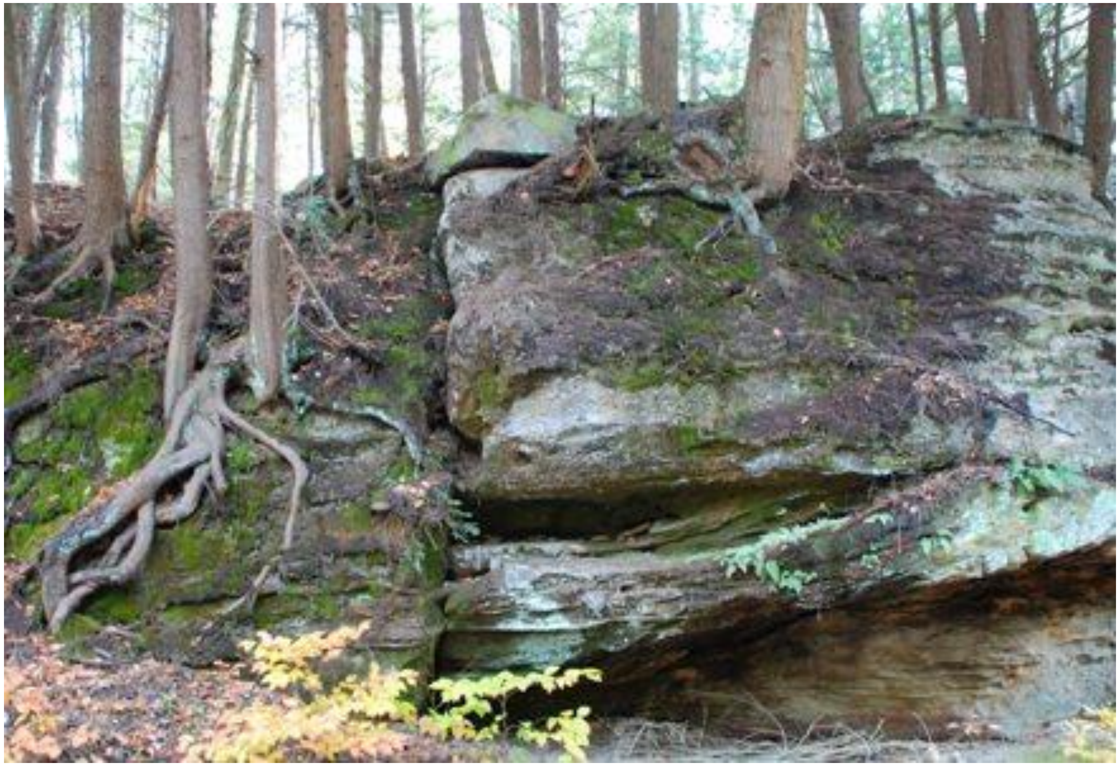
Chemical weathering on rocks: examples

- Discoloration on the outer surface of rocks is the evidence of chemical weathering

A recently broken piece of sandstone shows differential chemical weathering (probably mostly oxidation) progressing inward

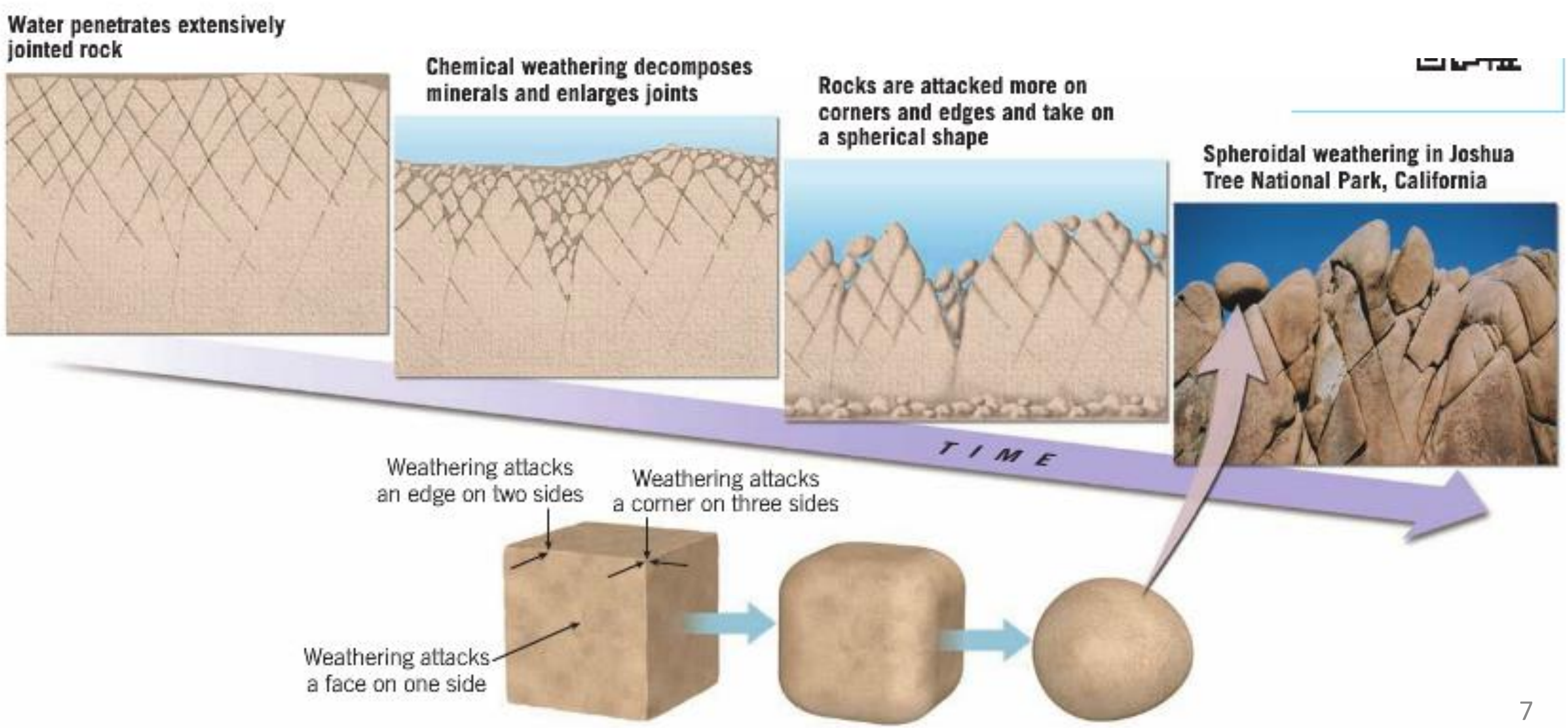
Biological activity and erosion

disintegration of rocks by organisms often combines both chemical and mechanical weathering



