Sedimentary Rocks

- Sedimentary rocks consist of material (**sediments**) derived from pre-existing rocks and minerals
- These sediments are then transported in a medium (usually a fluid, such **water or air**, but occasionally solids, like in ice) by traction, suspension, or solution.

- They are subsequently **deposited** and **lithified**, or turned into a single solid rock.
- Many are deposited in **lakebeds** or on the **ocean floor**.

- There are three types of sedimentary rock:
- **clastic**
- **chemical**
- **bioclastic**

Clastics

- This type of sedimentary rock consists of **clasts** (fragments) produced without organic activity.
- Another term for these rocks is **siliciclastic**
- This indicates that the grains are predominantly silicate minerals, like quartz, muscovite, and feldspar.

- There are 5 steps to form a sedimentary rock
- WETS+

W

- **weathering** produces grains or clasts from a pre-existing rock (igneous, metamorphic, or sedimentary)
- Example: **ice wedging**

E

- **erosion** separates grains from their neighbours, or entrains them to get them moving
- Example: **wind**

T

- **transport** carries them, usually to a place of lower gravitational potential energy; grains are modified during transport through attrition (loss of material) and sorting
- Example: **glacial erratics**

S

- **sedimentation** or deposition occurs when the transport medium is no longer able to move the clasts
- Example: **Richmond and Delta**

+L

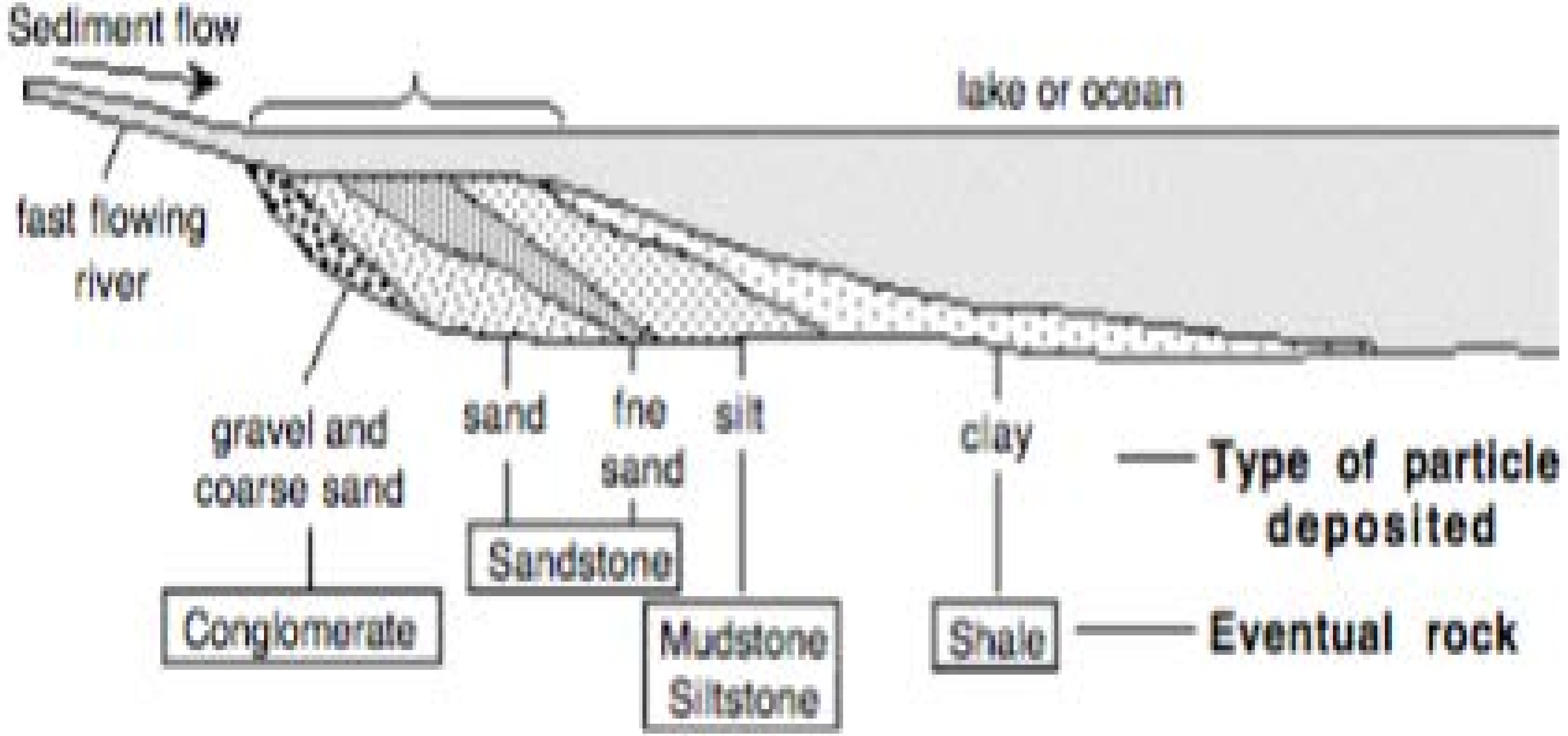
- **lithification** converts the unconsolidated sediment into sedimentary rock, usually through a number of processes
- Example: **Sandstone, Shale**

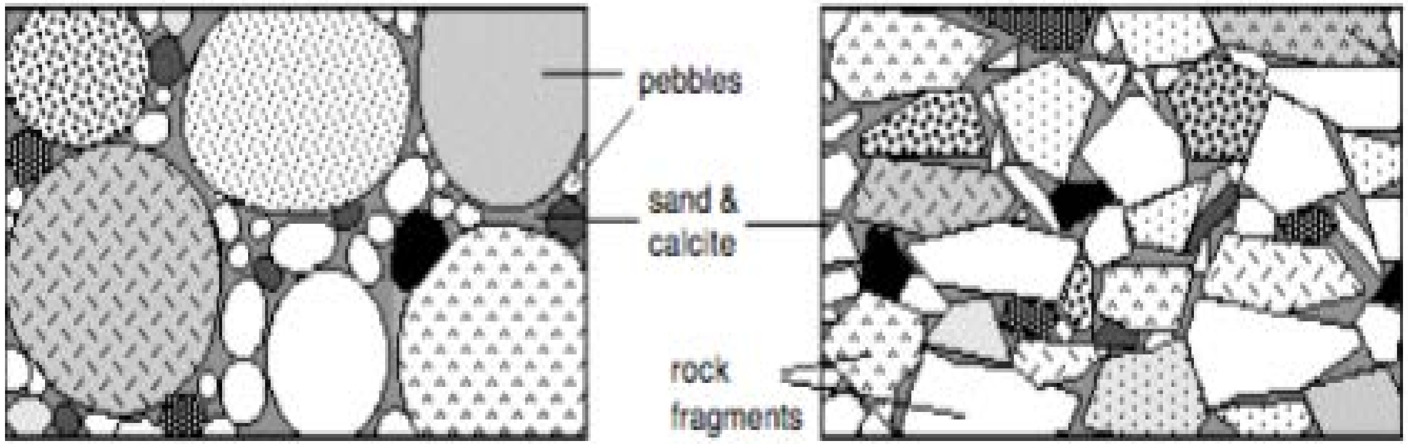
- While water is the most important force of erosion, wind, landslides, and glaciers can also move and deposit sediments in new locations.
- Glaciers and landslides tend to produce poorly-sorted and angular sediments after transportation
- water and wind tends to produce well-sorted and well-rounded sediments.

