Weathering, Erosion and Deposition

- Weathering
- Processes of mechanical weathering
- Processes of chemical weathering
- Resistance to weathering
- Soil profiles

What is weathering?

- **Weathering is the physical breakdown (disintegration) and chemical alteration (decomposition) of rocks to form soil or loose particles at or near Earth's surface.**

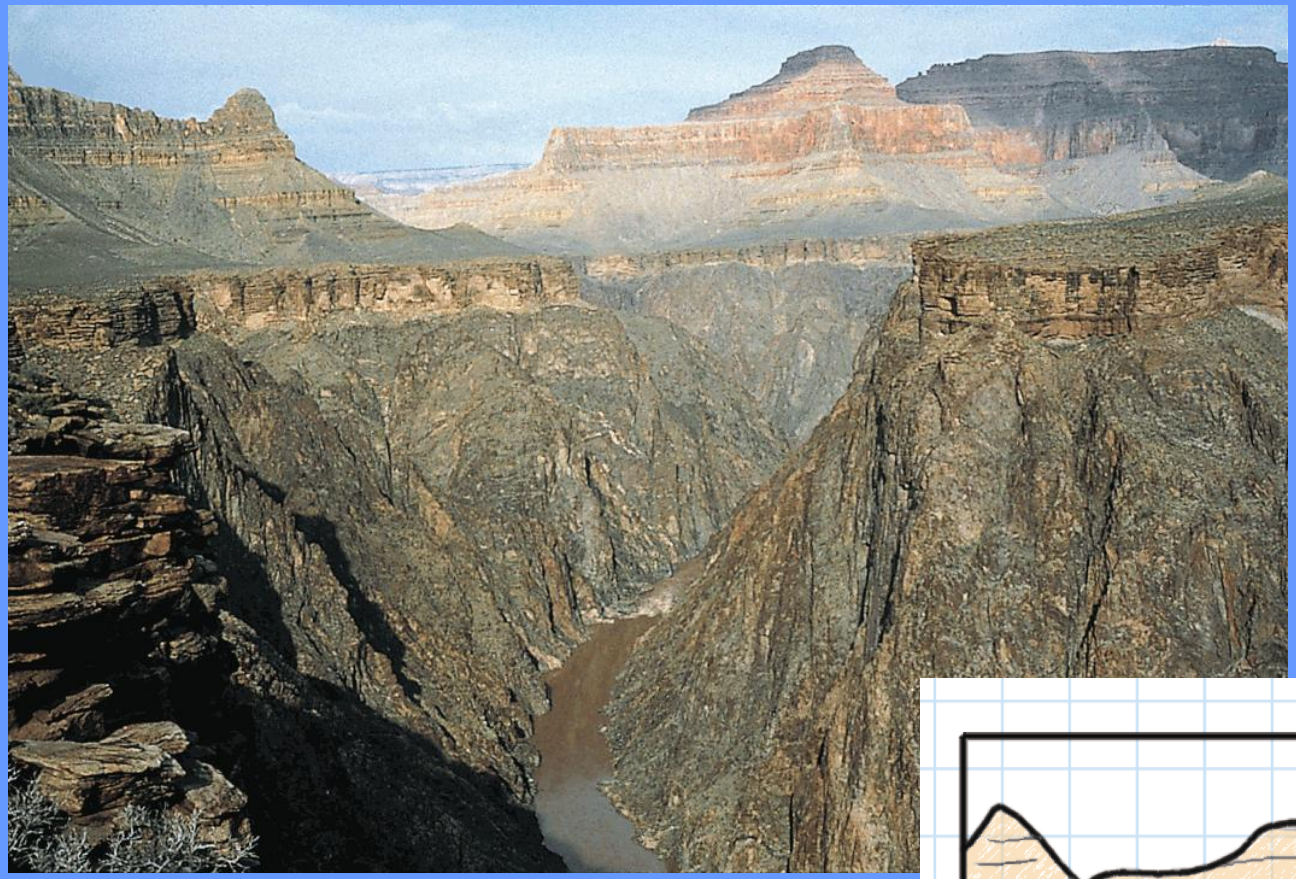
  Weathering causes deterioration of building materials. It also weakens rocks, a great concern when weathered rocks are used for foundation.

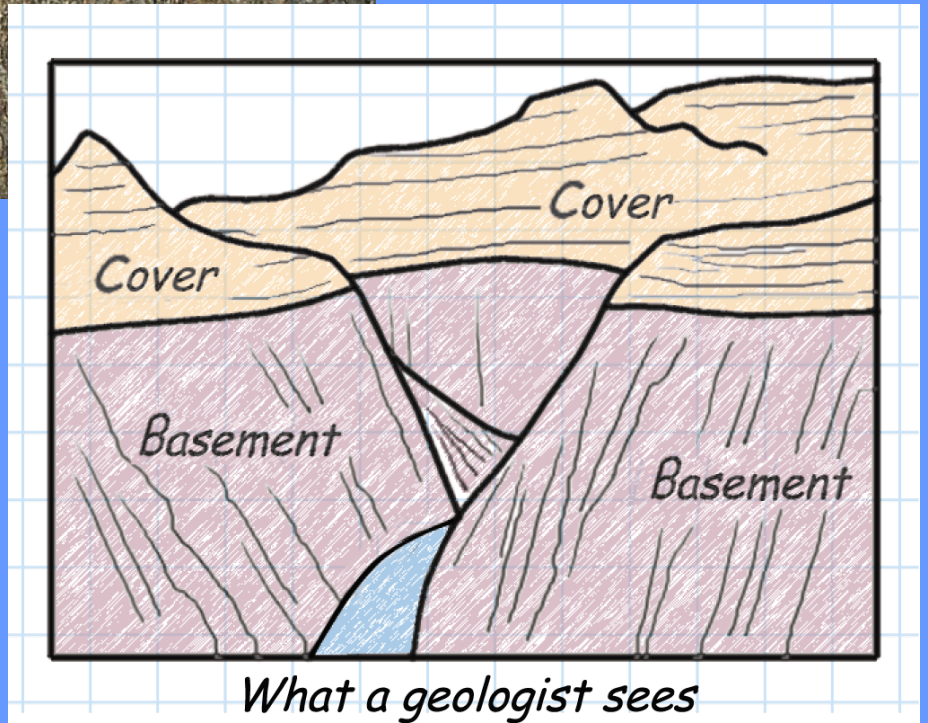
- **WeatheringTypes:**

  1.Mechanical weathering is accomplished by **physical forces** that break rock into smaller and smaller pieces without changing the rock's mineral composition.

  2.Chemical weathering involves breaking down rock components and **internal structure** and forming **new compounds**.

- Whereas weathering breaks rocks apart, **erosion** removes rock debris by mobile agents such as water, wind, or ice.





What a geologist sees

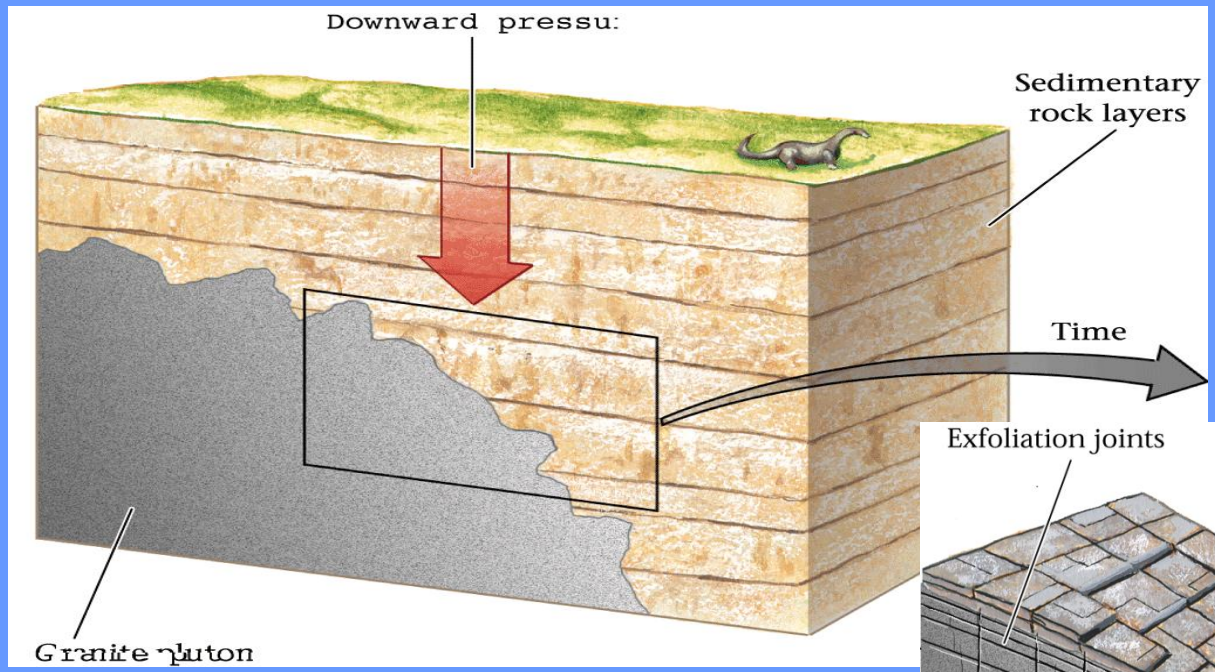
Contrasts between

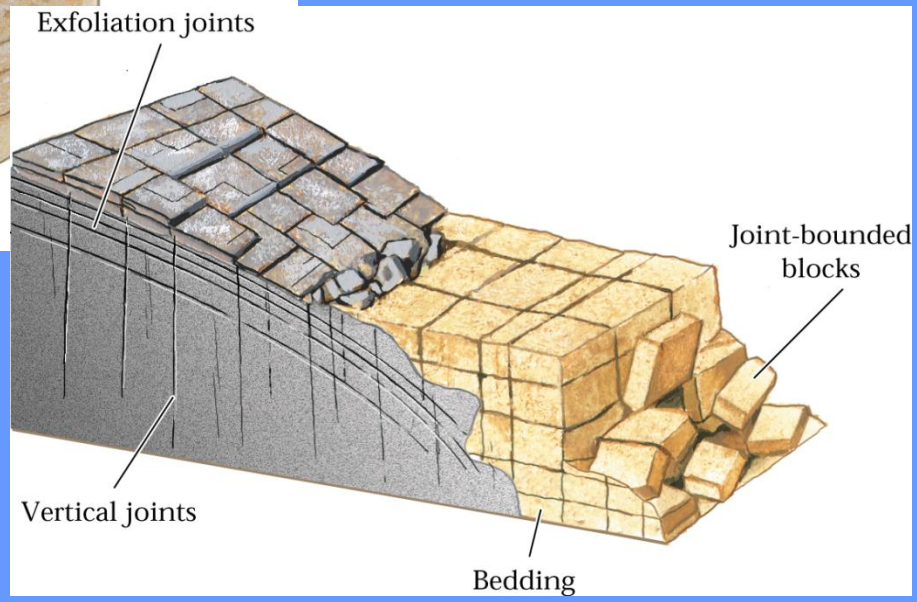
Mechanical weathering: **unloading**

- Upon removal of overburden (unloading), the elastic component of rock deformation is recovered and the rock expands, e.g. the overlying rocks are eroded or rocks are removed from a quarry.