From weathering to erosion

- The fragments generated by weathering can be removed under the force of gravity and/or surface processes



weathering and erosion

- Weathering is the breakdown of rock exposed to the action of surface processes, weather/climate
- Erosion removes the weathered fragments under the force of gravity
- Everything on the surface of Earth undergoes erosion, in time, even the tallest mountains will be weathered down

Erosion generates landscapes

- Rocks do not weather uniformly → differential weathering.
- Diverse rocks eroded in diverse climates → variety of landscapes

Bryce Canyon NP

Arches NP

Mammoth Cave NP

Yosemite NP

Transport

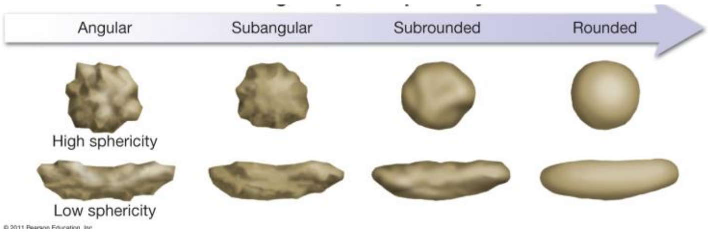
- Transport is the process of moving the eroded fragments by the action of surface agents such as:
    - water (streams, currents)
    - ice (glaciers)
    - wind
    - gravity

Changes to shape and size of fragments as they are transported

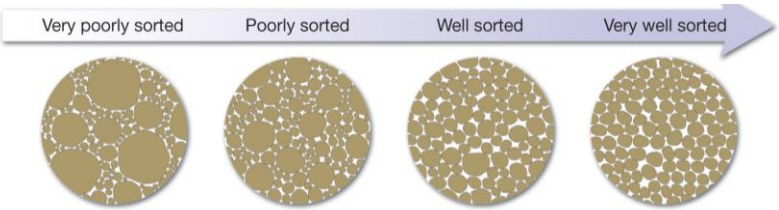
- **Size** larger fragments are found near their sources, small fragments were transported and deposited far away from their rock source

- **shape:** Angular to smooth

  The longer fragments travel, the smoother they become

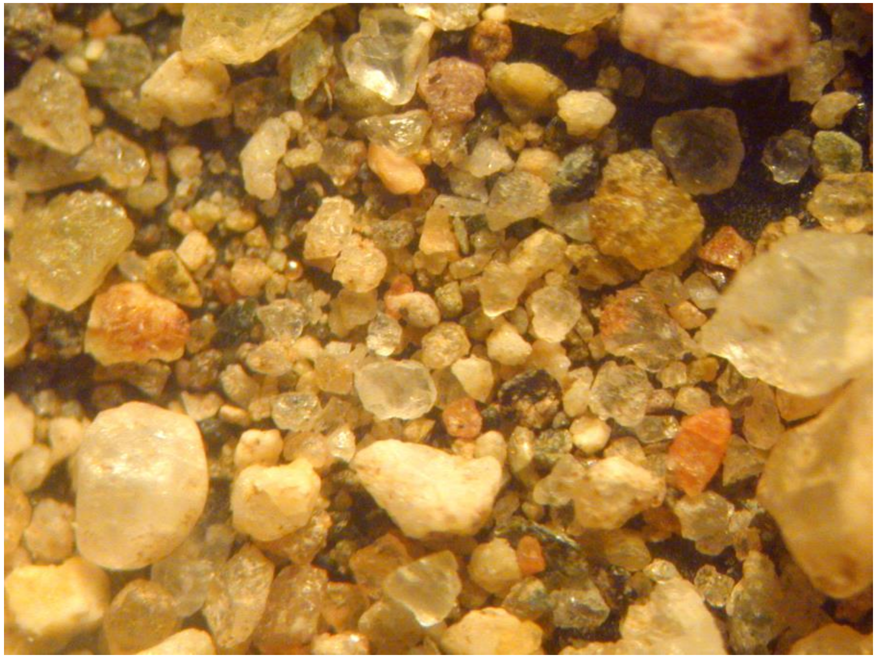


- **sorting:** distribution of sizes among the sediments
  - Mature sediments are well sorted



Changes to fragments from transport

- Note the change is size and shape (Maturity)
  - Photos of sand samples taken at the same scale (FOV 3cm across)



Mason Neck, VA

Siesta Key beach, FL

Step 3: Deposition

- When surface processes change/slow down, they lose their transport capacity, and the transported fragments are deposited.
- The geographic setting where the fragments accumulate is known as a depositional environment
  - Sediment is the name we give to transported fragments when they are deposited