Size Classification

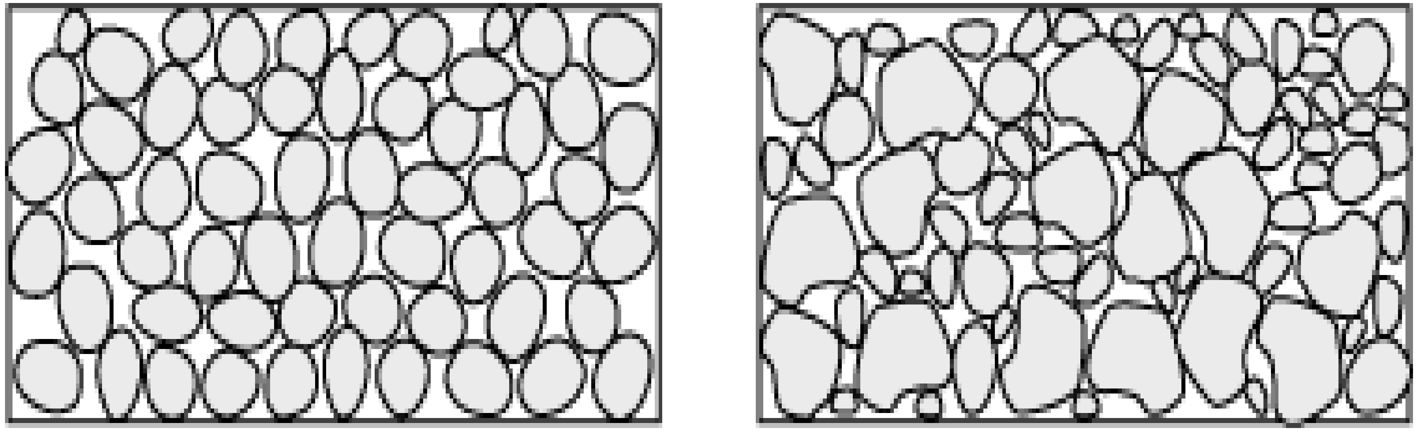
- The basic rock names depend on the **size** of the larger clasts in the rock, as well as a few other textural criteria. How **round** or **angular** the clasts are will also factor into the name.
- the **sorting** will affect the name. If the rock is well sorted, all of the clasts are a similar size. If it is poorly sorted, they have a wide range of sizes.

GRAIN SIZE	>2 mm	1/16-2 mm	<1/16 mm
SEDIMENT NAME	Gravel	Sand	Mud
ROCK NAME	Conglomerate (rounded) or Breccia (angular)	Sandstone or Arenite	Mudstone (blocky) or Shale (fissile)


Sediment flow
lake or ocean
fast flowing river
gravel and coarse sand
sand
fne sand
silt
clay
Type of particle deposited
Sandstone
Conglomerate
Mudstone Siltstone
Shale
Eventual rock



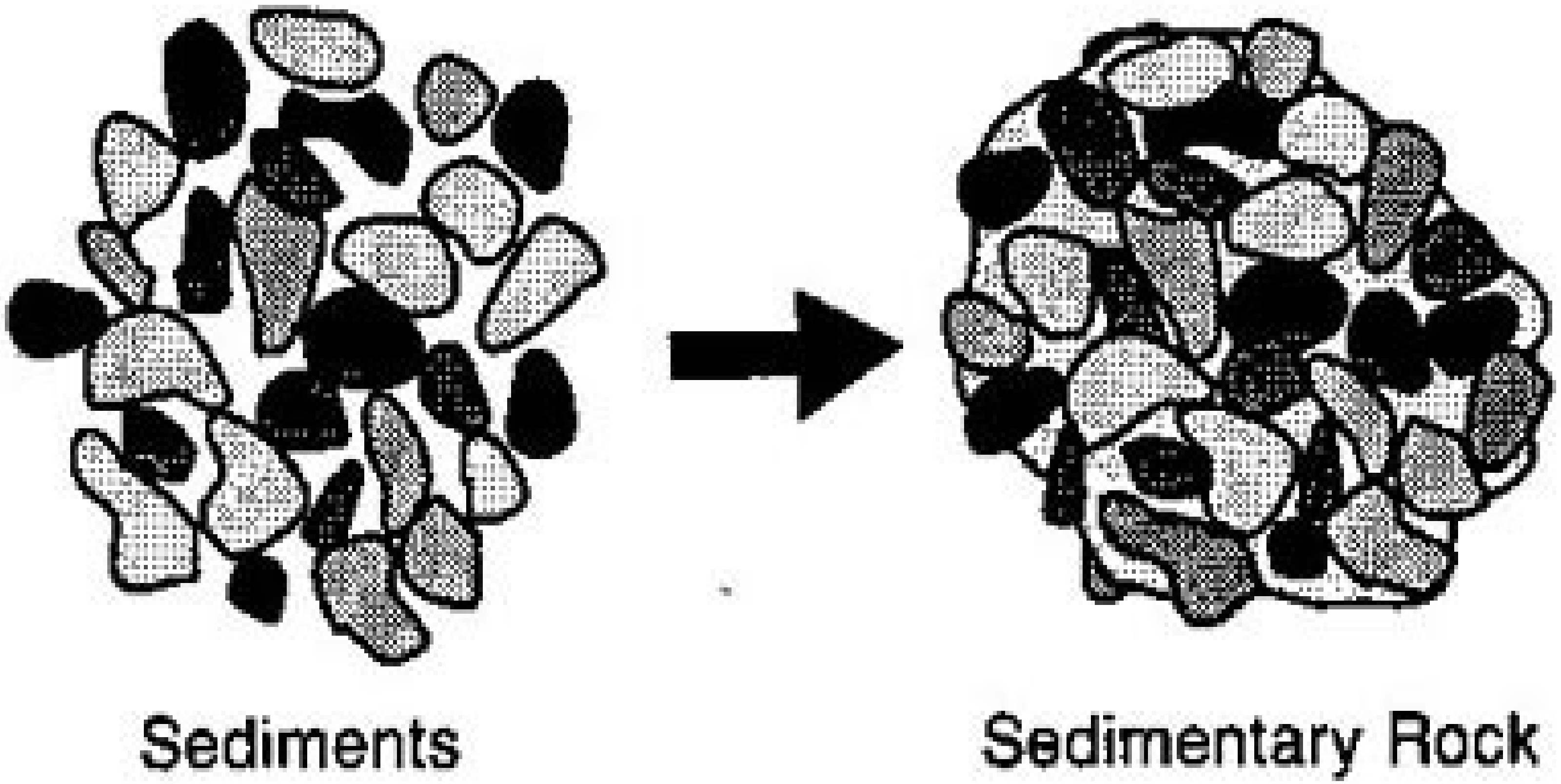
Conglomerate (x 1/4) Breccia (x 1/4)



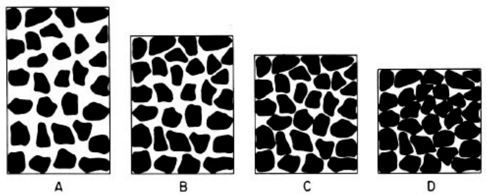
Well sorted Poorly sorted

Mineralogy

- Clastic sedimentary rocks are dominated by the stable **silicates**, namely quartz, the feldspars, biotite, and muscovite, with lesser rock fragments.
- They can also include minor or **accessory** minerals including some metamorphic silicates, oxides, and rarely sulfides