- The expansion caused by unloading may be sufficient to fracture the rock. Such naturally formed cracks are called, **joints**.

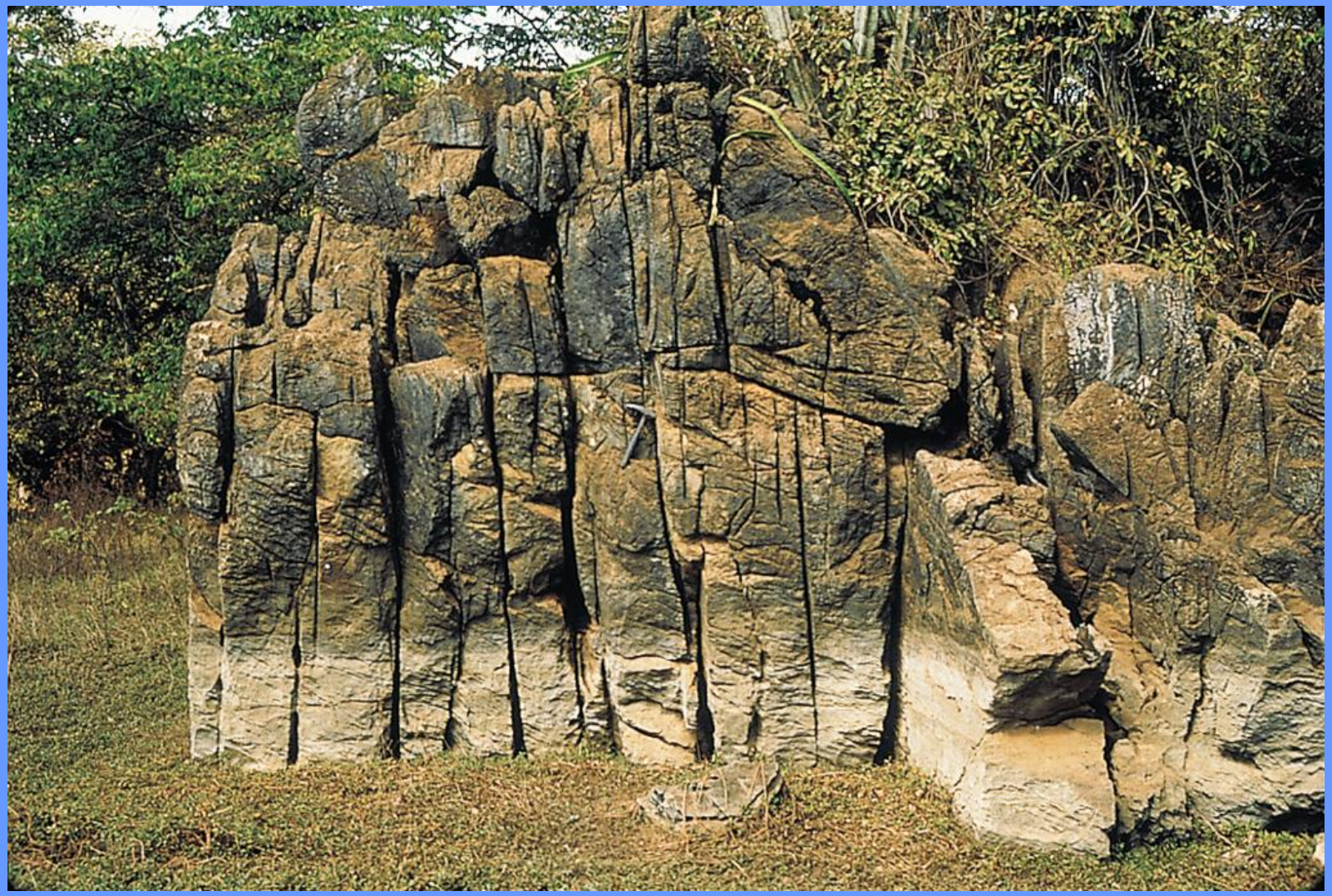
- The unloading of large platoon may split into sheets that are **parallel** to the mountain face, a process called ***exfoliation*.** It is also known as ***sheeting*** if the expansion occurs in granite to form rock slabs.



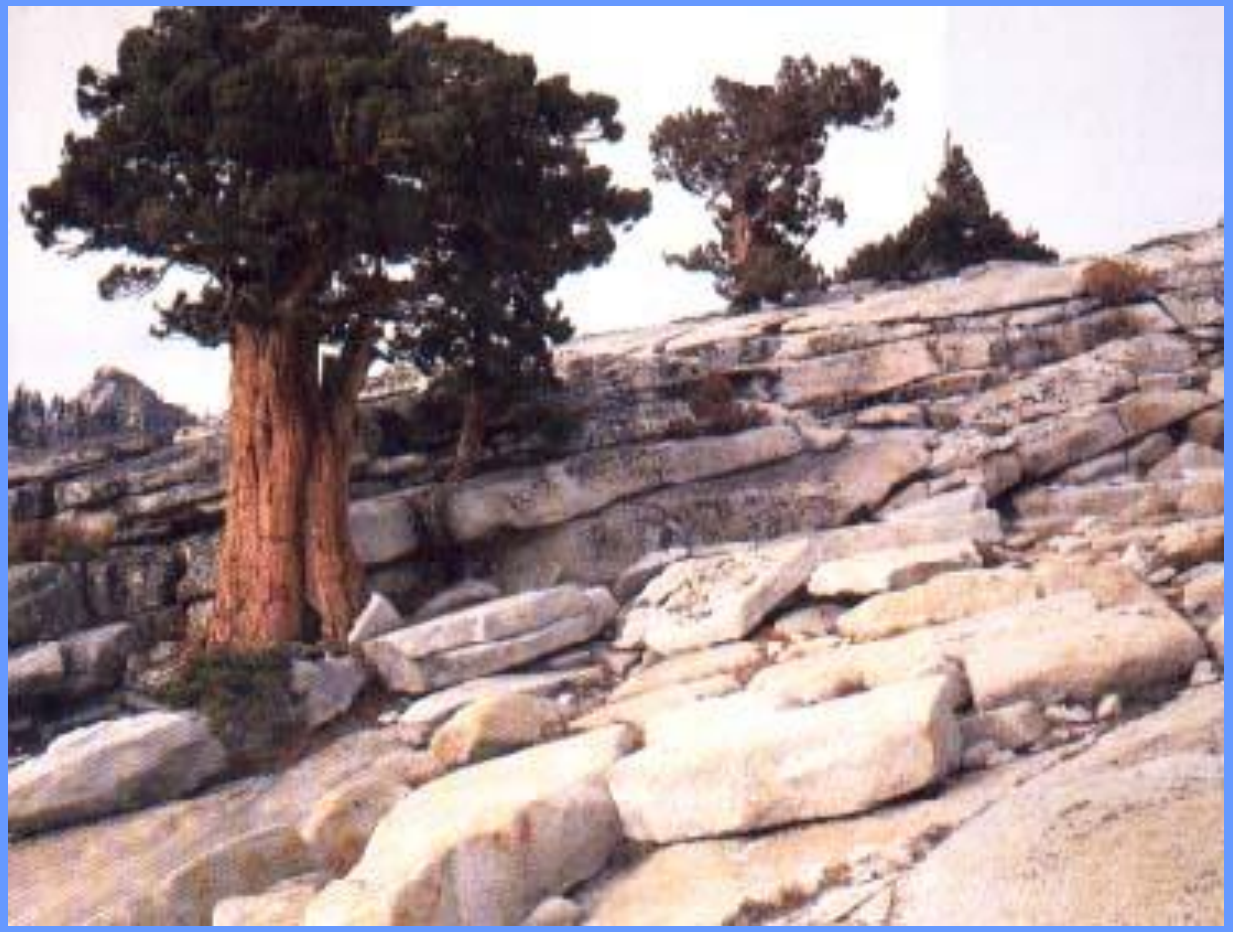


The exposure of once-deep rocks cause them to crack. Here, the platoon develops exfoliation and vertical joints, while the sedimentary rock layers developed mostly vertical joints.

Exfoliation joints in the Sierra Nevadas.



Vertical joints in sedimentary rock (Brazil).