The beach is a depositional environment, sand is a type of sediment

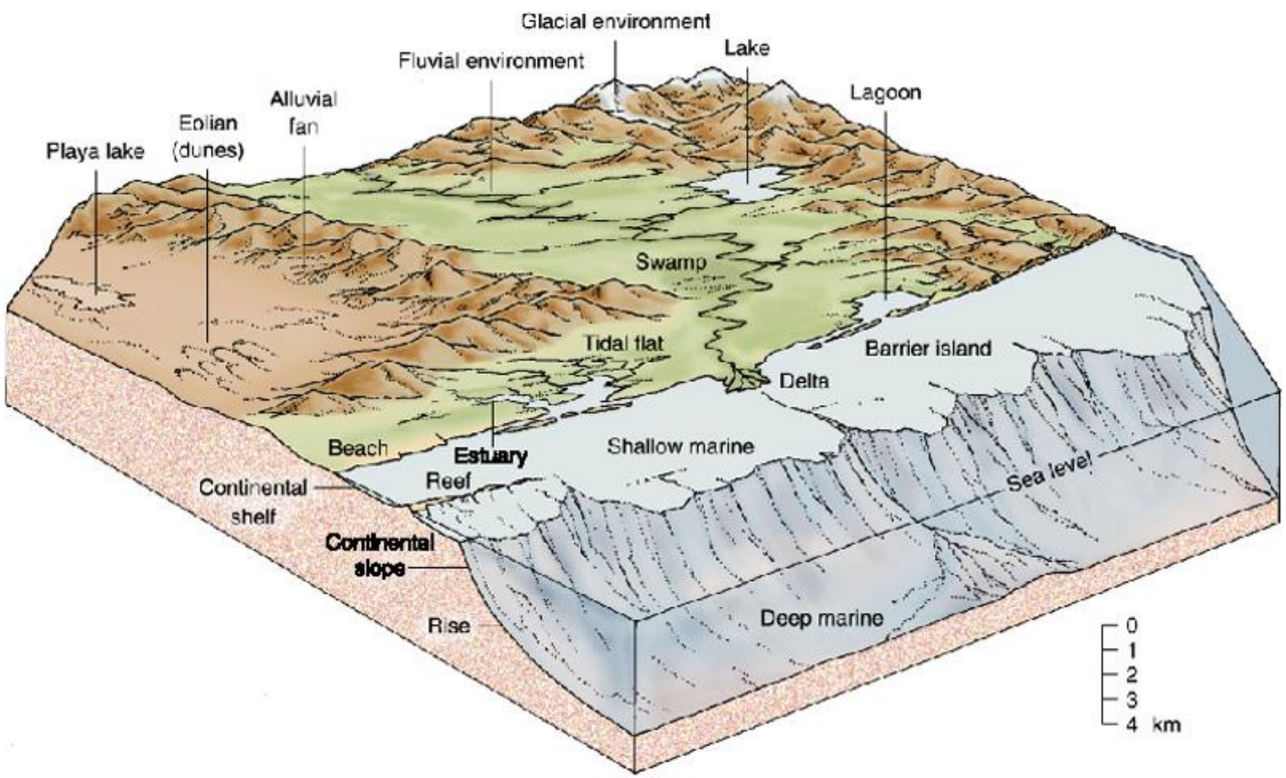
Drakes Estero estuary outlet and Pacific coast, Point Reyes National Seashore, California.

NPS Photo.

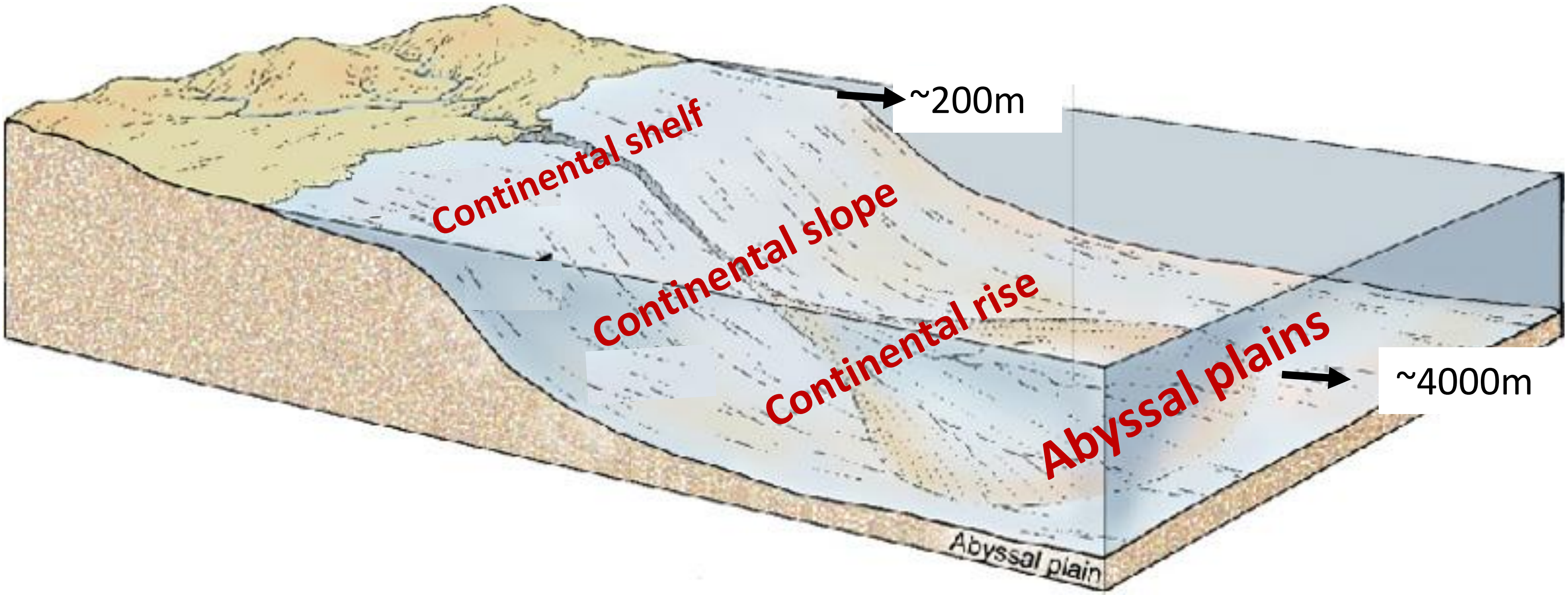
Earth's surface (depositional) environments

Earth's environments are divided into 3 groups:

- Marine environments (at sea, always under sea level)
- Transitional environments (along contact between ocean and land)
- Continental environments (on land)



Marine Depositional Environments

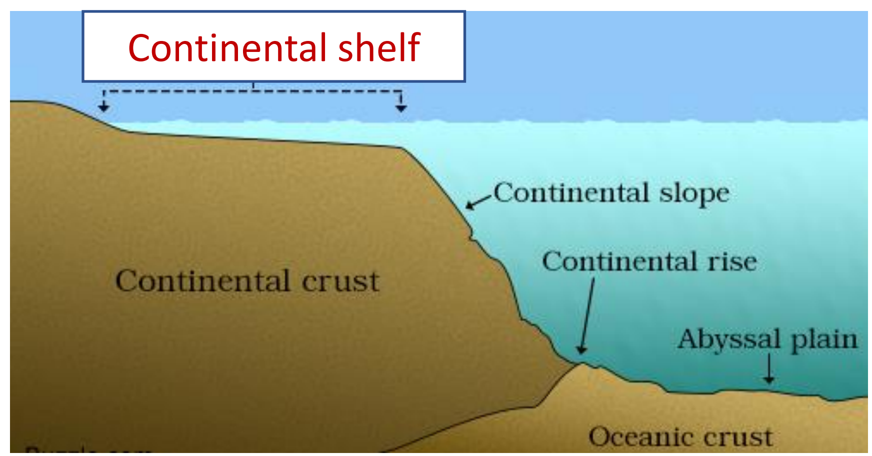


Marine environments: the Continental Shelf

The continental shelf is the flooded edge of the continent

Gentle slope, shallow water depth (< 200 m) and variable width, exposed to action of waves, tides, and currents