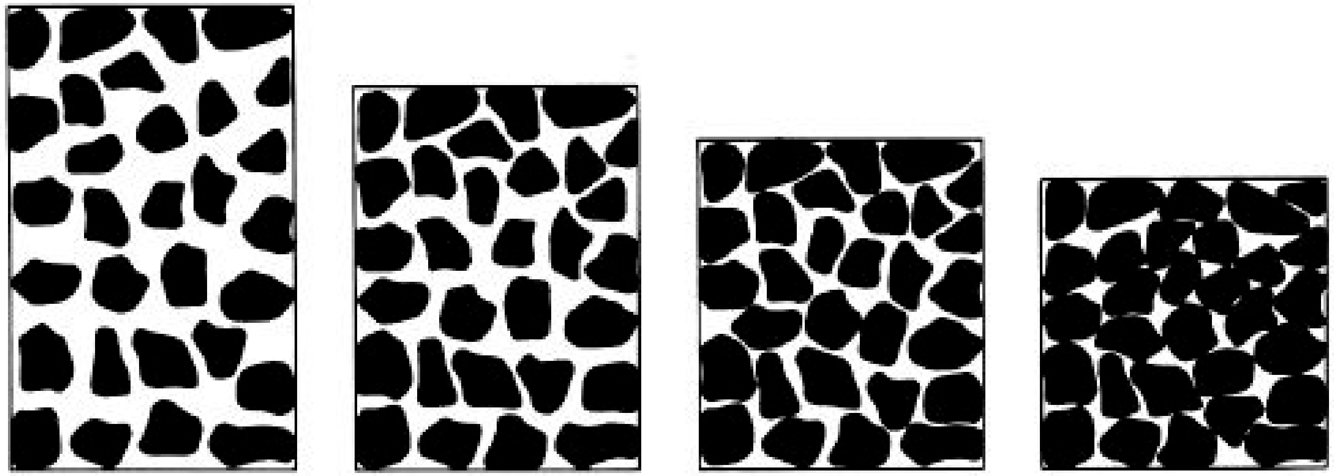

Sediments
Sedimentary Rock

Diagenesis



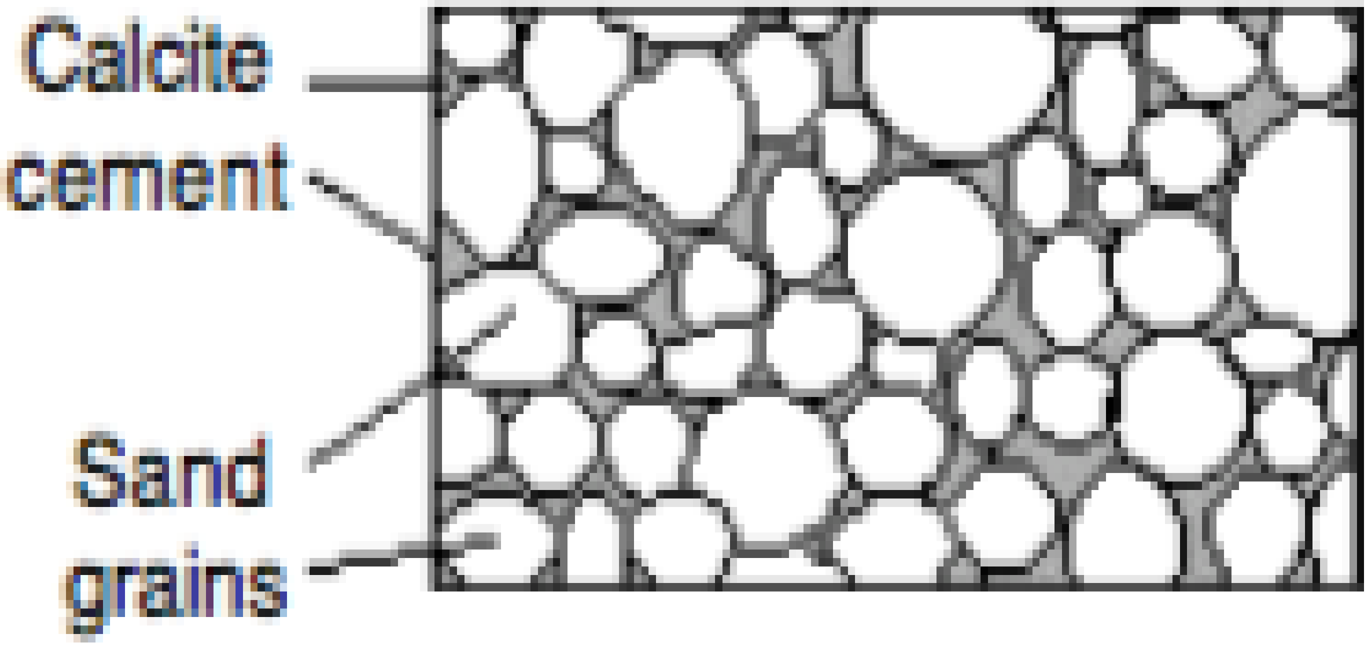
- **Diagenesis** is the set of processes by which sediment becomes 'lithified' (turned into rock). The main ones are:

- • **Compaction** – squeezes sediments closer together
- • **Cementation** – glues the sediments together



A B C D

- Ocean, lake, and ground water all contain **dissolved** minerals including silica (from quartz), lime (from calcite), and iron (from iron-containing minerals), which may form cements.
- When cement minerals **precipitate** into pore spaces between sediments they bind the fragments together, turning loose **unconsolidated** (loose) sediments into firm cemented rock.
- In fine sediments such as clay or silt, sometimes the **pressure** of sediments continuing to pile up is enough to lithify the sediment.



Sandstone (x10)

Chemical Sedimentary Rocks

- Chemical sedimentary rocks are formed from mineral grains that precipitate out of solution by evaporation or chemical action.
- **Evaporites** form when water evaporates, leaving behind formerly dissolved minerals.
- **Precipitates** form from a chemical reaction that causes them to "fall out" of the solution.

- If you set a shallow dish of sea water out in the sun, the water would soon evaporate, leaving behind a layer of salt. On a much larger scale, shallow inland seas or lakes have evaporated to leave behind thick layers of salt or other minerals.
- This intense evaporation occurs around desert latitudes (centred on 30° N and S Lat) leading to **precipitation** of minerals in isolated bodies of seawater. These evaporate minerals form a significant resource (e.g. halite, gypsum, potash, lithium salts).

- In other cases, a **chemical reaction** will cause an extremely fine powder to precipitate or fall out a solution producing a layer of fine chemical sediment. Usually, chemical sediments are fairly pure minerals.

Chem. Sedimentary Rock	Type	Description
Rock Salt (Halite)	Evaporite	Sodium chloride (rock salt) formed when sea water evaporates.
Limestone	Precipitate	Calcium carbonate; usually dark and hard with very small crystals. Reacts with acid.
Chert	Precipitate	Precipitated quartz from silica-rich solutions percolating through rocks; often found in geodes; also known as flint, agate, onyx or amethyst.

- Q: What are some potential resource applications of evaporites?

Organic/Bioclastic Sedimentary Rocks

- Biochemical rocks owe their origin to **biological** activity. Most of these rocks are carbonates, but can be made from other minerals. Biological sediments are formed when an organism precipitates a **shell** or **skeleton** from the chemicals in water. Once the organism dies, a shell or skeleton is deposited.
- Coral reefs, shells, and other carbonate **remains** can lithify to form an **organic limestone**. These carbonates typically form in **shallow, tropical** marine environments, such as the Caribbean. The silica skeletons of diatoms and radiolarians can form organic chert, which is composed of SiO_2.

Organic Sed. Rock	Mineral Composition	Description
Organic Limestone	Calcite	Compressed and cemented sea shells and other marine debris from the sea floor or ancient coral reefs.
Chalk	Calcite	Soft form of limestone made from shells of microscopic animals called Foraminifera
Diatomite	Quartz	Compressed and layered diatoms (microscopic algae with a hard silica skeletons). Also known as diatomaceous earth.
Chert	Quartz	Very fine grained. Formed from the remains of diatoms and radiolarians. Can be chipped to make tools, such as knives. When hit with steel, it can spark to make a fire.
Coal	Carbon	Layers of compressed natural material, ranging from partially carbonized lignite to fully carbonized anthracite.

-
- Q: What are some potential resource applications of organic sedimentary rocks?

Sedimentary Structures

- Sedimentary structures are **visual features** found in sedimentary rocks that tell you information about what the conditions were like when the rock was formed.
- They are like clues, which you can use to visualize or predict what the depositional environment was like when the rock was deposited, thousands or even millions of years ago.