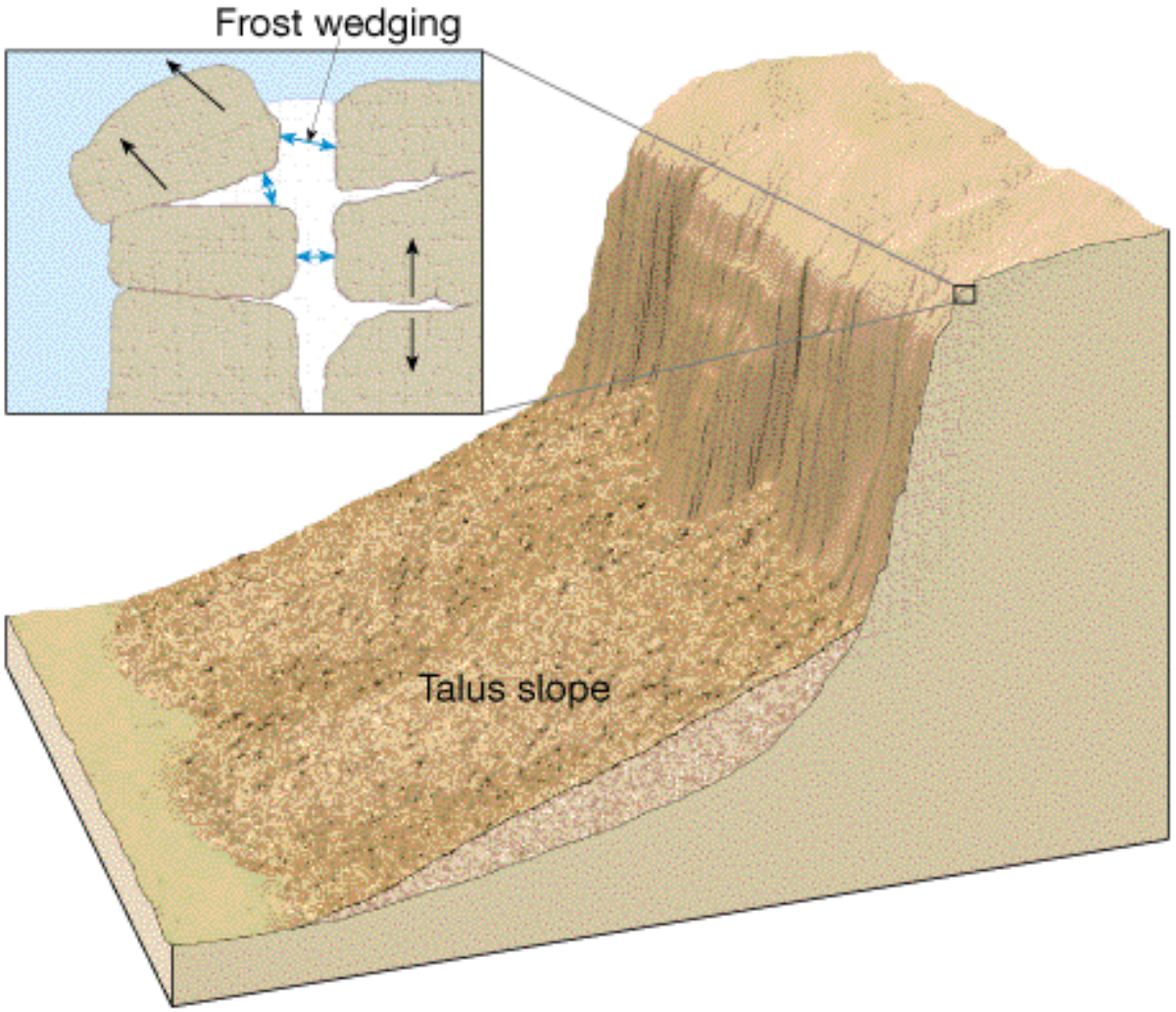
- Sheeting of in granite in Yosemite National Park, CA. Sheeting occurs as erosion removes the overlying rock cover and reduces the confining pressure. The bedrock expands, and large fractures develop parallel to the surface. Frost wedging may later enlarge the fractures.

- **Mechanical weathering**: **Frost Wedging (Ice Wedging)**

- Liquid water expand by 9% in volume when freezing. So one of the most effective mechanical weathering processes is the wedging action of repeated cycles of **freezing and thawing** of water in rock fractures.

- Conditions for frost wedging include moisture, rock fracture or weakness planes, and temperature fluctuation around the freezing point.

- A product of frost wedging is **talus slope** made of angular rock pieces piling up at the base of steep cliffs.



- An illustration of frost wedging.

Talus slopes near Banff, Canada.

- **Salt Wedging:** Growth of salt crystals shattered the wood fence posts near the shore of the Great Salt Lake, Utah. Saltwater seeps into the wood, and as it evaporates, salt crystals grow, expand, and break apart the wood fibers. (Hamblin and Christiansen).

- **Mechanical weathering: thermal expansion and contraction**

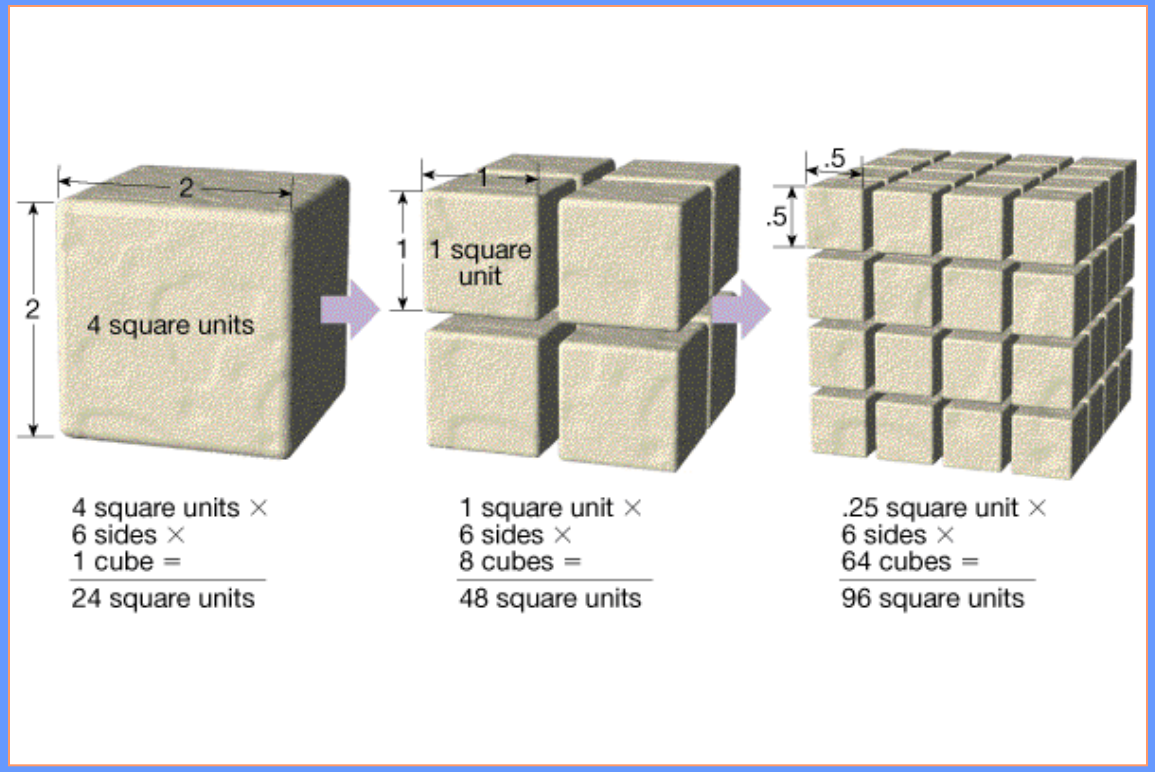
- As temperature changes, not all parts of a rock or all its minerals expand or contract by the same amount. So when rocks are heated or cooled, the mineral grains are subjected to differential stresses.

- These stones were once rounded stream gravels; however, long exposure in a hot desert climate disintegrated them. (C.B. Hunt, USGS).

Processes of chemical weathering

- When rock comes in contact with components of the surface and atmosphere (water, oxygen, carbon dioxide), **chemical reactions** occur that alter and destroy minerals of the rock. **Water** is the most important agent of chemical weathering.

surface area effects



- Chemical weathering occurs at the surfaces of rocks, thus, the greater the **surface area**, the more intense the weathering. Thus the breaking of rock into smaller pieces by mechanical weathering greatly accelerates chemical weathering.

Chemical weathering: **dissolution**

- Water is an excellent solvent, capable of dissolving many chemical compounds. This is the result of polar nature of water molecules: the oxygen end has a small negative charge, the hydrogen end has a small positive charge..

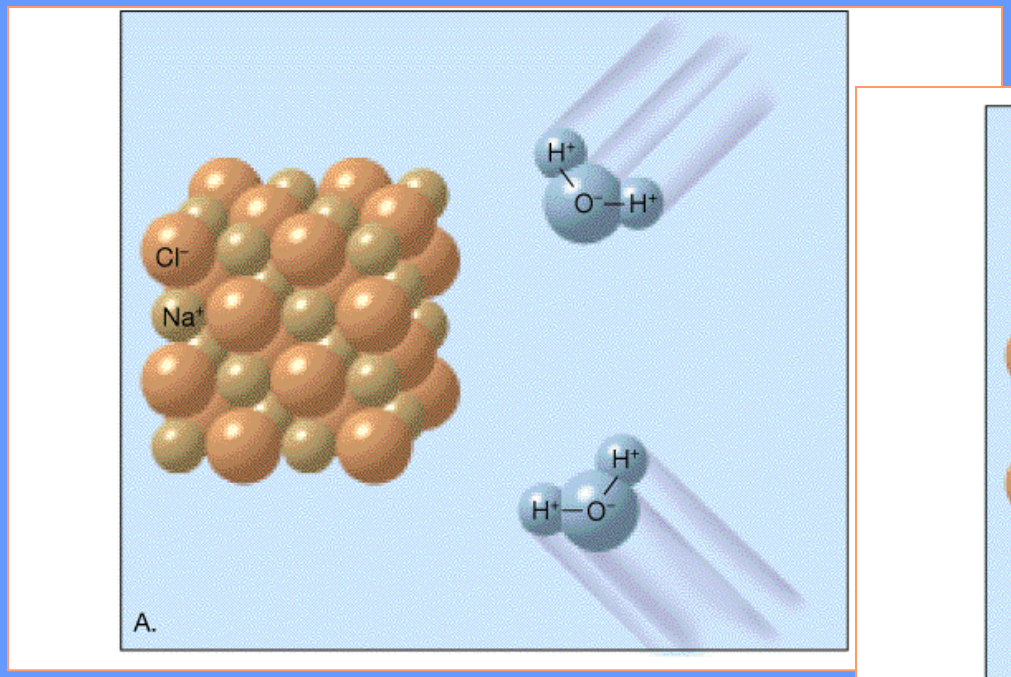
- In addition, CO2 in the atmosphere and soils reacts with water to produce carbonic acid.