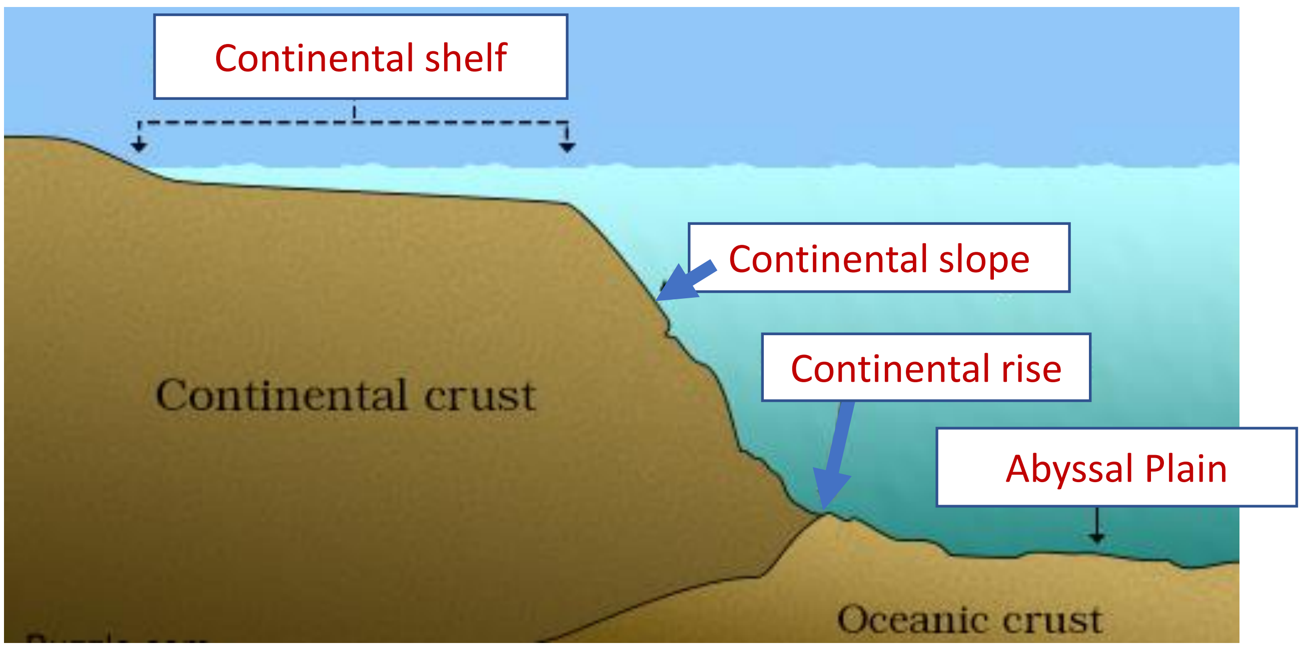
Most sediments end up accumulating on the shelf



Marine environments

Continental slope

The edge of the continental lithosphere.
Erosion prevails steep slope with deep canyons carved by submarine landslides



Continental rise

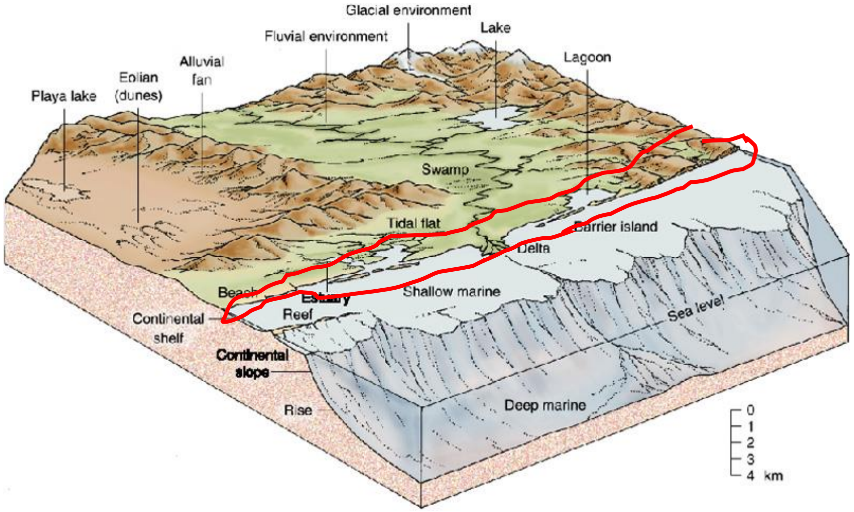
Gentler slope formed by the accumulation of the sediments that fell from the shelf

Abyss or Abyssal plain

the deepest and widest section of the ocean floor, it includes divergent plate boundaries, hot-spot related volcano and trenches of convergent plate boundaries.

- It is covered by finest sediment transported from land

Transitional Environments



- Environments at or near the transition between the land and the sea. Examples:
- Mouth of rivers: delta and estuary