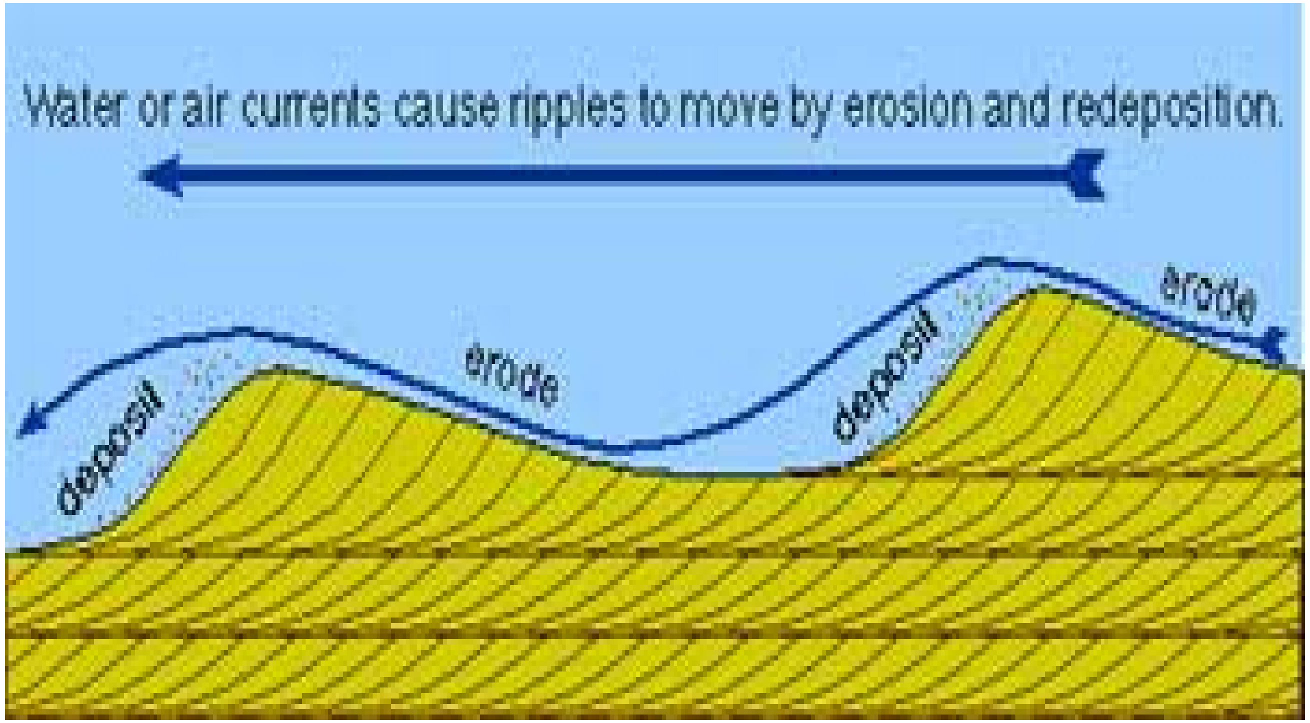
Stratification

- **Layering** is an inherent property of a sedimentary environment as new sediment is added to existing layers. The **strata** (layers) are often visible because of differences in the colour or texture (sediment sizes) of successive layers.
- Strata thicker than 1cm are commonly referred to as **beds**. Thinner layers are called **laminations** or **laminae**. The upper and lower surfaces of these layers are called bedding planes.

Cross-Bedding

- This structure forms from water or other fluid moving over deposited sediment. Sediment fill be picked up upstream, lifted over the crest, and be deposited downstream.
- The crests of these structures **migrate** in the direction of the current. **Sand dunes** in the desert would have this structure. They can also be found in mud at the beach.

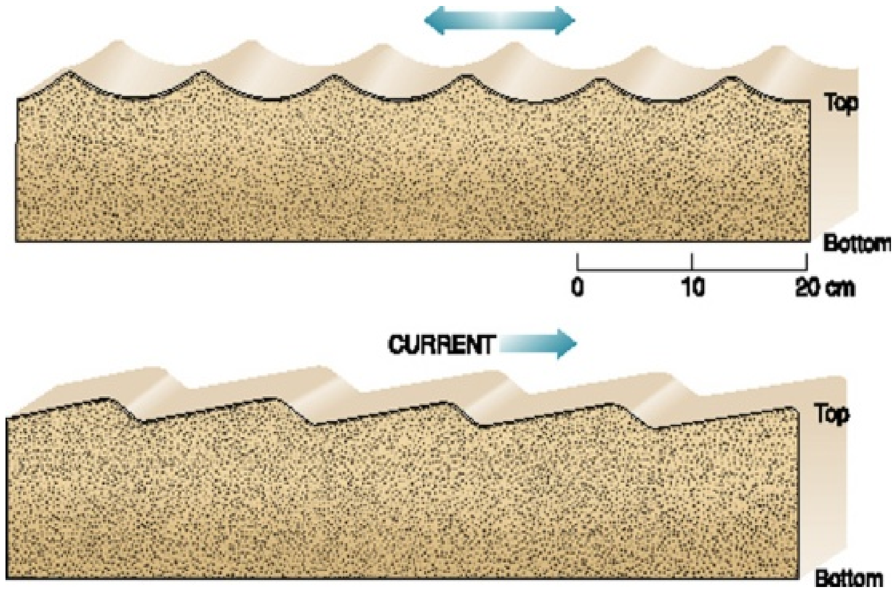
- The layers are frequently on an **angle** (‘cross-bedding’) rather than normal horizontal layering. These angled beds indicate the **direction** of fluid flow.



https://www.youtube.com/watch?v=cJo0fTpJypg

Ripple Marks

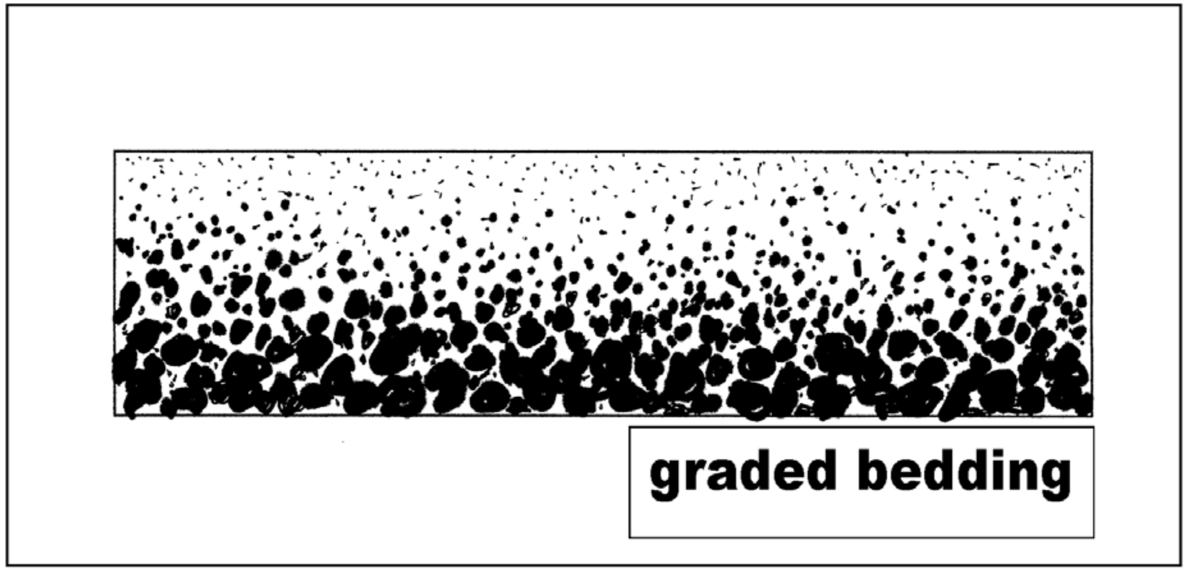
- Ripple marks are caused by the flow of water currents over sediments.
- They may be **symmetric** if the currents flow back and forth, or **asymmetric** when currents only flow in one direction. A cross section may show cross bedding.