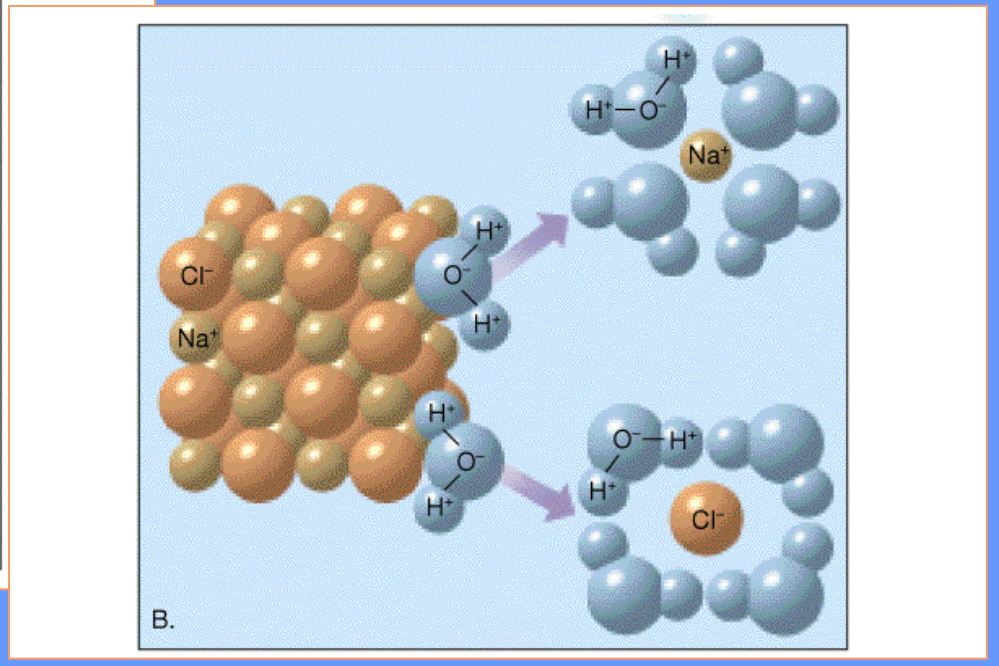
  $H_2O + CO_2 \rightarrow H_2CO_3$.

  The carbonic acid readily reacts with **calcite** (e.g. in limestone and marble):

  $CaCO_3 + H_2CO_3 \rightarrow Ca^{2+} + CO_2 + H_2O$.

Dissolution



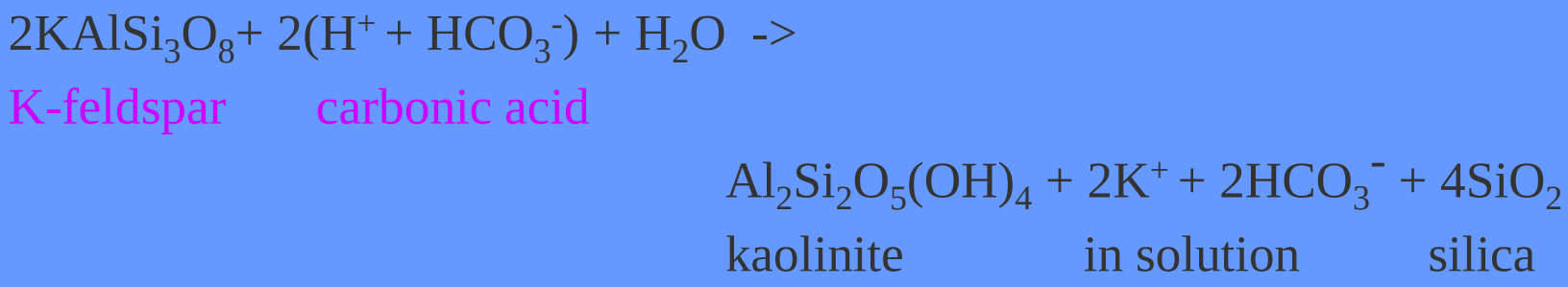


- Illustration of halite dissolving in water. A) Sodium and chloride ions are attached by the polar water molecules. B) Once removed, these ions are surrounded and held by a number of water molecules.

Dissolution enlarges joints of a limestone and dissolves away sharp edges (Irland).

Chemical Weathering: Hydrolysis

- **Hydrolysis** is the reaction of acidic solutions with silicates (the most common mineral group). For example, the weathering of K-feldspar of granite is as follows.

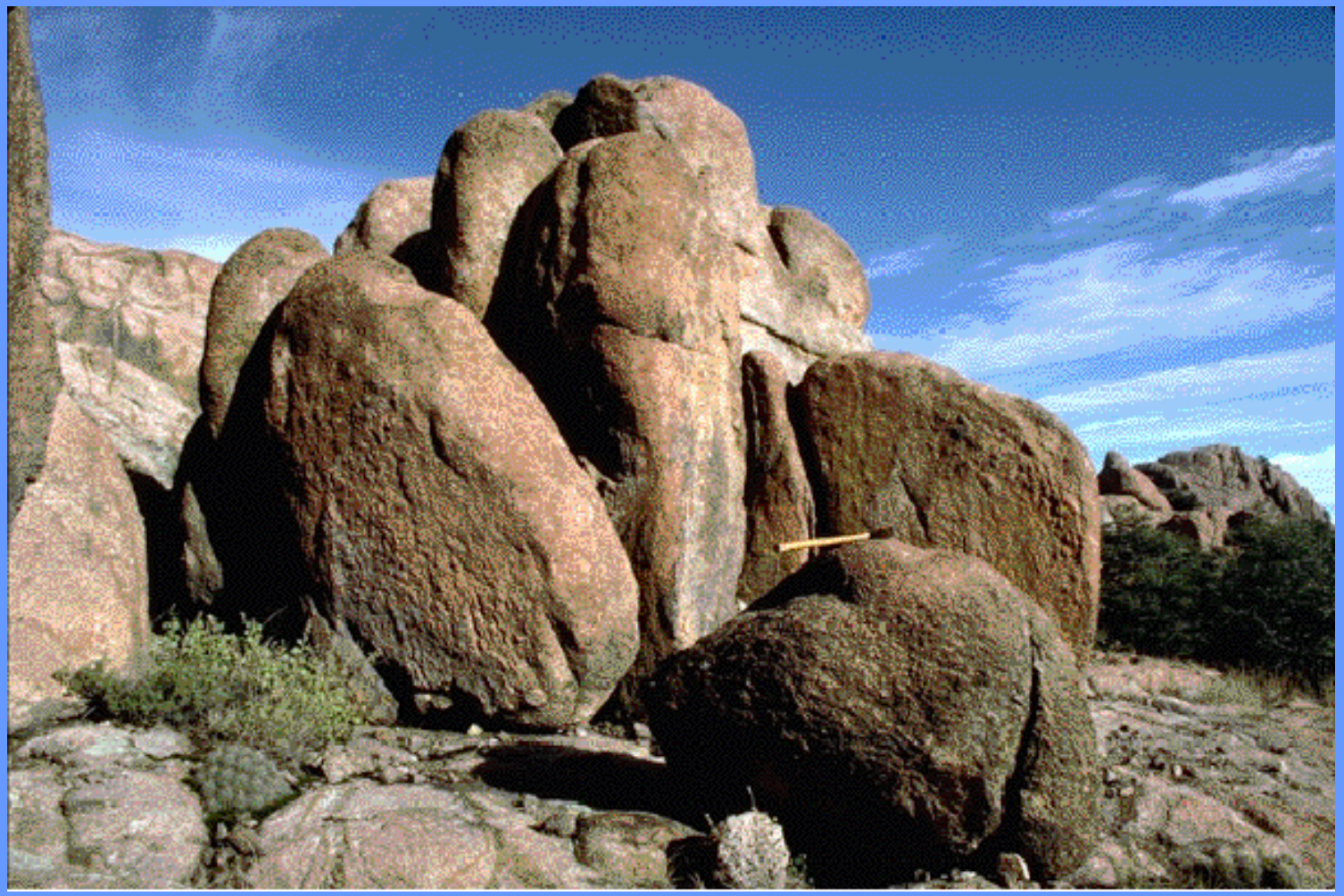


- An product of the chemical breakdown of K-feldspar is **clay mineral**, kaolinite, which is very stable at the surface. Consequently, clay minerals make up high percentage of soils.