Beaches/ Cliffs
Barrier Islands

Tidal flats

land covered and uncovered by water as the tides rise and fall

A comparison of low tide vs. high tide at the mouth of Geographic Creek. NPS

Coastline wetlands/swamps

Everglades, FL

Continental Environments

All the landscapes of dry land

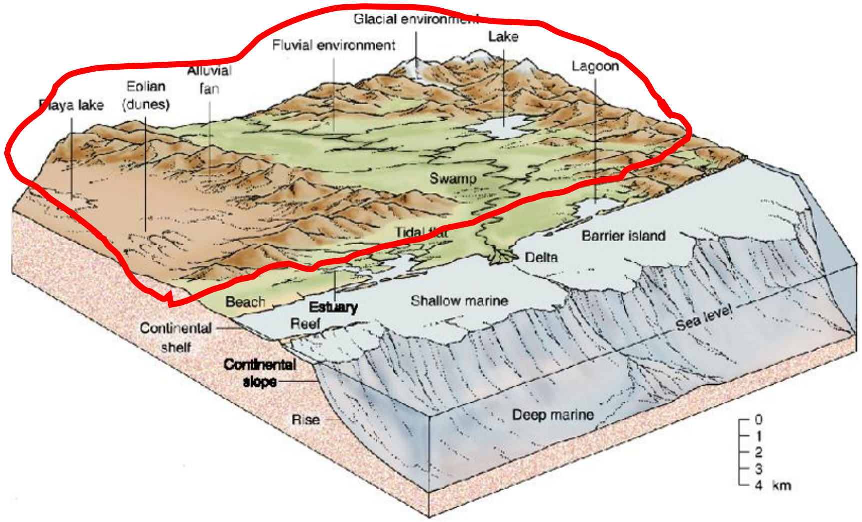
A few examples

Rivers/fluvial

Lacustrine

Mountains/ Glacial

Eolian/Desert

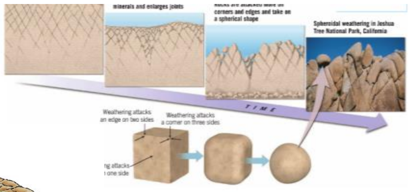


The making of sedimentary rocks

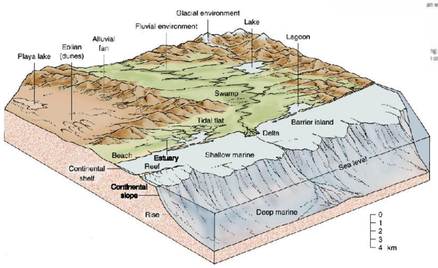
- All sedimentary rocks are formed by surface processes that start with weathering of preexisting rocks.
- Sedimentary rocks make the top 10% of the crust, just a few kilometers!

- The making of sedimentary rocks is a 3-step process:

  1:Erosion = Weathering + Mass Wasting



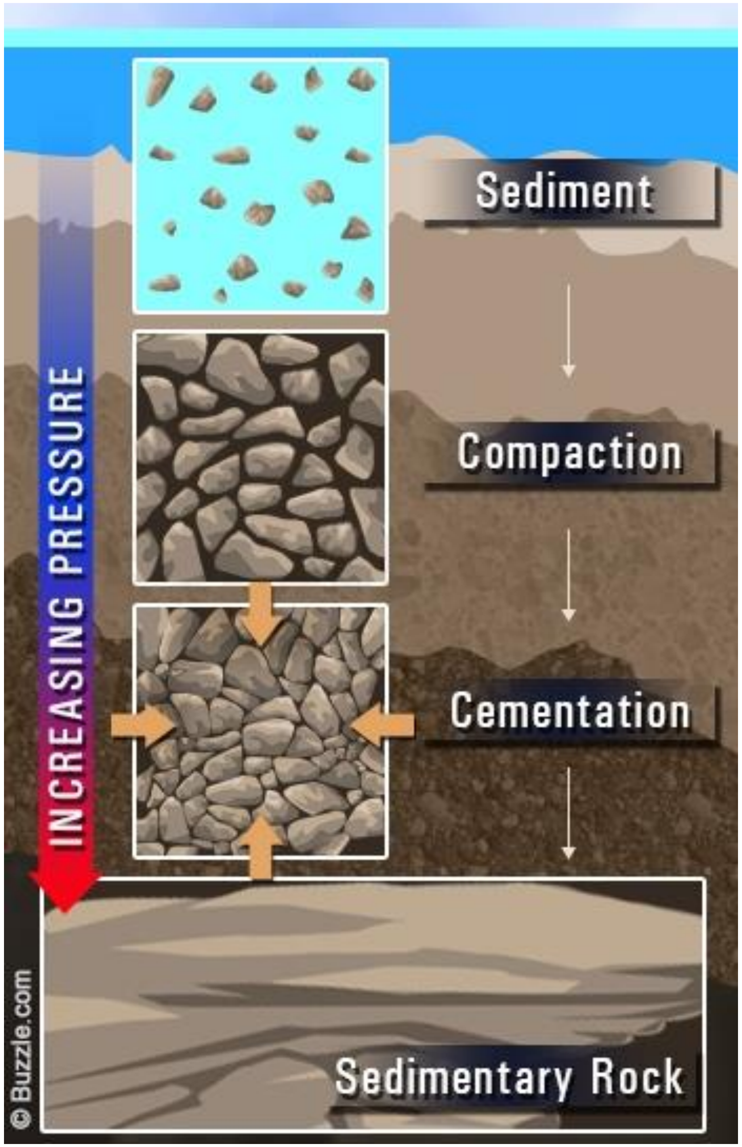
  2: Transport and Deposition



  3: Diagenesis→ Sedimentary Rocks

Diagenesis: from sedimentary deposits to sedimentary rocks

- When accumulating, the sediments compact under their own weight
- Compaction eliminates spaces and fluids in between the sediments
- Diagenesis - the transformation of sediments into a sedimentary rock – occurs at about T=250C.
  - Compaction changes in pressure and temperature and the fluids work like a cement (glue!) to consolidate the sediments until they become a sedimentary rock



Types of sedimentary rocks: detrital/clastic

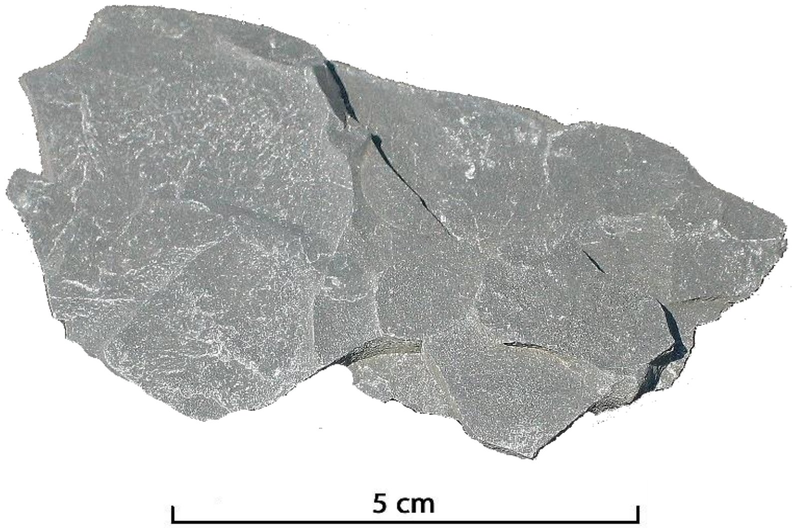
Sedimentary rock types are studied based on the source of the material