Compass
TRANSLINK

Graded Bedding

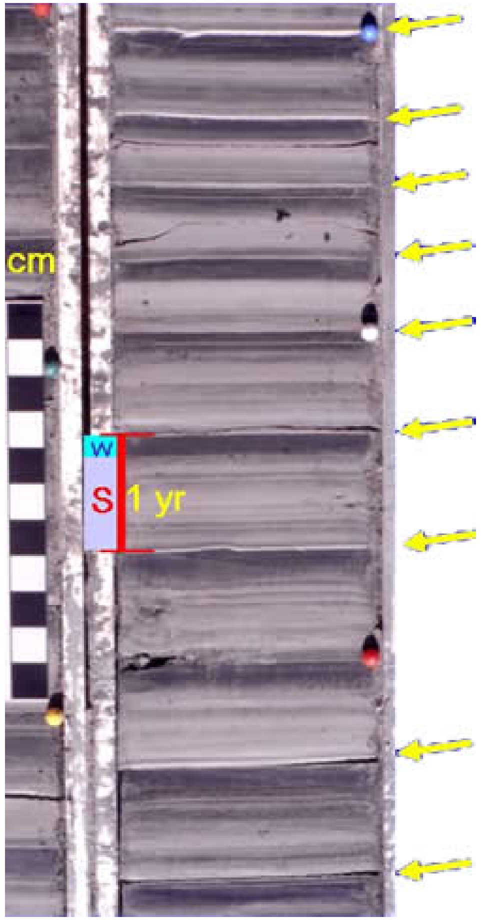
- As **mixed** sediments slow down the larger particles settle more quickly than the finer particles.
- This can result in strata that are graded from bottom to top, with coarse sediments on the bottom and fine sediments on top. This occurs when sediment travels via wind or water.



Varves

- Varves are a special type of layering that form in **glacial lakes**. Each varve represents sediment deposition over one year. **Coarse** material is found at the bottom of each varve (silt or sand) representing the spring and summer (meltwater) runoff.

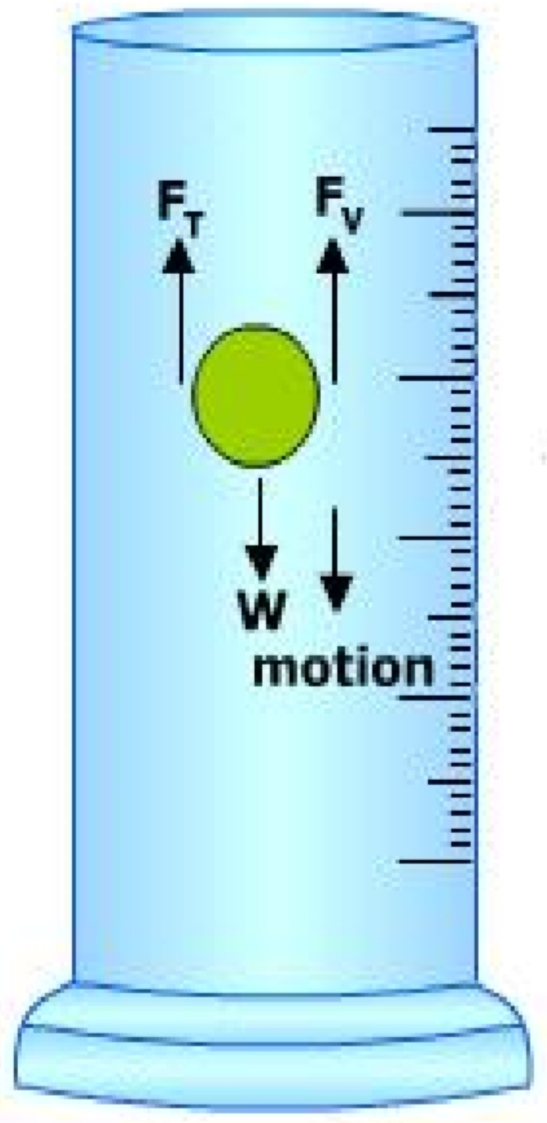
- **Finer** (darker colored) material is found at the top representing slow settling of clays and organic matter (leaves, etc.) from suspension during the winter months when the lake is covered with ice.
- Counting of varves has been used to measure the **ages** of some sedimentary deposits, or to determine how many years between ‘geological events’ (floods, volcanic eruptions, droughts, etc.).


cm
w
S
1 yr

Mud Cracks

- Mud cracks occur when **fine-grained, water-laden** (mud) ground dries out. Their presence indicates that the sediments were deposited in water, and that they **dried** out by exposure to air before lithification.

Stokes Law



The various forces acting on the body are:

Weight of the body, acting downwards

Viscous drag $F_{V,}$ acting upwards (opposing motion of the body)

Upthrust or Buoyant force (F_T) of liquids, equal to weight of the displaced liquid.

As the body falls, its velocity and the viscous drag increase due to gravity. There comes a stage, when all the three forces balance each other i.e., the net forces acting on the sphere is zero. When these conditions are achieved, the body starts moving with a constant velocity. This constant velocity is called as the terminal velocity.

Aside…Stokes Law

- grain falls until terminal velocity is reached
- $V = CD^2$
  - V = velocity
  - C = constant
  - D = particle diameter
- other variables include density of fluid and particle, viscosity, and shape factors
- only works on particles > 0.2 mm diameter because of electrostatic forces

Fossils

- Fossils are the **remains** of organisms left behind in rocks. Although soft tissues are usually destroyed quickly, hard parts are better **preserved**.
- **Animal burrows** can also be preserved as a type of fossil.

Taphonomy

- Everything that happens to an organism from the time it dies until the time it is discovered.
- Taphonomic processes **inhibit** the process of fossilization. The more processes that happen, the less preserved the fossil will be. There are several different types of taphonomic processes.

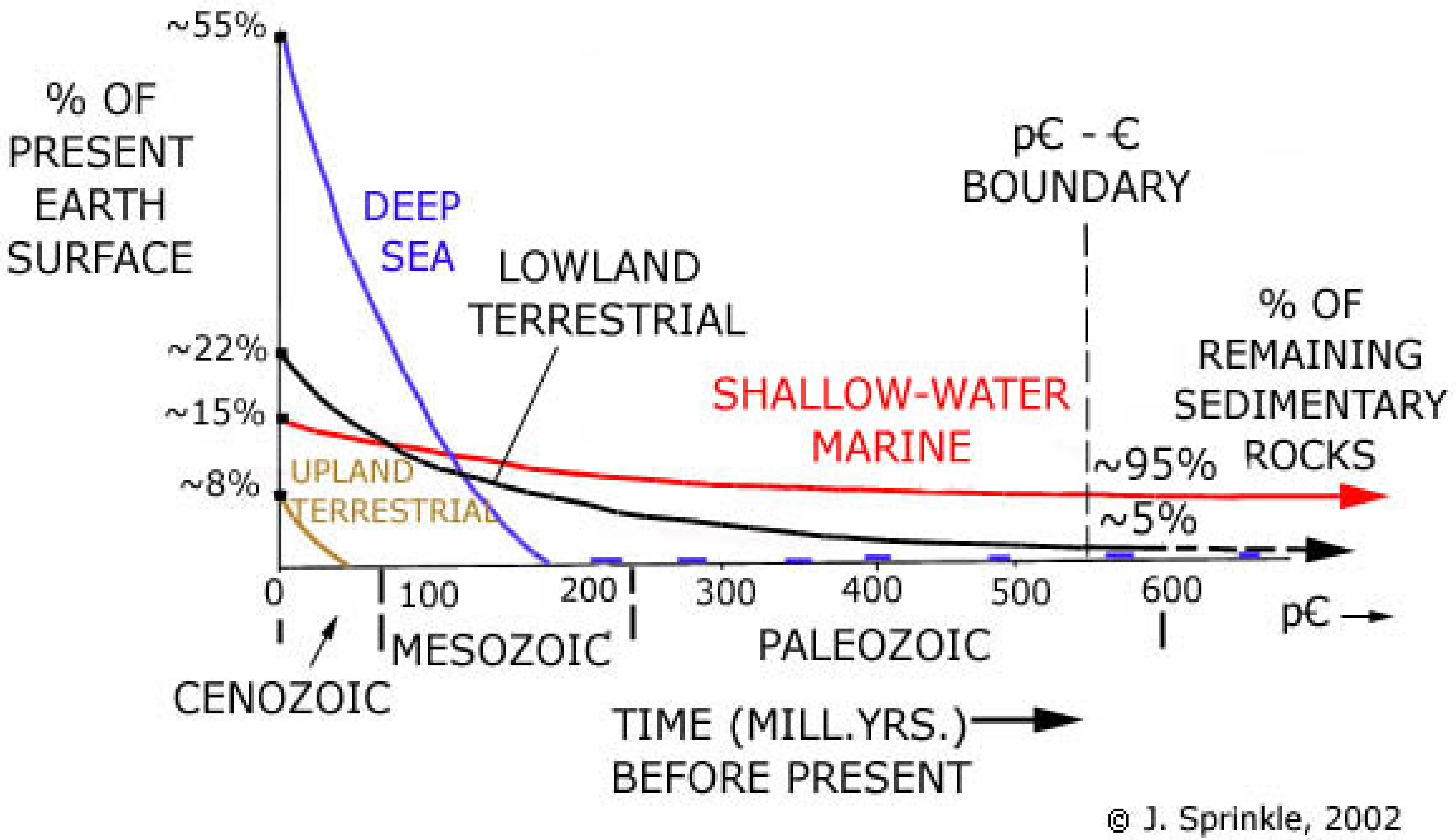
- **Biological** processes include predators and scavengers. They will disturb and destroy the remains.
- **Physical** processes include transport and compaction. A river can transport the remains to new locations. Transport can also break the remains apart. Compaction will crush the remains, and can also break them.
- **Chemical** processes can dissolve any hard parts. Acids will work to dissolve the remains.