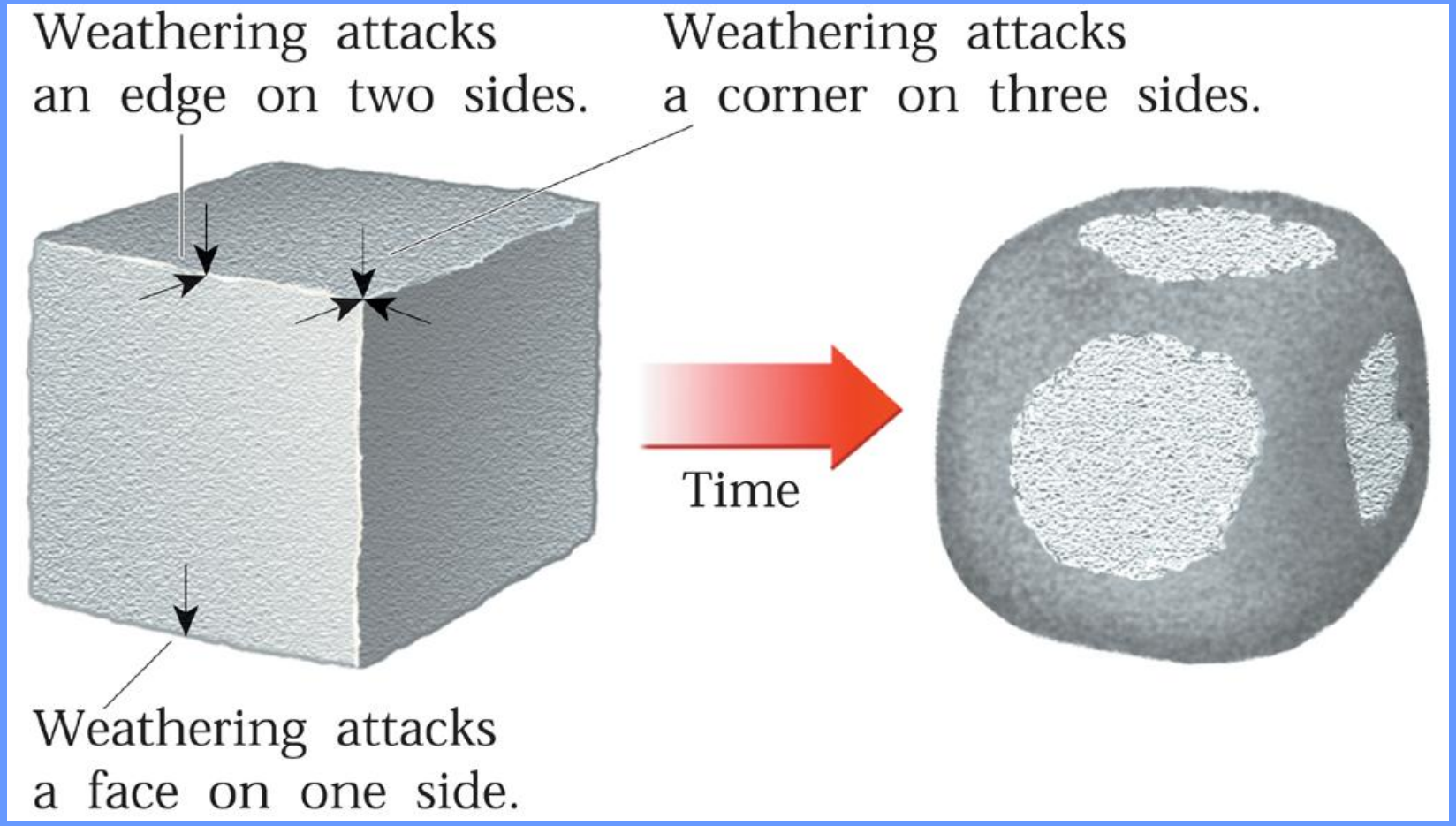
- **Chemical weathering**: **oxidation**
- **Iron-rich minerals is subject to oxidation**, which occurs when oxygen (dissolved in the water) combines with iron to form iron oxide.

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

The once shiny, metallic **pyrite** is now oxidized and dull from chemical weathering.



- Rounded blocks of granitic rocks near Prescott, Arizona.



- Weathering attacks more vigorously at edges and most vigorously at corners, resulting in a rounded block.

Resistance to weathering

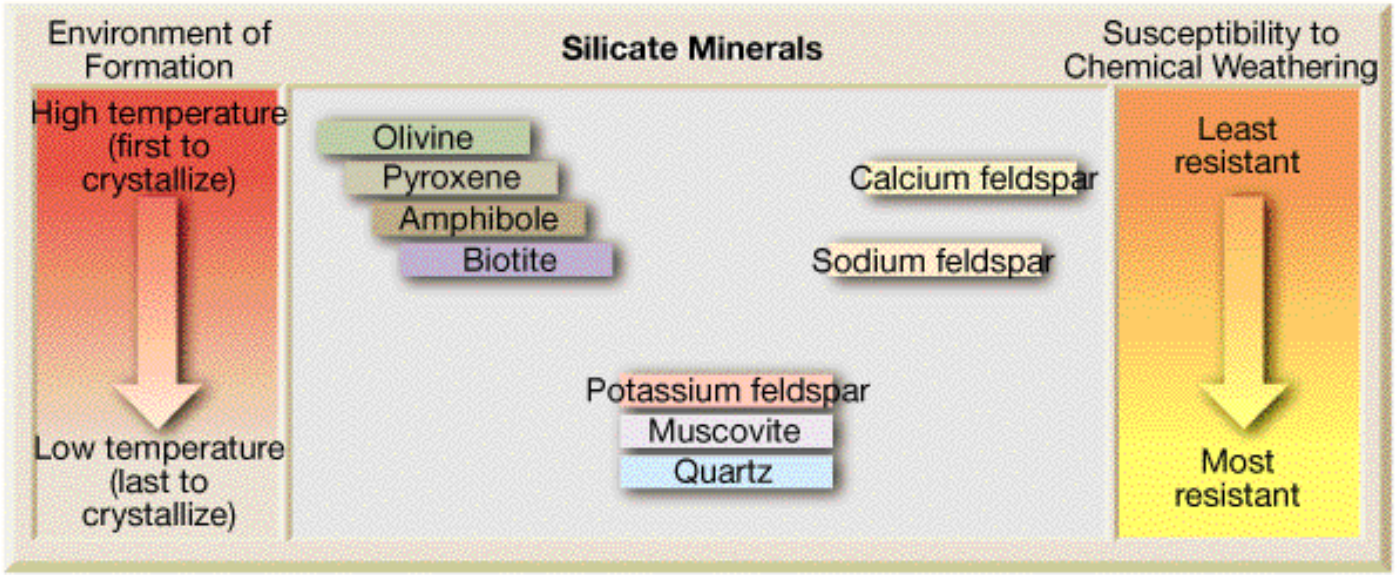
- **Rock characteristics**

  Some minerals are more susceptible to chemical weathering than others. For silicates, the order of weathering (Goldrich's mineral stability series) is the same as the order of crystallization (so called Bowen's reaction series).

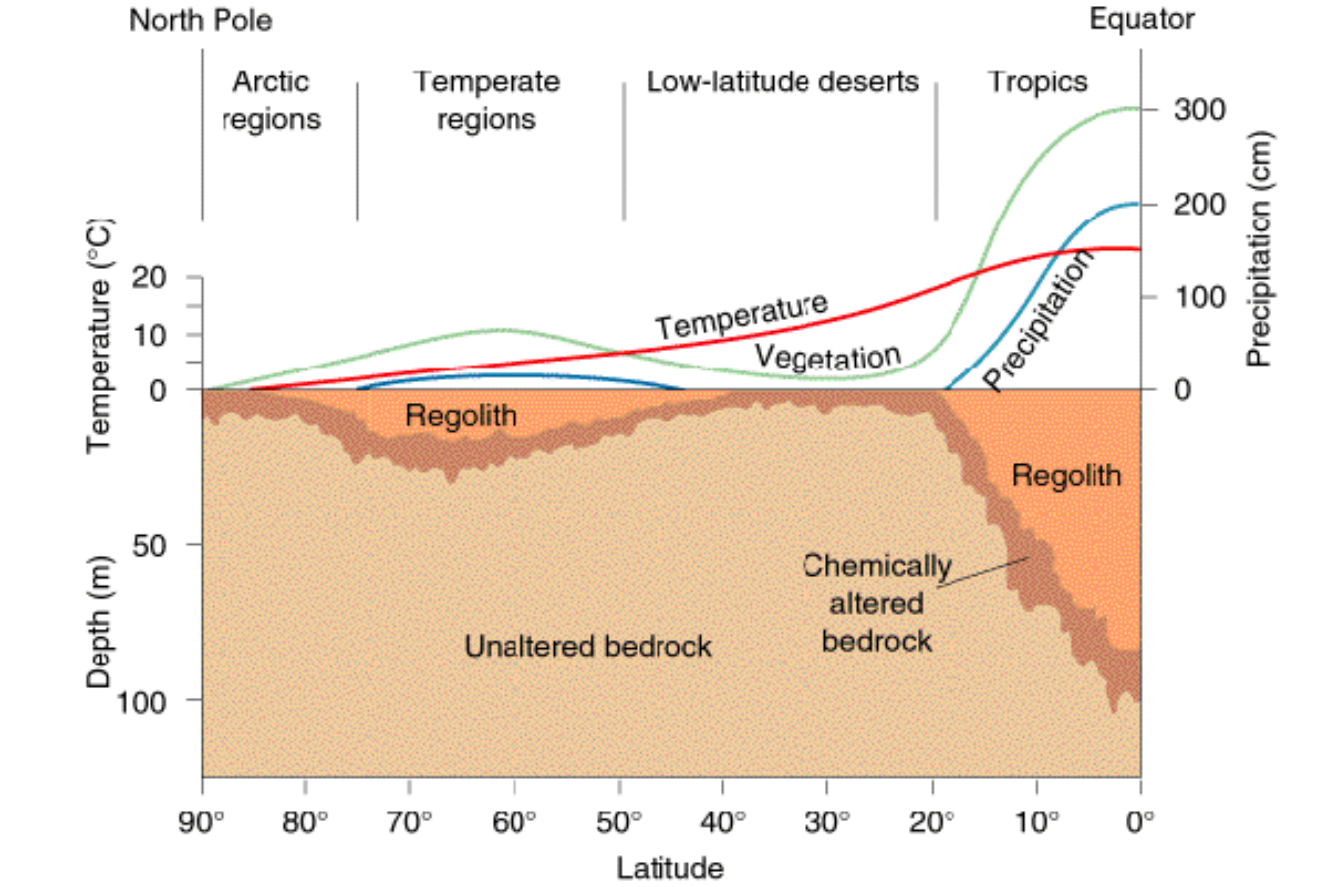
- **Climate**

  Climate is perhaps the single most important factor influencing weathering. **Temperature and moisture** have strong influences on both mechanical weathering (e.g. frost wedging) and chemical weathering. Thus chemical weathering is ineffective in polar regions or arid regions because of the lack of free water.