- **Detrital (clastic) rocks** – formed from solid particles of transported sediment that experienced diagenesis
    - They are classified based the size of the fragments
    - fragments can be of rocks, or minerals, like quartz, silicates including clay minerals
        - Matrix finer fragments filling in the gaps
        - Cement can be silicate, calcite and oxides

Typical clastic sedimentary rock

Finest size fragments: mudstone

- Mudstone are the most common sedimentary rock composed of clay with mud-sized particles deposited very far from the rock source, in quiet water, low energy environments
  - Shale are a type of mudstone that break up easily in flat pieces
  - Siltstone are mudstone that contain certain amount of quartz micro-grains



Mudstone (above) and shale with fossils (right)

sand size fragments: Sandstone

Composed of sand-sized particles

- There are many sandstones, varying in composition and texture depending on the sedimentary environment in which they formed

Quartz Sandstone

- Mostly made of well sorted quartz grains → transported a long way before depositing
- Sedimentary environments for quartz sandstone are shallow water in transitional environment, e.g. a sandy beach like Siesta Key beach

Many types of Sandstone

- Sandstone can vary in composition and texture
  - different colors, the fragments may differ in sorting and roundness
  - Studying the details will indicate the original sedimentary environment

Arkose is a common sandstone with many feldspars forms in CONTINENTAL environments

Greywacke contains darker silicates and rock fragments and forms near the slope and rise environments from erosion of nearby volcanoes

Coarse fragments: Conglomerate

- Conglomerate has rounded, poorly sorted fragments supported by a matrix of finer fragments
- A conglomerate forms in a high energy environment

like a beach or a stream channel

Breccia

- Breccia has angular fragments
- Breccia forms from material deposited by gravity, with little or no transport

example: a rock fall

Types of sedimentary rocks: Chemical and biochemical

- Chemical and biochemical sedimentary rocks form from molecules that precipitated to crystallize.
  - If the process is caused by an organism, then they rocks are called biochemical.
- They are <u>classified by composition</u>
- The formation of chemical sedimentary rocks is similar to the precipitation of rock candy or carbonates in hard water heaters

Common chemical sedimentary rocks
Limestone

- Limestone is mostly composed of calcite that forms by precipitation or evaporation
- There are many types of limestone, depending on the environment of formation
- A few examples:

  Fossiliferous/reef limestone

  can form in reef environments, contains fossils of organism that build a reef and of those who dwelled in it

Micrite limestone forms from lime mud forms from calcareous algae in quiet waters where there is no oxygen (dark grey color) like a quiet bay or a deep lake

Limestone variety

Coquina is a limestone forms from a beach with shells

Travertine limestone forms from precipitation of calcite at hot springs in continental environments

Mammoth hot springs, Yellowstone NP

Evaporites

- Evaporites are chemical sedimentary rocks that form in arid climates where rate of evaporation is high. This can be in transitional and continental environments

Example of most common evaporites

Rock Salt - Halite

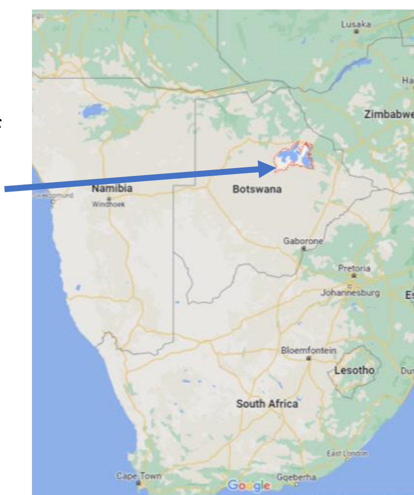
Rock Gypsum - Alabaster

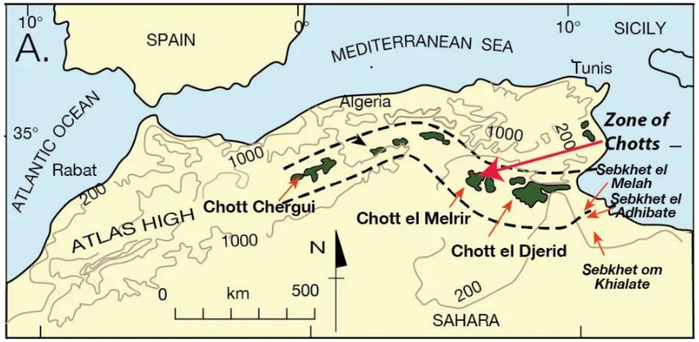
Examples of evaporite environments

Bonneville salt flats, Utah

California HW395 salt ponds inhabited by halophile bacteria

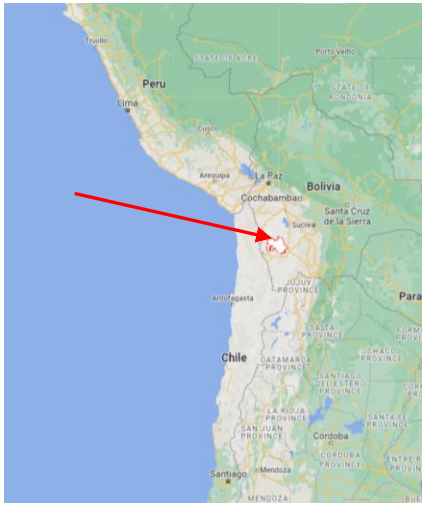
The Makgadikgadi salt Pans area of Botswana is the largest complex of evaporite in the World.