How to Become a Fossil

- To become a fossil, the remains need to get **buried**, and stay buried. The organism should have some hard tissues, such as bones or teeth.
- Soft tissues like skin and organs are rarely preserved.
- Next, the remains need to be buried. **Rapid** and deep burial is best, as it will avoid many taphonomic processes.

- A place with a **high sedimentation** rate is ideal, such as a delta, floodplains, or volcanic ash field.
- Rate of sediment >> rate of erosion

- The **water chemistry** should also be favourable, so that the skeleton can be replaced with minerals.
- Fossils finds are generally biased towards **shallow marine** sediments, as the following diagram shows.

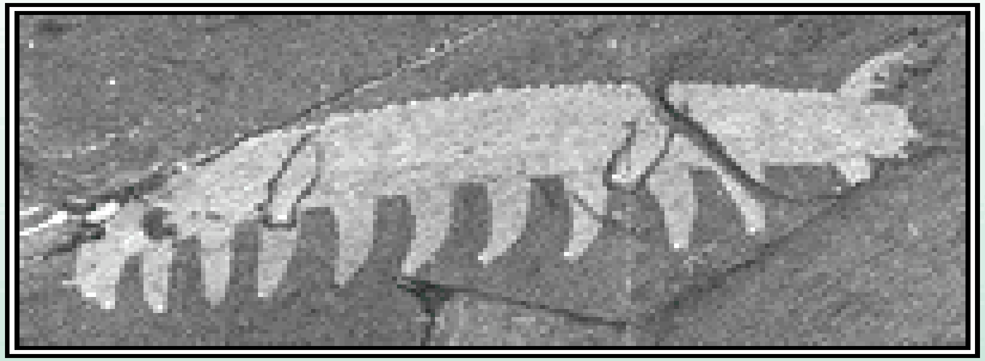


~55%
% OF
PRESENT
EARTH
SURFACE
DEEP
SEA
LOWLAND
TERRESTRIAL
pЄ - Є
BOUNDARY
% OF
REMAINING
SEDIMENTARY
ROCKS
~22%
~15%
SHALLOW-WATER
MARINE
~8%
UPLAND
TERRESTRIAL
~95%
~5%
0
100
200
300
400
500
600
pЄ →
MESOZOIC
PALEOZOIC
CENOZOIC
TIME (MILL.YRS.)
BEFORE PRESENT
© J. Sprinkle, 2002

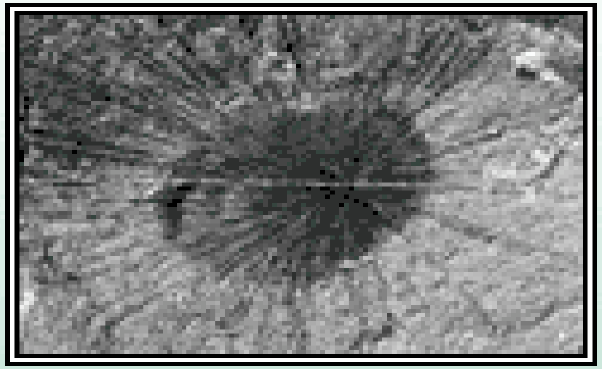
Types of Preservation

- **Soft-bodied Preservation**
  - This is **very rare**, and only occurs in exceptional conditions. The Burgess Shale near Field, B.C. has many soft bodied fossils.

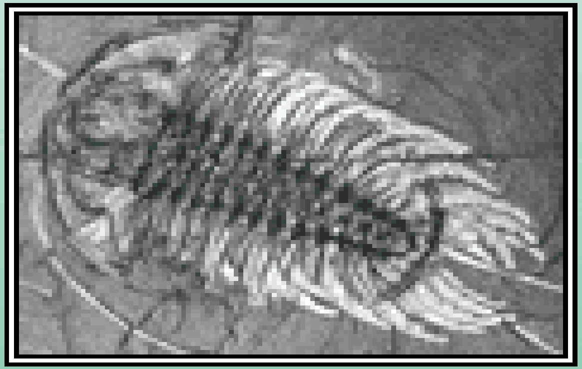
Cambrian Critters from the Burgess Shale



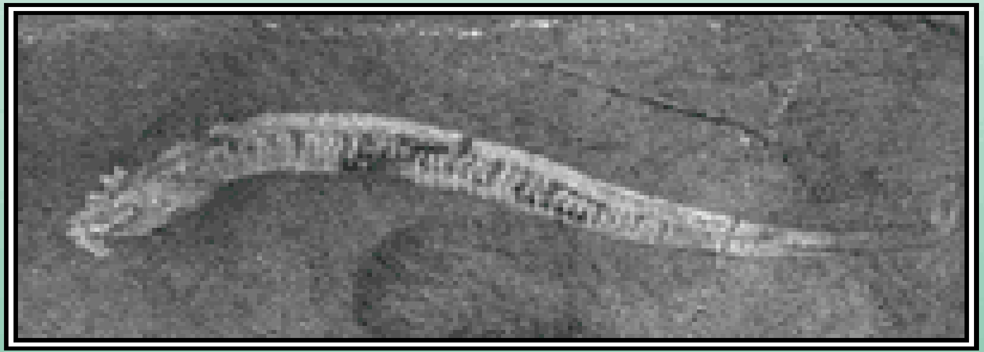
Aysheaia: a velvet worm



Choia: a sponge



Olenoides: a trilobite



Pikaia: a chordate

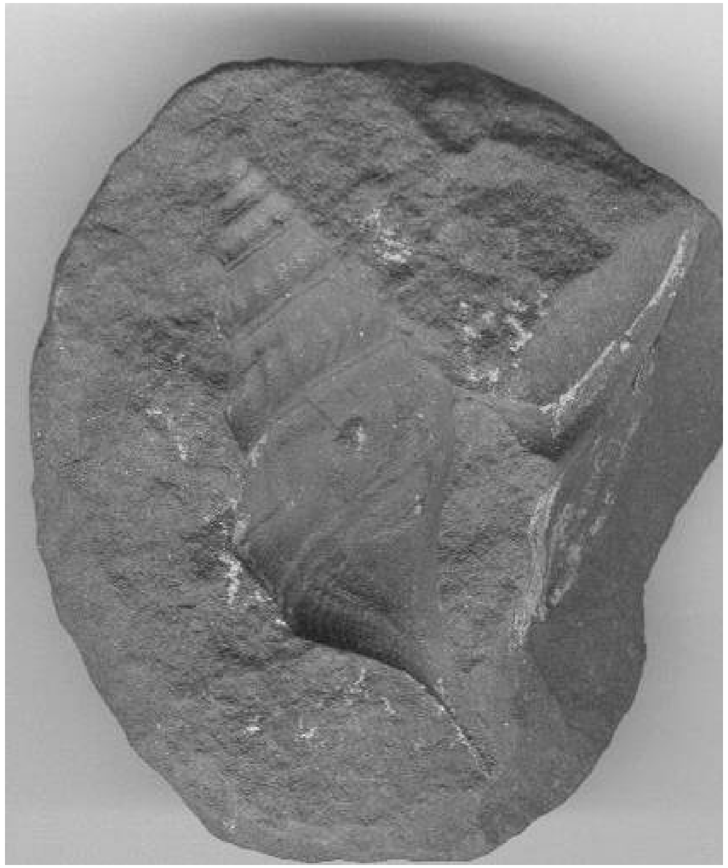
Recrystallization & Replacement

- **Groundwater** can fill in space inside the remains with new minerals
- Groundwater can also dissolve the remains, and replace them with a new mineral, such as quartz or calcite.


mm
1
2
3
PAR1

Mold and Cast

- A **mold** fossil forms when the organic matter of the organism decomposes and leaves a cavity.
- **Casts** form when the cavity fills with sediment or minerals that harden.