- Some rocks are more susceptible to chemical weathering than others. The granite headstone (left) was erected in 1888, a few years after the marble headstone in 1885 (right).



- The weathering of common **silicate minerals**: The order of weathering (Right, Goldrich's mineral stability series) is the same as the order of crystallization (so called Bowen's reaction series, Left).



- Climate controls the type and extent of weathering because of the combined effects of precipitation, temperature, and vegetation. **Weathering is most pronounced in the tropics**, where these factors reach maximum; and weathering is minimum in deserts and polar region, where these factors are minimal.

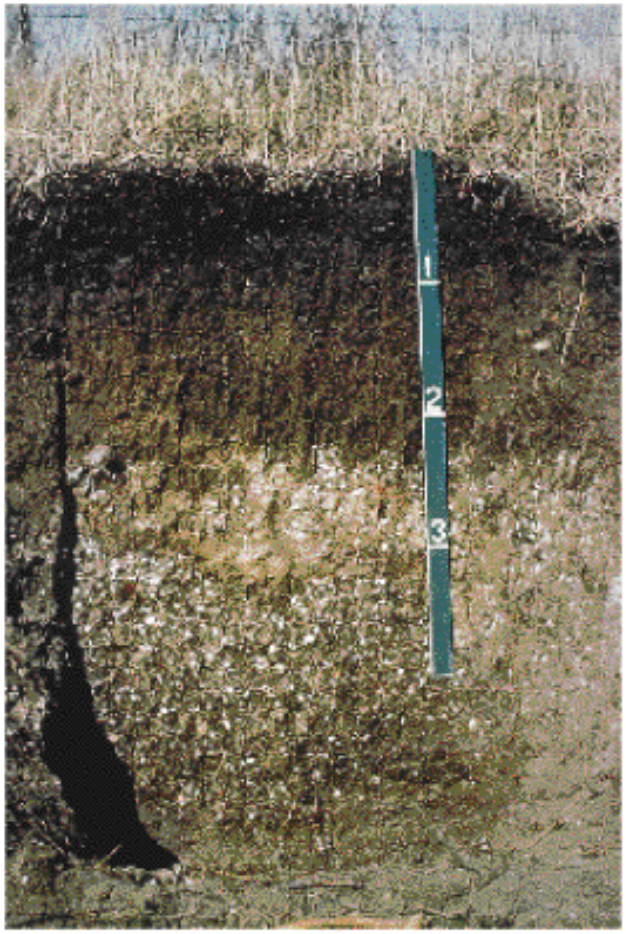
Soil profiles

- One consequence of weathering is the formation of the **soil profile**, a vertical cross section from surface down to the parent materials. A well-developed soil profile shows distinct horizons. The major horizons are A, B, and C horizons.

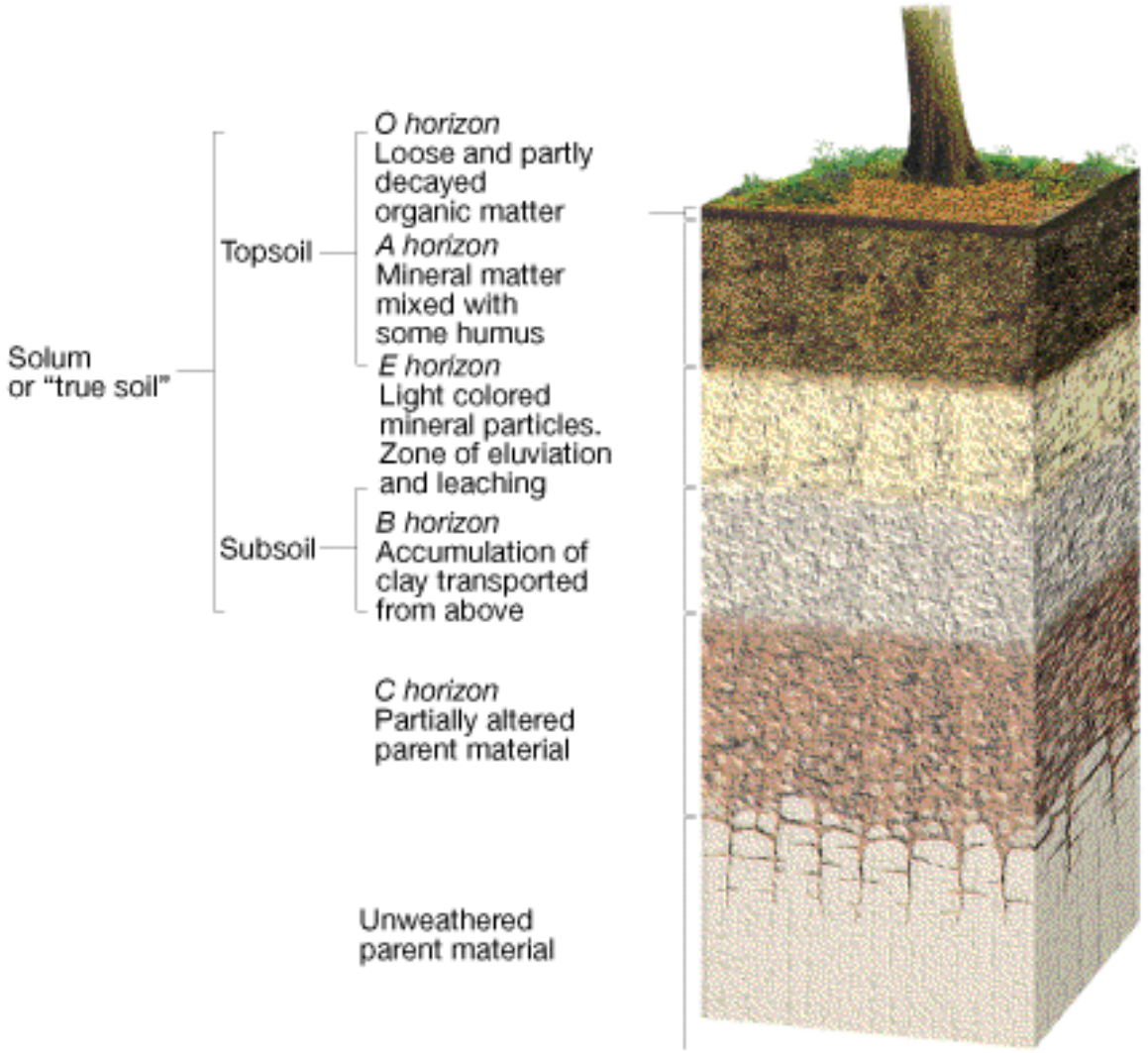
- **The A horizon** is the **top soil**. It is a zone where downward percolating water removes soluble soil components into deeper zones (called **leaching**). It is also commonly rich in decomposed organic mater (humus).

- **The B horizon** is the **sub soil** or the zone accumulation where the material removed from above accumulates. The accumulation of fine clay particles enhances water retention in the subsoil. Organic matter is less abundant in the B horizon.

- **The C horizon** marks the transition from the **soil profile to the unweathered parent material below.**



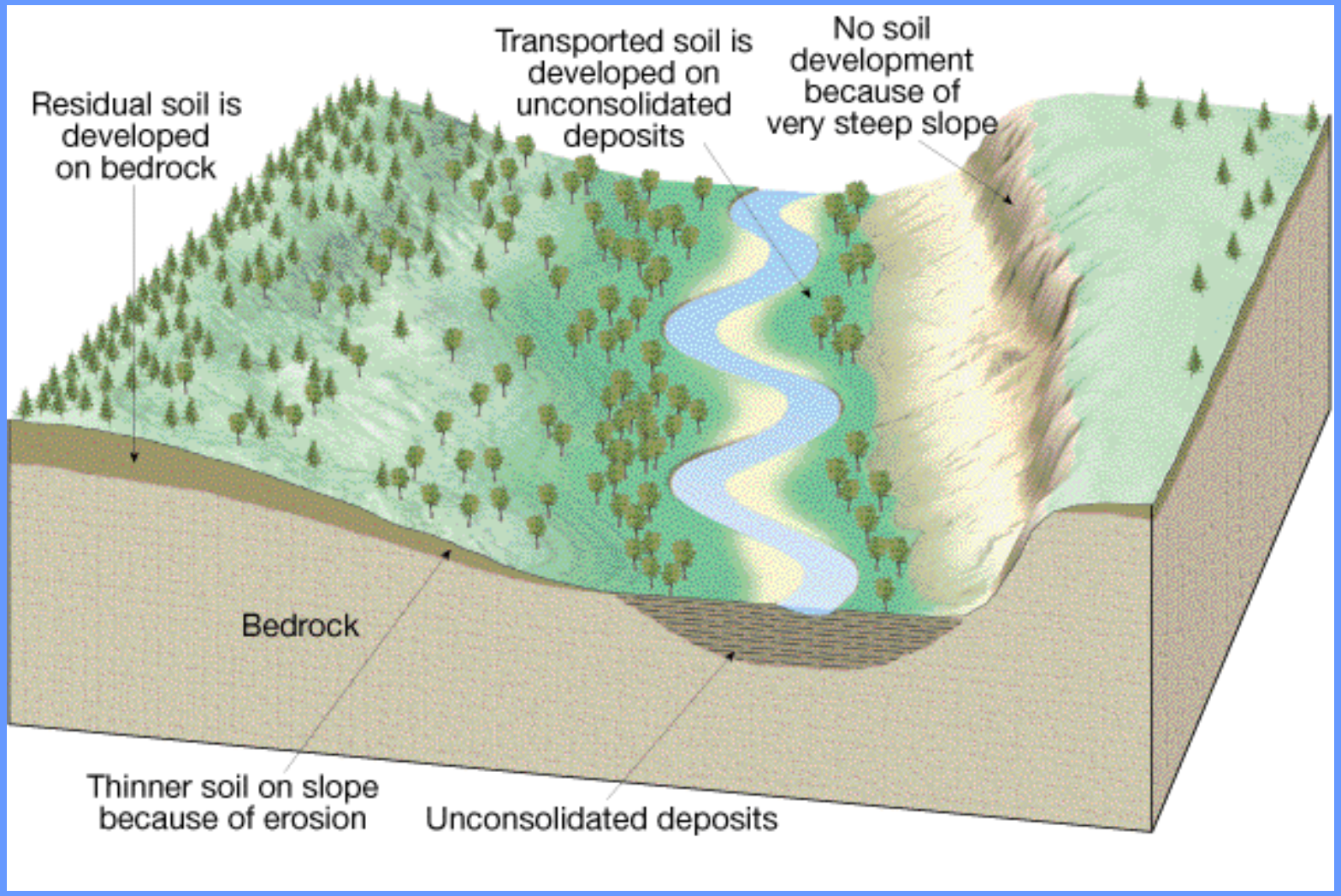
- A soil profile is a **vertical cross-section from the surface down to the parent material. Well-developed soils show distinct layers (called horizons).**



- Idealized soil profile from a humid climate at mid latitudes. The major horizons are A, B, and C.