Chott el-Jérid, Tunisia

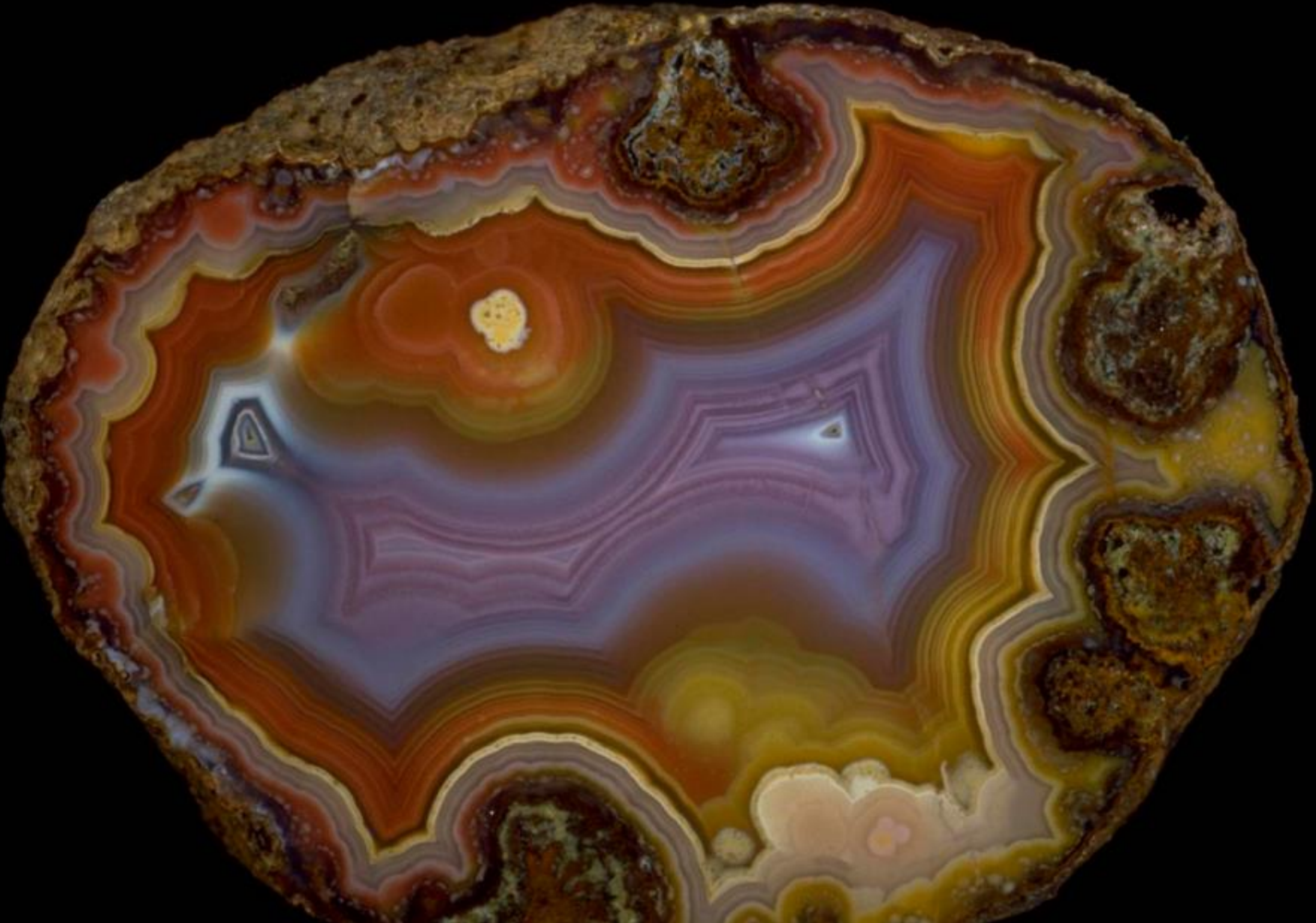
Salar-de-uyuni, Bolivia



Chert

- Chert is a microcrystalline rock composed of silica
- Chert formation is complex. Its depositional environment is mostly related to biochemical processes, but it can also form during diagenesis

- There are many varieties of chert, flint, jasper, agate
- this rock can have many colors due to oxides and other compounds present when it forms



The sedimentary rocks are the archive of Earth's history

- Sedimentary rocks form on the first few km (~10%) of the crust
- They can contain fossils, the remains of prehistoric life that buried in the sediments undergoes diagenesis → sedimentary rocks are the archives of Life of Earth

1 -Layers and Laminations

Sedimentary rocks form layers of all sizes. Each layer correspond to a full cycle of deposition and compaction of sediments

Layers can be massive and have a great areal extension like in the Gran Canyon

Very fine layers are called laminations, they form in calm water, often by biological activity of microscopic algae

3 - Ripples

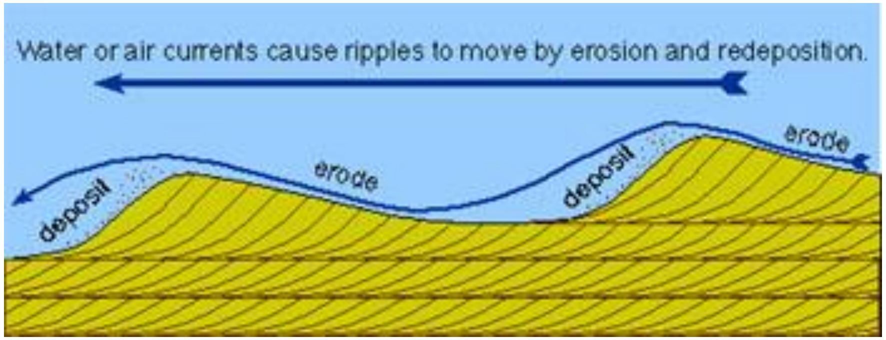
- Ripples are sedimentary structures that form as water flows along a layer of sediment or as wind blows over sediments

Modern ripples can form in shallow water and on top of wind-swept surfaces

Ripples in sedimentary rocks

3b – Cross bedding

- Cross bedding is the structure of ripples seen in cross section
- The inclination of the cross-beds indicates the direction to which the wind/water carried the sediments



Which way did the current travel?

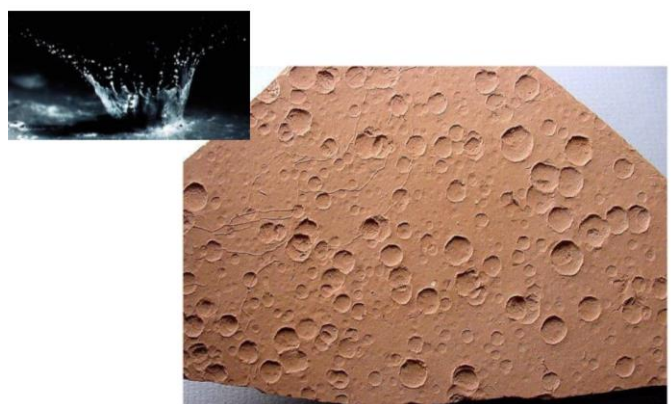
large cross bedding forms from dunes of a desert

There are many sedimentary structures

The arrangement of the sedimentary rock grains can preserve important information about processes going on during deposition of the sediments. Examples:

Mudcracks

Raindrops



Trace fossils - Bioturbation

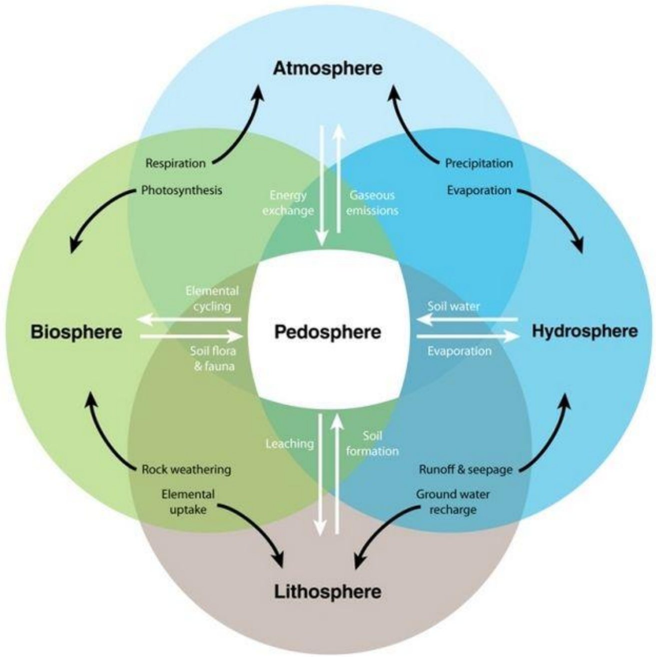
- In addition to fossils, sedimentary rocks can preserve evidence of the activity of animals in the form of bioturbation.

dinosaur's footprints are bioturbation!

Soil

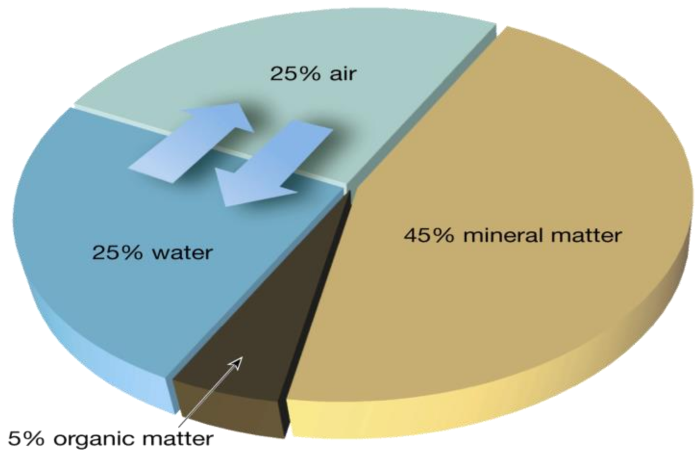
Where the Earth system merge

Soils form on the top part of sedimentary deposits, in between fragments and water, air and organic material take hold.



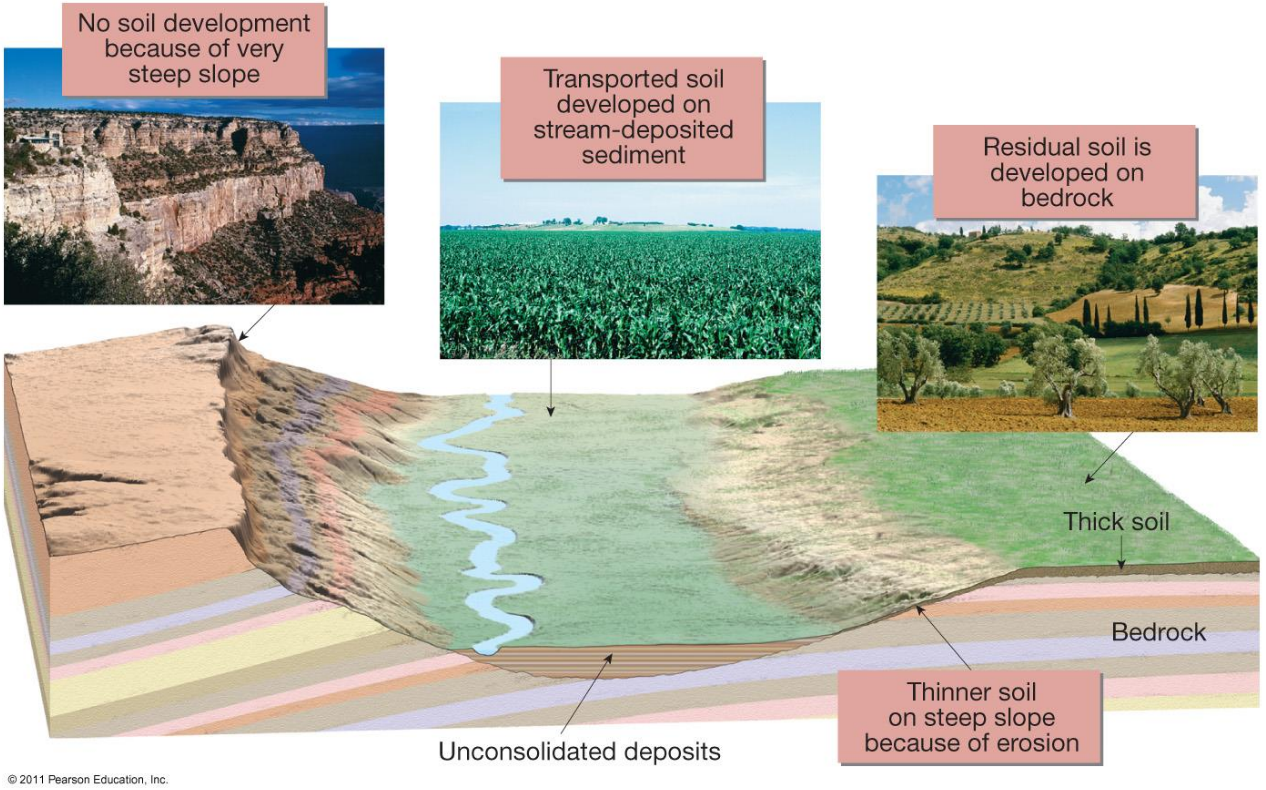
Soil's general make up is a combination of

- Minerals
- Organic matter
- Water
- Air



Variety of Soils

- Soil types depend on local geology and climate
- Different soils are suited to different types or agriculture and development



Extreme soil erosion "dust bowl"

Change in precipitation and relatively poor agricultural practice, resulted in significant loss of soil-water and organic matter. The soil turned into a deposit of sand