Weathering

- If you look at beach sand you can see that it is made of many small particles that were once part of larger rocks. These larger rocks, when exposed to the weather, can be broken down into these small particles in processes known as weathering.

- **Physical** weathering is the gradual breakdown of rocks by such processes as cracking, splitting, or impacting, but the composition of the new smaller particles does not change.
- **Chemical** weathering is the breakdown of rocks by chemical attack to form new materials with a different composition.
- **Biological** weathering can be physical, chemical, or both, but requires a living organism.

- Since different rocks are made in different ways, and are also made of different materials, not all rocks weather at the same rate. Some rocks are very resistant to weathering, while others aren’t.

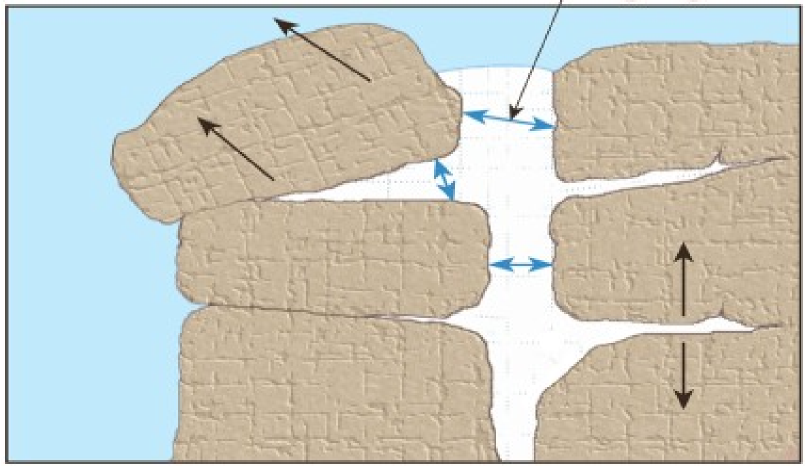
- **Erosion** is the movement of weathered rock from its original location to somewhere else.
- As well as gravity effects causing mass wasting, there are four main other causes of erosion, transportation and deposition
- running water, wave action, wind and glaciers, of which running water effects are by far the most damaging overall. All of these effects owe their origin and energy to the Water Cycle.

Abrasion

- The repeated **crashing** of rocks against each other chips off the rough corners, making the rocks rounded.
- This is a major process in rivers, streams, and beaches where water is continually tumbling rocks against each other. Pebbles and rocks become **smooth and round**.
- Hard quartz sand carried by wind or water also abrades the rocks. Waves will also cut into beach cliffs.

Frost Action

- In cold weather, water that has seeped into cracks in the rocks freezes, **expanding** in volume and causing the cracks to open further.
- If deep cracks form over time rock can shatter or to break off from cliff faces. This effect also occurs in water saturated soils.



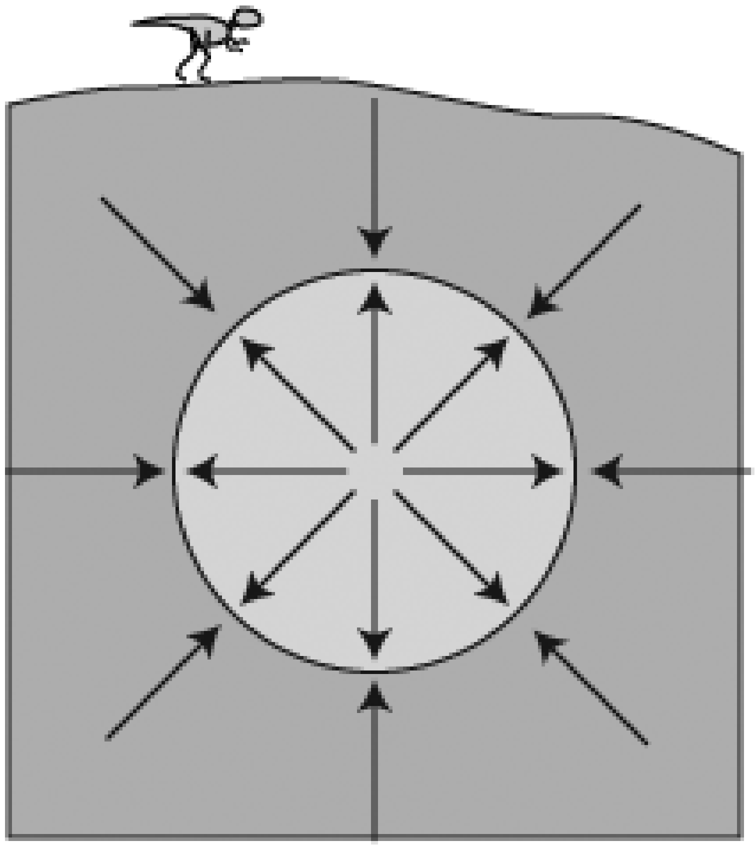
Temperature Changes

- Changes in temperature can result in the repeated **expansion and contraction** of rock, or different minerals within the rock.
- This may result in cracking of the rock material. Normally this is a small effect unless the rocks are saturated with water, or if the temperature changes are extreme, such during a forest fire.

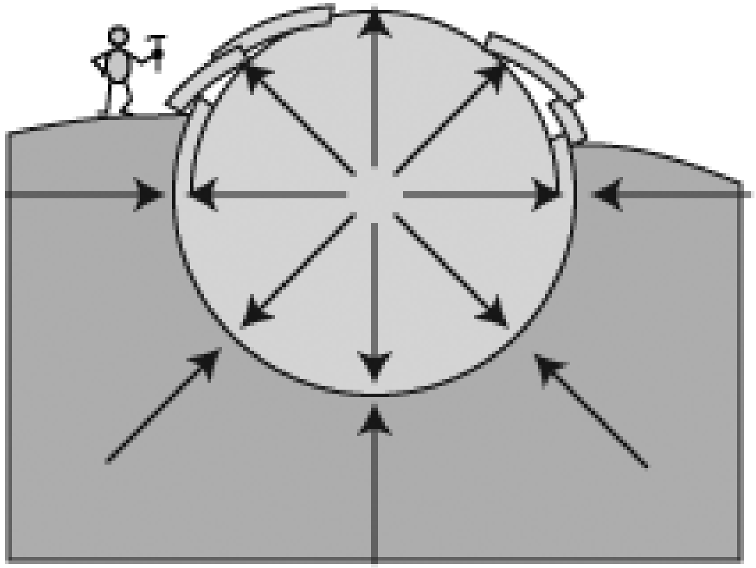
Exfoliation

- This is the peeling or fracturing into layers of the outer parts of a rock from the **release of tension** in the outer layers of the rock mass.
- This is very common in large surface exposures of plutonic rock.
- As the overlying rock is weathered and eroded away, downward pressure is released and the plutonic rock tends to expand, frequently bowing into an arc with long curved breaks between layers, and vertical stress relief cracks or joints.

Time 1: An intrusion solidifies in equilibrium with country rock. Outward pressure balances inward pressure.



Time 2: Erosion unroofs the intrusion. Outward pressure is no longer balanced. Exfoliation occurs.