- **Soil formation**: **parent material**

- The parent material of soils can be (1) the underlying bedrock -- in this case, the soils are termed **residual soils**; or (2) transported deposits -- in this case, the soils are termed **transported soils**.



- The parent material for **residual soils** is the underlying bedrock, whereas **transported soils** form on unconsolidated deposits. Note as slopes become steeper, soil becomes thinner.

Chemical Weathering of Igneous Rock Minerals

- ***Oxides > Hydroxides***
- ***Ferromags > Mg-Fe Clay***
- ***Feldspar > Al-Clay + Na^{+} + K^{+} + Ca^{++}***
- ***Mica > Al-Fe Clay + Na^{+} + K^{+} + Ca^{++}***
- ***Quartz > Quartz Sand***

Erosion and Transport

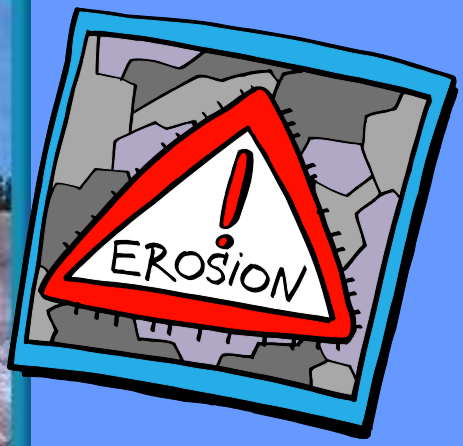
- Erosion is the reduction of exposed landforms.
- Transport is the movement of eroded material down slope.
- Transport by water sorts the particles by size.
- Because different minerals dominate different size fractions, the deposited material differs from the parent rock in mineralogy and chemistry.

Weathering Products Are Sorted by Size

- **Coarse particles** require moving water or wind
  - Rock grains: Pebbles, Cobbles, Boulders
  - Quartz: Pebbles and Sand
- **Fine particles** require standing water.
  - Clays Very fine (<10 mm)
- **Dissolved ions** *require evaporation*
  - $Na^{+} + K^{+} + Ca^{++}$ *Dissolved*

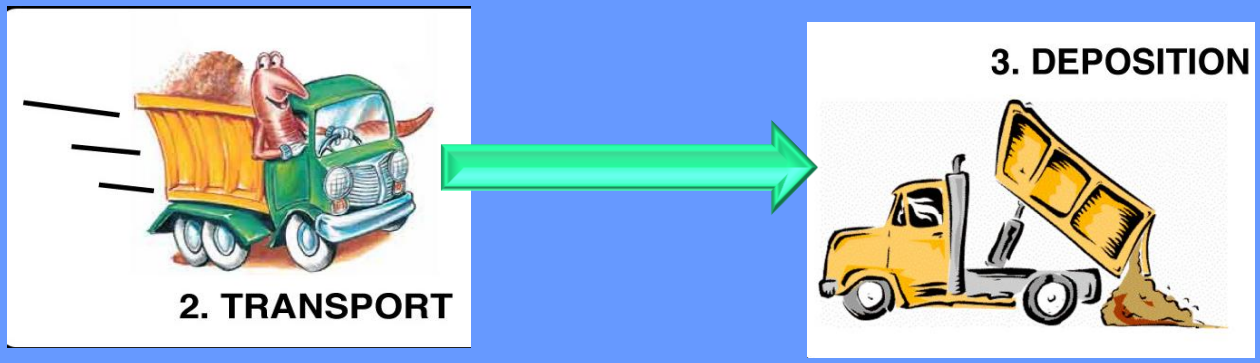
What is Erosion?

- Erosion is the removal and transport of material from one place to another
- **Gravity is a huge erosion force**
- Agents of erosion are wind, water, and glaciers



What happens to the sediments?

- When sediments are eroded, they are not lost from Earth—they are just relocated
- Deposition is when sediments are moved and deposited or "dropped off"



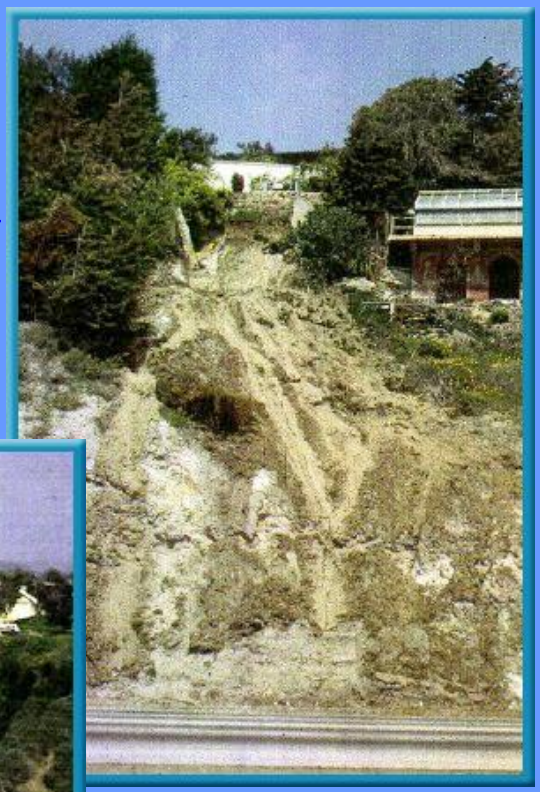
- Weathering, erosion, and deposition act together in a cycle that wears down and builds up Earth's surface

What are the agents of Erosion?

- There are 5 agents of erosion:
  - Gravity
  - Running water
  - Glaciers
  - Waves
  - Wind

How does Gravity cause Erosion?

- A mass movement is any type of erosion that happens as gravity moves materials down slope
  - **Landslides**
  - **Mudslides**
  - **Rock slides**



What are the different types of massmovement?

- **Landslide** is the most destructive kind of mass movement. **It is when rock and soil slide quickly down a steep slope**
- **Mudflow** is a rapid downhill movement of a **mixture of water, rock, and soil.** Usually occurs after heavy rains in normally dry areas.

What are the different types of mass movement?

- **Slump** is a mass of rock and soil suddenly **slips down a slope. The difference is that the material in a slump moves in one large mass.**

- **Creep** is **very slow downhill movement of rock and soil**. Often a result of freezing and thawing of water in cracked layers of rock beneath the soil. **It is so slow,** you can hardly notice it!