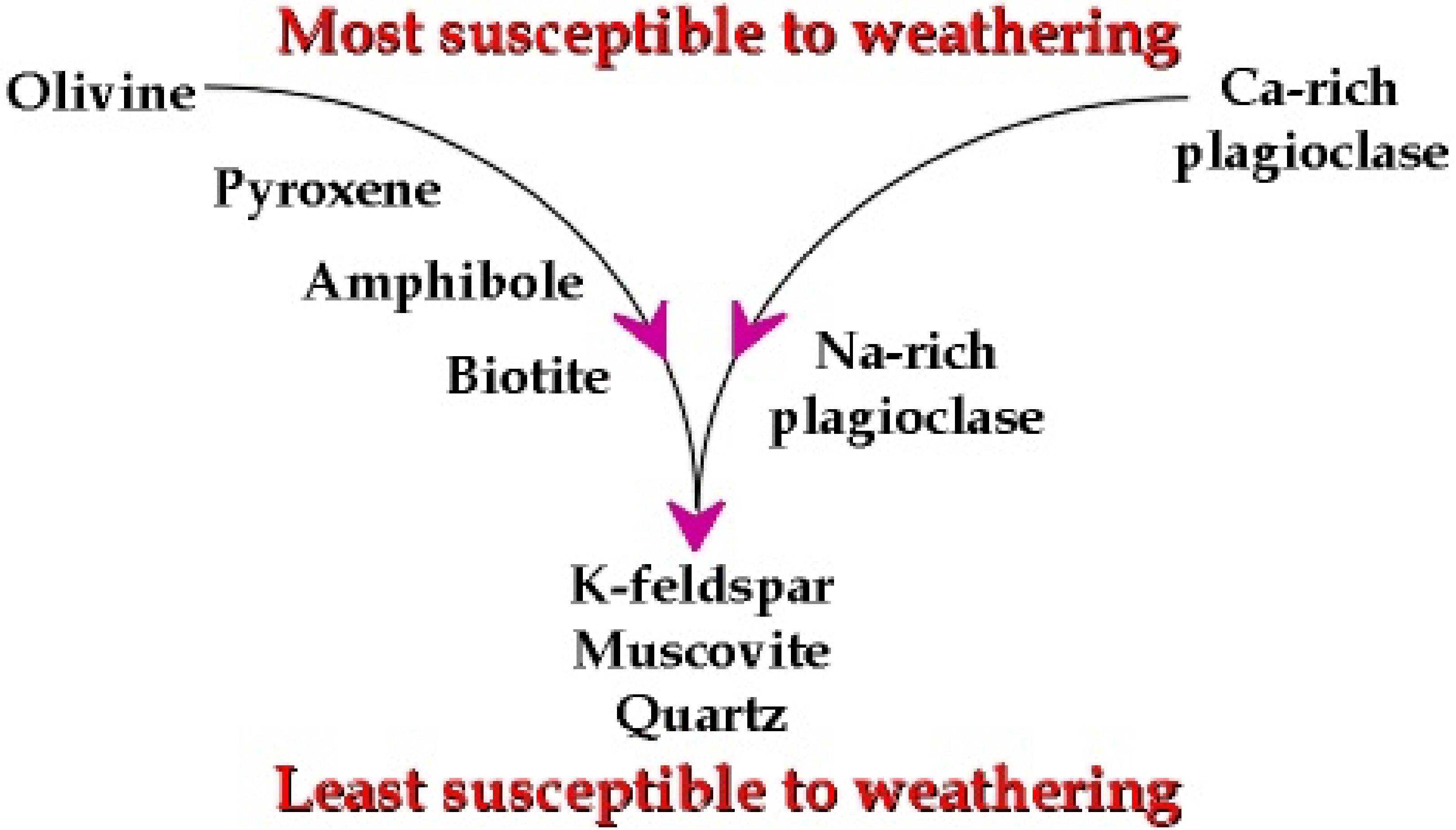
Plant Roots

- Some cases of rock splitting are caused by the **roots** of potentially large plants such as trees and shrubs.
- The seeds settle in a crack in a rock formation and as the tree grows the crack becomes wider, exposing the rock to more weather.

Chemical Weathering

- In these weathering processes, chemical reactions cause rocks to break apart. In all of these processes, **new materials** are formed.
- **Water** is the most important chemical weathering agent, dissolving soluble minerals. Some gases, such as oxygen and carbon dioxide, dissolve in water to form weak acids that also react with rock minerals.

- Generally, the further away a mineral is from its formation conditions, the more prone it is to chemical attack. Minerals near the end of Bowen’s Reaction Series are more stable at surface conditions, while minerals at the top of the series are less stable.


Most susceptible to weathering
Olivine
Pyroxene
Amphibole
Biotite
Ca-rich plagioclase
Na-rich plagioclase
K-feldspar
Muscovite
Quartz
Least susceptible to weathering

- **Carbonic Acid**, H_2CO_3, is a common reactant in chemical weathering. It is produced when, CO_2, dissolves in water, as shown by the following chemical reaction.

- H_20 + CO_2 = H_2CO_3
- Water + carbon dioxide = carbonic acid

Mineral	Composition	Colour	Weathering Product
Quartz	Silica (SiO_2)	Colourless/White	Quartz - very resistant
Plagioclase feldspars	Sodium (Na)	White	Clays
Plagioclase feldspars	Calcium (Ca)	Grey	Clays
Orthoclase Feldspars	Potassium (K)	Pink	Clays
Muscovite Mica	Potassium (K)	Light tan	Clays
Pyroxenes	High iron, magnesium	Dark green, Black	Iron Oxides
Amphiboles	High iron, magnesium	Dark green, Black	Iron Oxides
Biotite Mica	High iron, magnesium	Dark green, Black	Iron Oxides
Calcite	Calcium carbonate	Colourless/White	Dissolves

Acid Rain

- **Air pollution**, particularly in the form of Acid Rain, has rapidly increased the rate of weathering in some areas.
- Many industrial processes such as the refining of ores to make metals, the burning of coal in power stations to generate electricity, and the combustion of fossil fuels for transportation, produce gases such as sulphur dioxide, nitrogen oxides and carbon dioxide. These gases dissolve in rain to produce relatively strong acids (much stronger than the natural carbonic acid).

- Acid rain rapidly attacks stone and rock in polluted areas. **Old stone carvings**, particularly those made of limestone or marble, are being quickly destroyed in industrialized countries, as are those made of sandstone in which calcite is the predominate cementing material

Erosion

- Erosion is the **removal** of rocks and soil by wind, water, ice and gravity.
- **Wind, water, ice** and **gravity** are also known as the agents of erosion.

Wind

- Wind can play a role by carrying material (especially sand and clay) from one place to another.
- As the wind blows, it **picks up** small particles of sand/sediment and **blasts** large rocks with the sand/sediment, cutting and shaping the rock.

- The intensity of wind erosion is determined by:
- Sum (amount of sand)
- Speed
- Slope
- Q: What can people do to decrease the effects of wind erosion?

How are the Sahara desert and Amazon Rainforest Connected?

- https://www.youtube.com/watch?v=ygulQJoIe2Y

Rain

- When rain falls to the Earth it can evaporate, sink into the ground, or flow over the land as **runoff**. When it flows over land, erosion occurs. Runoff picks up pieces of rock and "runs" downhill cutting tiny **grooves** (called rills) into the land.

- How intensity of rain erosion determined by:
- Sum (amount of water)
- Slope
- Speed
- Type of Surface
- Q: What can people do to decrease the effects of rain erosion?

Glaciers

- Glaciers wear down the landscape by picking up and carrying debris that moves across the land along with the ice.
- Glaciers can pick up and carry sediment that ranges in size from **sand grains** to boulders **bigger than houses**. Moving like a conveyor belt or a bulldozer, a single glacier can move **millions of tons** of material!

- How much erosion takes place is determined by the:
- **Sum (Glaciers are massive!)
- Slope
- Speed
- Surface
- Q: What effects have glaciers had in the Lower Mainland?

- Climate 101: Glaciers
- National Geographic Video
- https://www.youtube.com/watch?v=WJgpDyP9ewQ

Gravity

- Gravity Erosion is better known as **Mass Movement** and is defined as the transfer of rock and soil down slope by direct action of gravity without a flowing medium (such as water or ice).
- Some of the best examples of Mass Movement are:
- Creep
- Rock fall
- Slump
- Landslides
- Avalanches

- Q: Where might mass movement be an issue?

Hope Slide, BC

Frank Slide, AB