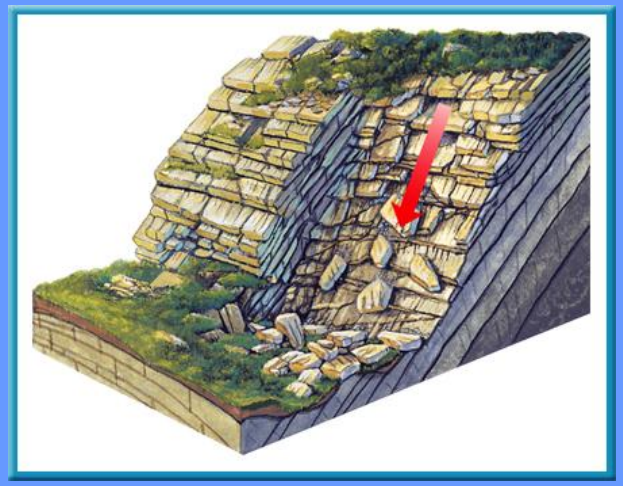
Summary

1. What is erosion?

   The removal and transportation of material

2. What type of mass movement is shown in this illustration?

   Rock Slide

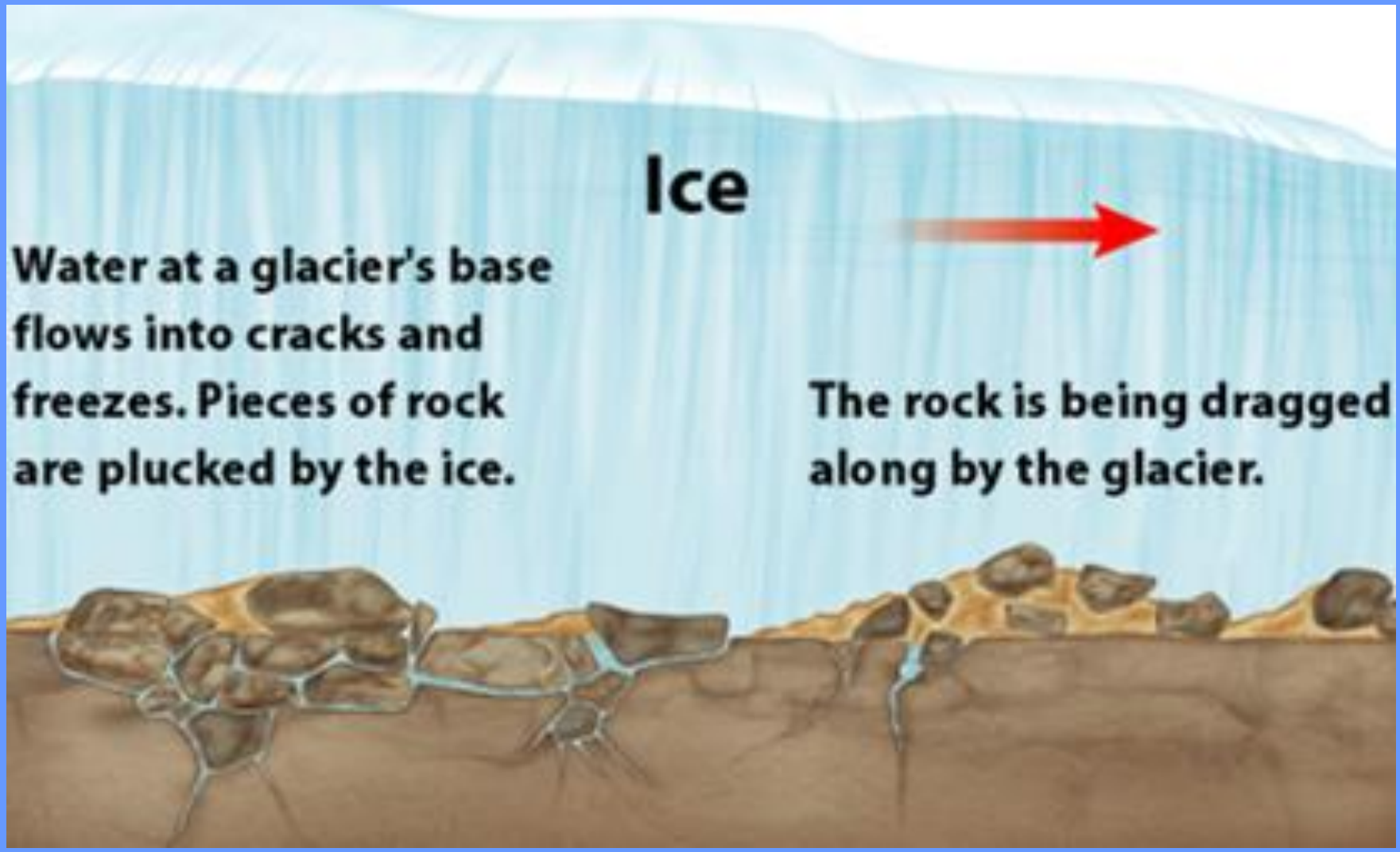


3. What are the 5 agents of erosion?

   Gravity, glaciers, running water, waves, and wind

How do Glaciers cause Erosion?

- A **glacier** is a large mass of ice and snow moving on land under its own weight
- As glaciers pass over land, they erode it, changing features on the surface
- Glaciers then carry eroded material along and deposit it somewhere else.
- There are 2 types of glaciers: **Continental and Valley Glaciers**


Ice
Water at a glacier's base flows into cracks and freezes. Pieces of rock are plucked by the ice.
The rock is being dragged along by the glacier.

What are Continental Glaciers?

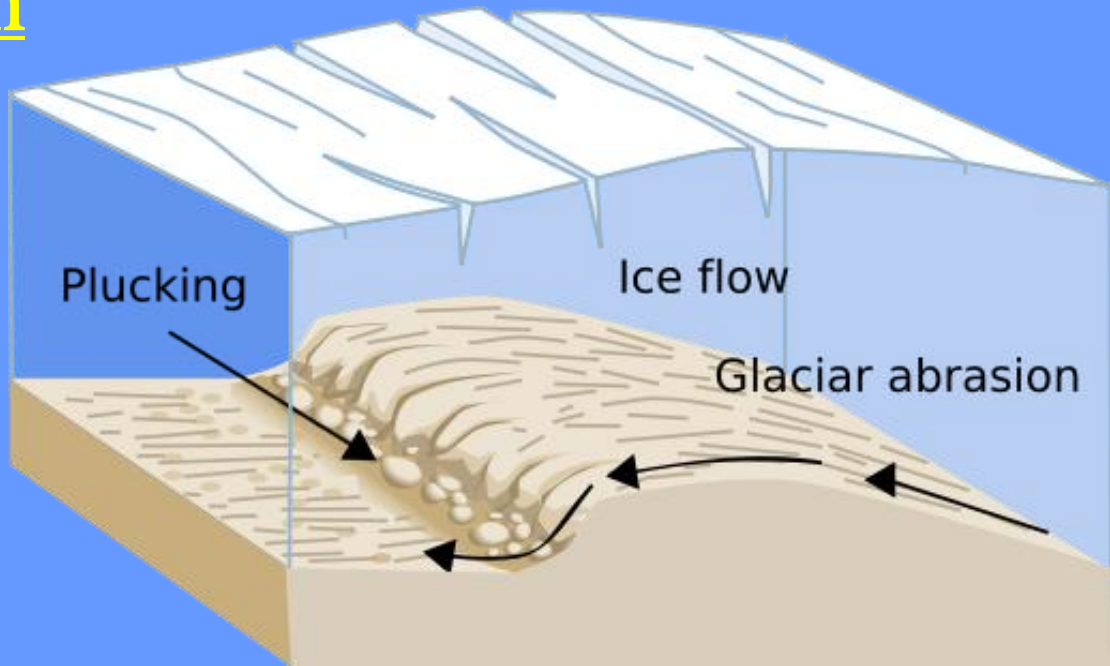
- **Continental Glacier is a glacier that covers much of a continent or large island**
- Today, they cover about **10% of Earth's land and cover most of Antarctica and Greenland**
- These glaciers can flow out in all directions

What is a Valley Glacier?

- **A Valley Glacier is a long, narrow glacier that forms when snow and ice build up high in a mountain valley**
- The sides of the mountains keep these glaciers from spreading out in all directions
- Usually these glaciers are smaller than continental glaciers, but can be kilometers long

How do Glaciers shape the land?

- The movement of a glacier changes the land beneath it
- Although glaciers work slowly, they are a major force of erosion
- The two process by which glaciers erode the land are **plucking and abrasion**



How do Glaciers shape the land?

- As a glacier flows over the land, it picks up rocks in a process called plucking
- Due to the glaciers extreme weight, it can break rocks apart and then the rocks freeze to the bottom of the rock carrying it with it when it moves
- As rocks remain on the bottom of the glacier and it drags them across the land, abrasion occurs as it scratches the bedrock

How does wind contribute to erosion?

- **Wind by itself is the weakest agent of erosion,** however, it can be a powerful force in shaping the land areas where there are few plants to hold the soil in place
- Wind causes erosion by **deflation** and **abrasion**

How does wind contribute to erosion?

- **Deflation** is the process where wind blows loose sediment, removing small particles

- The stronger the wind the heavier sediment that can be moved

How does wind contribute to erosion?

- **Abrasion** by wind-carried sand can polish rock, but causes little erosion

- It was once thought that the sediment carried by wind cut the stone shape, but now more evidence shows that most landforms are the result of weathering and water erosion

What are some landforms created by wind erosion?

- **Sand dunes** are mounds of sediment drifted by the wind
- Dunes can be see along shore of oceans, but are common in desert regions

- **Loess** are fine, wind blown sediment like silt and clay
- Loess help to form fertile soil and create valuable farmlands

1. What are two ways in which glaciers erode Earth's surface?

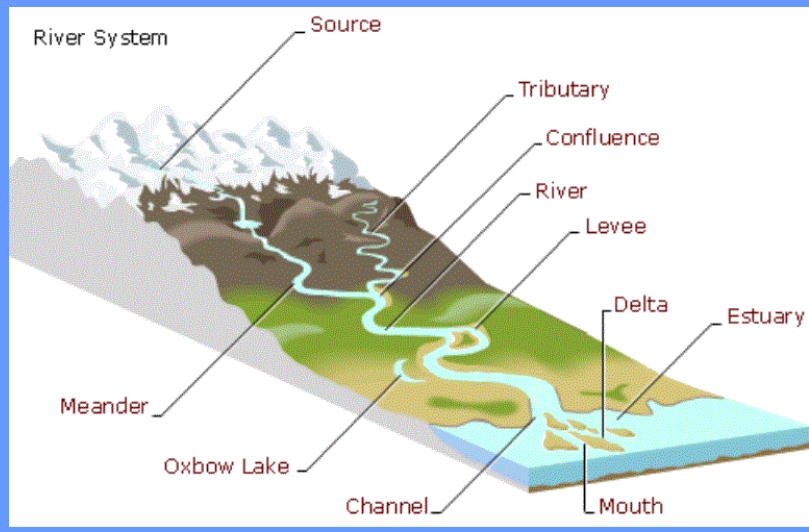
Plucking and Abrasion

2. What is the difference between a continental and a valley glacier?

Continental glacier covers much of a continent or large island, where a valley glacier is a long, narrow glacier found in a mountain valley

How is water an agent of Erosion?

- **Moving water is the major agent of erosion that has shaped Earth's land surface**
- **Through erosion, a river creates valleys, water falls, flood plains, and other landforms**
- **Deposition of sediments creates landforms such as deltas and also adds soil to a river's flood plain**
- **A <u>delta</u> is sediment that are deposited where a river flows into an ocean or lake building up a landform**



How is water an agent of Erosion?

- **Ground water** is another agent of erosion through the process of chemical weathering
- **Ground water** is water that fills the cracks and spaces in underground soil and rock layers
- Ground water containing carbonic acid can break down limestone **creating caves or caverns**.
- Stalactites and stalagmites are also formed from the deposit of calcite due to chemical weathering

How do waves contribute to Erosion?

- **The energy in waves comes from wind that blows across the water's surface**
- Waves shape the coast through erosion by breaking down rock and transporting sand and other sediment
- **Waves shape a coast when they deposit sediment, forming coastal features *such as beaches***

1. What is the source of the energy in ocean waves?

   Energy is transferred to ocean waves from wind

2. What process is the cause of ground water erosion?

   Chemical weathering